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## Public perceptions of pharmacogenomic services in Ireland - Are people with chronic disease more likely to want service availability than those without? A questionnaire study



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## ABSTRACT

**Background:** As pharmacogenomic services begin to emerge in primary care, the insight of the public is crucial for its integration into clinical practice.

**Objectives:** To establish perceptions of pharmacogenomics (awareness, understanding, openness to availability, perceived benefits and concerns, willingness to pay, and service setting) and investigate if they differ between those with and without chronic disease(s).

**Methods:** An anonymous, online questionnaire generated using Qualtrics® and circulated via social media and posters placed in eight participating community pharmacies was conducted with Irish adults. The questions were designed to consider existing literature on patient perceptions of pharmacogenomics. Descriptive statistics were used to summarize questionnaire responses. Chi-square test was used to compare categorical variables, while independent sample *t*-test and one-way ANOVA were used to compare the mean values of two (with and without chronic disease) and three groups (multimorbidity (two or more chronic conditions) and polypharmacy (prescribed four or more regular medicines) (MMPP), a single chronic disease, and those without existing medical conditions) respectively Logistic regression was used to evaluate age and gender adjusted associations of chronic disease(s) with responses. A *p*-value <0.05 was considered statistically significant.

**Results:** A total of 421 responses were received, 30% (*n* = 120) of whom reported having a chronic disease. Overall, respondents reported low awareness (44%, *n* = 166) and poor knowledge (55%, *n* = 212) of pharmacogenomics. After explaining pharmacogenomics to respondents, patients with chronic disease(s) were 2.17 times more likely (*p* < 0.001) to want pharmacogenomic services availability than those without existing conditions, adjusted for age and gender (driven by preferences of those with MMPP than those with single chronic disease). Respondents demonstrated a high level of interest and noted both the potential benefits and downsides of pharmacogenomic testing. Willingness-to-pay was not associated with having a chronic disease and respondents were more positive about primary care (community pharmacy or general practice) rather than hospital-based pharmacogenomics implementation. **Conclusion:** The Irish public in general and those with chronic disease in particular are strongly supportive of pharmacogenomic testing, highlighting an unmet need for its incorporation in medicines optimization. These data underline the need for more research on the implementation of community-based pharmacogenomics services for MMPP patients and ubiquitous pharmacogenomics education programs.

### 1. Introduction

Pharmacogenomic testing supports precision approaches to medicine by enhancing identification of potentially ineffective and/or harmful drugs, thereby improving drug therapy efficacy and reducing the incidence

of adverse drug responses.<sup>1–5</sup> Pharmacogenomics remains at the forefront of precision medicine and is gaining momentum in healthcare delivery in some countries, with various completed and ongoing implementation studies in the United States (US), Canada, Europe, and Asia.<sup>1–3</sup> Pre-emptive testing is emerging as a best practice, aiming to provide pharmacogenomic

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data for optimization of drug therapy at point of initial prescribing.<sup>6–8</sup> However, integration of pharmacogenomic testing into clinical practice is largely limited to specialist secondary and tertiary care settings.<sup>2,3</sup>

Pharmacogenomics is emerging in primary care, where importantly, most prescribing and dispensing of medicines occurs.<sup>9</sup> Pharmacogenomic testing could have a high impact on medicines prescribed across primary care. For example, Youssef et al. analyzed a large community pharmacy database in the United Kingdom (UK) and concluded that should the UK population undergo a pre-emptive panel-based pharmacogenomic test, approximately 9% of the first prescriptions for 56 pharmacogenomic drugs would require a therapeutic intervention according to guidelines published by the Clinical Pharmacogenetics Implementation Consortium (CPIC) and/or the Dutch Pharmacogenetics Working Group (DPWG).<sup>10</sup>

Although pharmacogenomics promises to personalize drug therapies, its application in routine patient care is encumbered by limitations in the scientific evidence, training of professionals, concentration of testing in specialist settings, concerns over data sharing, and costs of testing.<sup>2,3,11–14</sup> It is envisaged that overcoming these barriers will provide the impetus for the widespread adoption of pharmacogenomic guidelines (such as those published by CPIC and the DPWG), enabling the realization of the potential of pharmacogenomic testing in primary care.<sup>1</sup>

A recent systematic review on the use of pharmacogenomic interventions for patients with multimorbid chronic disease (the presence of two or more chronic diseases) and polypharmacy (the concomitant use of four or more prescribed medicines) (MMPP) suggested that the incorporation of pharmacogenomics in medicines optimization could have significant benefits for these patients.<sup>15–18</sup> Medicines optimization is a patient-centred approach aimed at ensuring the best clinical outcomes for patients through the safe and effective use of medicines. However, current approaches to medicines optimization do not incorporate pharmacogenomics and the scientific evidence base for application of pharmacogenomics amongst patients with chronic diseases, multimorbidity and polypharmacy is limited.<sup>18</sup>

Patient perceptions are important during the development and implementation of a new clinical service as they can help guide both service development as well as individual clinician practices. Studies from the US reported varying public and patient awareness of pharmacogenomics (48–88%) but high level of interest in using a pharmacogenomic service (81–83%).<sup>19–21</sup> Patients' attitudes towards pharmacogenomics were generally very positive,<sup>21</sup> while others would be more willing to use a pharmacogenomics service if it was paid for by their health insurance company.<sup>19</sup> Concerns have been raised regarding the potential for discrimination, the personal implications of additional risk information, and the practical issues of cost and follow-up care.<sup>22</sup> In Germany, the UK and Australia, the public are generally supportive of pharmacogenomic testing, but expressed additional concerns regarding patient autonomy, the unavailability of suitable drugs based on genetic makeup, and storage and privacy of genetic information.<sup>23–25</sup> Participants of an Icelandic study were concerned that drugs developed based on pharmacogenomics would be more expensive and result in greater health disparities.<sup>26</sup>

While these studies provide crucial information on attitudes towards pharmacogenomics, there is potential for transition in patient perceptions owing to the shifting nature of the public's familiarity with genetic testing and continual declines in its expense.<sup>27</sup> Therefore, the aim of the present study was to investigate the previously unexplored public perceptions of pharmacogenomic services in Ireland. The specific objectives were to establish participants' awareness, understanding, openness to availability, perceived benefits and concerns, willingness to pay, and preferred location (s) for provision of these services. We hypothesized that perceptions of pharmacogenomics would significantly differ based on the view of those with and without chronic disease(s).

## 2. Methods

### 2.1. Questionnaire development

The questions were designed based on existing literature on patient perceptions of pharmacogenomics,<sup>19–26</sup> and results of a recent systematic

review which concluded that more work is needed on pharmacogenomic testing as part of medicines optimization for MMPP patients.<sup>18</sup> In the questionnaire, pharmacogenomic testing was defined as 'the use of genetic information to tailor pharmaceutical treatments to an individual',<sup>28</sup> and information provided on where it is performed, testing methods and types, and examples of commonly implicated medications. Consent was required at the beginning of the questionnaire to proceed.

The questionnaire (attached as Supplementary Material) was divided into four sections with 58 questions. **Section 1** Demographic information (11 questions); **Section 2:** Healthcare experiences and accessibility (17 questions); **Section 3:** Pharmacogenomics (7 questions); and **Section 4:** Factors associated with choosing to have a pharmacogenomic test (23 questions). In **Sections 1, 2 and 3**, respondents had to choose from fixed-response options. In **Section 2**, the presence and number of medical conditions and prescribed medications were assessed to ascertain the proportion of MMPP patients. In **Section 4**, respondents had to rate their response to particular statements using five-point Likert scales. A small number of questions with open-ended responses were also included.

The questionnaire was face and content validated by six staff members (pharmacist and non-pharmacist) of the School of Pharmacy and Pharmaceutical Sciences, Trinity College Dublin.<sup>29</sup> Their feedback was incorporated into the questionnaire. Revisions to the questionnaire were made to minimize redundancy, clarify intention of questions, and reduce length. It was estimated that it would take approximately 15–20 min to complete the questionnaire.

### 2.2. Questionnaire distribution

The anonymous, online questionnaire was generated using Qualtrics®,<sup>30</sup> a survey software tool used to design, send, and analyze surveys online. Posters with a QR code linked to the online questionnaire were displayed on the researchers' social media pages and that of the School of Pharmacy and Pharmaceutical Sciences, Trinity College Dublin. Patient advocacy groups were tagged on the social media posts, promoting a broad engagement.

This project was undertaken as part of an MPharm project, and the posters were displayed on site in the eight participating pharmacies where the MPharm students (CO'B, CM, ED, JML, LF, MO'M, SK, SKn) involved in this study were completing their internships. The questionnaire went live in April 2021 and remained open to the public for four weeks. Weekly reminders were posted on social media to promote recruitment. To be eligible to participate in this study, it was required that respondents be over the age of 18 and living in Ireland. Furthermore, given the online nature of the questionnaire, a certain degree of IT literacy was required to participate.

### 2.3. Sample size

Based on data from the Tailored Antiplatelet Therapy Following PCI (TAILOR-PCI) study, we assumed that 77% of respondents would be interested in pharmacogenomic services.<sup>31</sup> It was hypothesized that respondents with chronic disease would be more interested in pharmacogenomic services than those without existing conditions owing to their more prevalent experience with medications and healthcare services. Accordingly, our study was powered to identify a 15% relative difference in positive response to availability of pharmacogenomic services between those with and without chronic disease. Respondents without existing conditions were considered likely to outnumber those with chronic disease, hence, a 2:1 enrolment was used. For a desired power of 0.80 and Type I error rate of 0.05, we estimated that at least 354 evaluable responses were required (118 with chronic disease and 236 without any existing medical conditions).

### 2.4. Data analysis

All viable data were coded for and entered into the computer program SPSS (v27.0) for statistical analysis. Multivariable modelling was conducted in R (v4.1.3). Standard descriptive analyses (frequencies (n) and

proportions (%) were used to summarize the questionnaire responses. Missing data in individual questionnaires were coded as such and omitted from the analysis. The percentage values quoted are based on the number of respondents to individual questions. To investigate if perceptions differ amongst those with a chronic disease, these respondents were subdivided into MMPP and single chronic disease.

Cross-tabulations (Chi-square test) and multiple linear regression analyses were performed to investigate whether chronic disease status (MMPP, single chronic disease, no existing medical condition) had any impact on pharmacogenomic awareness, openness to availability, perceived benefits/risks, and willingness to pay (WTP). Bivariate and multivariate analyses were conducted, with the former comparing those with chronic disease to those without (independent sample *t*-test), while the latter involved comparisons between those with MMPP, a single chronic disease, and respondents without existing conditions (one-way ANOVA). Odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were then computed, using a significance level of 5% for all statistical tests. A small number of questions with open-ended responses were also included. These responses were manually reviewed, and content analysis conducted.

### 2.5. Ethical approval

Ethical approval was granted by the School of Pharmacy & Pharmaceutical Sciences Research Ethics Committee in March 2021 (Ref. 2021-02-01).

## 3. Results

### 3.1. Responses

A total of 421 respondents started the questionnaire, with complete responses obtained from 354 of these respondents. The participants did not have to complete every question to proceed and could cease participation at any stage; thus, the proportions quoted in this section are based on the number of respondents to individual questions. The majority of respondents (50%,  $n = 209$ ) heard about the questionnaire by word of mouth, followed by social media (35%,  $n = 147$ ) and an unspecified 'other' method (8%,  $n = 36$ ). Only 28 respondents (7%) were recruited from a participating pharmacy.

### 3.2. Demographics

Respondents' demographics details are shown in Table 1. Respondents were 72% female ( $n = 303$ ), between 25 and 64 years (63%,  $n = 265$ ), and predominantly of European descent (94%,  $n = 396$ ). Respondents with a chronic disease were older than those without existing medical conditions (median age 35 vs 30 years,  $p < 0.001$ ). Furthermore, MMPP respondents were older than their single chronic disease counterparts (median age 50 vs 30 years,  $p < 0.001$ ). A long-term medical condition was reported by 30% of respondents ( $n = 120$ ), while 40% regularly take medications ( $n = 159$ ).

### 3.3. Pharmacogenomics awareness and knowledge

Respondents' perceptions of pharmacogenomics are shown in Table 2. Awareness of pharmacogenomics between those with and without a chronic disease was not found to be statistically significant ( $p = 0.939$ ), regardless of adjusting for age and gender (OR 1.18, [95% CI 0.74–1.87]). Overall, respondents' understanding of pharmacogenomics and its application in healthcare was poor or very poor (55%,  $n = 212$ ); however, 86% of respondents were aware that genetics could have an impact on the effectiveness of their medications ( $n = 218$ ).

Of those who had heard of pharmacogenomic testing, 77% reported their understanding of its applications in healthcare was excellent or good ( $n = 84$ ) ( $p < 0.001$ ). Pharmacogenomics awareness and knowledge was associated with age (18–24 years) ( $p < 0.001$  and  $p = 0.010$ ), a college degree ( $p < 0.001$  and  $p = 0.006$ ), current/previous employment in a health-

related profession ( $p < 0.001$  and  $p < 0.001$ ), and experience with medication side effects ( $p < 0.001$  and  $p = 0.003$ ).

### 3.4. Openness to availability of pharmacogenomic services

General information was provided about pharmacogenomic testing followed by a question on openness to availability of pharmacogenomic services in Ireland (Table 2). Receptiveness to pharmacogenomic services was associated with a college degree ( $p = 0.044$ ), current/previous employment in a health-related profession ( $p = 0.018$ ), history of medication side effects ( $p = 0.013$ ), previous genetic test ( $p = 0.039$ ), and awareness and understanding of pharmacogenomics and its applications in healthcare ( $p < 0.001$ ).

The majority of respondents with and without a chronic disease were open to pharmacogenomic services in Ireland (83% and 72% respectively) ( $p = 0.055$ ). Adjusting for age and gender, respondents with a chronic disease were 2.17 times more likely ([95% CI, 1.23–4.00],  $p < 0.001$ ) to want pharmacogenomic service availability than respondents without existing conditions. This result was driven by significant age and gender adjusted increases in positive responses from those with MMPP versus respondents without any chronic disease (OR 2.46, [95% CI, 1.13–6.00],  $p = 0.033$ ), rather than those with a single chronic disease only (OR 1.96, [95% CI, 0.97–4.29],  $p = 0.074$ ).

### 3.5. Perceived benefits and risks of pharmacogenomic testing

Respondents were asked about their perceived benefits of pharmacogenomic testing after learning about each specific use/benefit (e.g., to predict their risk of a side effect, to optimize their medicines) (Fig. 1). Most respondents (65–95%) expressed interest in pharmacogenomic testing for the various purposes presented (strongly agree and agree) which was not associated with chronic disease status. Interest in pharmacogenomic testing was highest in order to select the most effective medicine for their condition and was similar amongst those with and without a chronic disease (94% and 95% respectively) ( $p = 0.348$ ). Additional benefits captured by the free text option included: reduce costs (for patients and payers); reduce hospitalization (due to side effects and inefficacy); more efficient use of resources (reduce waste); improve standard of care (reduce trial and error and drug interactions, improve timing and adherence); improve understanding (of self and interactions, peace of mind, control, confidence).

Conversely, respondents were asked about their perceived risks/concerns of pharmacogenomic testing (Fig. 2). Respondents expressed varying concern (15–61%) for the risks presented (strongly agree and agree) which was also not associated with chronic disease status. In contrast, respondents expressed most concern for expensive pharmacogenomic tests (63% and 60% of those with and without a chronic disease respectively) ( $p = 0.418$ ). Additional risks/concerns captured by the free text option included: test accessibility, efficiency, quality and invasiveness; healthcare professional education; disclosure to employer, insurance and mortgage provider; and genetic information ownership and consent.

### 3.6. Willingness to pay for pharmacogenomic testing

Respondents' WTP for pharmacogenomic testing was assessed for three scenarios (Fig. 3). As shown, between 81 and 86% of respondents would not surpass the €100 price mark for all the pharmacogenomic tests listed. Annual household income was associated with respondents' WTP (Table 3). Overall, the higher earners were willing to pay more for the different types of pharmacogenomic tests. Furthermore, respondents with poorer perceptions of their health were more likely to pay the maximum price (€750) for pre-emptive and whole-genome sequencing tests ( $p = 0.003$ ).

Experience with stopping a medicine due to side effects ( $p = 0.021$ ) and inefficacy ( $p = 0.003$ ) was associated with WTP for reactive and pre-emptive testing. Chronic disease status was not associated with WTP for

**Table 1**  
Demographic characteristics of questionnaire respondents by chronic disease status.

	%Overall	%NCD (n = 301)	%CD (n = 120)	p <sup>a</sup>	%SCD (n = 65)	%MMPP (n = 55)	p <sup>b</sup>
Education (n = 421)				0.604			0.034*
At least a college degree	77.9	78.7	75.8		84.6	65.5	
Less than a college degree	22.1	21.3	24.2		15.4	34.5	
Job status (n = 401)				0.530			0.702
Employed	84.0	83.2	86.4		87.3	85.1	
Unemployed	16.0	16.8	13.6		12.7	14.9	
Health-related profession (n = 421)				0.723			0.219
Yes	50.1	50.8	48.3		55.4	40.0	
No	49.9	49.2	51.7		44.6	60.0	
Health insurance (n = 419)				0.831			0.279
Yes	74.7	74.2	75.8		81.5	69.1	
No	25.3	25.8	24.2		18.5	30.9	
Life insurance (n = 419)				1.000			0.980
Yes	40.8	40.8	40.8		40.0	41.8	
No	59.2	59.2	59.2		60.0	58.2	
Multimorbidity (n = 120)				–			<0.001*
≥ 2 long-term conditions	39.2	0.0	39.2		0.0	85.5	
1 long-term condition	60.8	0.0	60.8		100	14.5	
Polypharmacy (n = 163)				0.004*			<0.001*
≥ 4 regular medicines	12.9	2.99	19.8		0.00	38.8	
< 4 regular medicines	87.1	97.0	80.2		100	61.2	
Health status (n = 394)				<0.001*			<0.001*
Excellent	42.6	50.0	25.8		43.1	5.45	
Good	44.2	42.7	47.5		41.5	54.5	
Average	12.2	6.93	24.2		15.4	34.5	
Poor	1.02	0.36	2.50		0.00	5.45	
Experienced a side effect (n = 362)				<0.001*			<0.001*
Yes	45.9	38.1	62.6		61.3	64.2	
No	54.1	61.9	37.4		38.7	35.8	
Stopped a medicine due to side effects (n = 376)				0.019*			0.005*
Yes	30.6	26.6	39.3		31.2	49.1	
No	69.4	73.4	60.7		68.8	50.9	
Stopped a medicine due to inefficacy (n = 373)				0.007*			<0.001*
Yes	31.4	26.8	41.4		28.6	56.6	
No	68.6	73.2	58.6		71.4	43.4	

CD chronic disease, MMPP multimorbid chronic disease and/or polypharmacy, NCD no chronic disease, SCD single chronic disease.

\* Significant at  $p < 0.05$ .

<sup>a</sup> Independent t-test for variables with two groups.

<sup>b</sup> ANOVA for variables with more than two groups.

**Table 2**  
Respondents' perceptions of pharmacogenomic by chronic disease status.

	% Overall	%NCD (n = 269)	%CD (n = 118)	p <sup>a</sup>
Pharmacogenomics awareness (n = 382)				0.939
Yes	43.5	43.8	42.7	
No	56.5	56.2	57.3	
Pharmacogenomics knowledge (n = 386)				0.123
Excellent	8.03	9.33	5.08	
Good	18.7	17.5	21.2	
Fair	18.4	15.7	24.6	
Poor	27.7	28.4	26.3	
Very poor	27.2	29.1	22.9	
Previous genetic test (n = 371)				0.053
Yes	9.70	7.60	14.8	
No	90.3	92.4	85.2	
Open to pharmacogenomic services (n = 387)				0.055
Yes	75.5	72.1	83.1	
No	2.07	2.23	1.69	
Don't know	22.5	25.7	15.3	
Likelihood to test if receiving a medication that may be affected by genetics (n = 387)				0.290
Very likely	67.7	64.7	74.6	
Somewhat likely	25.6	27.5	21.2	
Not very likely	4.91	5.58	3.39	
Not at all likely	1.81	2.23	0.85	

CD chronic disease (includes MMPP multimorbid chronic disease and/or polypharmacy and SCD single chronic disease), NCD no chronic disease.

<sup>a</sup> Independent t-test for variables with two groups.

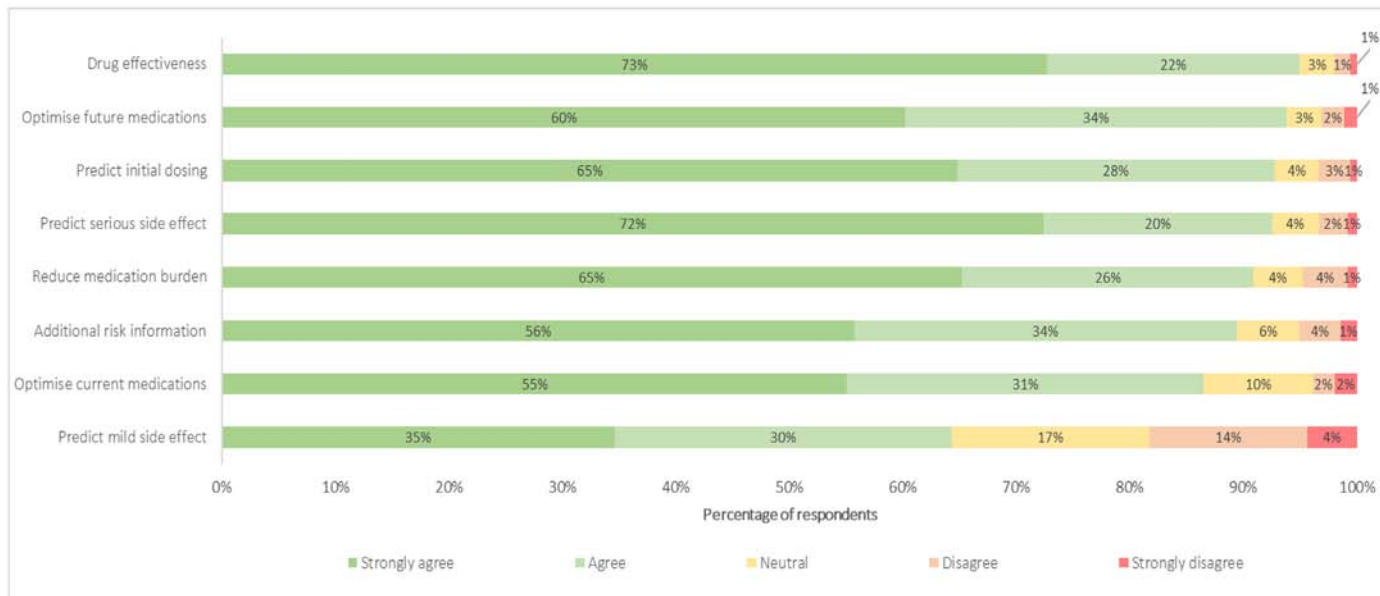
reactive and pre-emptive pharmacogenomic tests (Table 4). Interestingly, respondents without any chronic disease were willing to incur more costs for whole-genome sequencing than patients with a chronic disease ( $p = 0.009$ ). A high level of interest in insurance reimbursement for pharmacogenomic testing was shown, which was not affected by chronic disease status ( $p = 0.067$ ) (Table 4).

### 3.7. Preferences for location of pharmacogenomics services

Respondents were more interested in a pharmacogenomic service provided in the primary care setting (community pharmacy or general practice), rather than hospital setting. In further analyses, community pharmacies were found to be frequented more often than general practice, with 55% of respondents attending their local community pharmacy at least monthly ( $n = 233$ ). In comparison, a similar proportion of respondents (54%,  $n = 228$ ) attend their general practitioner once yearly or less frequently, while very few respondents (9%,  $n = 36$ ) attend at least once a month.

Understandably, respondents with chronic disease attend both community pharmacy ( $p < 0.001$ ) and general practice ( $p = 0.011$ ) more frequently than respondents without any chronic disease. Furthermore, a significantly higher proportion of those with MMPP attend both settings more frequently than single chronic disease respondents ( $p < 0.001$ ). Overall, 73% of respondents selected community pharmacy as the most convenient healthcare service to them ( $n = 288$ ).

Respondents were positive about community-based pharmacogenomics services, with 44% ( $n = 170$ ) expressing a preference for community



**Fig. 1.** Bar charts of respondents' likelihood to have a pharmacogenomic test for certain benefits/uses. Likelihood assessed using a 5-point Likert scale, where 1 = strongly agree (green), 5 = strongly disagree (red). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

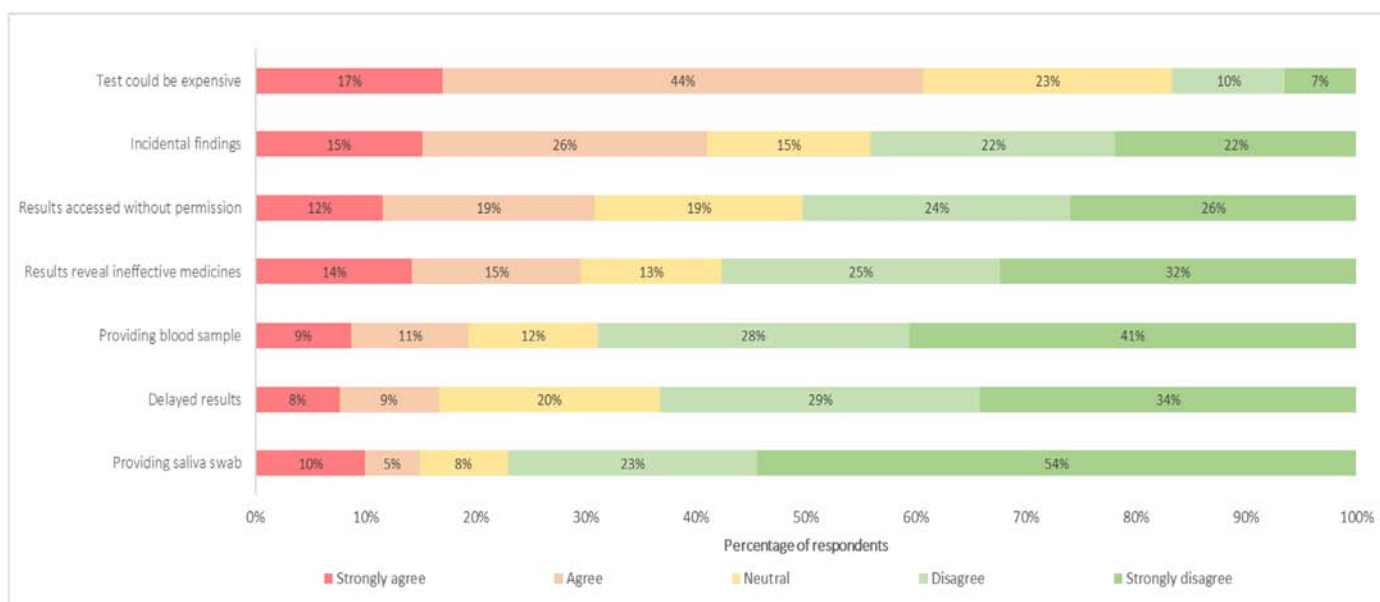
pharmacists to be the healthcare professional responsible for pharmacogenomic testing, 32% ( $n = 124$ ) preferring general practitioners, and 20% ( $n = 77$ ) preferring a hospital healthcare professional. Choice of healthcare professional to provide pharmacogenomic services was not associated with chronic disease status ( $p = 0.646$ ). In addition, 4% ( $n = 16$ ) selected the 'other' option, which included collaboration between primary care healthcare professionals and specialists/specialized centers with understanding of pharmacogenomics.

**4. Discussion**

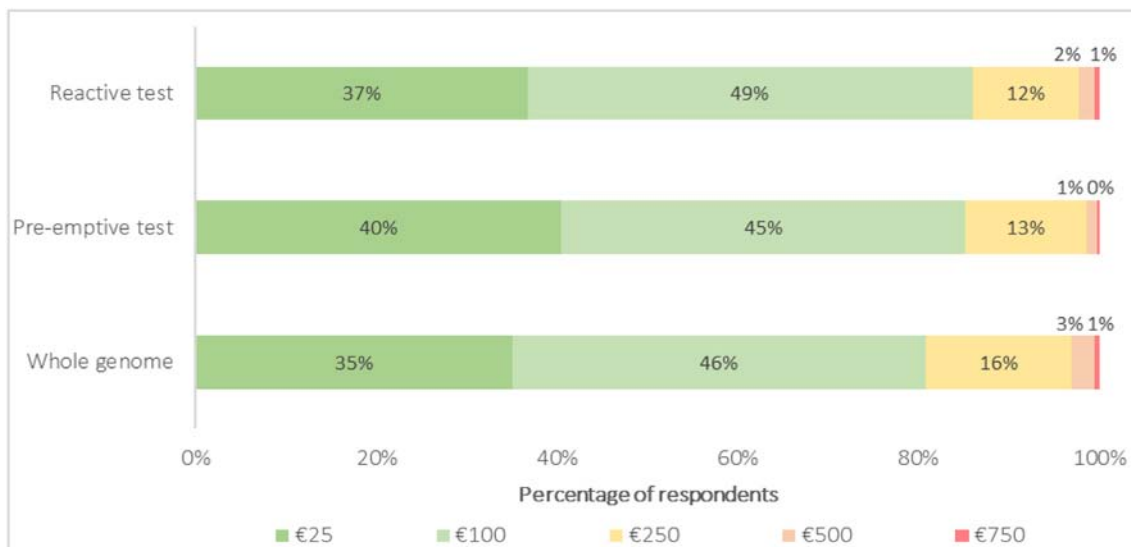
The present study provides a comprehensive and up-to-date account of public perceptions of pharmacogenomic services in Ireland and addresses the views of those with and without chronic disease. This work builds on

a previous systematic review, which concluded that more work is needed on pharmacogenomic testing as part of medicines optimization for multimorbid chronic disease and polypharmacy patients.<sup>18</sup> In this study, respondents with chronic disease were more than twice as likely to value pharmacogenomic service availability than respondents without existing medical conditions, when adjusted for age and gender. Furthermore, it appears that this was driven more by preferences of those with multimorbidity and polypharmacy than with single chronic disease. Compared to those without existing medical conditions, these respondents were older, had poorer perceptions of their health, and were more likely to report medication adverse effects and non-persistence, which may have influenced their receptiveness to pharmacogenomic services.

Our findings also suggest that while over half of the respondents were not confident in their understanding of pharmacogenomics, the majority



**Fig. 2.** Bar charts of respondents' likelihood to have a pharmacogenomic test for certain risks/concerns. Likelihood assessed using a 5-point Likert scale, where 1 = strongly agree (green), 5 = strongly disagree (red). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



**Fig. 3.** Bar charts of respondents' willingness to pay for the different types of pharmacogenomic tests. Reactive pharmacogenomic testing was defined as a test in response to unexplained side effects, pre-emptive as a test to ensure suitable medication use before those medicines are indicated, and whole genome sequencing as a test to ensure suitable medication use and also provide additional risk information.

have a high level of interest and positive perceptions of its potential benefits, which were similar amongst those with and without chronic conditions. Over 90% of participants indicated they would be interested in testing to optimize their medicines, enhance prescribing, predict their risk of serious adverse events, and to reduce their medication burden. Thus, reflecting the findings of the Mayo-Baylor RIGHT10K Study survey of 4624 patients 95% of respondents felt that pharmacogenomic testing would help them avoid exposure to medication that might be harmful.<sup>8</sup>

Nevertheless, the promise of pharmacogenomic tests to improve outcomes through individualized medicines also has potential downsides. As such, its implementation in primary care in Ireland may be challenging, warranting careful consideration of stakeholder views. Consistent with previous studies, a majority of respondents desired health insurance

co-funding for pharmacogenomics services. Few respondents (14–19%) were willing to pay more than €100 for the service, compared to 24% of participants with first-hand knowledge of the potential benefits of pharmacogenomic testing in a survey study by Bielinski et al.<sup>32</sup> This may be due to the fact that pharmacogenomic effects are not something a patient can physically feel, making it difficult for patients to incur costs regardless of perceiving the benefits.

**Table 3**  
Association between respondents' willingness to pay for the different types of pharmacogenomic tests and annual household income.

Income	€25	€100	€250	€500	€750	N	p <sup>c</sup>
<b>Reactive pharmacogenomic test WTP</b>							
<€20,000	42.9%	52.4%	4.8%	0.0%	0.0%	21	0.004*
€20,001–€60,000	41.3%	48.3%	8.4%	2.1%	0.0%	143	
€60,001–€100,000	32.4%	55.6%	12.0%	0.0%	0.0%	108	
€100,001–€140,000	42.5%	47.5%	7.5%	2.5%	0.0%	40	
≥€140,001	22.0%	36.6%	31.7%	4.9%	4.9%	41	
Income	€25	€100	€250	€500	€750	N	P*
<b>Pre-emptive pharmacogenomic test WTP</b>							
<€20,000	50.0%	50.0%	0.0%	0.0%	0.0%	20	0.007*
€20,001–€60,000	44.6%	42.4%	11.5%	0.7%	0.7%	139	
€60,001–€100,000	41.1%	43.9%	14.0%	0.9%	0.0%	107	
€100,001–€140,000	37.5%	57.5%	2.5%	2.5%	0.0%	40	
≥€140,001	22.0%	39.0%	36.6%	2.4%	0.0%	41	
Income	€25	€100	€250	€500	€750	N	P*
<b>Whole-genome sequencing WTP</b>							
<€20,000	55.0%	40.0%	5.0%	0.0%	0.0%	20	0.004*
€20,001–€60,000	40.4%	44.0%	10.6%	3.5%	1.4%	141	
€60,001–€100,000	31.5%	47.2%	19.4%	1.9%	0.0%	108	
€100,001–€140,000	29.3%	63.4%	4.9%	2.4%	0.0%	41	
≥€140,001	22.0%	36.6%	39.0%	2.4%	0.0%	41	

WTP willingness to pay.

\* Significant at p < 0.05.

<sup>c</sup> Chi-square test.

**Table 4**  
Respondents' willingness to pay for the different types of pharmacogenomic test (reactive, pre-emptive, whole-genome sequencing) and level of agreement with insurance reimbursement by chronic disease status.

	%Overall	%NCD (n = 246)	%CD (n = 111)	p <sup>a</sup>
<b>Reimbursed by insurance (n = 351)</b>				
Strongly agree	59.3	57.4	63.3	0.067
Agree	26.5	30.2	18.3	
Neutral	10.8	8.68	15.6	
Disagree	1.71	1.65	1.83	
Strongly disagree	1.71	2.07	0.92	
<b>Reactive test WTP (n = 357)</b>				
€25	36.7	34.1	42.3	0.582
€100	49.3	50.8	45.9	
€250	11.8	12.6	9.91	
€500	1.68	1.63	1.80	
€750	0.56	0.81	0.00	
<b>Pre-emptive test WTP (n = 351)</b>				
€25	40.5	37.6	46.8	0.101
€100	44.7	46.3	41.3	
€250	13.4	15.3	9.17	
€500	1.14	0.83	1.83	
€750	0.28	0.00	0.92	
<b>Whole genome sequencing WTP (n = 354)</b>				
€25	35.0	32.8	40.0	0.009*
€100	45.8	46.3	44.5	
€250	16.1	19.3	9.09	
€500	2.54	1.64	4.55	
€750	0.56	0.00	1.82	

CD chronic disease (includes MMPP multimorbid chronic disease and/or polypharmacy and SCD single chronic disease), NCD no chronic disease, WTP willingness to pay.

\* Significant at p < 0.05.

<sup>a</sup> Independent t-test for variables with two groups.

Unsurprisingly, respondents' financial situation was a key driver of a willingness to incur any out-of-pocket costs for pharmacogenomic testing. These findings add evidence to the concern that future benefits of pharmacogenomics may be disproportionately allocated to those with more financial resources.<sup>13</sup> Thus, more work is needed to avoid widening health disparities amongst patients with economic vulnerability. Respondents also expressed concerns over the potential for ancillary risk information and unauthorized access to their test results. Therefore, strict incidental findings and data sharing policies are required to provide security and enable data sharing amongst healthcare professionals caring for the patient without any privacy issues.

Pharmacogenomics services are predominantly delivered in specialist settings, yet the majority of medical care is provided in the community/primary care setting. Respondents reported a preference for primary care pharmacogenomic services versus the hospital settings. Particular interest was shown for community pharmacies, perhaps enhanced by ease of access. Community pharmacy-based pharmacogenomic testing models implemented and evaluated in the US,<sup>33–38</sup> Canada,<sup>39,40</sup> and the Netherlands demonstrate promise.<sup>41–43</sup> Herein a collaborative approach involving pharmacogenomic-trained pharmacists acting as a conduit between the data, general practitioners and patients will be necessary to enable the implementation of pharmacogenomics and resultant medicines optimization.<sup>8</sup> This finding mirrors results from a focus group study by Hindi et al., demonstrating the access and convenience of community pharmacy for services including “medication reviews and routine check-ups for well managed long-term conditions” was preferable compared with general practice.<sup>44</sup> Moreover, community pharmacists are the last healthcare professional to see a patient before they commence a new medication and are therefore ideally located to provide pharmacogenomic services.

One of the most influential prerequisites for successful implementation of pharmacogenomics is its general acceptance amongst patients and healthcare professionals. A recent systematic review by Hansen et al. emphasized lack of knowledge amongst these stakeholders as an important barrier to its implementation in primary care.<sup>45</sup> Gibson et al. demonstrated 52% of patients from a community pharmacy in the US were unfamiliar with pharmacogenomics (versus 56% in our study).<sup>19</sup> Other studies found that general practitioners were unsure how to incorporate pharmacogenomics in their practice and needed more education on pharmacogenomics, including interpreting results.<sup>46–48</sup> To this end, Haga et al. demonstrated general practice-based pharmacists can increase the likelihood of pharmacogenomic test utilization.<sup>47</sup> While community pharmacists are interested in pharmacogenomics and motivated to provide such services, further education is also required here.<sup>37,39,45,49,50</sup>

The exigent need for pharmacogenomics education was mirrored in the present study and reflects the intensive work required to implement a pharmacogenomics program in practice. At present, pharmacogenomic testing is not yet commonplace in Ireland. Consequently, it was unsurprising that pharmacogenomic awareness and knowledge was poor. Effective pharmacogenomic education programs for healthcare professionals, as well as the public, are required for the success of its implementation.<sup>2,3,8,45,51,52</sup> Comprehensive continuing professional development courses for healthcare professionals, such as those that developed in the Pharmacists: Personalized Medicine Experts study and the Mayo-Baylor RIGHT 10 K program,<sup>8,53</sup> may help by improving knowledge, readiness, and expertise in applying pharmacogenomics to patient care.<sup>53,54</sup> Furthermore, incorporation of pharmacogenomics and personalized medicine education into the curricula of health science faculties is vital to address the lack of preparedness in the primary care workforce and to prevent education creating a bottleneck in the implementation of personalized medicine.<sup>11,55–57</sup>

#### 4.1. Limitations

The present work has a number of limitations. Firstly, response bias is likely; respondents participating in this study are likely different from those who did not. Secondly, the data collected in this study was self-reported by respondents and not verified with general practice or pharmacy records. Thirdly,

the questionnaire respondents are not representative of the wider population. Respondents were predominantly between 25 and 64 years of age, with older and younger adults being under- and over-represented respectively. The online dissemination method may have been less accessible to older adults, as only 12 respondents  $\geq 65$  years participated, meaning older people with multimorbidity and polypharmacy are under-represented. Conversely, based on the responses of those with multimorbid chronic disease and polypharmacy, older people may have more experience with side effects and medications impacted by pharmacogenomics. Indeed, respondent characteristics were not equally dispersed in many categories, including the relatively high proportion of those with third level education, high income, and a healthcare background. These factors may have contributed to the overall positive response to pharmacogenomics. Fourthly, although respondents over the age of 18 years from Ireland were the target population, there is the possibility of unbeknownst ineligibility given the online nature of the questionnaire. Finally, the views of healthcare workers on pharmacogenomics were not specifically assessed in this study. More work is required to ensure that the needs and preferences of a broader range of people with chronic disease are accounted for in the development, implementation, and evaluation of pharmacogenomic services.

#### 5. Conclusion

The findings of this study underline that significant research, educational programs, and service development are required for the implementation of community-based pharmacogenomic services delivered by, or in collaboration with, community pharmacists. The previously unexplored public perceptions of pharmacogenomic services in Ireland suggest that while over half of the respondents were not confident in their understanding of pharmacogenomics, the public is strongly supportive of pharmacogenomic testing, highlighting an unmet need for its incorporation in medicines optimization. This is especially the case for people with chronic disease, who were over two times more likely to desire pharmacogenomic services availability than those without any chronic disease. While respondents had positive perceptions of the potential benefits of pharmacogenomics to improve drug therapy outcomes, concerns were raised regarding test expense, incidental findings, and genetic data privacy. Collaborative practice amongst primary healthcare providers is essential for the realization of pharmacogenomics and respondents were particularly interested in community-based services, expressing preferences for pharmacist involvement. While the high level of interest in pharmacogenomic testing is encouraging, this may not translate to high uptake due to the cost of testing, where reimbursement will undoubtedly have an impact.

#### CRedit authorship contribution statement

**Joseph O'Shea:** Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Project administration, Supervision. **Cristín Ryan:** Conceptualization, Methodology, Investigation, Writing – review & editing, Project administration, Supervision. **Joseph Gallagher:** Writing – review & editing, Supervision. **Claire O'Brien:** Conceptualization, Methodology, Data curation, Investigation, Writing – review & editing. **Conor Morris:** Conceptualization, Methodology, Data curation, Investigation, Writing – review & editing. **Eoin Dwyer:** Conceptualization, Methodology, Data curation, Investigation, Writing – review & editing. **James Mc Laughlin:** Conceptualization, Methodology, Data curation, Investigation, Writing – review & editing. **Laura Fitzpatrick:** Conceptualization, Methodology, Data curation, Investigation, Writing – review & editing. **Maire O'Meara:** Conceptualization, Methodology, Data curation, Investigation, Writing – review & editing. **Sarah Kelly:** Conceptualization, Methodology, Data curation, Investigation, Writing – review & editing. **Sophie Knox:** Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Writing – review & editing, Project administration, Supervision. **Mark Ledwidge:** Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Writing – review & editing, Project administration, Supervision.

## Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.rcsop.2022.100182>.

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