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## **Critical appraisal of the views of healthcare professionals with respect to pharmacogenomics and personalized medicine in Greece**

Yuan Mai <sup>1,\*</sup>, Christina Mitropoulou <sup>2,\*</sup>, Xanthippe Papadopoulou <sup>1</sup>, Athanassios Vozikis <sup>3</sup>,  
David N. Cooper <sup>4</sup>, Ron H. van Schaik <sup>2</sup>, George P. Patrinos <sup>1,#</sup>

<sup>1</sup> University of Patras, School of Health Sciences, Department of Pharmacy, Patras, Greece; <sup>2</sup> Erasmus MC, Faculty of Medicine and Health Sciences, Department of Clinical Chemistry, Rotterdam, the Netherlands; <sup>3</sup> University of Piraeus, Department of Economics, Piraeus, Greece; <sup>4</sup> Institute of Medical Genetics, School of Medicine, Cardiff University, Cardiff, United Kingdom

\* These authors contributed equally to this work

Running head: Healthcare professionals' opinion over personalized medicine in Greece

# Corresponding author at:

Department of Pharmacy, School of Health Sciences, University of Patras,  
University Campus, Rion, GR-26504, Patras, Greece

Telephone/Fax: +30-2610-969.834,

E-mail: [gpatrinos@upatras.gr](mailto:gpatrinos@upatras.gr)

## Abstract

In the post-genomic era, genetics has gradually begun to assume a central role in modern medical practice. However, in many European countries, very little is currently known regarding the level of awareness of healthcare professionals with respect to pharmacogenomics and personalized medicine. We have previously conducted a pilot nationwide survey to assess how the general public and physicians in Greece perceive genetics. Here, we report ~~our~~the findings ~~from~~of a more in-depth study, involving healthcare professionals, namely 86 pharmacists and 208 physicians, to assess their level of awareness of pharmacogenomics and personalized medicine. Our findings indicate that a substantial number of pharmacists (around 60%) consider their level of knowledge of personalized medicine to be very low, ~~while~~with around 80% of the pharmacists and 58% of physicians ~~indicated~~intimating that they would be unable to provide sufficient information or explain the results of pharmacogenomic tests to their customers or patients, respectively. This situation ~~is~~may be directly related to the low level of their undergraduate education in genetics and pharmacogenomics, as indicated by ~~the~~an assessment of the pharmacists' knowledge of basic genetics ~~knowledge~~. Further, our surveys revealed that physicians are more ~~frequently~~often involved with genetics and pharmacogenomics in their routine practice than pharmacists, and have more frequently advised their patients to undergo genetic and/or pharmacogenomic testing. Interestingly, although only 7% of the pharmacists provide sample collection kits for downstream genetic analysis over the counter, a much larger proportion, ~~i.e.~~(30%), are in favor of direct-to-consumer genetic

testing in principle. Overall, a large proportion of healthcare professionals are of the opinion that, in relation to personalized medicine in Greece, a well-regulated environment and legal framework are conspicuous by their absence. These findings provide the basis for an improved assessment of the views of healthcare professionals in relation to personalized medicine in Greece. It is to be hoped that this survey will not only improve, but also ~~and~~ expedite, the integration of genomics into the ~~current~~ medical decision-making process in Greece but will also set the stage for replicating these surveys in other European populations.

**Key Words:** Public health genomics, healthcare professionals, physicians, pharmacists, genetics education, pharmacogenomics

## Introduction

Personalized or genomic medicine exploits genomic information not only in the context of rationalizing drug ~~use~~-prescription but also by influencing the overall medical decision-making process to the benefit of both the patient and the national healthcare system. Analysis of an individual's or a family's whole genome sequence(s) would, in principle at least, enable physicians to make assessments of disease risk, determine an individual's pharmacogenomic profiles and, hence, arrive at decisions regarding treatment modalities [1,2]. In recent years, personalized healthcare has become a reality by combining whole-genome information with a patient's clinical profile [3]. As a result, not only can preventive medicine strategies be optimized but ~~also~~-conventional therapeutic interventions can also be individualized. The latter constitutes a major challenge for customizing patient care [4].

Unfortunately, the level of public awareness of genetics and its impact ~~to~~-upon society is often rather low, and the same is true for healthcare professionals who are supposed to be in the front-line of delivering these services to the general public. The lack of genetics awareness among healthcare professionals constitutes a major barrier to expediting the implementation of genomic medicine with its potential to adjust conventional treatment modalities according to a patient's genomic profile. This situation ~~results in~~ is exacerbated by a poorly developed and regulated genetic testing landscape in many European countries, as indicated by the paucity of the literature on this topic both in European countries and the United States [5-7]. Thus, determining the level of awareness of the general public and healthcare professionals with respect to genetics and genomic

medicine and their potential benefits to society, together with the challenges and pitfalls that need to be overcome, has become a major goal. For this reason, we have initiated nationwide surveys in Greece to critically ascertain patients' and healthcare professionals' views about genetics, pharmacogenomics and personalized medicine.

We have previously reported our results from a nationwide survey to study the attitudes and views of the private genetic testing laboratories in Greece [8]. We have also performed pilot surveys of the views of the general public and physicians in Greece, with the aim of understanding both the wishes and needs of patients and physicians in relation to genetics and genetic testing and to identify regulatory deficiencies and gaps in the existing legal provision [9,10].

Here, we report our findings from a thorough survey of healthcare professionals, specifically physicians and pharmacists, to ascertain their opinion of various issues pertaining to genetics, personalized medicine and ~~its~~ their impact on society. This study provides useful insights ~~and which can we hope will be potentially~~ replicated in other European countries, ~~with the aiming to of~~ engaging healthcare providers more actively in all aspects of genomic medicine. ~~This which~~ will in turn facilitate the incorporation of genomic medicine into everyday clinical practice.

## Methods

### *Research design*

A cross-sectional survey design was used for this study which was conducted between June 2010 and September 2012. We formulated two independent questionnaires

(see **Supplementary information**) from which the data on individual perceptions of genetics, pharmacogenomics and personalized medicine were generated. We provided the necessary clarifications to questions posed by the survey respondents when required to do so, in order to ensure that a valid response was given to each question.

In both questionnaires, non-random sampling was employed. One hundred and thirty seven pharmacists, selected from three cities mainly in Western Greece, were personally interviewed, using a questionnaire that was divided into four sections: (a) the first section (questions 1-5) requested demographic information such as age, gender and place and level of studies (BSc, MSc/PhD), (b) the second section (questions 6-7) aimed to assess their professional experience, (c) the third section (questions 8-15) aimed to assess the genetics knowledge of the respondents, and (d) the fourth section (questions 16-35) posed 20 questions regarding various aspects of genetics, such as awareness of and personal opinions about genetics, genetic tests and the use of pharmacogenomic testing from health care providers.

A similar questionnaire was distributed to 208 physicians from all medical specialties who attended the national (Greek) medical conference in May 2011 and May 2012, to ensure a broad coverage of physicians from all specialties and from all geographical regions within Greece, and contained the following sections: (a) the first section (questions 1-5) requested demographic information such as age, gender, place and level of studies (MD, MSc/PhD) and specialty, (b) the second section (questions 6-8) aimed to assess their professional experience, and (c) the third section (questions 9-23) contained 15 questions regarding various aspects of genetics, such as awareness of and

personal opinions about genetics, genetic tests and the use of pharmacogenomic testing from health care providers. Ten questions were identical between the questionnaires for the sake of comparison (**Supplementary information**).

### ***Measures***

The questionnaires provided prospective data for this analysis. The dependent variables were derived from the questions in both questionnaires, scored using either a binary model (0=No, 1=Yes), or the Likert-type scale (1-5). Independent variables comprised the demographic characteristics of respondents, specifically their age, gender, level of study and place where they performed their studies, and their professional experience.

### ***Statistical analysis***

All statistical analyses were performed using the Statistical Package for the Social Sciences, version 18.0 (SPSS Inc., Chicago, IL, USA) and the chi-square test. We also checked the data for completeness and frequency distributions. Mean values, standard deviations, and percentages were computed to describe the distribution of independent variables. Cross-tabulation tables (contingency tables) were created to display the relationship between two or more (nominal or ordinal) variables using the chi-square test. Probabilities of less than 0.05 were considered to be statistically significant, when testing null hypotheses.



## Results

The overall sample sizes and characteristics of the surveyed pharmacists and physicians groups are shown in **Table 1**. Every effort was made in the context of both the general public [[GEORGE: Do you mean the pharmacists?](#)] and [the](#) physicians' groups to be as representative as possible regarding age and gender.

**Figure 1A** depicts the most common medical specialties of those physicians who responded to our survey. A full list of [these medical](#) specialties is provided in the **Supplementary information**. **Figure 1B** depicts the pharmacists' professional experience, from which it can be seen that almost 60% of the pharmacists who participated in this survey had practiced pharmacy for more than 10 years, with the vast majority (84/86; 97.7%) of them either being employed in, or owning, a private pharmacy.

The opinions of the physicians and pharmacists were assessed with respect to the following three issues: (a) level of awareness of genetics and pharmacogenomics, (b) involvement with genetics, genetic testing and pharmacogenomics, and (c) professional opinions regarding ethical, legal, societal and regulatory issues pertaining to genetics and pharmacogenomics. The pharmacists were also interviewed to assess their basic knowledge of genetics, since their [formal](#) genetics education is often very limited.

### *Awareness ~~over~~ of genetics and pharmacogenomics*

We first attempted to assess the level of awareness of healthcare professionals of genetics and pharmacogenomics. Around 60% of the pharmacists interviewed admitted that their level of genetics knowledge [was](#) very low, while an almost equal number of

pharmacists [GEORGE: percentage?] professed awareness of pharmacogenomics and its relationship with personalized medicine (**Fig. 2**). Some 58% of the pharmacists felt that they knew very little or nothing ~~or had very poor knowledge of~~ about genetics (Q16B), ~~and~~ pharmacogenomics and personalized medicine (Q17B), while a mere 4.6% felt that their knowledge level of genetics, pharmacogenomics and personalized medicine was high or very high (**Figs. 2A, B**). Almost 45% of physicians ~~admitted~~ volunteered that their knowledge level of pharmacogenomics and personalized medicine (Q12A) was poor or very poor, while around 24% of respondents felt that their knowledge level of genetics, pharmacogenomics and personalized medicine was high or very high (**Fig. 2C**). A similar response pattern was also observed in physicians and pharmacists with regard to ~~ing~~ self-assessment of the undergraduate level of their education in genetics and pharmacogenomics (Q20A and Q20B, respectively; **Fig. 2D**). Finally, approximately 78% of the physicians and 58% of pharmacists would be interested in attending educational events in relation to genetics and pharmacogenomics (**Supplementary information**), indicating their willingness, at least in principle, to improve their knowledge of this emerging field in medicine.

Genetic and pharmacogenomic tests are gradually becoming integrated into the modern medical decision-making process. Indeed, there are an increasing number of genetic tests that are being made available worldwide from genetic laboratories, but also directly to the consumer via the internet, or (even more recently) over the counter in pharmacies. We asked the pharmacist's group whether they provide genetic analysis kits (e.g. buccal swabs or saliva collection kits) over the counter. ~~Our data~~ The responses given

~~show indicated~~ that only 7% of the pharmacists provide such genetic analysis kits over the counter, while almost 9 out of 10 pharmacies do not (Q22B; **Fig. 3A**). ~~Interestingly, a~~ significantly larger proportion of pharmacists, ~~i.e. (45%)~~, were aware that genetic analysis kits are considered ~~to be a~~ medical devices and as such they require regulatory clearance to be sold over the counter in pharmacies (Q23B). However, a smaller proportion (31%) were aware that certain drug labels specify that it is recommended to undertake a pharmacogenomic test prior to obtaining the drug in question so as to avoid an adverse drug reaction (Q26B; **Fig. 3A**).

It is broadly accepted that pharmacogenomics contributes towards a reduction not only in healthcare costs by minimizing adverse drug reactions, but also in the overall cost of developing new drugs by stratifying patients' subgroups in clinical trials. Therefore, we posed these questions to pharmacists in order to ascertain whether they are familiar with these issues. We found that around 60% of the respondents ~~believing pharmacists~~ believed that pharmacogenomics can help to ~~reducing~~ the occurrence, overall frequency and severity of adverse drug reactions (Q31B), while 65% believed that pharmacogenomics can help to reduce healthcare costs by rationalizing drug use (Q33B; **Fig. 3B**). However, only one third of the responding pharmacists believed that pharmacogenomics would play a role in reducing the cost of developing new drugs (Q32B; **Fig. 3B**).

### ***Involvement with genetics, genetic testing and pharmacogenomics***

Subsequently, we addressed the level of involvement of physicians and pharmacists with genetics, genetic testing services and pharmacogenomics. Firstly, we asked physicians

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and pharmacists about the extent to which pharmacogenomics and pharmacogenomic testing were involved in their daily practice. From their responses, we surmise that physicians are more frequently involved with genetics and pharmacogenomics in their routine practice than pharmacists. However, more than half of the respondents ~~in~~ stated that their level of involvement was low, with 53% of physicians and 73% of pharmacists being only rarely becoming involved with pharmacogenomics (**Fig. 4A**).

When we ~~assessing~~ enquired whether physicians had ~~ve~~ advised their patients to undergo genetic and/or pharmacogenomic testing, more than half (*i.e.*, 53%) stated that they have advised their patients to do so. By contrast, a mere 15% of the pharmacists stated that they had ~~ve~~ advised their clients to undergo genetic and/or pharmacogenomic testing (**Fig. 4B**). The same pattern was also observed when physicians and pharmacists were asked whether their patients had sought their advice in relation to undertaking genetic and/or pharmacogenomic testing (42% vs. 9%, respectively; **Fig. 4B**). At the same time, 79% of the pharmacists indicated that they could not provide sufficient information to their clients or explain the results of pharmacogenomic tests to them (Q27B); ~~while~~ this percentage was much lower in the physicians group (58%; Q16A: **Fig. 4C**).

#### ***Professional opinions on ethical, legal, societal and regulatory issues pertaining to genetics and pharmacogenomics***

Genetic analysis must always comply with various ethical, legal, societal and regulatory guidelines. As such, we sought the opinion of our groups of healthcare professionals on this important ~~matter~~ topic.

A large proportion of healthcare professionals (69% of physicians and 77% of pharmacists) believe that in Greece there is currently neither a well-regulated environment nor the appropriate legal framework ~~to covering~~ genetic and pharmacogenomic testing to protect the general public and ensure privacy, informed consent, control of the costs of genetic analysis, monitoring of the accreditation of genetic laboratories, etc; **Fig. 5A**). In particular, 72% of the pharmacists thought that pharmacogenomic information could potentially be maliciously exploited by employers and insurance companies in order to discriminate against certain patients or population subgroups (not shown).

An even bigger proportion, namely 86% of physicians and 66% of pharmacists disagreed with the idea of direct-to-consumer genetic testing (**Fig. 5B**), while 62% of physicians and 66% of pharmacists believed that the cost of pharmacogenomic testing should be covered by insurance companies (**Fig. 5C**). Overall, the majority of healthcare professionals (50% of physicians and 70% of pharmacists) agreed that the results of pharmacogenomic testing would have a positive impact only affect patient medical care ~~for the patients~~ by rationalizing their drug prescription and dosage, their frequency of medical appointments and overall diagnoses (**Fig. 5D**).

#### *Assessing genetics knowledge among pharmacists*

Finally, we wished to assess how well educated pharmacists are in relation to genetics and pharmacogenomics. Our data revealed that the younger pharmacists and those with a graduate degree (MSc and/or PhD) are better informed about genetics as compared to the older generation of pharmacists and those who have not studied at postgraduate level. Thus,

77% of the younger pharmacists (<35 yr old) correctly stated that the DNA is 99% identical ~~among-between~~ different individuals compared to 44% of the older pharmacists (>35 yr old; Q8B;  $p<0.001$ ). ~~Also~~In addition, 8 out of 10 pharmacists ~~correctly stated~~realised that the statement “... adenine only pairs with cytosine and thymine only pairs with guanine” (Q10B) was wrong, while 6 out of 10 pharmacists ~~correctly stated~~noticed that the statement “Humans have 48 chromosomes” (Q9B) was wrong. In both cases, pharmacists with a post-graduate education ~~gave~~tended to give more correct answers ( $p<0.001$ ). All of the younger pharmacists (<35 yr old) correctly stated that DNA changes are capable of influencing drug response compared to just 82% of the older pharmacists (Q13B;  $p=0.015$ ), while 97% of the younger pharmacists opined that DNA changes could result in adverse drug reactions as compared to almost 62% of the older pharmacists (Q14B;  $p<0.001$ ). Further, 71% of younger pharmacists were of the opinion that pharmacogenomic analysis is not appropriate for all drugs, while this percentage is lower for older pharmacists (Q15B;  $p=0.042$ ). When we assessed the influence of post-graduate education on genetics knowledge, we found that pharmacists with a graduate title (MSc and/or PhD) have a better genetics education compared to those ~~that~~who have not followed post-graduate studies (not shown). These data are summarized in **Figure 6**.

## Discussion

In recent years, it has become clear that pharmacogenomics has the potential to ensure optimal treatment and medication use in a growing number of diseases. The advent of high-throughput genotyping and whole-genome sequencing analysis has revolutionized

medical practice bringing the ~~notion-concept~~ of personalized genomic medicine ever closer to reality, and resulting in a steady increase in the number of genetic tests becoming available, a number which is expected to increase steadily in the years to come [11].

Given the potential of genomic medicine to grow exponentially, it is imperative that comprehensive analyses are performed in various countries to assess the level of awareness of healthcare professionals in relation to genomics and personalized medicine ~~to expedite so that~~ the delivery of genomic services may be expedited in their respective healthcare systems. Genetics education and communication will also play an important role in increasing the level of awareness of the general public with respect to genomic medicine so that they come to appreciate the benefits that this new discipline can offer [12].

There are currently very few studies that have attempted to fine map the differences between individual countries regarding the level of education and awareness of healthcare professionals in relation to pharmacogenomics and genomic medicine. In contrast to the United States, significant differences have been documented between individual European countries, even between European Union member states [5-9], and in-depth analysis, based upon comprehensive surveys is still lacking. We have previously attempted to explore how both the general public and medical practitioners perceive genetics and genetic testing services in Greece [8,9] and to correlate this information with the existing private genetic testing environment in Greece [10]. For the first time in Europe, ~~These~~ surveys paid, ~~for the first time in Europe,~~ special attention to attitudes to

This study has attempted to shed new light into the ways that healthcare professionals perceive genomic medicine, and pharmacogenomics in particular. This study differs significantly from that recently conducted in Greece [8] in the following ~~re~~aspects: (a) this study comparatively evaluated the views of physicians and pharmacists in relation to key aspects of genomic medicine, (b) both questionnaires were designed (using the Likert scale) in such a way as to allow better analysis of the responses of the target groups, (c) this study attempted to correlate genomic knowledge with professional and training experience, and (d) this study ~~has~~ highlighted the willingness of both target groups to participate in continuous educational events over pharmacogenomics.

As with our previous study, we opted to carry out personal interviews rather than acquire information by means of impersonal electronic surveys since it ~~not only~~ allowed us to provide clarification to the respondents when required to do so. The latter could also have introduced bias since ~~these most computer literate~~ individuals ~~who are most computer literate~~ are also likely to be the best informed about genetic testing. Pharmacists were approached in their practice, whereas physicians were selected while attending two major annual national medical conferences in Athens. However, ~~contrary in comparison~~ to our previous study, we ~~have~~ significantly expanded the questionnaires, since we sought a more detailed evaluation of the views of our target groups.

### ***Perception of genomic medicine and pharmacogenomics***

Integration of genomic information into the mainstream medical decision-making process depends upon several parameters. Increased awareness of various aspects of



genomic medicine greatly facilitates the entire process. Our results indicate that approximately 60% of the pharmacists who responded to our survey ~~admitted~~ ~~that~~ considered their level of genetics knowledge ~~was to be~~ low, a proportion comparable to the pharmacists who admitted very limited or no knowledge of pharmacogenomics and its relationship with personalized medicine (**Fig. 2**). Only 4.6% of pharmacists felt that their genetics and pharmacogenomics knowledge was high. This situation contrasts with that for the physicians as a group; the ~~percentage-proportion~~ of the physicians who admitted their level of knowledge ~~level-of-very~~ pharmacogenomics and personalized medicine was poor or very poor was significantly lower (45%), while 24% of the physicians felt that their level of knowledge of genetics, pharmacogenomics and personalized medicine was high or very high (**Fig. 2C**;  $p < 0.05$ ). This difference can most ~~likely-easily~~ be explained by the fact that genetics and molecular biology courses are included for a longer period of time in the medical schools in Greece compared to the schools of pharmacy. It is unfortunate that in the latter schools ~~in Greece~~, the undergraduate curricula only ~~touch-upon~~ address these topics quite superficially. When physicians and pharmacists were asked to self-assess the level of their undergraduate education with respect to genetics and pharmacogenomics, similar responses were given (**Fig. 2D**).

The educational level of the physicians and pharmacists with respect to genetics and pharmacogenomics could also be defined in relation to their level of involvement with genetic and pharmacogenomic testing services. Our results show that although physicians are more frequently involved with genetics and pharmacogenomics in their routine practice

as compared to pharmacists, more than half of them indicated that the level of their involvement with pharmacogenomics was low (53% of physicians vs. 73% of pharmacists). Moreover, significantly more physicians (53%) have advised their patients to undergo genetic and/or pharmacogenomic testing, compared to 15% of pharmacists (~~45%~~; **Fig. 4B**). And a comparable trend was also observed when physicians and pharmacists were asked whether their patients had enquired about undertaking genetic and/or pharmacogenomic testing (42% vs. 9%, respectively; **Fig. 4B**). These data are comparable with our previous survey [48%; 8].

Interestingly, a large proportion of pharmacists (79%) felt that that they could not provide sufficient information or explain the results of pharmacogenomic tests to customers, while only 5% stated that they could satisfactorily explain the results of pharmacogenomic tests, a response which is directly proportional to their genetics education. This result is similar to a recent study performed in a Canadian pharmacist respondent group, only 7.7% of whom felt comfortable advising patients and interpreting their pharmacogenomic test results [15]. As previously indicated, the proportion of physicians stating that they were unable to explain genetic and pharmacogenomic test results was much lower than the pharmacists while reciprocally the proportion of physicians who stated that they were in a position to adequately interpret genetic test results was significantly higher than the pharmacists (58% and 15%;  $p < 0.01$ ).

In recent years, kits for sample collection for downstream genetic tests have become widely available over the counter in pharmacies. Our group of pharmacists indicated that only 7% of them sell such kits over the counter, whereas almost 9 out of 10 pharmacies

do not. Such collection kits are considered medical devices and as such, special clearance is required from regulatory agencies to sell them. Interestingly, only 45% of the pharmacists ~~that-who~~ responded to our survey were aware that the genetic analysis kits are considered medical devices. Surprisingly, 8% and 22% of pharmacists agreed or somewhat agreed with the ~~notion-idea~~ of direct-to-consumer genetic and pharmacogenomic testing, compared to 5% and 9% of physicians, respectively. Although the results from the physicians group were in full agreement with our previous surveys [8,9], the smaller proportion of the pharmacists who were opposed to direct-to-consumer (DTC) genetic and pharmacogenomic testing is of special interest, warranting further investigation, and could be partly explained by the limited information available to this professional group regarding the risks of DTC genetic testing. The issue of DTC genetic testing is a controversial one and there are considerable differences in the regulatory framework between the US and Europe [16]. ~~Also~~ Moreover, considering the absolute need for a doctor to mediate between the patient and the diagnostics company offering the pharmacogenomic test, extra caution should be exercised with DTC pharmacogenomic testing [17], particularly those sold ~~over~~ the Internet, since a large ~~number-of-them~~ proportion may be ~~indeed~~ inaccurate or even completely useless. It is ~~truly~~ unfortunate that there are ~~some~~ few Greek companies that are offering pharmacogenomic tests using the DTC model, some of them via the Internet [GEORGE: Is this what you want to say. You were actually saying the opposite!]. This ~~discrepancy is also indicative a symptom~~ of the lack of a well-regulated testing with the aim of protecting the general public and ensuring privacy, consented

analysis, control of genetic analysis costs, monitoring genetic laboratories accreditation, a point made by both respondent groups (**Fig. 5**).

It is broadly accepted that pharmacogenomics has the potential to improve quality of life at the same time as reducing healthcare costs by minimizing adverse drug reactions at both a personal and national level. Around 60% of the responding pharmacists believed that pharmacogenomics ~~can~~ has the potential to help to reduce the incidence and severity of adverse drug reactions, while 65% believed that pharmacogenomics can contribute towards reducing healthcare costs by rationalizing drug use. At the same time, 62% of physicians and 66% of pharmacists believe that the cost of pharmacogenomic tests should be covered by insurance companies. –Surprisingly, only 31% of the respondent pharmacists were aware that certain drug labels indicate that a pharmacogenomic test should be undertaken prior to obtaining or being prescribed the drug in order to avoid adverse drug reactions.

Overall, the majority of healthcare professionals (50% in the physicians group and 70% in the pharmacists group) agree that the results of pharmacogenomic testing will positively affect medical care for the patients by rationalizing their drug type and dose, their frequency of medical appointments and overall diagnoses.

#### ***Knowledge and education of pharmacists in relation to pharmacogenomics***

In several countries, pharmacists are considered to be experts in medication and as such, they are expected to be able to use pharmacogenomic information appropriately in order to individualize treatment regimens. Pharmacists can be particularly useful in the implementation of pharmacogenomics, mainly by assisting clinicians to ensure that all

available pharmacogenomic information is considered in the medical decision-making process, or by acting as educators ~~for~~to patients and healthcare professionals ~~to~~in the context of raising awareness of pharmacogenomics. As such, pharmacogenomics should have an integral part in modern undergraduate curricula in schools of medicine~~at~~ and pharmacy~~schools~~. Our findings suggest that younger pharmacists and those with graduate degrees, despite having less professional experience, are likely to have a better understanding of genetics and pharmacogenomics (**Fig. 6**). This could be because genetics and molecular biology have only recently been added to the undergraduate pharmacy curriculum. These findings ~~also~~ concur with ~~those findings~~ of a recent survey of 284 pharmacists practicing in the province of Québec (Canada) with more than 95% of respondents~~s~~ willing to recommend pharmacogenomic testing, and 97% of respondents~~s~~ indicating that they would like to undertake continuing education related to pharmacogenomics [15]. This latter proportion was much higher than in our own survey (58% for pharmacists and 78% for physicians, respectively).

It should be noted that, in our own study, 51 pharmacists who were approached refused to participate in the survey (37%); 14 of these were unaware of the term *pharmacogenomics*. It is also noteworthy that 6 of the pharmacists [GEORGE: who declined to take part?] stated that this survey was insulting, maintaining that pharmacists should not participate in this type of survey, while 12 pharmacists gave other excuses for not participating. Taken together, these findings indicate that although most pharmacists have a positive view ~~of~~ pharmacogenomics and are willing to increase their knowledge of pharmacogenomics with a view to gradually integrating it into their clinical practice, good

education will be required if the integration of pharmacogenomics into patient care is to be optimized.

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**Table 1**

Survey sample composition and demographic elements, as revealed by Section I of the questionnaires (see **Supplementary Information**). <sup>a</sup>: Questionnaires were given only to adult respondents with a minimum age of 18-years. <sup>b</sup>: Only 1 respondent indicated that they had studied in Italy. The remainder did not provide this information. <sup>c</sup>: Five respondents indicated that they had performed their post-graduate studies abroad, namely Italy , Germany and Sweden (1 respondent each), whereas 2 did not indicate the country in which they performed their post-graduate studies.

	Pharmacists (n)	Pharmacists (%)	Physicians (n)	Physicians (%)
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<b>Sample size</b>	86	100	208	100
<b>Age (years)</b>				
<35 <sup>a</sup>	31	36.1	72	34.6
35-60	50	58.1	126	60.6
>60	5	5.8	10	4.8
<b>Gender</b>				
Male	48	55.8	120	57.7
Female	38	44.2	88	42.2
<b>Place of study</b>				
Greece	55	63.9	136	65.4
Abroad	31	36.1 <sup>b</sup>	72	34.6
<b>Graduate studies</b>				
Yes	12	13.9 <sup>c</sup>	80	38.5
No	74	86.1	128	61.5

## Figure legends

### Figure 1

**Main respondent group characteristics.** Depiction of the most common medical specialties of the physicians who responded to our survey (**A**) and of the pharmacists' professional experience (**B**).

### Figure 2

**Assessing the genetics knowledge of the respondent groups. A and B.** Graphical representation indicating the pharmacists' level of knowledge of genetics (Q16B) and pharmacogenomics and personalized medicine (Q17B), **C.** Comparative analysis of the self-assessed level of knowledge of physicians' (Q12A) and pharmacists' (Q17B) of pharmacogenomics and personalized medicine. **D.** Comparative analysis of undergraduate level of education of genetics and pharmacogenomics, based on the self-assessment of physicians (Q20A) and pharmacists (Q20B).

### Figure 3

**Evaluating pharmacists' opinions and attitudes with respect to pharmacogenomics.**

**A.** Graphical display of the pharmacists' attitudes to providing genetic analysis kits over the counter (Q22A), their awareness that the genetic analysis kits are considered a medical device (Q23B) and the recommendation for a pharmacogenomic test in certain drug labels (Q26B). **B.** Pharmacists' opinions regarding the contribution of pharmacogenomics

towards reducing the occurrence and the overall frequency and severity of adverse drug reactions (Q31B), healthcare costs (Q33B) and costs of developing new drugs (Q32B).

#### Figure 4

**Involvement with genetics, genetic testing and pharmacogenomics.** **A.** Level of involvement of physicians and pharmacists with pharmacogenomics in their daily practice. **B.** Graphical display indicating whether physicians (Q13A) and pharmacists (Q24B) have advised their patients and clients, respectively, to undergo genetic and/or pharmacogenomic testing and reciprocally, whether physicians' and pharmacists' clients (Q14A and Q25B, respectively) had requested them to undertake genetic and/or pharmacogenomic testing. **C.** Assessment [GEORGE: self-assessment?] ~~of~~ as to whether physicians and pharmacists can provide sufficient information or explain the results of pharmacogenomic tests (Q16A and Q27B, respectively).

#### Figure 5

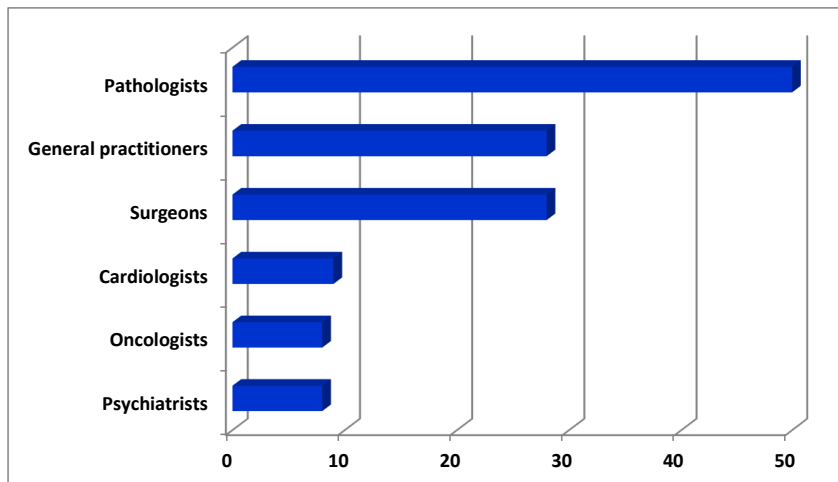
**Professional opinion on ethical, legal, societal and regulatory issues pertaining to personalized medicine.** **A.** Opinions ~~from~~ of physicians and pharmacists (Q19A and Q30B, respectively) as to whether an appropriate legal framework to cover genetic and pharmacogenomic testing exists in Greece. **B.** Opinions of physicians (Q17A) and pharmacists (Q28B) of direct-to-consumer genetic testing. **C.** Opinions of physicians (Q18A) and pharmacists (Q29B) regarding the reimbursement of expenses of pharmacogenomic testing by insurance companies. **D.** Opinions of physicians (Q11A) and

pharmacists (Q19B) in relation to whether the results of pharmacogenomic testing would positively affect patients' medical care.

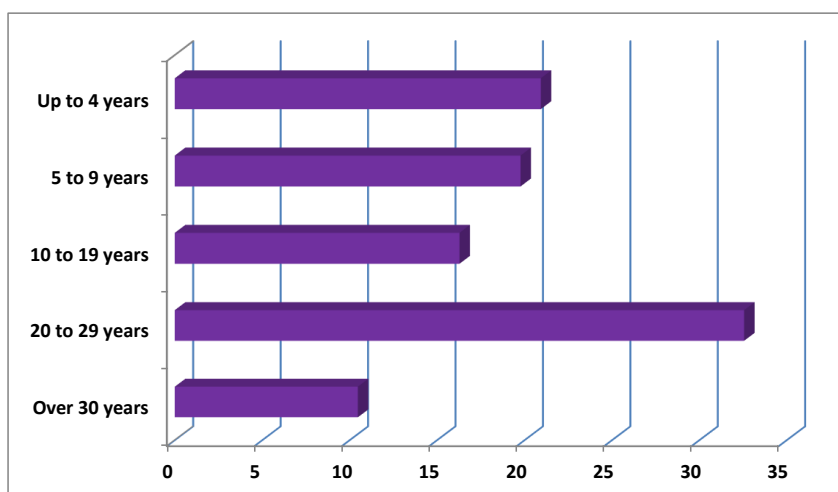
**Figure 6**

**Assessing genetics knowledge in pharmacists.** Graphical display of the correct answers of pharmacists in various questions pertaining to basic genetics (Q8B-Q11B) and pharmacogenomics knowledge (Q12B-Q15B).

**A**



**B**



**Figure 1**

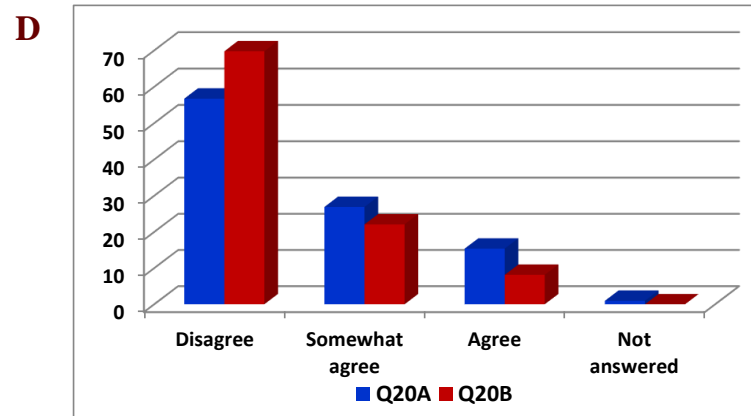
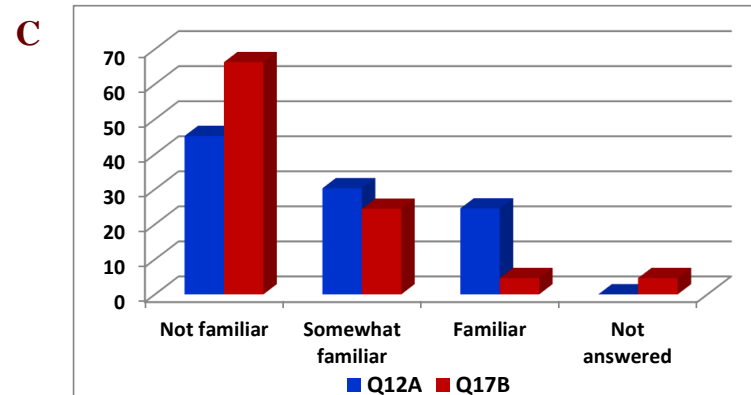
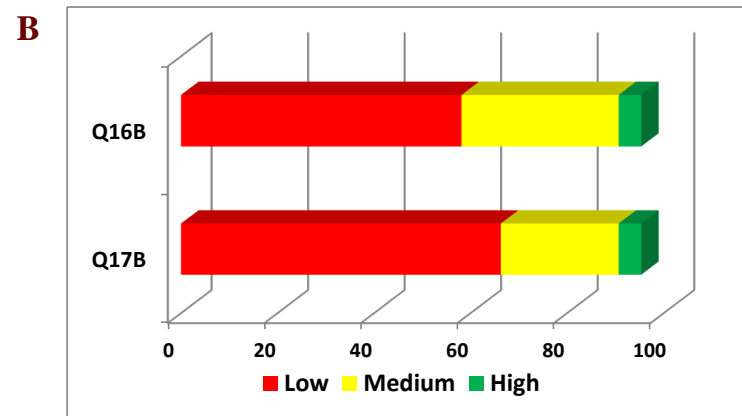
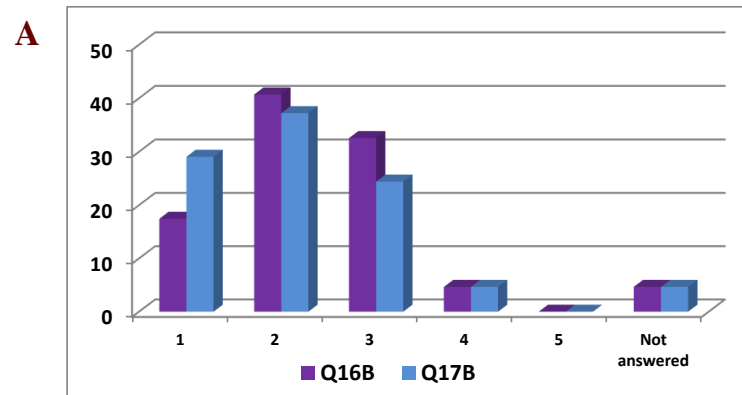
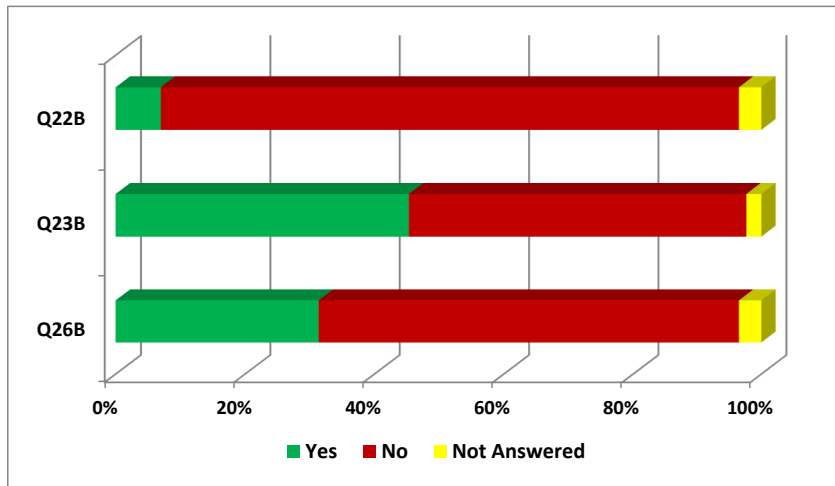
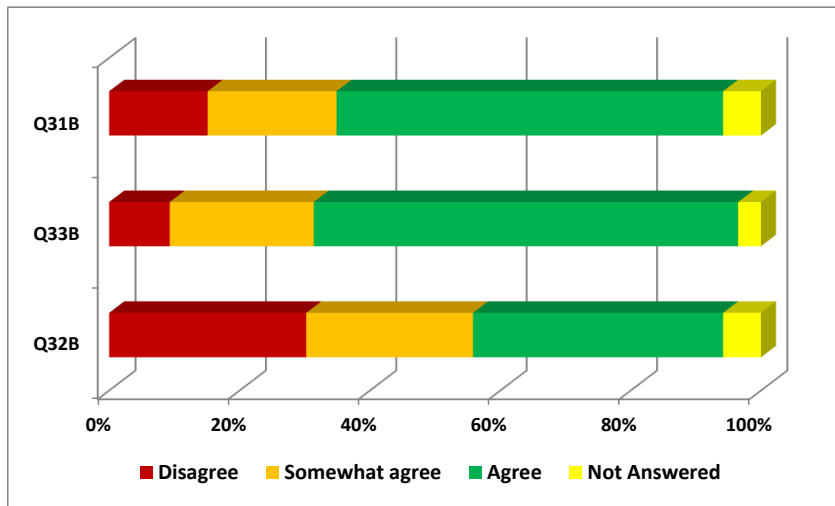


Figure 2

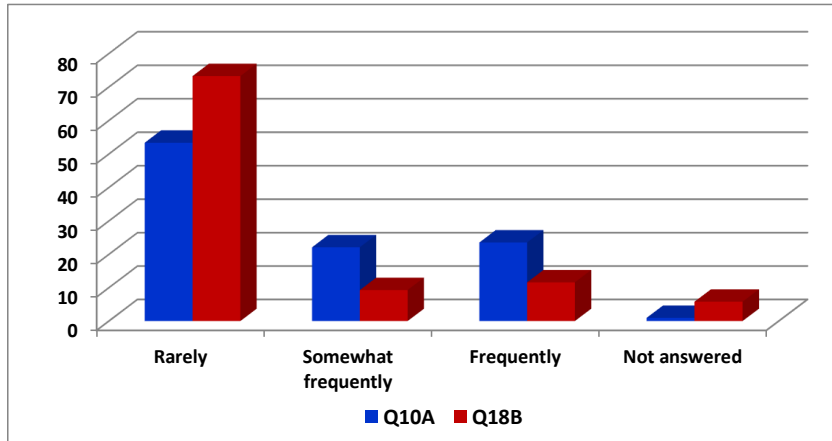
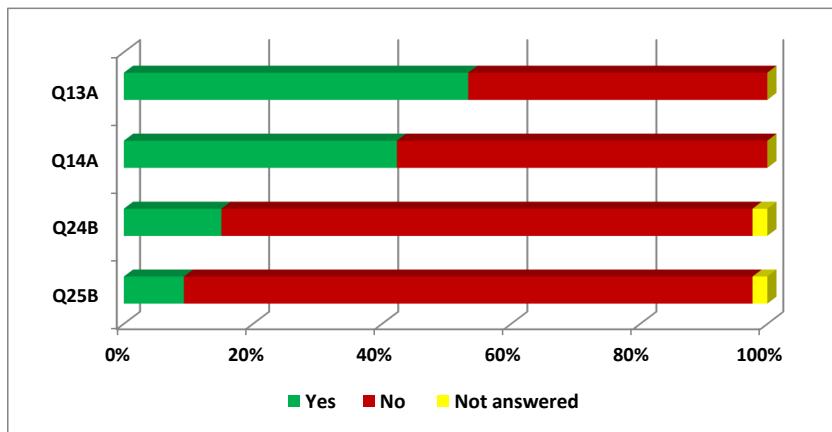
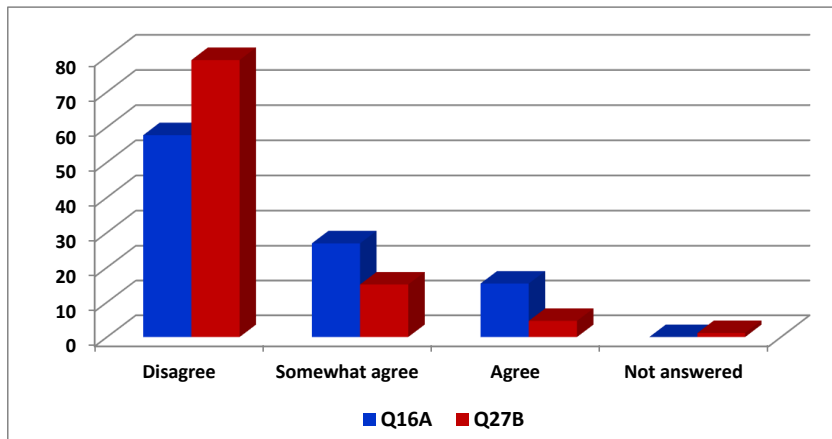
**A**



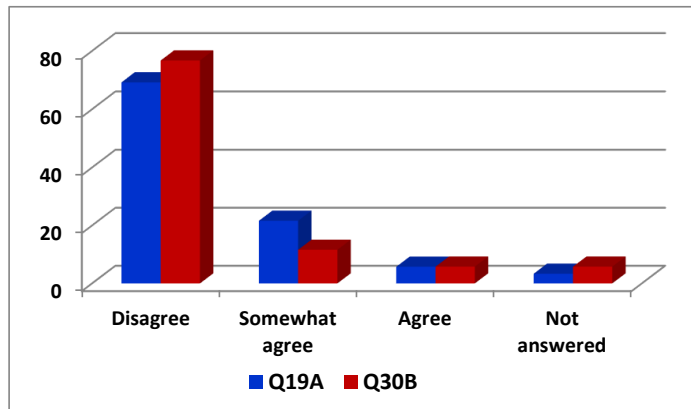
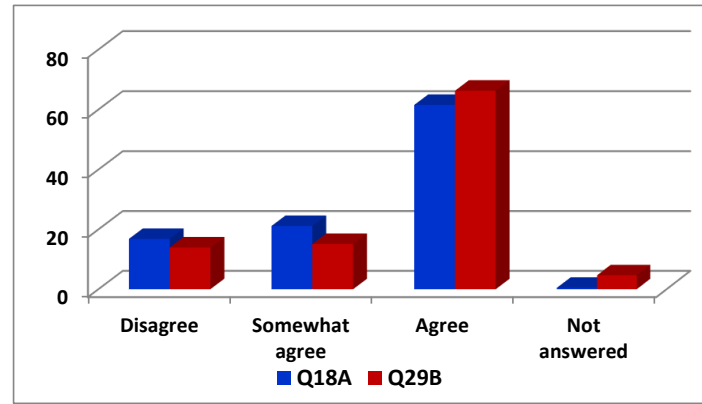
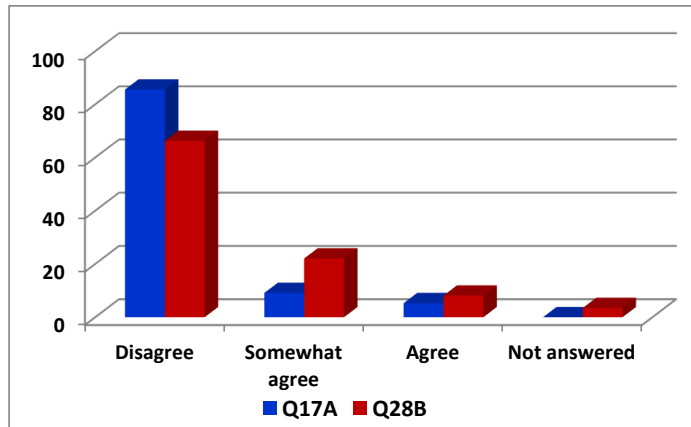
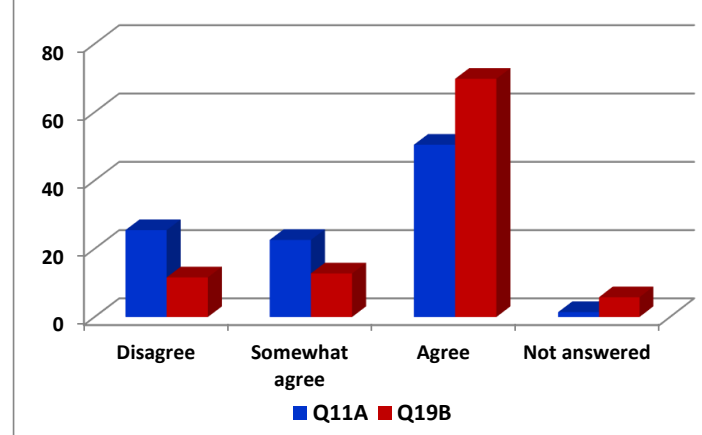
**B**



**Figure 3**

**A****B****C****Figure 4**



**A****C****B****D****Figure 5**

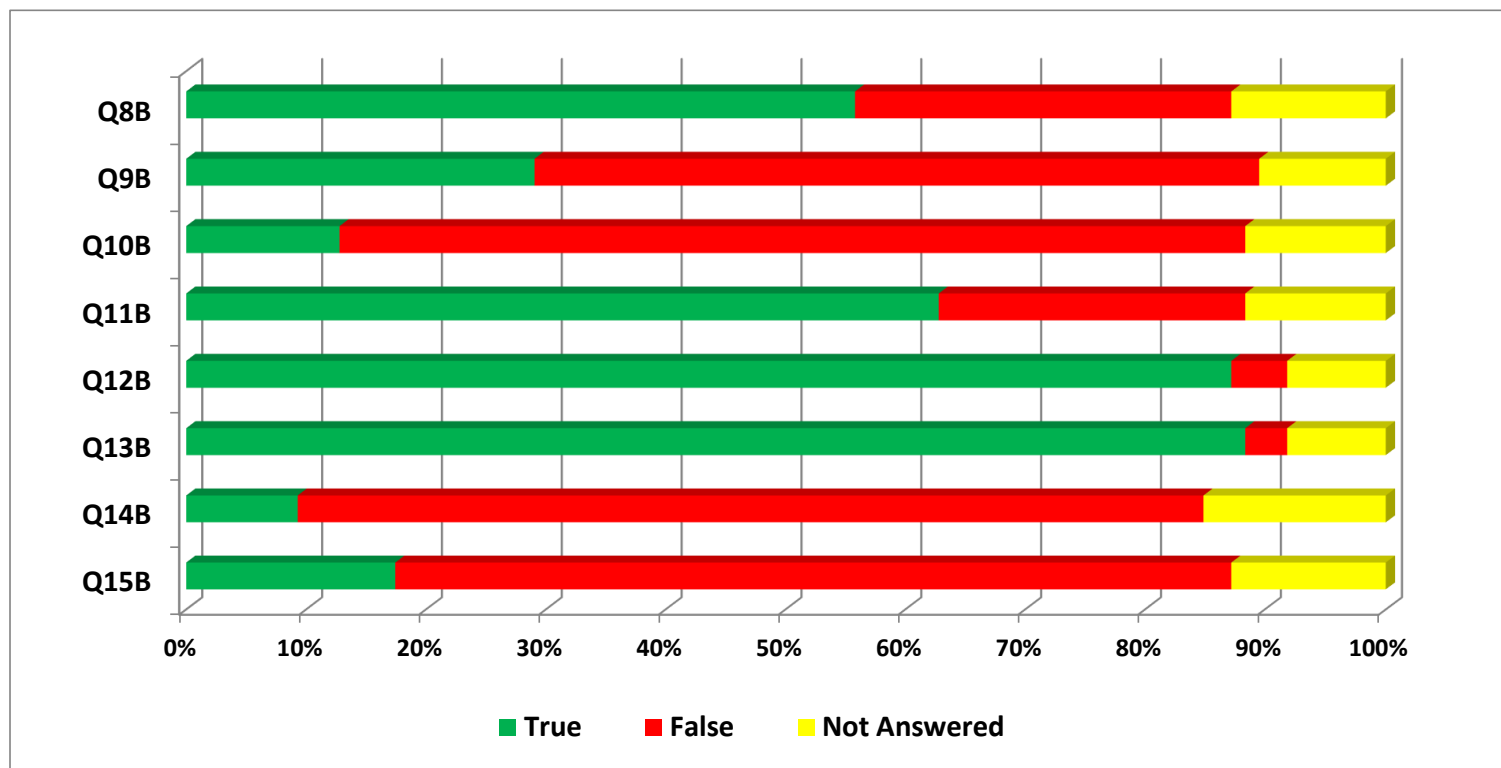


Figure 6