Advancing Global Precision Medicine: An Overview of Genomic Testing and Counseling Services in Malaysia

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Abstract

Precision medicine, genomic and diagnostic services are no longer limited to developed countries. This broadening in geography of biomarker applications and omics diagnostics also demands empirical study of implementation, diagnostic testing, and counseling practices in the field. For example, the Malaysian population has large ethnic diversity and high prevalence of genetic disorders such as hemoglobinopathies and metabolic disorders. Increased morbidity and mortality from such diseases have a direct impact on society and health system sustainability and for this, decision-making becomes of utmost importance. We report here on our findings on the landscape of genomic testing and genetic counseling services in Malaysia. We first defined the framework of all Malaysian stakeholders that offer genomics services and next, we identified the related information gaps, as depicted through the service providers’ online websites. Our research framework revealed that there is a very diverse spectrum of genomics services in Malaysia, in which wet- and dry-laboratory services integrate. Moreover, we identify the current gaps and possible remedies to improve the quality of genomic and predictive analytics, not to mention considerations to ensure robust ethics and responsible innovation. To our knowledge, this is the first such study to be performed for a Southeast Asian country. Our genomics and precision medicine services mapping strategy presented in this study may serve as a model for field assessment at regional, national, and international levels as precision medicine is expanding globally and new governance challenges and opportunities continue to emerge for smart implementation science.

Keywords: precision medicine, public health genomics, Malaysia, genetic counseling, genetic testing

Introduction

Precision medicine and predictive analytics are no longer limited to developed countries. This broadening in geography and scope of applications for biomarkers and omics diagnostics also demands study of implementation, diagnostic testing, and counseling practices in the field. A case in point is Malaysia, a Southeast Asian country, consisting of two distinct areas: the Peninsular Malaysia and the north-west Borneo Island. In 2016, the population of Malaysia was estimated at 31.7 million people (Malaysia Department of Statistics, 2016).

Malaysia is a multiracial, multicultural, and multilingual country with diverse ethnic groups due to its strategic location. Indeed, the Peninsular Malaysia is a trade center between the East and the West. Malaysia comprises three major genetically distinct ethnic groups, namely Malay, Chinese, and Indian, as well as numerous indigenous populations, such as the Orang Asli, Sabahan, and Sarawakian. Each population is organized into subethnic groups, which further enriches the genetic makeup in Malaysia (Halim-Fikri et al., 2015). These groups exhibit great genetic diversity, sharing distinct features (Deng et al., 2014).

Considering that there are different genetic traits prevailing in the region, the Malaysian population exhibits a plethora of genetic disorders. Circulatory and respiratory system disorders and neoplasms are listed as the leading causes of death (Malaysia Ministry of Health, 2016), while hemoglobinopathies (Ahmad et al., 2013; George and Ann, 2016)
2010) and various metabolic disorders, such as type-2 diabetes (Abu Seman et al., 2013), pose significant public health issues. These diseases have high rates of morbidity and mortality (Howson et al., 2017) with a direct impact on Malaysian patients, society, and the healthcare system overall.

Recent advances of genomics technology and high-throughput sequencing have contributed to a better understanding of the genetic basis of inherited disorders and brought the prospect of prevention and tailor-made treatment closer to fruition (Hong and Oh, 2010). Globally, genetic services are still lacking standard operating procedures, when public and/or private providers of such services are considered, and thus, several legal, societal, and responsible innovation concerns and challenges often arise (Balmer et al., 2015; Burke et al., 2001; Gallagher et al., 2017; Guston, 2015; Lea and Williams, 2001; Lea et al., 2011; Mason et al., 2017). In Malaysia, there is a strong interest in the exploration of genetic diversity and the elucidation of genetic basis of diseases, which is reflected both in the expansion of knowledge through research work and the application of this knowledge in clinical practice.

To name a few, genome-wide association studies (Molineros et al., 2017; Sun et al., 2016), the establishment of databases that allow the storage and management of genetic and clinical data (Halim-Fikri et al., 2015; Hassan et al., 2016; Pulley et al., 2010) as well as the organization of conferences to raise awareness (Stückle, 2015) are among the endless efforts made so far to advance the integration of genomics into medicine in Malaysia. Since 2015, the University of Malaya is engaged in collaborative work with the Golden Helix Foundation (www.goldenhelix.org) to establish public health policies in the areas of pharmacogenomics and precision medicine. In addition, significant steps toward the implementation of precision medicine in clinical practice have been taken by public and/or private providers of genetic services. However, these steps are still at an early stage and for this, there is great potential for improvement, as far as the Malaysian public health genomics status is concerned.

To date, there are very few studies that address the landscape of the genomic testing services offered by private and public genetic laboratories on a country-specific basis, while this topic has never been addressed in any of the Southeast Asian countries. In this study, we aimed to provide a comprehensive outline of the genomic testing and genetic counseling services in Malaysia and propose further actions to empower their quality, after assessing their accessibility and reliability and the range of such services offered to customers, most of whom are patients.

Materials and Methods

Using Google, Google scholar, and Bing search engines, we first explored and identified all private and public Malaysian genetic testing laboratories that offer genetic services (counseling and testing) and share such information online. For this, a series of keywords have been used: “genetic/genomic testing AND Malaysia,” “genetic/genomic counseling AND Malaysia,” “omics AND Malaysia,” “pharmacogenetic/pharmacogenomic AND Malaysia,” and “public health genomics AND Malaysia.” Next, this information was updated and curated. Our strategy gave emphasis on the online information available per stakeholder, with a focus on the available dry- and wet-laboratory analyses they provide and their specifics, such as all related costs and timelines, sample storage and management, informed consent forms, accreditation, and privacy policies.

Results

Our research strategy and subsequent analyses identified a total of 20 Malaysian genetic testing laboratories, all located in Peninsular Malaysia, offering genomic services (including genomic testing and counseling). All laboratory names, website and related information are available upon request. Most stakeholders are private genetic laboratories (75%), while the remaining 25% are academic institutions or governmental agencies.

Genetic and genomic testing services

Our findings show that a variety of genomic services, namely genomic testing and genetic counseling, are taking place in Malaysia. Such services include paternity testing, family tree analysis, ancestry and prenatal testing, clinical tests, animal strain genetic testing, as well as lifestyle genomic tests (wellness and fitness) (Fig. 1). Interestingly enough, clinical and lifestyle (wellness and fitness) genomic tests are the most common genomic services pursued in Malaysia (40% of the genetic testing laboratories considered in this study).

Next, 35% of the Malaysian genetic testing laboratories offer prenatal testing services. We feel that this indicates a strong public health interest in early disease diagnosis and prevention. At the same time, the so-called lifestyle (wellness and fitness) genomic tests raise our awareness and responsible innovation concerns as the lifestyle-related genomic tests generally require further and robust evidentiary base. In contrast, various relationship/ancestry tests are only provided by very few genetic testing laboratories (15%). Only 3 out of the 20 genetic laboratories (15%) offer pharmacogenomic testing and a single private laboratory offers telomerase testing.

DNA sequencing services are also available in Malaysia (30% of genetic laboratories provide DNA sequencing services), followed by molecular microbiology analysis (25%) and genomic screening (25%). Several-omics and post-genomic biotechnology analyses, complementary to genetic/genomics, such as transcriptomics and proteomics, are provided by four laboratories, with one laboratory additionally providing metabolomic analyses. Yet, data and bioinformatics analysis do not play a fundamental role in Malaysia, with only four genetic laboratories offering such services (20%), three of which are private ventures. A limited number of genetic laboratories offer cytogenetic analyses (10%) or mitochondrial DNA analysis services (10%) (Fig. 2). Only one not-for-profit research institute maintains a Genomic Biobank and offers the respective services.

As far as the DNA sources used for genetic analysis are concerned, blood is the one most commonly used (86%), followed by buccal swabs (50%), tissue (43%), and saliva (43%). DNA isolation is also performed from semen and seminal fluids (29%), cigarette butts (21%), hair (21%), bones, and organs (21%). Items of everyday use, such as chewing gums, toothbrushes, tissues, and sanitary towels are also accepted by the service providers, especially for relationship, paternity, and infidelity tests (Fig. 3). The isolation
of DNA through such means raises several important ethical and possibly legal concerns over the right to privacy and consent of all parties involved.

We identified two genetic testing laboratories that offer several direct-to-consumer (DTC) testing services (paternity, relationship, and infidelity tests), with both of them offering "discreet delivering options." Statements such as "discreet testing services" and "discreet samples" are also included in the online material of other genetic testing laboratories, indicating a possible breach of privacy and thus, calls for...
further ethical and policy reflection over more rigorous regulation of such applications of diagnostic testing. The potential benefits and limitations of DTC genetic testing services is the subject of ongoing international debate in many countries and health systems (Burton, 2015; Covolo et al., 2015; Hamilton et al., 2017; Kalokairinou et al., 2017; Kechagia et al., 2014; Patrinos et al., 2013).

Genetic counseling services

Genetic counseling services appear to be extremely limited, since most genetic testing laboratories offer solely “DNA Test Reports” that provide the test results accompanied by ways to interpret them. Some paternity tests include conclusive results that “confirm” or “exclude” the alleged father. Only one private molecular diagnostics company offers complete genetic counseling support for physicians and patients. Overall, the lack of genetic counseling services raises critical concerns on the ability of consumers to understand test results toward decision-making. Furthermore, according to the available online information, it was not possible to clarify if genetic counseling services are provided by independent counselors devoid of conflict of interest with the stakeholders/genetic testing laboratories in question.

Regulatory framework for genomic testing and genetic counseling

Surprisingly, in several cases, information provided online is often incomplete. Indicatively, six genetic testing laboratories do not have any online information regarding the main DNA sources used for their services. The same is true for the type of accreditation and service costs, since only half of the genetic testing laboratories provide such information online. In particular, nine genetic testing laboratories indicate that they hold an ISO/IEC 17025, ISO 9001, ISO 15189, and AABB (American Association of Blood Banks; since 2005 it is only known by this acronym) accreditation online. There is only one public institution that is ASCLD/LAB (American Society of Crime Laboratory Directors/Laboratory Accreditation Board) accredited for forensic analysis in Malaysia.

Less than half of the genetic testing laboratories report online all related information about the cost of their services. The cost of paternity testing for two samples (child and father) is in the range of MYR 990 to MYR 1500 for personal use. For legal purposes, paternity tests cost MYR 1590–2230, depending on the genetic testing laboratory. Total costs of the genetic services provided are summarized in Table 1. The turnaround time for data generation ranges from 4 to 28 working days, depending on the type of genetic service, even though some “express” options are available by some genetic testing laboratories, based on the very few information we found online.

Ethical concerns with genetic and genomic services

Similarly, information is also scarce in the case of the responsible innovation and legal issues that accompany genomics services. Most genetic testing laboratories provide extremely limited information about DNA isolation and informed consents, as well as sample storage and privacy policy issues. Only two genetic testing laboratories (10%)...
Table 1. Genetic Services’ Costs in Malaysia

<table>
<thead>
<tr>
<th>Genetic testing services</th>
<th>Malaysian currency MYR*</th>
<th>EURO equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGS—IVF</td>
<td>35,000–40,000</td>
<td>6929–7919</td>
</tr>
<tr>
<td>“Discreet test”</td>
<td>400</td>
<td>79</td>
</tr>
<tr>
<td>Immigration test</td>
<td>2490–2980</td>
<td>493–590</td>
</tr>
<tr>
<td>Semen detection test</td>
<td>1450</td>
<td>287</td>
</tr>
<tr>
<td>Infidelity DNA test</td>
<td>&gt;2200</td>
<td>436</td>
</tr>
<tr>
<td>DNA sequencing services</td>
<td>20–25**</td>
<td>4.0–5.0</td>
</tr>
<tr>
<td>Paternity test</td>
<td>990–5300***</td>
<td>196–1049</td>
</tr>
</tbody>
</table>

*1 MYR =0.197984 EUR (current as of September 2017—please note that conversion rates might change over time).
**Per reaction.
***MYR 990–1500: Nonlegal paternity test; MYR 1590–2230: Legal paternity test; 5300 MYR: Prenatal paternity test; MYR 200: Extra samples submitted for analysis.
IVF, in vitro fertilization; PGS, preimplantation genetic screening.

Discussion

Our ability to analyze our genome and interpret the analysis output in a fast, cost-effective manner led to a rapid expansion in the number and quality of genomics services available worldwide. Today, genetic testing services are widely provided for research, prevention, diagnostic, and therapeutic purposes. In most countries, despite the increased number of supply and demand for such services, the context in which genomics services are provided is not clearly structured, suffering from major legislation gaps and being incapable to fully protect the patients and the general public from malicious practices (Bunnik et al., 2011; Sagia et al., 2011).

In Malaysia, the first genetic testing services were provided in 1994 by clinical geneticist Dr. Meow-Keong Thong, who has been trained abroad and returned to Malaysia for his secondary qualification (Lee and Thong, 2013). Since then, a variety of genetic testing services have been provided to patients (clinical tests) and healthy individuals, who want to maintain or improve their quality of life (health and fitness tests). Increasing funding toward the development and implementation of genomics services as well as the establishment of a regulatory framework resulted in a flourishing market in the field of genomics services. Notably, the Malaysian Medical Council (MMC) Guideline 010/2006 (Malaysian Medical Council, 2016) on medical genetics and genetic services provides guidance to healthcare professionals on genetic medical services and genetic testing (Lee and Thong, 2013).

However, there is still no formal recognition of the role of genetic counselors in the country and there are no legal requirements for the provision of genetic counseling services. In particular, there are few genetic counselors, who often lack the knowledge, expertise, and skills to properly inform interested parties, that is patients and their families, about the clinical phenotype and prognosis of a disease, the risks of disease recurrence, and the options for disease prevention and treatment (Lee and Thong, 2013; Ngim et al., 2013). This demonstrates the need for frequent assessment of practices and attitudes of Malaysian healthcare professionals and biomedical scientists providing independent genetic counseling and the existence of an appropriate and continuously updated real-time policy and legal frameworks for genetic counseling. Indeed, apart from the aforementioned MMC Guideline 010/2006, no other legislation, guideline, or white paper exists.

Such gaps led stakeholders involved in genomics services to take action, almost individually, resulting in greatly heterogeneous decisions and actions. A typical example is the Universiti Sains Malaysia, which has recently created internal guidelines and an updated consent model for genomics services in the context of genomics research (Sasongko et al., 2015). In addition, Malaysia is a multireligious society that consists of people seeking guidance from their religious leaders. In 2016, Olesen et al. (2016a, 2016b) demonstrated that religious beliefs led to different views on ethical issues related to the use of preimplantation genetic diagnosis and underlined the need to include the views of religious scholars, when it comes to new medical technologies in Malaysia. Thus, awareness should be raised for the existence of a common ethical framework for genomics services across the Malaysian population and stakeholders.

In this article, we explored the existing private and public genetic testing laboratories that offer genetic testing services in Malaysia and share all related information online. This was the first step of a long-term project in Public Health Genomics, in which the Golden Helix Foundation and the University of Malaya jointly participated, as part of their collaboration agreement. To our knowledge, this is the first such study to be performed for a Southeast Asian country, while very few similar studies have been performed for other countries and/or healthcare systems (Kechagia et al., 2014; Sagia et al., 2011).

Our findings confirm that a variety of genetic services are provided by public and private genetic testing laboratories, reflecting high customer demand, especially when clinical tests are considered in the light of genetic disease diagnosis and management (Demkow and Wolaniczyc, 2017). At the same time, there is a strong public interest in genetic tests that relate to quality of life, if health and fitness tests are taken into account (Fig. 1). Notably, such an interest holds despite the fact that current scientific knowledge is extremely limited and further research is necessary (Pavlidis et al., 2015a, 2015b; Pavlidis et al., 2016).

Interestingly, Malaysian genetic testing laboratories provide very few (if any) pharmacogenomic tests and services. We feel that health professionals and the general public are not fully aware of the benefits of pharmacogenomic testing in clinical decision-making, patient stratification, and even, preemptive pharmacogenomics (Stückle, 2015). This denotes a significant gap in genomics education of the healthcare professionals and lack of genetic awareness of the general public, also taking into consideration their significant interest in genomics.
for nutrigenomic testing and genetic testing for athletic performance, which currently lack sufficient scientific evidence for routine testing in our view (Kampourakis et al., 2014; Pavlidis et al., 2015a, 2015b).

We noticed that online marketing claims of some genetic testing laboratories often promote the benefits of testing in a genetically deterministic manner (Phillips, 2016). Such claims lead consumers to believe that the information they are acquiring through “genetic” testing will reliably serve decision-making. Yet, many of the genetic testing and analysis services offered should only be used as guidance for further testing or lifestyle changes and not as definitive diagnostic tools. Furthermore, genetic counseling services by qualified and independent genetic counselors and clinical geneticists need to be provided to ensure optimum and ethical decision-making.

Especially, the so-called DTC paternity and relationship (fidelity) tests in Malaysia call for further ethical reflection and the creation of credible and actionable oversight mechanisms and regulatory frameworks. Well-established concerns, such as misinterpretation of results, lack of consent of all parties involved, and reliability, have been thoroughly discussed so far (Gallagher et al., 2017; Lee and Thong, 2013; Patrinos et al., 2013; Phillips, 2016). The online marketing of “infidelity” or “discreet tests,” along with instructions on “everyday items” that can be used for DNA testing, underscores the aforementioned concerns. Regulation and legislation gaps result in reciprocal information gaps and several responsible innovation issues need to be addressed (Balmer et al., 2015; Guston, 2015; Kechagia et al., 2014; Kricka et al., 2011; Sagia et al., 2011).

During our survey, we identified several information gaps in the websites of the genetic testing laboratories we analyzed, especially regarding responsible innovation and legal issues that accompany genetic testing, such as sample collection, informed consent, privacy policies, data anonymity, and data management and storage, and the same was true for accreditation and data/services quality. The accreditation of a laboratory service is the official recognition of its technical competence and credibility, and as such, this information should be readily available on their website to properly inform the patient/interested customer. No doubt, there is an urgent need to bridge such gaps and rectify the situation (Mertens, 2006; Pulst, 2000).

Our study has a number of limitations. First, given the small number of information in a few cases, for example, for the main DNA sources, accreditation, and costs, percentages reported in this study (%) may be either underestimated or overestimated. The same may be true for the total costs of genetic testing services and the turnaround times. As our approach largely depends on search engines and inspection of the providers’ websites, data accuracy relies on their being accurately available online.

Conclusions and Future Perspectives

In this article, we explored genomic testing and genetic counseling services in Malaysia by defining first the framework of all Malaysian genetic testing laboratories, both private and public, which offer such services, and next, identifying the related information gaps as depicted through their websites. Our evaluation strategy revealed a variety of genomics services in Malaysia, which smoothly integrate wet- and dry-laboratory services. Notwithstanding, significant information gaps regarding laboratory accreditation and responsible innovation predominate.

In the context of our strategy and related findings, we feel that for all Malaysian genetic testing laboratories offering genomic testing and genetic counseling services, it is imperative to ensure information clarity and credibility, especially when it comes to their websites. This is a great opportunity for scientists, policy makers, health professionals, and other stakeholders in Malaysia to collaborate and educate each other toward the ethical and cost-effective implementation of genetic testing and counseling.

Aiming for global innovation assessment or governance, as well as smart implementation science, this strategy may also serve as a model for field assessment at regional, national, and international levels. Indeed, such need for new ideas, critical analyses, and governance mechanisms in global science becomes evident, especially when bioeconomy is considered (Birch, 2017).

Several scholars and various views are currently present, each understanding the value in bioeconomy in a distinct way, yet all resulting in understanding this exact value as social practice (Muniesa, 2011), being the net outcome of political-economic and technoscientific constitutive elements (Birch, 2017). Three key political-economic processes are of interest, namely financialization, capitalization, and assetization (Birch, 2017). Birch et al. (2016) calls for a postneoliberal science and innovation, which will be based on the principles of openness and collaboration coupled to fresh social scientific analyses. Again, open science and innovation are not an unalloyed good.

Overall, this study is the first to provide a comprehensive overview of the status of genetic testing services in Malaysia and the various legal and ethical issues that arise from these services. This study can not only serve as the basis for rectifying these discrepancies and fill in these gaps identified herein but can also be expanded to address the interplay between the various genetic testing laboratories and the other stakeholders in the field of Genomic Medicine, such as the Ministry of Health, the payers, physicians, and the general public, National Medicines Authority in Malaysia, and others. Last, this study can be used as a model for evaluation and replication in neighboring countries to provide a comparative overview of the status of genetic testing services in Southeast Asia.

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Abbreviations Used
DTC = direct-to-consumer
IVF = in vitro fertilization
MMC = Malaysian Medical Council
PGS = preimplantation genetic screening