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ORIGINAL ARTICLE

Preparing genomic revolution: Attitudes, clinical practice, and training needs in delivering genetic counseling in primary care in Hong Kong and Shenzhen, China

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ABSTRACT

Purpose: The aim was to evaluate knowledge, attitudes, and clinical practice concerning medical genetics, genetic testing, and counseling among primary care physicians (PCPs) in Hong Kong and Shenzhen, China.

Methods: The University of Hong Kong (HKU), HKU-Shenzhen Hospital, and Shenzhen Health Capacity Building and Continuing Education Center invited PCPs from Hong Kong and Shenzhen to participate in an online survey.

Results: The survey was completed by 151 PCPs and 258 PCPs from Hong Kong and Shenzhen, respectively. The majority agreed it was important to keep current with genetics (91%) and that personalized medicine was the future of healthcare (86%), yet only 10% reported that they had postgraduate training in genomic medicine. Seventeen percent of Hong Kong and 40% of Shenzhen's PCPs encountered genetic-related cases in the past 6 months, and they identified insufficient knowledge, few training opportunities, and self-rated low confidence in their skillsets as main barriers.

Conclusions: Our survey shows that Hong Kong and Shenzhen's PCPs are not yet fully utilizing potential benefits of genomic medicine in their clinical practice, which could be addressed with a combination of easily accessible educational resources, clear referral pathways and guidelines on genetic diseases, and cross-specialty collaboration between healthcare systems and professional bodies.

KEYWORDS

China, education, genetic testing, genomics, primary healthcare

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1 | INTRODUCTION

By incorporating patients' unique genetic information into healthcare, the medical application of genetic testing has been expanding from disease diagnosis to personalizing disease risk prediction and profiling of individuals' responses to drugs. Common and routine genetic testing has also moved from chromosome or targeted single gene testing to genomics testing as it has become more affordable and accessible to the general public. Nowadays, individuals can order a "direct-to-consumer" genetic test to learn about their genetic makeup without going through a physician. Simultaneously, genetic testing comes with many new uncertainties, especially in the realm of predictive genetic testing, which could be confusing to both patients and doctors. Gradually, primary care physicians (PCPs) could likely be the first port of contact (Darst et al., 2014; Kaufman et al., 2012; Wouden et al., 2016). Studies have shown that at least 10% of patients seen in primary care have a condition in which genetics has an influence (Paneque et al., 2016).

Since the 1990 s, PCPs were anticipating the growth of genomic medicine in their practice (Emery et al., 1999). Primary roles of PCPs were identified which included recognizing at-risk patients, making appropriate referrals, supporting patients, and coordinating surveillance and management. Subsequent studies over the past two decades have consistently shown that there is a lack of knowledge and confidence in PCPs providing care in genomic medicine (Carroll et al., 2019; Chambers & Axell-House, 2015). Whether there is inadequate physician communication and knowledge, or when a PCP is unprepared to engage in pre- and posttest genetic counseling, it can lead to poor medical care such as ordering unnecessary and expensive testing, leaving anxious patients perplexed with the testing result and its implications, and falsely reassuring patients with undetected genetic risks. The slow development of incorporating genomic medicine in primary care may be attributed by the lack of resources and awareness of genetic services and system issues such as the lack of doctor–patient interaction time (Carroll et al., 2019; Chambers & Axell-House, 2015; Harding et al., 2019).

In response to the needs of PCPs, professional bodies around the globe (e.g., Royal College of General Practitioners, Royal Australian College of General Practitioners, and American Academy of Family Physicians) have incorporated medical genetics education into their curriculum statements (RACGP et al., 2018; Recommended Curriculum; The RCGP Curriculum, 2016). Furthermore, educational and resource toolkits, continuous medical education, and continuous professional development training have been provided to equip their members with up-to-date knowledge and skills in this domain to improve patient care in the genomic era. At the University of Hong Kong (HKU), one of the two medical schools in Hong Kong, there is approximately 15 hr of didactic teaching in genetics along with opportunities for clinical training during clerkships. At the postgraduate level, there are short didactic courses and seminars available locally for those who are interested in genetics. However, genetic training is not mentioned as an objective in basic or higher training for family physicians. In contrast, in Mainland China, medical curricula offers about 36 hr of training in genetics mostly through didactic form. Their general practice residency training was only started in 2000 (Chen et al., 2007), and it was not until the end of 2013 that the Chinese Council released "Guidelines on the establishment of a standardized training system for residents," but requirements in genetics are still absent in this guideline (Sun et al., 2019). In both Hong Kong and Shenzhen, there is still a larger focus of training on specialists needs and little on primary care especially with the lack of access of in-person clinical training for PCPs.

Following the 2017 policy address, the Hong Kong government has recognized the need of developing and facilitating genomic medicine in Hong Kong. Alongside with the launching of the Hong Kong Genome Project (HKGP), the 2020 report from the Steering Committee on Genomic Medicine has identified and acknowledged the need of enhancing genetic and genomic literacy in healthcare professionals as genomics are diffusing into different clinical settings (Strategic Development of Genomic Medicine in Hong Kong, 2020). To date, most published studies on PCPs' knowledge, attitude, and confidence in genomic medicine were performed in non-Asian countries. No prior study has been performed in Hong Kong or Mainland China. This study aimed to assess the knowledge, attitude, confidence, and clinical practice of PCPs in delivering genomic medicine and identify their training needs for better formulization and development of educational plans and resources.

2 | MATERIALS AND METHODS

2.1 | Study sample

Working in collaboration with the Department of Family Medicine and Primary Care (FMPC) and Department of Paediatrics and Adolescent Medicine at HKU, FMPC of the University of Hong Kong-Shenzhen Hospital (HKU-SZH), and Shenzhen Health Capacity Building and Continuing Education Center, they invited PCPs from Hong Kong and Shenzhen to participate in an online survey. Despite their geographical proximity, the primary healthcare system and its development differ greatly in Hong Kong and Mainland China. Hong Kong operates on a dual-track healthcare system whereby the public system is complemented by a private sector (estimated to account for 70% of all primary care) which offers those who are willing to pay for access to more

flexible hours and range of services at patients' own expense (Strategic Review on Healthcare Manpower Planning & Professional Development, 2020). In contrast, the majority of PCPs in mainland China are employed by the government providing patient care in community health centers (CHCs). With the 2009 healthcare reform, access to and affordability of primary care have substantially improved through increased funding, universal health insurance coverage, the basic public health service program, and an essential drug system (Li et al., 2017). Currently, there are 692 CHCs in Shenzhen area employing around 4000 PCPs and supporting a catchment area of 12.5 million people ("深圳每个社区都有社康", 2019).

In Hong Kong, about 2000 active members of Hong Kong College of Family Physicians and PCP teachers from FMPC, HKU, were invited to participate. In Shenzhen, 700 PCPs from 100 randomly selected CHCs were invited to participate. In Hong Kong, the survey was conducted in English via a survey platform, Qualtrics XM, between July and August 2020. In Shenzhen, the survey was translated into simplified Chinese and was conducted from January 2020 to August 2020 via a survey platform, Survey Star, by Shenzhen Health Capacity Building and Continuing Education Center. Inclusion criteria were PCPs that were fully qualified and currently practicing in their localities. Participation of the survey was entirely voluntary. Before administering the survey, an introductory explanation stating the purpose of the survey was provided, and online consent was obtained.

Measurement instruments – The survey questionnaire consisted of five domains:

1. Demographic data;
2. Knowledge of common genetic diseases and understanding of genetic disease in their clinical practice;
3. Attitude toward genetic diseases, ethical issues with genetic testing, and confidence in managing patients with genetic-related issues;
4. Clinical experience and practice in managing patients with genetic-related issues; and
5. Training needs in genomic medicine and genetic counseling.

Majority of the questions in the two surveys were identical to enable comparison; however, a few questions were adapted to local practice. The confidence scale was adapted from Carroll et al., (2009). The respondents were asked to rate their confidence level (in a scale of 1 to 5: 5 = very confident; 3 = neutral; 1 = not confident at all) in 10 skillsets in genomic medicine. The knowledge test consists of seven questions related to genomic medicine knowledge. The final version took approximately 10 min to complete.

Baseline demographic data were summarized by descriptive statistics. *Chi*-square analyses were conducted to look for associations between demographic variables and outcomes. Outcomes included PCP's attitudes, PCP' understanding of genetic diseases, and training needs in genetic and related areas. Univariate linear regression analysis was performed to identify correlations between different variables and PCP's confidence score in the 10 skillsets in genomic medicine. Variables with p-value less than 0.1 were entered into the multiple regression. All tests for significance were two-sided and considered significant if they reached the 95% significance level. Data were analyzed using Statistical Package for the Social Sciences (SPSS Inc.).

3 | RESULTS

The survey was completed by 151 Hong Kong PCPs and 258 Shenzhen PCPs with respective response rates of 8% (151/2000) and 37% (258/700). Table 1 shows the participants' demographics and knowledge test results. Hong Kong's PCPs were predominately male (67%), while Shenzhen's PCPs were a balanced mix. Sixty percent of Hong Kong's PCPs graduated before 2000 compared with 27% of Shenzhen's. In terms of service organizations, about half (49%) of Hong Kong's PCPs worked in the public sector, whereas the majority (98%) of Shenzhen's worked in the public sector in CHC or government hospitals. No participant got all questions in the knowledge tests correct with the average scores of 3.01 and 2.95 (out of 7) for Hong Kong and Shenzhen's PCPs, respectively.

PCPs' attitude toward various aspects in genomic medicine is summarized in Table 2. The majority of PCPs agreed that it was important to keep up to date with the latest information on genetic disorders (91%) and that personalized medicine is the future of healthcare (86%). Yet, they perceived ethical controversies associated with genetic testing (68%) and insufficient time during clinical consultation to discuss genetic issues (55%) as potential barriers. The overall responses to the statements "over-testing in genetic testing" and "genomic medicine is ready for clinical practice" were mixed with no clear consensus, reflecting a wide range of opinions and uncertainties among the PCPs on this topic. In response to "there are ethical controversies with genetic testing," a higher percentage of Shenzhen's PCPs (26%) chose "not sure" compared with their Hong Kong counterparts (6%).

PCP's opinion on the usefulness of genetic testing on different conditions and their clinical practice related to genomic medicine are summarized in Table 3. About 80% of PCPs felt that breast, ovarian and colorectal cancers and congenital anomalies were conditions worth performing genetic testing. The largest discrepancy was the opinion toward the usefulness of genetic testing for adverse drug reaction where 63% of Hong Kong's PCPs felt adverse drug reaction was worth

TABLE 1 Demographics of PCPs and the knowledge test results

Characteristics	Hong Kong ($n = 151$) Count (%)	Shenzhen ($n = 258$) Count (%)
Gender		
Male	103 (66.88)	113 (43.80)
Female	48 (33.12)	145 (56.20)
Year of graduation		
Before 2000	92 (60.13)	108 (41.86)
2000–2010	53 (34.64)	80 (31.01)
Post−2010	8 (5.23)	70 (27.13)
Undergraduate genomic medicine training		
Yes	61 (39.61)	67 (25.97)
No	93 (60.39)	191 (74.03)
Postgraduate genomic medicine training		
Yes	14 (9.09)	24 (9.30)
No	140 (90.91)	234 (90.70)
Service organization		
Private clinic/hospital	77 (51.00)	5 (1.94)
Government clinic (Hong Kong)/ community health center (Shenzhen)	42 (27.81)	227 (87.98)
Government hospitals	18 (11.92)	26 (10.07)
Others (Department of Health, University, NGO)	14 (9.28)	–
Knowledge test results[a]		
All correct	0 (–)	0 (–)
Mostly correct	16 (11.03)	13 (5.04)
Sometimes correct	40 (27.59)	150 (58.14)
Occasionally correct	61 (42.07)	88 (34.01)
All wrong	28 (19.31)	7 (2.71)
Average no. correct answers out of 7 questions	3.01	2.95

[a]There are seven multiple-choice questions, of which five or more are mostly correct, three to four questions are sometimes correct and one to two questions are occasionally correct.

genetic testing compared with 44% of Shenzhen's PCPs. However, 78% of PCPs (68% Hong Kong; 84% Shenzhen) were unaware of the referral pathway for patients with suspected and confirmed genetic disorders. Seventeen percent of Hong Kong and 40% of Shenzhen PCPs had encountered patient cases related to genomic medicine in the 6 months prior to the survey.

In terms of self-rated confidence score in 10 skillsets in genomic medicine, Shenzhen's PCPs reported a significantly higher mean confidence score of 3.36 (SD 1.03) compared with that of 2.30 (SD 1.00) from Hong Kong (Table 4). Among the 10 skillsets, Hong Kong's PCPs were most confident in "obtaining information about genetic disorders from family history" (confidence score of 2.93 [SD 0.96] of 5) and least confident in deciding which "genetic testing should be done for suspected genetic disorders" (confidence score of 1.80 [SD 0.88] of 5). In comparison, PCPs from Shenzhen were most confident in referring the patient to "a relevant specialist for suspected genetic disorders" (confidence score of 3.65 [SD 0.93] of 5) and least confident in "explaining to patients on genetic testing results" (score 3.16 [SD 1.10] out of 5) and "on advising patients whether they should get a genetic test" (score 3.17 [SD 1.08] out of 5).

In both Shenzhen and Hong Kong, equal proportion of PCPs in their localities indicated that they had received training in genomic medicine at both the undergraduate (~60%) and postgraduate levels (~9%). Table 4 also shows PCPs' preference for genetics and related areas they would want more training in. For prenatal and pediatrics genetic disorders, the training demand was significantly higher in Shenzhen's PCPs (80.62%) compared with that of Hong Kong's (23.40%). For adverse drug reactions caused by drug-related genes, the training demand was significantly higher in Hong Kong's PCPs (55.32%) compared with that of Shenzhen's (12.2%). For common polygenic diseases and single-gene disorders, the training demands were similar among Hong Kong and Shenzhen's PCPs ($p > 0.05$).

Regarding associations between PCPs' characteristics and overall confidence score in genomic medicine (Table 5), Hong Kong's PCPs, who have had more clinical experiences (0.431 [−0.001, 0.864]) (i.e., graduation year before year 2000) and received undergraduate (0.391 [0.161, 0.621]) and postgraduate genomic medicine training(0.612 [0.223, 1.000]), felt they had sufficient time during clinical consultation to discuss genetic issues with patients(0.328 [0.011, 0.646]) and believed there were ethical controversies with genetic testing (0.350 [0.017, 0.683]) were associated with higher average confidence score ($p < 0.05$). For Shenzhen's PCPs, those who were well informed of the referral pathway for genetic diseases (0.435 [0.156, 0.715]), felt they had sufficient time during clinical consultation to discuss genetic issues (0.420 [0.179, 0.661]), they had encountered patient cases related to genomic medicine in the past 6 months (0.231 [0.036, 0.426]), and there was no evidence that genetic testing was beneficial to adult diseases (0.325 [0.055, 0.594]) were associated with significantly higher confidence score ($p < 0.05$).

4 | DISCUSSION

This is the first representative study to assess and compare the knowledge, attitudes, and clinical practice concerning

TABLE 2 Hong Kong's and Shenzhen's PCPs' attitude toward genomic medicine and ethical issues with genetic testing

	Hong Kong			Shenzhen			Overall		
	Agree	Disagree	Not sure	Agree	Disagree	Not sure	Agree	Disagree	Not sure
It is important to keep up to date with the latest information on genetic disorders	128 (86%)	1 (1%)	20 (13%)	244 (95%)	3 (1%)	11 (4%)	372 (91%)	4 (1%)	31 (8%)
Personalized medicine is the future of healthcare	121 (81%)	3 (2%)	25 (17%)	228 (88%)	9 (3%)	21 (8%)	349 (86%)	12 (3%)	46 (11%)
There are ethical controversies with genetic testing	122 (87%)	10 (7%)	8 (6%)	150 (58%)	41 (16%)	67 (26%)	272 (68%)	51 (13%)	75 (19%)
During clinical consultation, there is sufficient time to discuss genetic issues with patients	20 (13%)	78 (52%)	51 (34%)	67 (26%)	145 (56%)	46 (18%)	87 (21%)	223 (55%)	97 (24%)
Genetic medicine is ready for clinical practice	50 (32%)	50 (32%)	54 (35%)	37 (14%)	140 (54%)	81 (31%)	87 (21%)	190 (46%)	135 (33%)
There is over-testing in genetic testing	25 (18%)	64 (46%)	51 (36%)	50 (19%)	91 (35%)	117 (45%)	75 (19%)	155 (39%)	168 (42%)
There is not much evidence that genetic testing is beneficial adult diseases	12 (8%)	91 (61%)	46 (31%)	51 (20%)	171 (66%)	36 (14%)	63 (15%)	262 (64%)	82 (20%)

TABLE 3 PCP's opinion on the usefulness of genetic testing on different conditions and their clinical practice related to genomic medicine

	Hong Kong	Shenzhen
PCP's opinions on usefulness of genetic testing on		
Breast cancer or ovarian cancer	146 (95.42%)	221 (85.66%)
Congenital anomalies	125 (81.7%)	208 (80.62%)
Colorectal cancer	118 (77.12%)	202 (78.29%)
Developmental delay/ autism	103 (67.32%)	183 (70.93%)
Rare disease/orphan disease	99 (64.71%)	171 (66.28%)
Adverse drug reaction	96 (62.75%)	113 (43.8%)
Heart diseases	70 (45.75%)	82 (31.78%)
Others	8 (5.23%)	47 (18.22%)
Do you know the referral pathway for patients with suspected and confirmed genetic disorders?		
Yes	49 (32.03%)	42 (16.28%)
No	104 (67.97%)	216 (83.72%)
Clinical exposure to genomic medicine in the past 6 months		
Refer a patient with a positive family history for genetic testing	16 (10.74%)	65 (25.19%)
Consult a specialist for known genetic problems	12 (8.05%)	64 (24.81%)
Refer a patient to prenatal clinic for known genetic problems	7 (4.7%)	83 (32.17%)
Refer a child with developmental delays or learning difficulties for genetic testing	4 (2.68%)	57 (22.09%)
None of the above	123 (82.55%)	154 (59.69%)
Others	1 (0.67%)	0 (0%)

genetic testing and counseling among PCPs in Hong Kong and Shenzhen, China. PCPs in both places have positive attitude toward genomic medicine. A majority of PCPs (91%) agreed it was important for PCPs to keep current with the latest information on genetic disorders. This is higher than the 52.2% of PCPs agreeing to the same statement in 2019, suggesting a higher perceived importance of developing genomic medicine (Carroll et al., 2019). This also explains the high anticipation of personalized medicine being the future of healthcare. Doctors also expressed different degrees of concerns to ethical controversies with Hong Kong's PCPs (87%) showing more concern than Shenzhen PCPs (56%). The former is the most concerned about the psychological impacts and stigmatization as a result of genetic testing, while the latter is most concerned about privacy and confidentiality

TABLE 4 Self-rated confidence score in 10 skillsets in genomic medicine and PCPs' training preference in genetics and related areas

	Hong Kong (average, SD)	Shenzhen (average, SD)	*p*-value
1) Obtain information about genetic disorders from family history	2.93 (0.96)	3.59 (1.00)	<0.001
2) Clinical evaluation of genetic disorders	2.16 (0.92)	3.51 (1.04)	<0.001
3) Referral to a relevant specialist for suspected genetic disorders	2.95 (1.06)	3.65 (0.93)	<0.001
4) Decide which genetic testing should be done for suspected genetic disorders	1.80 (0.88)	3.26 (1.10)	<0.001
5) Discuss issues related to prenatal diagnosis with your patients	2.24 (1.01)	3.32 (0.97)	<0.001
6) Assess if the patient's genetic test results are meaningful	2.15 (0.97)	3.36 (1.02)	<0.001
7) Discuss the benefits, risks, and limitations of genetic testing with patients	2.27 (1.09)	3.29 (1.03)	<0.001
8) Discuss and counsel patients on whether they should get a genetic test	2.41 (1.04)	3.17 (1.08)	<0.001
9) Explain to patients on genetic testing results and provide genetic counselling	1.99 (0.99)	3.16 (1.10)	<0.001
10) Provide counselling on genetic screening strategies and lifestyle changes	2.14 (1.03)	3.34 (0.99)	<0.001
Total average	2.30 (1.00)	3.36 (1.03)	<0.001
Self-rated training preference in genetics and related areas			
1) Common polygenic diseases	94.33%	70.26%	0.043
2) Genetic disorders related to prenatal diagnosis/pediatrics	23.40%	80.62%	<0.001
3) Single-gene disorders	26.95%	34.11%	0.055
4) Adverse drug reactions caused by drug-related genes	55.32%	12.02%	<0.001

Self-rated confidence score in 10 skillsets in genomic medicine (Adapted from Carroll et al 2009 (Carroll et al., 2009). Confidence level in the scale of 1 to 5, with 5 being very confident and 1 being not at all confident)

issues. It is expected that the management of the ethical issues will be part of the future practice as direct-to-consumer testing has been gaining popularity in recent years (Harding et al., 2019).

Primary care in China was put in the forefront of the Chinese government agenda in 2009 to ensure basic medical services and primary healthcare were available for the whole country. Policies were introduced to help develop primary care. Although some specialists converted into PCPs at that time through training 3 months to 1 year, the majority of the PCPs have undergone 3-year training programs to be qualified after graduating medical school, which may reflect the higher proportion graduates post-2010 in Shenzhen compared with Hong Kong. In addition, Shenzhen's average age of residents is less than 30 as the city has grown in the past few decades due to internal migrants seeking work in the city.

Our survey showed that 78% of PCPs were unaware of the referral pathway for patients with suspected and confirmed genetic disorders and only 21% felt they had enough time to counsel patients on genetic disorders. Having sufficient time to discuss genetic issues and familiarity with the referral pathway to genetic specialist were shown to be positively correlated with PCPs' self-rated confidence score which explains why the average confidence in their genomic medicine skillset was not high. PCPs were least confident with explaining genetic testing results and providing genetic counseling. These tasks often require lengthier discussions and content-specific knowledge, which some may argue it would be better performed by medical geneticists or genetic counselors, but access to such service is often limited. While individual consultation length varies depending on the case and healthcare setting, a systematic review examining international variations in consultation time in 67 countries showed that mean consultation length in China was 2–3 min (Irving et al., 2017) and Hong Kong was 6.7 min (Chan, 2017). Short consultations may explain why a minority of PCPs had clinical exposure to genetic medicine in the past 6 months as they were unlikely to have time to uncover such information. Limited consultation time was a perceived barrier by doctors in other studies (Chambers & Axell-House, 2015; Harding et al.,

TABLE 5 Association between PCPs' characteristics and overall confidence score in genomic medicine

	Hong Kong (n = 151)		Shenzhen (n = 258)	
Characteristics	**Coefficient (95% CI)**	***p*-value**	**Coefficient (95% CI)**	***p*-value**
Graduate year (reference: Post−2010)				
Before 2000	0.431 (−0.001, 0.864)	0.051[a]	–	–
2000–2010	0.183 (−0.256, 0.623)	0.410	–	–
Undergraduates training (reference: No)				
Yes	0.391 (0.161, 0.621)	0.001[a]	0.145 (−0.082, 0.372)	0.210
Postgraduate training (Reference: No)				
Yes	0.612 (0.223, 1.000)	0.002[a]	0.218 (−0.123, 0.594)	0.226
Familiar with the referral pathway for suspected and confirmed conditions (reference: No)				
Yes	0.131 (−0.108, 0.370)	0.281	0.435 (0.156, 0.715)	0.002[a]
Encountered patient cases related to genomic medicine in the past 6 months (reference: No)				
Yes	0.192 (−0.098, 0.482)	0.191	0.231 (0.036, 0.426)	0.021[a]
Sufficient time to discuss with patients at consultation (reference: No)				
Yes	0.328 (0.011, 0.646)	0.043[a]	0.420 (0.179, 0.661)	0.001[a]
Believed there are ethical controversies with genetic testing (reference: No)				
Yes	0.350 (0.017, 0.683)	0.040[a]	–	–
Believed there is not much evidence that genetic testing is beneficial adult diseases (reference: No)				
Yes	–	–	0.325 (0.055, 0.594)	0.018[a]

[a]$p < 0.05$ by multivariate linear regression analysis.

2019). Ensuring sufficient time to explain the nature, risks, and benefits of genetic testing needs to be fully addressed if such service is being introduced.

Having a complete medical record, including the knowledge of the patient's background and their families', is an important prerequisite to establish relevant family history on genetic diseases and to deliver genetic counseling. Ninety-eight percent of the Mainland and 30% of Hong Kong PCPs work in the public sector where patients' electronic health records (eHRs) are readily available. eHRs make it easier to obtain the genetic family history and adverse drug reaction records and to expand PCPs' role in genomic medicine. As big data and machine-learning evolve, integrating genetic data can facilitate the management of genetic information and care of patients (Chan, 2017). Clinical decision support system (CDSS) could analyze data within eHRs to identify patients which may benefit from genetic testing such as patients with a family history of breast cancer or drug-related genes, to store results of adverse drug reactions, and to provide prompts and reminders to the doctors in implementing evidence-based clinical guidelines and testing. This new technology will potentially improve patient care in effectively identifying at-risk patients for testing, diagnosing patients with genetic diseases, reducing medical errors, and improving collaboration between PCPs and other medical specialties. As many private PCPs may not have the means to purchase CDSS, they may eventually lag behind in providing genetic care to their patients. The other benefit of the public system is that when referral systems are in place, it would be easier for patients to access genetic care, whereas in private clinics, costs and variable referral pathways may lead to barriers. For these reasons, PCPs in the predominately public system in Shenzhen may eventually take the lead in providing genetic care when the barriers to PCPs providing genetic care are overcome. In keeping with existing literature, there is a positive correlation between training in genomic medicine and PCPs' confidence in genomic medicine (Wilkes et al.,2017). Ninety percent of respondents reported that they had not had any postgraduate training in genomic medicine. Although 60% had undergraduate teaching in genomic medicine, developments in this subject have been changing rapidly, and this may also contribute to the relatively low self-rated confidence in skillset in genomic medicine. It is important to recognize other barriers to genomic medicine in primary care (Chambers & Axell-House, 2015; Vassy et al.,

2013). In the past decades, not only have there been unprecedented genomic discoveries but also major clinical advances in the management of common chronic diseases including cardiovascular diseases, diabetes, or cancer. In an environment with limited time for competing interests, PCPs may not prioritize learning about genomic medicine, which explains why few have actually received postgraduate training and the relatively low score on the knowledge questions. That traps its development in a vicious cycle; PCPs lack practical knowledge of genetics and confidence in providing services related to genetic conditions (Carroll et al., 2016; Houwink et al., 2012).

In terms of training needs, "genetic disorders related to prenatal diagnosis/pediatrics" was ranked the highest among Shenzhen's PCPs. This could be explained by the expanding use of noninvasive prenatal screening in Mainland China and the Chinese government's announcement of the unbidden "universal two-child" policy in 2015 preceded by the "one-child" policy, which is expected to increase the birth rate in China. With advanced parental age of those who are expecting a second child, there is an increased risk of the child having birth defects and severe genetic disorders. To meet the training demand, the Chinese Board of Genetic Counseling (CBGC) was established in 2015 and offered training courses in basic genomic medicine and genetic counseling (Chinese Board of Genetic Counselin; Sun et al., 2019). For Hong Kong's PCPs, their highest perceived training demand is "common polygenic diseases," such as cardiovascular disease, and this is in keeping with common chronic conditions seen in the local primary care. It is also important that such training could be easily accessed by practitioners with low-cost or travel expenses. Amidst the COVID pandemic, there has been accelerated movement toward online platforms for teaching, meetings, and healthcare services. The Gen-Equip project (www.primarycaregenetics.org) is a success story that offers free online training and resources to support PCPs and allied healthcare professionals to develop and utilize their skills and knowledge of genomic medicine for patient benefits (Jackson et al., 2019; Paneque et al., 2017). By taking a proper family history, initiating appropriate genetic or diagnostic testing, recognizing indications for subspecialty referral, PCPs are best positioned to provide comprehensive first-contact care in the era of genomic medicine.

5 | LIMITATIONS

Our study has several limitations. Firstly, although the response rate was relatively low, it was consistent to recruitment of other online surveys, and 409 individual responses were recorded, so it should be a representative sample of the cohorts. Secondly, a substantial response bias could have been introduced since the respondents might have been a group of PCPs more interested in the development in genomic medicine, and consequently, they were more motivated to participate in the survey. Thirdly, due to logistic considerations, the knowledge test only consisted of seven questions which might be limited in what they could have measured in terms of the true knowledge in genomic medicine. Nevertheless, the finding of this survey will assist us in developing further training and resources in genomic medicine in primary care.

6 | CONCLUSION

Our survey has shown that PCPs in Hong Kong and Shenzhen are not yet fully utilizing potential benefits of genomic medicine in their clinical practice, and we identified potential barriers to genomic medicine in primary care. These included insufficient knowledge, few training opportunities, and self-rated low confidence in their skillsets in genomic medicine. These barriers could be addressed with a combination of easily accessible educational resources in primary care genetics, clear established referral pathway and guidelines on genetic diseases, and cross-specialty collaboration between healthcare systems and professional bodies.

ETHICS DECLARATION

1. The name of the Institutional Review Board (IRB) or Research Ethics Committee (REC) that reviewed the study:
2. The Medical Ethics Committee in University of Hong Kong / Hospital Authority; Protocol number: HKWC-2020-0485; IRB no: UW 20-467
3. The University of Hong Kong-Shenzhen Hospital Ethics Committee Certification (香港大学深圳医院伦理委员会认证); reference no: [2019]271
4. Informed consent was obtained from all participants as required by the IRB or REC
5. Where individual patient/person data is included, the subjects are de-identified and only summary results are published in the article
6. Our study adhered to the principles set out in the Declaration of Helsinki

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, WCW WONG, upon reasonable request.

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