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Genetics and genomics knowledge and competency of Chinese nurses based on the theory of diffusion of innovation: A descriptive cross-sectional study

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ABSTRACT

Background: Nurses are responsible for providing genetics and genomics health care services, including disease risk assessment, medical referrals, and advocating for communities and individuals who probably benefit from genomics and genetics services.
Objective: This study aimed to investigate Chinese nurses' understanding and previous training in genomics and genetics. Additionally, we aimed to understand the degree to which Chinese nurses use genomics and genetics knowledge in their daily practice and to assess the learning needs regarding genomics and genetics.
Method: This study utilized the design of a descriptive cross-sectional study. From January 18 to March 15, 2022, 406 registered nurses from the Shandong province of China working in clinical institutions and with good English proficiency were recruited as study subjects. Nurses' demographic data and data related to genetic knowledge and competency were collected using the Genetics and Genomics Nursing Practice Survey (GGNPS) questionnaire. Kruskal Wallis and Mann-Whitney-U tests were utilized to investigate the descriptive statistics and non-normally distributed data.
Results: There are 406 nurses from Shandong Province, China participated in the study. Among them, BSN degrees accounted for 83.7%. Female nurses accounted for 96.8%, and 40% are clinical nurses. Among such nurses, 65.5% reported that genetics was involved in their nursing courses, and 56.2% planned to study more knowledge associated with genetics. The mean knowledge score was 7.35 (out of 12). Nurses' gender, primary role, genomics education, and experience caring for patients with common diseases influenced nurses' scores on genetic and genomics knowledge.
Conclusion: The genomics knowledge and competency of Chinese nurses need to be further improved. Incorporating genomics into the standard nursing curriculum can effectively reduce the knowledge gap. Simultaneously, it is also necessary to improve the attention of senior nurses and nursing managers to genomics nursing and improve the clinical practice environment.

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1. Introduction Background

Genomics' scientific and technological progress has given unprecedented opportunities for health care since the completion of the Human Genome Project. With these advancements, early screening and early treatment of diseases through genomics will become essential for future medical care. Rapid advances in genomics present opportunities and challenges for healthcare providers, especially nurses. Nurses with various professional roles are the largest part of the healthcare workforce [1–3], and they are also the first group to come into contact with patients. Therefore, genomics will be an important part of nursing practice, such as risk assessment of patients, collection of family history, education, and advocacy for individuals or groups that may benefit from genomics services [4,5].

2. Introduction

With the completion of the human genome project in 2003, scientists have gained enormous information about the intricacies of the human genome, and this effort has also provided new opportunities for the diagnosis and treatment of future diseases. The 2015 ″Precision Medical Plan" was proposed in the United States for the first time [6]. This proposed plan aims to help healthcare providers understand many factors affecting patients' health, diseases, or conditions, including environmental, lifestyle, genetic, and genomics understandings [6,7]. Since then, genetics and genomics have been highly valued as essential parts of precision medicine. As a vast group of healthcare providers, nurses should have genomics knowledge and competency to adapt to the current precision medicine era.

In the era of precision medicine, nurses, such as health appraisers and propagandists, played a vital role in clinical applications. Nurses can evaluate individuals by asking clients about the history of the three generations of the family and instruct them to conduct professional genetic consultations to further understand in detail [8]. Some studies have also surveyed the baseline level of the knowledge and ability of nurses in many countries and regions. Furthermore, studies have found that most nurses believe that genetics and genomics are important for their nursing practice, but they generally lack the ability, confidence, and high knowledge level.

China is the world's most populous developing country. In 2022, China's population reached 1.412 billion, and the base of the crowd with common diseases is also large. Notably, the number of hypertension cases reached 245 million. The number of people with diabetes reached 140 million. Additionally, in 2020, there were 4.57 million new cancers in China, accounting for 23.7% of the global new cancer. The occurrence and development of cancer, hypertension, diabetes, and other diseases have been proven to have an inseparable relationship with genetics and genomics. Based on the above reasons, health assessments related to genetics and genomics are necessary for the precision medicine era.

Since China launched the precision medical plan in 2016, several provinces have successively established the Precision Medicine Association. Based on this, Guangdong Province has established the Precision Nursing Association to formulate China's first "precise nursing system" regarding accurate nursing group standards [9]. They officially released the genome knowledge and capabilities that nurses should have in the era of precision medicine.

As one country with the largest nurse population worldwide, by the end of 2020, the total registered nurse number in China has exceeded 4.7 million [10]. However, few studies have evaluated the knowledge and competency of Chinese nurses' genetics and genomics. A national survey on the genomics ability of nurses of general tertiary hospitals and cancer hospitals in mainland China found that nurses' genomics knowledge level is medium and needs further genome training [11]. Therefore, there is an urgent need to understand Chinese nurses' competencies and roles to guarantee the adequacy of genomics medical services provided by China. For the sake of integrating genomics into nursing practice, it is essential to discuss nurses' knowledge, attitude, and ability to design appropriate educational models to advance genomics in nursing practice. Based on literature research, we found limited studies using the GGNPS to identify the nurses' genomics practice abilities. Assessing nurses' practice competencies through reliable survey tools has important implications for comparing genomics nursing education and practice levels across countries and regions and for future global collaborations.

3. Method

3.1. Study design

This study was completed during the popular period of COVID-19 in China. In order to strictly abide by China's epidemic prevention and control policies, researchers did not use a face-to-face way to issue and collect questionnaires to reduce personnel contact as much as possible. Instead, researchers used an online questionnaire collection platform, "Questionnaire Star" (https://www.wjx.cn/), to collect the questionnaire and conduct a descriptive cross-section survey. Notably, the network platform server has firewall protection to ensure data security. Additionally, it supports the function of questionnaires and multiple public-level settings, password protection, and other functions to ensure the security of important data. Simultaneously, the network platform sets up invalid questionnaire screening rules (such as filling in the minimum time rules and regional restrictions) to ensure the quality control of the recycling questionnaire and prevent the machine from answering and responding to nonsense(https://www.wjx.cn/).

3.2. Time and place

From January 18 to March 15, 2022, researchers recruited members of the Shandong Provincial Nursing Association, and they were also registered nurses working in Shandong medical institutions. Notably, the Shandong Provincial Nursing Association was established in 1950 and is affiliated with the Shandong Provincial Department of Health, China. It is one of the earliest communities in the

Shandong Provincial Association. It has a significant influence in Shandong Province and even China. Furthermore, as of 2022, more than 90,000 members have been included, including almost all registered nurses of all medical institutions in Shandong Province (www.sdhlxh.com) .

3.2.1. Sample and population

Nurses in Shandong Province, China, are the target group of this study. Considering that the GGNPS questionnaire involves the inspection of the "social system" dimension, compared with convenient sampling may be concentrated in the data brought by one or two medical institutions, researchers have conducted network sampling by relying on the Shandong Provincial Nursing Association platform. After obtaining the consent of the chairman of the Shandong Provincial Nursing Association, the researchers sent the questionnaire QR code to the WeChat Working Group of the Shandong Provincial Nursing Association to ensure that members could access the questionnaire. Participants can answer WeChat on a computer or mobile phone, but a WeChat signal can only be answered once. The upper limit of the WeChat working group was 500, and 424 nurses completed the survey with a response rate of 84.8%. A total of 18 people answered that they were considered invalid, 7 people did not answer all the questions,6 answered the same in each project, and 5 answered the time significantly. Finally, 406 respondents were selected for analysis. The flowchart of the collection data was shown in Fig. 1. These 406 respondents came from 29 medical institutions in 16 cities in Shandong Province, including 8 secondary medical institutions and 21 tertiary medical institutions.

3.3. Inclusion criteria

1. Chinese registered nurses who obtain a nursing certificate;
2. Members of the Shandong Provincial Nursing Association and in Shandong medical institutions are engaged in nursing work;

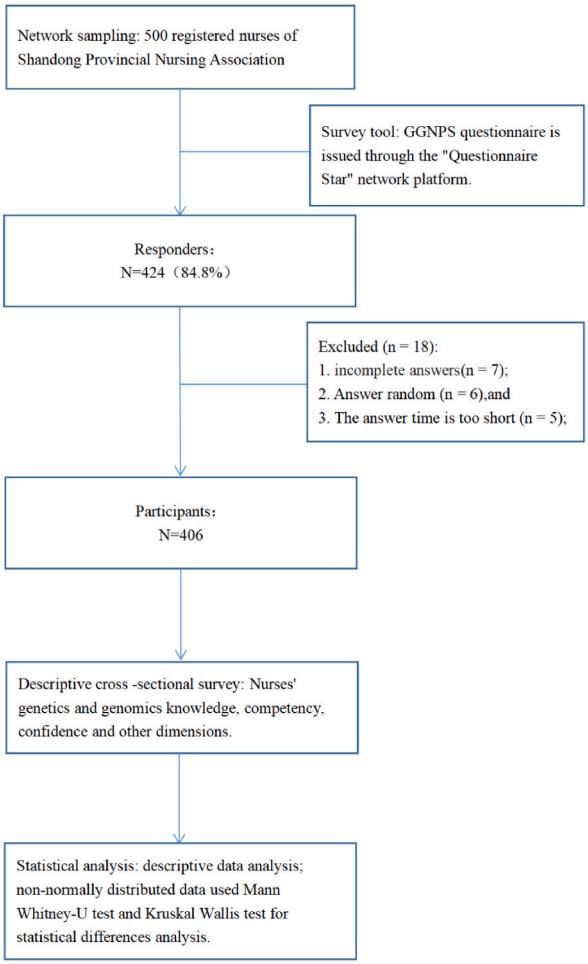

Fig. 1. The flowchart of the study.

3. The recruited registered nurses have high English proficiency. The criteria for high English proficiency are 1) IELTS (IELTS) score >6.0 or TOEFL (TOEFL) score >80 since January 2020, and/or nurses who have obtained the Chinese College English Test (CET-4) certificate during college; 2) Able to read academic literature and books in English proficiently.
4. Agree to participate in the survey.

3.4. Exclusion criteria

1. Nurses who are receiving internship training.

3.5. Instruments

The instrument applied in this study was the GGNPS questionnaire revised by Calzone et al. after testing for test-retest reliability [12]. We reached out to the original author and obtained her consent. This questionnaire has proven reliable and has surface and content validity [12,13].

The GGNPS comprises various question types, including true-false, single- and multiple-choice, and Likert scales. GGNPS includes eight sections, namely, 1) Receptivity and attitude of genomics, 2) confidence in family history evaluation, 3) adoption of family history through nurses actively caring for patients, 4) general genomics knowledge, 5) specific genomics knowledge, 6) personal genomics competency evaluation, 7) social system, and 8) demographic data. The GGNPS also contains questions about demographics, such as age, gender, highest nursing degree, primary role, and percent time caring for patients.

The above eight sections are items of attitudes, knowledge and competency, confidence, social systems, and adoption of the five measurement domains. We then combined the twelve questions of determining genomics knowledge to produce a knowledge score. The answers to all twelve items were rated as incorrect or correct. The total knowledge score is counted as the correct answer number in 12 items. The lowest and highest possible scores for this part are 0 and 12, respectively. Only the total knowledge scores for the individuals who responded to all twelve items were counted.

3.6. Ethics statement

This research was approved by the Academic Ethics Committee of the Second Affiliated Hospital of Shandong First Medical University (Approval No. 2022–01). The researchers explained the purpose of the study and the rights of the participants and obtained the consent of all questionnaire participants.

3.7. Statistical analysis

The software of IBM SPSS 26.0 was applied to analyze the data. Discrete data are represented by numbers (n) and frequency (%), and continuous data are represented by mean ± standard deviation (X ± SD). The data distribution was assessed with kurtosis and

Table 1
Demographic features of the nurses.

N = 406	X±SD	
Age (years)	33.25 ± 8.19	
Years working in nursing(min-max:0–25)	5.07 ± 3.43	
Gender	n	%
Female	393	96.8
Male	13	3.2
Highest nursing degree		
BSN	339	83.5
MSN	60	14.8
PhD	7	1.7
Primary role		
Nursing management	86	21.2
Nursing Education	86	21.2
Nursing Research	72	17.7
Caring for patients	162	39.8
Percent time caring for patients		
50~60%	76	18.7
61~70%	117	28.8
71~80%	109	26.9
81~90%	104	25.6

Of all nurses, 65.5% said that genetics and genomics were involved in their nursing courses, and 64.2% said they took a curriculum with genomics as an essential part after becoming registered nurses. More than half of nurses (56.2%) reported that they plan to further understand the genome, less than half (47.5%) said they were able to take courses during work hours, 46.3% would take courses on their own time and more than half of nurses indicated that part-time participation in genomics courses could not be guaranteed (Table 2).

skewness tests. Because the data were not distributed normally, Mann Whitney U and Kruskal Wallis analyses were applied. When the *p*-value is below 0.05, it could be viewed as statistically significant.

To identify the appropriate sample size, PASS 2021 Power Analysis and Sample Size Software (NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/pass.) was employed for the power analysis. The estimation of the samples of this study involves complex statistical inspection methods, such as the Kruskal-Wallis test. The "Primary Role" with the most packets of Demographic variables is the efficacy test group. For measuring the moderate effect of 80% power at the significance level of 0.05, the Kruskal Wallis Test for four groups requires a minimum sample size of 88 participants. To control the multiple tests, the power analysis considered a significance level of 0.001, in which case the required sample size was 172. The sample size of this study is sufficient.

4. Results

Table 1 displays the nurses' demographic features. For the 406 nurses, the average age was 33.25 ± 8.19 years (minimum 23 years - maximum 56 years). Female nurses accounted for 96.8% of all nurses, and BSN nurses accounted for 83.5%. 40% of nurses are clinical nurses, and the actual nursing time of nurses accounts for 50%–90% of the total working time, with an average proportion of 73% (Table 1).

4.1. Knowledge level of nurses

The average total score of knowledge was 7.35 ± 1.76 out of 12. The question with the highest rate of correctness was that 91.1% of nurses answered correctly that the genetic risk is clinically related to coronary heart disease. Only 39% of nurses answered the question correctly, "The DNA sequences of two randomly selected healthy individuals of the same sex are 90–95% identical." (Table 3)

4.2. Competency of nurses

According to nurses, when the patient said there was a disease in the family, the nurse generally collected the age at the time of diagnosis (46.5%), relationship to the patient (43.8%), race and ethnicity (34.9%), age at death (39.7%), and information on both households (48.5%). Only 14.0% of nurses reported hearing or reading the Basic Competencies and Curriculum Guide for Genetics and Genomics Nurses (Table 4).

4.3. Attitude and receptivity of nurses

Among the 406 nurses, 63.6% believed that genomics education regarding prevalent diseases was critical. 76.6% of nurses reported incorporating common disease genomics into their practice facilitated better treatment decisions, 64.8% believed that patient services could be improved, and 70.7% better adhered to clinical recommendations. Disadvantages reported by nurses were "Would take too much time" (63.3%), "Not reimbursable/Too expensive" (51.8%), "Would increase insurance discrimination" (58.7%), "Increase patient anxiety about risk" (57.9%) (Table 5).

4.4. Confidence of nurses

Most (78.8%) of nurses said they were confident in deciding what family history information was required to inform patients about their genetic susceptibility to common diseases. Besides, 54.9% of nurses were confident in discussing how family history influences

Table 2
The genomics education background and learning willingness of nurses.

N = 406	n	%
Genomics incorporating in the nursing course		
Yes	266	65.5
No	140	34.5
Participate in a course focusing on genomics		
Yes	261	64.2
No	145	35.8
Intend to learn more associated with genomics		
Yes	228	56.2
No	113	43.8
Do not know	65	
Be able to attend a course during work hours		
Yes	193	47.5
No	136	33.5
Do not know	77	19.0
To attend a course on own time		
Yes	188	46.3
No	124	30.5
Do not know	94	23.2

Table 3
Knowledge items, total score, and nurses' responses.

Total knowledge score (X ± SD)	7.35 ± 1.76	
Items	Correct answers	
	n	%
1.Do you think that genetic risk (e.g., as indicated by family history) has clinical relevance for coronary heart disease.	370	91.1
2.Do you think that genetic risk (e.g., as indicated by family history) has clinical relevance for breast cancer.	354	87.2
3. Do you think that genetic risk (e.g., as indicated by family history) has clinical relevance for ovarian cancer.	336	82.8
4. Do you think that genetic risk (e.g., as indicated by family history) has clinical relevance for diabetes.	335	82.5
5. Do you think that genetic risk (e.g., as indicated by family history) has clinical relevance for colon cancer.	322	79.3
6. Extent to which family history supports clinical decisions (such as administering drugs prescribed).	255	55.4
7. Most common diseases such as diabetes and heart disease are caused by a single gene variant.	187	46.1
8. A family history should be performed on every new patient, containing only2nd and 3rd degree relatives, like grandparents, uncles, aunts, and cousins.	184	45.3
9. Family history taking should be a critical part of nursing care.	161	39.7
10. A family history should be performed on every new patient, containing only 1st degree relatives, like children, parents,and siblings.	160	39.4
11. There is a role for nurses in counseling patients about genetic risks.	159	39.2
12. The DNA of sequences of two randomly selected healthy individuals of the same sex is 90–95% identical.	158	39.0

Table 4
Response results of Competency Items.

Competency Items	n	%
When patients indicate a disorder in the family, which of the following pieces of information do you collect in your standard family history assessment? Each family member's		
Age at diagnosis of condition		
Never	24	6.0
Sometimes	193	47.5
Always	189	46.5
Relationship to the patient		
Never	50	12.4
Sometimes	178	43.8
Always	178	43.8
Race or ethnic background		
Never	59	14.5
Sometimes	205	50.6
Always	142	34.9
Age at death from a condition		
Never	49	12.0
Sometimes	196	48.3
Always	161	39.7
Both sides of the family (maternal/paternal)		
Never	43	10.6
Sometimes	166	40.9
Always	197	48.5
Thinking about how you support clinical decisions (such as administering drugs prescribed), how important do you think each of the following is to consider?		
Genetic Test Result		
Not at all	28	6.9
Essential	259	63.8
Don't know	119	29.3
Family history		
Not at all	62	15.2
Essential	255	62.8
Don't know	89	22.0
Have you heard or read about the Essential Competencies and Curricula Guidelines for Nurses in Genetics and Genomics?		
Yes	57	14.0
No	349	86.0
Please rate your understanding of the genetics of common diseases.		
Excellent	98	24.1
Good	247	60.8
Poor	61	15.1
In describing your genetic/genomics knowledge, would you consider it to be		
Excellent	135	33.3
Good	195	48.0
Poor	76	18.7

Table 5
Response results of Attitude/Receptivity Items.

Attitude/Receptivity Items	n	%
How important do you think it is for the nurse to become more educated about the genetics of common diseases?		
Very important	116	28.6
Somewhat important	142	35.0
Neutral	43	10.6
Not very important	87	21.4
Not at all important	18	4.4
Better treatment decisions (e.g., which drugs to prescribe)		
Advantage	311	76.6
Disadvantage	95	23.4
Improved services to the patients		
Advantage	263	64.8
Disadvantage	143	35.2
Better adherence to clinical recommendations among patients		
Advantage	287	70.7
Disadvantage	119	29.3
Would take too much time		
Advantage	149	36.7
Disadvantage	257	63.3
Not reimbursable/Too costly		
Advantage	196	48.2
Disadvantage	210	51.8
Need to "re-tool" professionally		
Advantage	177	43.6
Disadvantage	229	56.4
Increase patient anxiety about risk		
Advantage	171	42.1
Disadvantage	235	57.9
Would increase insurance discrimination		
Advantage	168	41.3
Disadvantage	238	58.7

the supposed screening interval, and 67% were confident in accurately identifying which patients will benefit from referral to receive special genetic counseling and the susceptibility testing of common diseases. Additionally, 72.2% of nurses were confident in providing patients with information about the genetic testing risk for common diseases (Table 6).

4.5. Social systems

Among the nurses screened, 56.2% said they planned to learn more about genomics, more than half (52.5%) said they could not attend classes during working hours, and 46.3% would take classes in their own time. Only 36.2% of nurses reported that senior staff felt that genomics was an essential part of these nurses' nursing roles. Additionally, only 27.1% of nurses report that senior staff considers genetics and genomics a significant part of their nursing role (Table 6).

4.6. Decision/adoption

At the time of surveying, 43.2% of nurses said that they generally or always gathered complete family history, 83.6% said patients had discussed genetics with them, 15.1% frequently utilized the information of family history to facilitate clinical decision-making, and 5.6% of nurses reported always facilitating referrals to genomics services in the past three months (Table 7).

Genomics knowledge scores were significantly different from the gender of nurses ($P = 0.001$), primary nursing role ($P < 0.001$), and experience in common diseases ($P < 0.001$). Additionally, the knowledge scores of nurses who have received genomics courses in schools or clinical institutions are higher than those who have not received any genomics courses ($P < 0.001$). Notably, no statistically significant differences in education level, nursing years, professional title, and active patient care (Table 8).

5. Discussion

This research was implemented to evaluate the nurses' genomics knowledge and competency in China and the factors influencing their knowledge level. To our knowledge, this is one of the few studies assessing the knowledge and competency of Chinese nurses' genetics and genomics. ZHAO et al. surveyed 2118 nurses in 12 tertiary hospitals in five provinces in China through Layered entire group sampling and learned about the level of nurses in many regions in China [11]. Considering the differences in the medical level of each province in China, understanding the nursing level of specific provinces also plays a vital role in the progress of the nurses' genome understanding in the region. This study uses Shandong Province, China, as the research location and relies on the Shandong Provincial nursing association. Furthermore, the sample source was expanded through network sampling, and the data bias from the convenient sampling was also avoided. The following is a discussion of the five dimensions.

Table 6
Response results of confidence and social system items.

Items	n	%
Confidence		
Determine what information of family history is required to tell something about a the genetic susceptibility of patients to common diseases.		
Confident	320	78.8
Not at all confident	86	21.2
Explore how family history influence the recommended screening intervals.		
Confident	223	54.9
Not at all confident	183	45.1
Decide which patients would benefit from a referral for genetic counseling and possible testing for susceptibility to common diseases.		
Confident	272	67.0
Not at all confident	134	33.0
Access reliable and current information about genetics and common diseases.		
Confident	288	70.9
Not at all confident	118	29.1
Provide patients information related to the risks of genetic testing for common diseases.		
Confident	293	72.2
Not at all confident	113	27.8
Give patients information about the benefits of genetic testing for common diseases.		
Confident	237	58.4
Not at all confident	169	41.6
Give patients information about the limitations of genetic testing for common diseases		
Confident	268	66.0
Not at all confident	138	34.0
Facilitate referrals for genetic services for common diseases.		
Confident	277	68.2
Not at all confident	129	31.8
Social system		
Do you intend to learn more about genetics?		
yes	228	56.2
no	113	27.8
Do not know	65	16.0
Would you be able to attend a course during work hours?		
yes	193	47.5
no	136	33.5
Do not know	77	19.0
Would you attend a course on your own time?		
yes	188	46.3
no	124	30.5
Do not know	94	23.2
Do you think your senior staff members see genetics as an important part of your role?		
yes	147	36.2
no	142	35.0
Do not know	117	28.8
Do you think your senior staff members see genetics as an important part of their role?		
yes	110	27.1
no	188	46.3
Do not know	108	26.6

5.1. Knowledge

In this study, the nurses' knowledge level measured by the GGNPS questionnaire was found to be moderate (7.35/12), which was slightly lower than the knowledge score of American nurses measured by the GGNPS questionnaire (8.99/12) [14]; and Ilknur Yesilçinar et al.'s knowledge score (9 out/12) genomics knowledge of Turkish nurses using the GGNPS questionnaire [4]. It was also lower than Zhao et al. evaluation of the level of genetics and genome knowledge of nurses in five provinces in China (8.30/12) [11]. In research conducted by Efrat Dagan et al., The GGNPS questionnaire was not used as a measurement tool but reported a lower level of genomics knowledge among Israeli nurses [15].

Although the knowledge level of nurses is average, in some areas, more than half of the nurses could not correctly answer. Only 39% of the nurses answered, "The DNA sequences of two randomly selected healthy individuals of the same sex are 90%–95% identical." Correctly. Additionally, 46.1% of them correctly answered: "The most common diseases, for instance, heart disease and diabetes, resulted from the single gene mutations." These findings are critical to be conscious of and improve, as nurses need to understand the genetic basis of common diseases to better assist their front-line care. Most nurses know that genetic risks are clinically associated with breast, ovarian, and colon cancer. In contrast, over 80% of nurses know coronary heart disease and diabetes are clinically associated with genetic risk. Based on existing research, Chinese nurses have higher awareness rates of genetic risk of coronary heart disease and diabetes than Turkish nurses [4] and American nurses [14]. This study suggested that the school genomics education and continuing education of nurses effectively raised the amounts of the correct responses, consistent with Calzone et al. [16]. Such researches suggest that genomics education is required during school and after graduation. Studies have also shown that

Table 7
Response results of Decision/Adoption items.

Decision/Adoption[a]	n	%
In the last 3 months, how often have you gathered a complete family history from the patient that includes the below components: information on disorders from three generations, and age at diagnosis and death for each affected family member?		
Always	32	8.6
Often	129	34.6
Occasionally	169	45.3
Rarely or never	43	11.5
In the past three months, has any patient initiated a discussion with you about genetics?		
yes	312	83.6
no	61	16.4
In the past 3 months, how often have you used family history information when facilitating clinical decisions or recommendations for your patients?		
Frequently	7	1.9
Occasionally	53	14.2
Rarely	213	57.1
Never	100	26.8
In the past 3 months, how often have you facilitated referrals to genetic services?		
Frequently	21	5.6
Occasionally	135	36.2
Rarely	133	35.7
Never	84	22.5

[an] Only nurses actively take care of patients answered the questions.

Table 8
The comparison of knowledge scores and demographic features of Nurses (N = 406).

Demographic items	$\bar{x}$	±SD	Z/X^2	*P*
Gender			−3.21	0.001[a]
Male	9.00	1.63		
Female	7.30	1.74		
Highest nursing degree			3.875	0.144[b]
BSN	7.42	1.78		
MSN	7.08	1.63		
PhD	6.67	1.13		
Primary role			28.174	< 0.001[b]
Nursing management	7.95	1.93		
Nursing education	6.99	1.41		
Nursing research	6.71	1.57		
Seeing the patients	7.51	1.78		
Experience in caring for patients with common diseases			−3.613	< 0.001[a]
Yes	7.48	1.74		
No	6.46	1.66		

When *p* value was lower than 0.05, it can be regarded as statistically significant.
[a] Mann-Whitney *U* test.
[b] Kruskal Wallis test.

genomics education can improve nurses or nursing students [17,18]. Therefore, it is imperative to tailor a genomics education system for the nurses in China to fill their gaps in genomics knowledge.

In the current study, the level of genomics knowledge among nursing educators and researchers was lower than in other nursing groups, which contrasts with Ilknur Yesilçinar et al.findings [4]. This may be related to nursing educators and researchers having less time on the clinical front line, a lack of understanding of patients with common diseases, and curiosity about the occurrence and development of diseases. On the contrary, nurses on the clinical front line have more time to understand the needs of patients and have a stronger desire to learn about the disease. However, the knowledge level of front-line nurses and nursing managers is high. Thus, raising their level of knowledge is crucial for integrating genetics into practice for nursing educators and researchers, especially nursing educators whose knowledge level has improved.

5.2. Competency

Regarding competency, less than half of the nurses gathered the family history, including age, age of death, relationship with the patient, and both sides of the family. Only 34.9% knew the race and ethnicity of the collected patients. Notably, the genomics competency of Chinese nurses is insufficient. Even if they ask about patients' family history, they often miss some vital information, which is not conducive to a comprehensive assessment of patients' family history information, and may even lead to misdiagnosis. Therefore, nurses' accurate and comprehensive genomics competency is a prerequisite for successfully implementing genomics nursing practice. However, only 14.2% of nurses reported hearing or reading about the basic abilities and course guide for genomics

and genetics nurses. This also reflects the lack of genomics competency of nurses. A literature review found that this study was similar to studies [14,19], in which nurses had insufficient knowledge of family history collection or clinical evaluation skills.

Family history is the cheapest and most effective genetic diagnostic tool. It is a gateway to identifying individual genetic disorders. Thus, healthcare providers should take the family history evaluation as a conventional and effective tool in clinical genetics [14,20]. Nurses have unique advantages in communicating with patients and participating in health education. They always serve the front line of clinical practice and are the first to contact patients. They are more willing to listen and can build solid, trusting relationships with patients, which provides an excellent opportunity to develop genomics and genetics in clinical practice. Coupled with clinicians' increased focus on patients' disease and symptoms, family history and genomics were not prioritized [21]. Therefore, combining genetics with genomics in nurse practice can profoundly affect disease prevention, early screening, treatment, and care plan optimization.

5.3. Attitude and receptivity

Most nurses, 74.1%, believed that education on the genomics of common diseases was very significant. Likewise, most nurses believe that incorporating genomics into nurse practice results in better treatment decisions, improved patient care, and compliance with clinical recommendations. In a large investigation performed by Calzone et al., nurses suggested that incorporating genomics into nursing practice could improve patient services and clinical decision-making [16]. In other studies, nurses have also affirmed the significance of genomics to nursing practice [4,15,22–24,25]. This is an interesting issue because many research reports say that most nurses believe that genomics must be included in nursing practice. Simultaneously, reviewing these studies shows that nurses' genomic knowledge and ability level is relatively low. The positive attitude of nurses in incorporating genomics into nursing practice has formed a sharp contrast to their relatively weaker genome knowledge and ability, which seems to be a common problem encountered by today's nurses worldwide.

5.4. Confidence

In this study, most nurses (78.6%) expressed confidence in determining what information about family history is required to inform patients about their genetic susceptibility to common diseases, a result similar to that of Ilknur Yesilçinar et al. [4], but contrary to other research findings. In a study by Calzone et al., only one-third of nurses were confident in determining what information about family history is required to explore the genetic susceptibility of patients to common diseases, for instance, diabetes, heart disease, and cancer [14]. Higher self-confidence and lower genome knowledge level, also proves that Chinese nurses are not fully prepared for the collection of standard family history information. They did not correctly understand these contents, underestimating the difficulty of nursing practice, and they seemed a bit too confident. The study observed that half of the nurses (54.7%) were confident in exploring how family history influenced the supposed screening interval, which is likely associated with the lack of genomics knowledge because the interval of screening time is different for different diseases. Thus, these findings support the idea that nurses require a better understanding of the process. While the majority of nurses were confident in serving patients and communicating about disease susceptibility, and delegating referrals, only 43.2% of nurses said that they frequently or always gathered the complete family history in the last 3 months, a finding that is in line with other Studies are similar [4,26]. A few nurses (15.1%) often utilize family history information when promoting clinical decision-making, and only 5.6% reported always facilitating referral to genomic services. Based on our findings, nurses expressed confidence in informing the patients about the limitations, benefits, and risks of genetic testing for common diseases. Fascinatingly, the rate of nurses including it in clinical practice is very low. In addition, nurses considered that their senior staff did not regard genomics as s significant role for nurses. Unfortunately, these factors may hinder nurses from incorporating family history records into clinical practice.

5.5. Social systems

In the study, more than two-thirds of nurses (65.5%) said that their nursing course included genomics and that they had taken a course in which genomics was essential after becoming a registered nurse. However, in other research in diverse countries, the number of nurses reporting a genomics education was low. In one study in Turkey, only one-third of them (34.5%) had a genomics education [4], and only a minimal number of nurses (6%) had taken courses with genomics as a significant component. In two studies in the US, more than two-thirds of nurses did not attend the course with genomics as a key component after becoming a registered nurse [14,22]. Furthermore, in a Brazilian study, 57.4% of them did not bring genomics education into nursing courses [26].

Unlike other studies, less than half of the nurses in the current research (46.3%) intended to attend classes on their own time. This result is similar to the study results of ZHAO et al. [11]. In their research, 47.4% of Chinese nurses said they would participate in the course study in their own time. In contrast, multiple other studies report that more than 70% of nurses planned to learn more about genomics in their own time [4,14,26,27]. This may be related to the enormous workload of Chinese nurses. Evidence shows that in 2020, the number of nurses per 1000 people in China was only 3.35, while according to previous WHO statistics, the number of nurses per 1000 people in the USA is 15.7, and the numbers in Australia and Israel are 13.2 and 6.6, respectively [10,28]. As suggested by these values, many Chinese nurses are likely to undertake heavier workloads and utilize much of their energy and physical strength during their shifts, so their enthusiasm for learning in their free time may be limited. A qualitative study by Chinese scholars supported this concept and reported that many Chinese nurses are usually busy with clinical work and do not want to study during their available free time [29]. Additionally, 63.9% of nurses reported that senior staff, including nursing managers, did not consider genomics

essential to nurses' roles.

This result is also very similar to the research results of ZHAO et al. [11]. In their research, only 36.4% of Chinese nurses believe that their senior staff believes that genetics/genome is important to nurses. Therefore, Chinese nursing managers may not spend too much time on nurses' genomics education activities. The existence of these issues will be a possible hindrance to integrating genomics knowledge into clinical practice. This dilemma has also been reported in other studies, where many nurses felt that genomics was unimportant for senior staff or nurses' roles in clinical settings [16]. Therefore, raising awareness of bringing genomics into the nursing practice among the senior nursing staff and managers will help address these limitations and advance the combination of nursing practice and genetics.

5.6. Limitations and advantages

This study has two limitations. First, because the selected nurses with BSN or above with good English proficiency are selected, this survey cannot fully represent the genomics level of Chinese nurses with different educational backgrounds. Second, in the network sampling used in this survey, the respondents are mainly concentrated in Shandong Province, China, so there is regional bias and cannot represent the overall level of genomics of Chinese nurses nationwide.

The strength of this work is to give a baseline evaluation of the nursing practice of Chinese nurses in genomics and genetics. With the GGNPS questionnaire, parallel comparisons can be made with the results of baseline surveys conducted by other countries, which helps China understand the current gap in genomics nursing practice in other countries and promotes the development of global genomics nursing practice.

6. Conclusions

This study suggests that although Chinese nurses have average knowledge scores, there is still a lack of critical knowledge, containing the genomics foundation of common diseases and fundamental genomics principles. They generally underestimate the difficulty of collecting standard family history information. The lack of knowledge, competency, and excessive self-confidence have been formed in sharp contrast. Social system support will be vital to bring genomics into the nursing practice. Educational efforts should also focus on nursing managers and seniors to increase their awareness of the importance of genomics. Considering the strenuous workload of Chinese nurses, they should be appropriately relieved to allow them to devote more time to their studies. Furthermore, tailor-made educational activities should be developed for these nurses, as they can give the essential educational resources to bring genomics into the daily nursing practice.

Author contribution statement

Ke Wang: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Min Diao: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Jordan Tovera Salvator: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supplementary material/referenced in article.

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Declaration of competing interest

There is no conflict of interest exists in the submission of this manuscript, and all authors approve the manuscript for publication. I would like to declare on behalf of my co-authors that the work described was original research that has not been published previously and is not under consideration for publication elsewhere, in whole or in part. All the authors listed have approved the manuscript that is enclosed.

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Appendix A. Supplementary data

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