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Study on the construction of a Chinese cardiovascular physician competency model

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Since the beginning of the 21st century, China's socioeconomic progress has altered lifestyles, accelerated urbanization, and population aging, significantly raising the risk of cardiovascular diseases (CVD). Currently, CVD stands as China's primary cause of death, necessitating the establishment of a high-quality cardiovascular workforce. While international research on competence models for cardiovascular physicians exists, the unique characteristics of Chinese CVD warrant a tailored approach. Despite numerous studies on competence models for clinical physicians in China, a model specific to cardiovascular physicians, aligned with the Chinese context, is lacking. This study aims to develop such a model to address CVD challenges and aid in recruitment, assessment, and training, aligning with the objectives of the "Healthy China 2030" plan. Utilizing a modified Delphi method, this study conducted two rounds of Delphi surveys involving 20 experts from renowned cardiovascular departments in Guangdong Province, China, based on literature reviews, behavioral event interviews, and expert consultations. Rigor and scientific validity were enhanced through measures such as experts' positive coefficient, experts' authority coefficient, and experts' coordination coefficient. Weightings for primary and secondary indicators were calculated using the Analytic Hierarchy Process and percentage weighting methods. The final cardiovascular physician competency model, tailored to the Chinese context, was determined. In both rounds of the Delphi surveys, the experts' positive coefficient exceeded 80%, the authority coefficient exceeded 0.7, and the *p*-values for the coordination coefficient were less than 0.01. These results indicate high accuracy and reliability, with strong expert consensus. The study developed a competency model comprising 8 primary indicators and 60 secondary indicators, with assigned weightings for each indicator. By utilizing an improved Delphi consensus process, the research team developed a competency model tailored to the Chinese context for cardiovascular physicians. This model encompasses various elements of clinical performance and professional behavior, and it is designed to provide effective guidance for the recruitment, evaluation, and residency training of cardiovascular physicians in China.

Keywords Cardiovascular diseases (CVD), Cardiovascular physicians, Competency model, Chinese context, Delphi method

Since the beginning of the 21st century, with the rapid progress of China's socioeconomic development, significant changes have occurred in the lifestyles of Chinese people. Moreover, accelerated urbanization and population aging have led to a marked increase in the risk of cardiovascular diseases (CVD) among the Chinese people[1,2]. Currently, CVD has become the leading cause of death in China[3]. To address the challenges posed by CVD, it is essential to establish a high-quality cardiovascular workforce. McClelland proposed the concept of competence, suggesting that competence is a deep-seated characteristic that distinguishes individuals with outstanding achievements from ordinary ones[4]. This concept of competence is crucial for accurately and rapidly selecting, appointing, and training high-quality personnel in the cardiovascular workforce[5].

Internationally, research on the competence model of cardiologists has already begun. Since the release of the first Core Cardiovascular Training Statement (COCATS) in 1995, the American College of Cardiology (ACC) has defined the knowledge, experience, skills, and behaviors required for clinical cardiologists[6]. Subsequent revisions have shifted towards competency-based training, guided by the six domains of competence established

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by the Accreditation Council for Graduate Medical Education (ACGME) and the American Board of Medical Specialties, as well as the American Board of Internal Medicine (ABIM)[7]. The ACC has adopted a similar approach to emphasize the consistent lifelong learning abilities that practicing cardiologists should maintain[8]. Additionally, the Royal College of Physicians and Surgeons of Canada's CanMEDS framework outlines seven roles for physicians to fulfill their professional duties[9]. The European Society of Cardiology (ESC) has also developed a comprehensive series of core curricula in areas such as general cardiology[10] cardio-oncology[11] percutaneous valvular and structural heart disease interventions[12] preventive cardiology[13] and cardiovascular nursing[14] facilitating the standardization and coordination of training and assessment within the field. Furthermore, countries and regions such as the United Kingdom, Japan, and Singapore have respectively integrated Western research findings with their own traditional culture and social background to conduct relevant studies on the competence composition of physicians[15].

Chinese CVD has its own characteristics, including changes in the epidemiology of CVD due to the interrelated changes in population, environment, lifestyle, and healthcare. These changes include an increase in the burden of atherosclerotic CVD (ischemic heart disease and ischemic stroke), a decrease in the mortality rate of hemorrhagic stroke, various epidemiological trends of CVD subtypes in different regions, an increase in the number of patients with moderate ischemic heart disease and ischemic stroke, and the exacerbation of the aging of CVD patients. Other characteristics also highlight issues that need special attention, such as the high proportion of out-of-hospital deaths among ischemic heart disease patients due to insufficient pre-hospital care, a significant gap between guideline-recommended targets and levels of lifestyle indicators, and a large number of patients with undiagnosed, untreated, or uncontrolled hypertension, hypercholesterolemia, or diabetes[16–24].

Currently, many scholars have conducted research on the competence model of clinical physicians in China. For example, in 2015, Professor Baozhi Sun's team proposed a general competence model for clinical physicians in China[25,26]. Additionally, some scholars have proposed competence models for general practitioners, department heads, emergency physicians, clinical medical teachers, and traditional Chinese medicine physicians. However, a competence model specifically tailored to cardiovascular physicians with Chinese characteristics has not yet been established[27–30]. This context is shaped by several unique factors, including distinct epidemiological trends in cardiovascular diseases[31]sociocultural values[32]healthcare delivery systems[33]medical education structures[34]and patient expectations[35]. These factors collectively influence the competency requirements of cardiovascular physicians and differentiate them from those in other countries or regions. Therefore, constructing a competency model that reflects these contextual realities is essential. This model can also serve as a reference for public health departments in the recruitment, assessment, and residency training of cardiovascular physicians, laying the foundation for further realizing the objectives of the "Healthy China 2030" plan.

Materials and methods

Ethics statement

This study was conducted in accordance with the Declaration of Helsinki. Ethics approval was obtained from the Research and Ethics Committee of the Second Affiliated Hospital of Guangzhou Medical University. The study design and information sheets were reviewed and deemed appropriate by the committee. All 20 experts provided written informed consent and voluntarily participated in the study. Participant information was kept confidential, and participants had the right to withdraw from the study at any time.

Modified Delphi method

This study employed the modified Delphi method to develop a competency model for cardiovascular physicians tailored to the Chinese context. The Delphi method, developed by the RAND Corporation, is a consensus-building approach that gathers a panel of experts to systematically obtain structured feedback through questionnaire surveys based on consensus opinions[36,37]. Widely used in medical research, it remains one of the most common methods for selecting quality indicators in healthcare. The process involves multiple rounds of questionnaire responses from experts, with anonymity maintained within the expert panel. Experts receive feedback on aggregated responses after each round and have the opportunity to revise their answers[38,39]. To meet the study's objectives, various adaptations of the Delphi method, collectively referred to as "modified Delphi method," were employed while adhering to its fundamental principles[40–42]. The study conducted two rounds of questionnaire surveys with an expert panel via email or mail from April to June 2024. Throughout the application of the modified Delphi method, the study followed established research and Delphi survey technical guidelines[43–46].

The establishment of the initial competency model

The modified Delphi method used in this study consisted of two stages: (1) conducting a literature review, behavioral event interviews, and expert consultations to compile an initial set of competencies and develop the Delphi questionnaire; (2) conducting two rounds of Delphi surveys with cardiovascular internal medicine experts to achieve consensus on competencies tailored to the Chinese context and construct the competency model. The research process is illustrated in Fig. 1.

Selection of study participants and experts

This study selected cardiovascular physicians and experts from Guangdong Province as representatives for the research. This decision was primarily based on Guangdong's significance as a major economic and cultural hub in southern China, characterized by its typical geographical location, economic status, and population composition. Firstly, Guangdong's status as a port city facilitates frequent international exchanges, allowing doctors in this region easier access to advanced international medical technologies and concepts[47,48]. Secondly, as a pioneering region in China's reform and opening-up policies, Guangdong boasts abundant medical resources and advanced

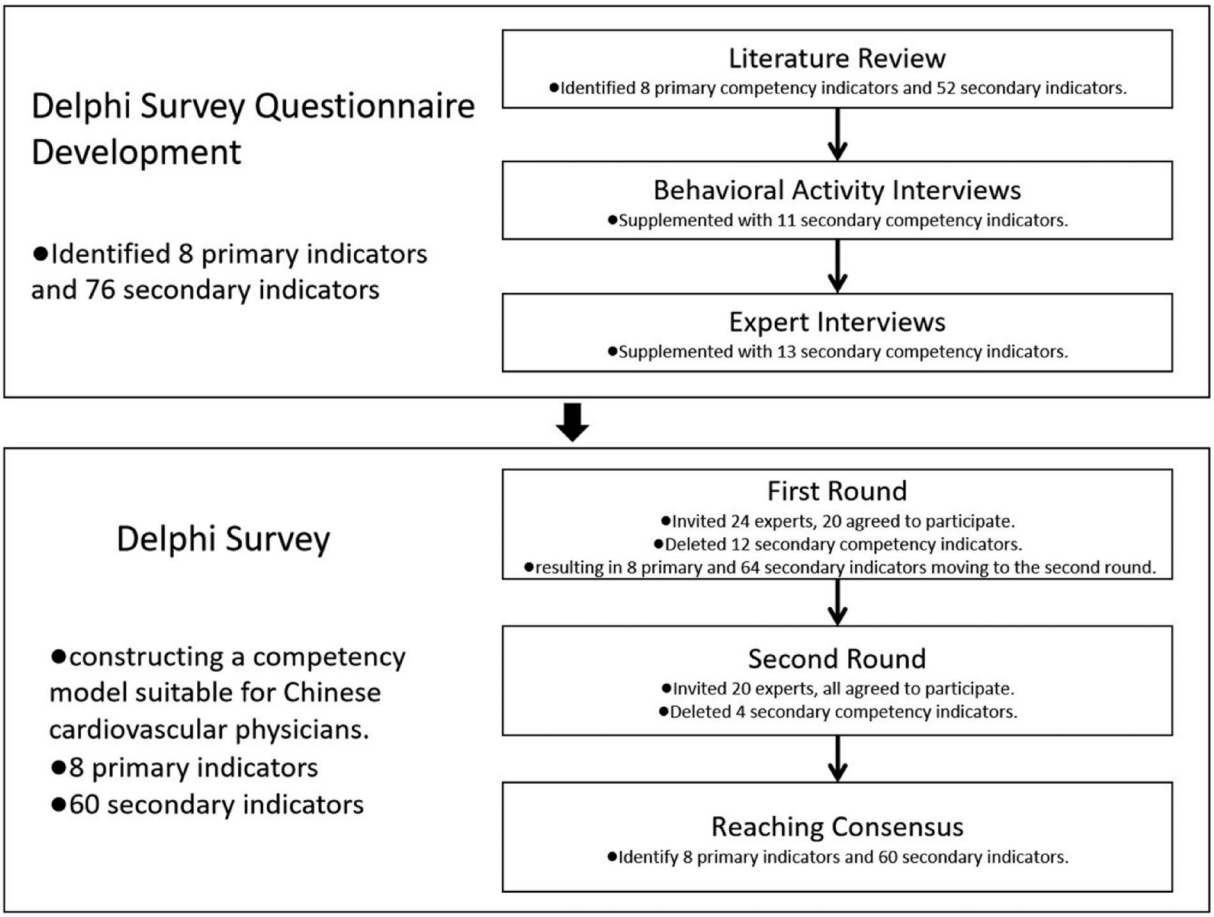

Fig. 1. Research process diagram.

medical equipment, conducive to establishing a high-level competency model[49,50]. Additionally, the diverse population composition in Guangdong, consisting of residents from various regions and cultural backgrounds, ensures the representativeness of the research data[51,52]. Importantly, the prevalence of cardiovascular diseases in Guangdong aligns with the typical characteristics of CVD in China, making it an ideal location to study and address the challenges posed by CVD in China and provide robust support for the construction of a competency model tailored to the Chinese context[3,16,53].

It is acknowledged that this sample may not fully represent physicians in rural or resource-limited areas, where cardiovascular diagnosis and treatment is typically provided by general internal medicine departments in primary or lower-tier secondary hospitals[54,55]. According to China's Hospital Classification Management Measures, only secondary and tertiary hospitals are required to establish independent cardiovascular departments[56]. In rural areas, patients with complex or severe cardiovascular conditions are typically referred to higher-level hospitals via China's hierarchical diagnosis and treatment system, which is supported by a cross-regional and multi-tiered health insurance reimbursement framework[57,58]. Despite these regional differences, the study adopts a competency-based framework grounded in the understanding that core competencies—defined as the deep, underlying attributes distinguishing superior from average clinical performance—are consistent across practice settings[59,60]. The model developed in this study reflects high-level competency expectations, which serve as benchmarks for excellence rather than basic entry-level standards. Furthermore, the study recognizes the importance of competency stratification, as outlined in frameworks such as the ESC Core Curriculum and CanMEDS, where competency levels (e.g., 1–2 for generalists and 4–5 for subspecialists) vary by clinical role and context[11,61]. Future research is warranted to explore how such stratified models can be adapted to suit the needs of low-resource settings, thereby supporting more context-sensitive workforce development across China. Therefore, selecting physicians and experts from Guangdong Province for this study is particularly significant, given the province's advanced medical infrastructure and diverse patient population, making it an appropriate setting for modeling high-level cardiovascular diagnosis and treatment competencies.

The physicians and experts participating in the behavioral event interviews and expert interviews all come from the Cardiovascular Disease Research Institute of Guangzhou Medical University.

The research team selected 20 experts from well-known hospitals in Guangdong Province, specializing in cardiology. This number aligns with the Delphi method's requirement for the number of experts, which ranges from 15 to 50[62]. The participating experts were from the following hospitals: The Second Affiliated Hospital of Guangzhou Medical University, The First Affiliated Hospital of Guangzhou Medical University, The Third

Affiliated Hospital of Guangzhou Medical University, The Affiliated Panyu Central Hospital of Guangzhou Medical University, Shenzhen Longcheng Hospital, Guangdong Provincial People's Hospital, Guangzhou Red Cross Hospital, Zhujiang Hospital of Southern Medical University, Southern Medical University Hospital of Integrated Traditional Chinese and Western Medicine, Sun Yat-sen Memorial Hospital, Sun Yat-sen University, The First Affiliated Hospital of Guangzhou University of Chinese Medicine, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangdong Armed Police Corps Hospital, Guangzhou Women and Children's Medical Center, and The First Affiliated Hospital of Jinan University. The criteria for selecting the experts included: (1) possessing solid knowledge in general cardiology and internal medicine, along with recognized academic achievements and reputation in the field of cardiology; (2) holding a senior professional title; (3) having 10 or more years of clinical experience; and (4) being involved in the training, teaching, and practice of cardiology. Expert information is detailed in Table 1.

Preparation of the Delphi questionnaire

Literature review

First, the research group referenced the framework of the General Competency Model for Chinese Clinical Physicians from China Medical University and established eight primary indicators, including clinical skills and medical services, disease prevention and health promotion, information and management skills, medical knowledge and lifelong learning ability, interpersonal communication skills, teamwork skills, scientific research skills, and Core Values and Professionalism[25,26]. Then, in March 2024, a search was conducted in the WOS database for publications related to cardiovascular physicians. Specifically, we used the search strategy ((“Cardiovascular” AND (“Physicians” OR “doctor”) AND (“competency” OR “competencies” OR “core competencies” OR “evaluation” OR “measurement” OR “tool” OR “indicator”))) to retrieve 1951 publications. After excluding publications unrelated to cardiovascular internal medicine by filtering through Web of Science Categories, Citation Topics Meso, and Citation Topics Micro, 226 publications were retained. Subsequently, each publication's content (including titles and abstracts) was manually reviewed to eliminate duplicates, literature reviews, and irrelevant publications, ensuring that the selected publications addressed the construction of competency models for cardiovascular physicians. Finally, 50 articles were retained for further analysis (Supplementary Table 1).

From these sources, secondary indicators were extracted, and a panel of two reviewers (ML and HL) was formed to screen them based on the following criteria: (1) indicators measuring physicians' abilities; (2)

Category	Participants	Number(*n*)	Percent(%)
Gender	Female	7	35
	Male	13	65
Education	Bachelor's degree	4	20
	Master's degree	5	25
	Doctoral degree	11	55
Professional title	Junior	0	0
	Interme	0	0
	Senior	20	100
Years of clinical experience	≤ 5	0	0
	6–10	0	0
	11–15	4	20
	16–20	5	25
	> 20	11	55
Practice environment	Academic Medical Center	18	90
	Service-Oriented Hospital	2	10
Field of expertise	Coronary heart disease	17	85
	Arrhythmia	14	70
	Heart failure,	15	75
	Hypertension,	15	75
	Cardiovascular Imaging	3	15
	Interventional cardiology	9	45
	Cardiac electrophysiology	4	20
	Cardiovascular genetics	1	5
	Cardiovascular rehabilitation	7	35

Table 1. Expert information. Table presents a statistical overview of the cardiology subspecialties of the experts. While these experts specialize in various areas of cardiology, all possess a solid foundation in general cardiology, including key skills like history taking, clinical examination, and patient communication. These core competencies are essential for assessing cardiologists' behavior and decision-making during the initial stages of a consultation, ensuring a comprehensive evaluation of their overall competence.

indicators relevant to the work of cardiovascular physicians; (3) indicators relevant to the requirements of cardiovascular physicians in China. When there was uncertainty about whether to retain a particular indicator, the research team collectively discussed and made decisions. The screening process identified 52 secondary indicators (Supplementary Table 2).

Behavioral event interviews
The research team recruited 22% of cardiovascular physicians from the Guangzhou Cardiovascular Disease Research Institute as participants (half defined as "high achievers" and half considered "low achievers," as shown in Supplementary Table 3) for behavioral event interviews. The classification was based on departmental recommendations and peer evaluations, which considered clinical performance, teamwork, communication skills, and professional development potential over the past two to three years. A total of 10 individuals were interviewed, resulting in 10 valid interview records. Subsequently, we supplemented the secondary indicators, resulting in the identification of 63 secondary indicators (Supplementary Table 2).

Expert interviews
The research team invited senior experts from the Guangzhou Institute of Cardiovascular Diseases for expert interviews. During these interviews, the entries obtained from literature analysis and behavioral event interviews were discussed to further refine or modify relevant items. Additionally, important abilities or qualities of cardiovascular physicians were supplemented, leading to the construction of an initial competency model. This model comprises 8 primary indicators and 76 secondary indicators (Supplementary Table 2).

Design of the Delphi questionnaire
The research team designed the Delphi questionnaire based on the initial competency model. The questionnaire comprises sections detailing the research background, objectives, expert demographics, criteria for indicator selection, a survey on the importance of primary indicators, and evaluation tables for the primary and secondary indicator systems. Assessment criteria include importance, feasibility, sensitivity, familiarity, criteria for judgment and impact level, and suggestions for modification. The scoring range and relevant guidelines for the assessment criteria are elaborately outlined (Supplementary Questionnaire 1).

Delphi questionnaire survey

The study employed two rounds of Delphi questionnaire surveys. Throughout the survey process, only the researchers knew the identities of the participants and could access each participant's responses. Participants were unaware of each other's names or responses. They could not view the replies of other participants or the round-by-round summary of results sent by the researchers, and they responded independently of other participants for each subsequent round.

First round
The first round of Delphi surveys was conducted from April to May 2024, lasting for 4 weeks. Experts were required to assess each indicator and provide feedback. After the completion of the first round of Delphi surveys, data were collated and analyzed, and adjustments to the indicators were made based on expert feedback.

Second round
The second round of Delphi surveys was conducted from May to June 2024, spanning 4 weeks. The survey was sent to the experts who participated in the first round. In the second round questionnaire, the competencies that had reached consensus or were modified based on expert feedback from the first round were retained. Additionally, statistical charts of the data from the first round survey were provided to the experts along with the second round questionnaire.

Consensus criteria
In Delphi studies, there are no exact consensus criteria[63]. In this study, the criteria for consensus are as follows: (1) At least two of the boundary values for importance, feasibility, and sensitivity meet the standard; (2) In the first round of surveys, modification of indicators requires suggestions from at least one expert, while in the second round, suggestions from at least two experts are necessary for modification; (3) The survey is terminated after two rounds, indicating consensus among the group members.

Statistical analysis

Positive coefficient of experts
The expert coefficient refers to the effective response rate of the expert consultation questionnaire, which can reflect the level of active participation by the experts. Generally, a 50% effective response rate is considered the minimum acceptable level, 60% is regarded as a good level, and 70% is considered to meet a very high standard[64].

Coefficient of experts' authority
The authority of experts (Cr) is determined by two factors: their professional knowledge in assessing the indicators (Ca) and their familiarity with the issue (Cs). The specific calculation method is as follows: (1) To evaluate Ca, experts are asked to assess the impact of their professional knowledge on judging the indicators from four aspects: "work experience", "theoretical analysis", "peer knowledge", and "intuition". When $Ca = 1$, the expert's professional knowledge has the highest impact on their judgment, and when $Ca = 0$, the expert's professional knowledge has no impact on their judgment, based on the valuation criteria outlined in Supplementary Table 4. (2) To evaluate Cs, experts are required to self-assess their familiarity with the issue using a Likert scale method

divided into five levels. When Cs = 1, the expert's familiarity with the issue is the highest (very familiar), and when Cs = 0, the expert's familiarity with the issue is the lowest (not familiar), based on the valuation criteria outlined in Supplementary Table 5. (3) Cr=(Ca + Cs)/2; values greater than 0.7 are considered acceptable[46].

Coefficient of experts' coordination

The level of expert coordination serves as a crucial indicator for assessing the consistency of indicators among experts, encompassing both the Kendall W coordination coefficient and the coefficient of variation for each index. The coefficient of variation plays a pivotal role in determining which indices should be excluded[65]. A smaller coefficient of variation indicates a higher degree of expert coordination.

Calculation and standards for boundary values

Drawing on previous research that utilized the Delphi method for competency studies, this research establishes boundary values for importance, feasibility, and sensitivity in the questionnaire. These boundary values include the mean boundary value, the coefficient of variation boundary value, and the full score frequency boundary value[46]. For example, the boundary value for importance is calculated as follows: the mean boundary value is determined by subtracting the standard deviation of importance from the mean of importance (importance mean boundary value = importance mean - importance standard deviation). The coefficient of variation boundary value is computed by adding the standard deviation of the coefficient of variation of importance to its mean (importance coefficient of variation boundary value = importance coefficient of variation mean + importance coefficient of variation standard deviation). The full score frequency boundary value is found by subtracting the standard deviation of the full score frequency of importance from its mean (importance full score frequency boundary value = importance full score frequency mean - importance full score frequency standard deviation).

For the importance of a competency to be considered as meeting the standard, it must satisfy at least two of the following conditions: the mean exceeds the mean boundary value, the coefficient of variation is below the coefficient of variation boundary value, and the full score frequency surpasses the full score frequency boundary value. The same method applies to calculating boundary values for feasibility and sensitivity, and evaluating whether an individual's feasibility or sensitivity meets the standard.

Calculation of weighted index

To determine the importance of each competency, in the second round of the survey, the research team employed the Scale Matrix Judgment Method. This involved having each expert compare the primary indicators in each row and column and then calculating the weights of the primary indicators using the Analytic Hierarchy Process (AHP). As for the weights of the secondary indicators, the team utilized the Percentage Weight Method for calculation.

Descriptive analysis was utilized to depict the characteristics of participants and outcomes. Mean (with standard deviation, SD) was used to report continuous variables, while frequency (%) was used for categorical variables. Data management and analysis were performed using SPSS 26.0 and YAAHP (Yet Another Analytical Hierarchy Process, https://www.metadecsn.com/yaahp/).

Results

Positive coefficient of experts

In the first round of the Delphi survey, 24 questionnaires were distributed, and 20 were successfully retrieved, resulting in a response rate of 83%. In the second round, 20 questionnaires were distributed, and all were successfully retrieved, achieving a 100% response rate. Both rounds met relatively high standards, indicating that the experts demonstrated significant interest and enthusiasm for this research.

Coefficient of experts' authority

The authority coefficients of the experts in the two rounds of the Delphi survey ranged from 0.7 to 0.9, both exceeding 0.7. This indicates that the results of both rounds have high accuracy and reliability (Supplementary Table 6).

Coefficient of experts' coordination

In the two rounds of the Delphi survey, the mean coefficient of variation (Mean CV) for both primary and secondary indicators gradually decreased, indicating that expert opinions became more convergent with each successive round. Additionally, the coordination coefficients for both primary and secondary indicators increased, suggesting an improvement in the degree of consensus among experts. After two rounds of surveys, the P-values corresponding to the coordination coefficients were all less than 0.05, demonstrating a good level of agreement among the experts and indicating that the results are reliable (Table 2).

Consensus process

First round

Statistical analysis of the first round of Delphi questionnaire results showed that the boundary values for the primary indicators "Information and Management Skills" and "Core Values and Professionalism" did not meet the study's predetermined thresholds. However, given the importance of Information and Management Skills in enhancing the efficiency of cardiovascular healthcare[66,67] and the critical role of Core Values and Professionalism in physicians' practice[68,69]expert consultation concluded that these competencies are essential for effective diagnosis and treatment. Therefore, despite not meeting the predefined thresholds, these indicators were retained (Supplementary Table 7).

Round	Indicator level	Importance				Feasibility				Sensitivity			
		Mean CV	W	χ^2	*P*-Value	Mean CV	W	χ^2	*P*-Value	Mean CV	W	χ^2	*P*-Value
First	Primary Indicators	0.171	0.295	41.264	< 0.01	0.243	0.062	8.649	0.279	0.274	0.08	11.186	0.131
	Secondary Indicators	0.148	0.139	207.857	< 0.01	0.213	0.181	271.224	< 0.01	0.198	0.168	252.497	< 0.01
Second	Primary Indicators	0.051	0.774	108.321	< 0.01	0.067	0.553	77.462	< 0.01	0.085	0.749	104.832	< 0.01
	Secondary Indicators	0.034	0.617	777.225	< 0.01	0.04	0.763	960.898	< 0.01	0.041	0.739	930.533	< 0.01

Table 2. Coefficient of experts' coordination. Mean CV: mean coefficient of variation. W: Kendall W coordination coefficient. χ^2:Chi-square.

Among the secondary indicators, 18 did not meet the study's boundary value requirements. Following expert consultation, 12 indicators were excluded, while 6 were retained. These 6 indicators primarily cover areas such as interprofessional collaboration, understanding the healthcare system, utilizing information technology, promoting cardiovascular health, and fostering effective communication and critical thinking skills. Experts deemed these competencies essential for the effective practice of Chinese cardiovascular physicians and for improving clinical outcomes and patient satisfaction, thus they were retained (Supplementary Table 8).

Therefore, based on the consensus criteria, 8 primary indicators and 64 secondary indicators were included in the second round (Supplementary Questionnaire 2).

Second round

After conducting statistical analysis of the second round of Delphi questionnaire results, it was found that the boundary values for the two primary indicators, "Information and Management Skills" and 'scientific Research Skills", did not meet the study's requirements. However, following expert consultation, both indicators were retained. In particular, Scientific Research Skills are increasingly recognized as crucial in the training of future cardiovascular professionals[70–72] (Supplementary Table 9).

Among the secondary indicators, 10 did not meet the study's boundary value requirements. Following expert consultation, 4 indicators were excluded, while 6 were retained. These 6 indicators, covering areas such as personalized cardiovascular disease prevention, interprofessional collaboration, understanding the healthcare system, effective communication, critical thinking, and maintaining personal health, were considered essential components of the competency framework for Chinese cardiovascular physicians and were thus retained (Supplementary Table 10).

The Delphi process concluded with consensus on 60 secondary indicators under 8 primary indicators. These are: Clinical Skills and Medical Services (17 competencies), Disease Prevention and Health Promotion (3 competencies), Information and Management Skills (6 competencies), Medical Knowledge and Lifelong Learning Ability (5 competencies), Interpersonal Communication Skills (9 competencies), Teamwork Skills (3 competencies), Scientific Research Skills (3 competencies), and Core Values and Professionalism (14 competencies) (Table 3).

Indicator system and weighting results

After completing the two rounds of Delphi surveys, the research team employed the Analytic Hierarchy Process (AHP) and percentage weighting method to determine the weights for primary and secondary indicators, resulting in the assigned weights for each indicator. Additionally, in developing the competency scale, the team followed a hierarchical approach to ensure better alignment with clinical practicality, proposing an enhanced Likert scale method tailored for physician competency models. Finally, based on the Onion Model, a competency model for cardiovascular physicians suited to the Chinese context was established. (Table 3; Fig. 2)

Discussion

Although research on cardiovascular physician competency models is already very systematic internationally, factors such as China's unique geographic and cultural environment, healthcare industry, medical education system, and policies and regulations directly impact the actual work and competency requirements of physicians[33,57,73–76]. Therefore, directly adopting international cardiovascular competency models may not fully meet China's practical needs. To address this issue, our research developed a customized competency model for cardiovascular physicians within the framework of the Chinese clinical physician competency model[25,26]. Using an improved Delphi method, we conducted literature reviews, behavioral event interviews, and expert consultations, followed by two rounds of Delphi surveys with 20 renowned cardiovascular experts from Guangdong Province. In both rounds of the Delphi surveys, the expert authority coefficients exceeded 0.7, and the p-values of the expert coordination coefficients were less than 0.01, indicating high accuracy and reliability of the results. Ultimately, this research developed a competency model tailored to the Chinese context for cardiovascular physicians, comprising 8 primary indicators and 60 secondary indicators, each with assigned weights.

In the meantime, this competency model is based on the onion model and is divided into three layers: knowledge, skills/abilities, and motivation/values. The outermost layer represents the professional knowledge required by Chinese cardiovascular physicians in their work, including "Clinical Skills and Medical Services" ,"Disease Prevention and Health Promotion" and "Information and Management Skills". These are the basic competencies necessary to fulfill their duties. The middle layer comprises the skills and abilities that

Primary indicators	Weights of primary indicators	No.	Secondary indicators	Weights of secondary indicators	Integrated weights	Familiarity of the physician				
						Unable to perform at all (1 point)	Can perform under supervision (2 points)	Can perform independently (3 points)	Can guide junior physicians (4 points)	Deep understanding and personal insight (5 points)
P1.Clinical skills and medical services	0.195	P1S1	Able to systematically and accurately obtain patient history for cardiovascular conditions, including history of present illness, past medical history, family history, and risk factors, with a particular focus on common cardiovascular diseases such as coronary artery disease, hypertension, heart failure, and arrhythmias.	0.0599	0.0117					
		P1S2	Proficient in performing standardized cardiovascular physical examinations, capable of identifying typical signs of heart failure, valvular diseases, pericardial disorders, and peripheral vascular diseases, and independently interpreting abnormal findings.	0.0605	0.0118					
		P1S3	Capable of selecting and interpreting a wide range of cardiovascular diagnostic tests, including ECG, Holter monitoring, echocardiography, coronary CT angiography, cardiac MRI, laboratory investigations, functional assessments (e.g., cardiac function tests, exercise ECG, stress echocardiography, pharmacologic stress tests, myocardial perfusion imaging), and invasive diagnostic procedures such as cardiac catheterization, electrophysiological studies, and pacemaker function evaluation, to support accurate diagnosis of coronary artery disease, valvular disease, cardiomyopathies, pulmonary hypertension, and related conditions.	0.0602	0.0117					
		P1S4	Able to communicate effectively within multidisciplinary teams regarding cardiovascular patient care, clearly articulating clinical judgments and management plans, especially in acute conditions such as acute coronary syndromes, decompensated heart failure, and life-threatening arrhythmias.	0.0599	0.0117					
		P1S5	Capable of formulating individualized treatment plans based on evidence-based medicine, integrating the latest Chinese clinical guidelines and international scientific evidence, including pharmacologic therapy, interventional and surgical treatments, and rehabilitation strategies.	0.0593	0.0116					
		P1S6	Skilled in recognizing and participating in the emergency management of cardiovascular emergencies, including acute myocardial infarction, severe arrhythmias, acute heart failure, aortic dissection, and pulmonary embolism, with the ability to operate effectively in emergency or ICU settings.	0.0599	0.0117					
		P1S7	Able to independently assess and triage cardiovascular patients, develop preliminary diagnostic and treatment plans, and recognize the need for referral or multidisciplinary collaboration.	0.0596	0.0116					

Continued

Primary indicators	Weights of primary indicators	No.	Secondary indicators	Weights of secondary indicators	Integrated weights	Familiarity of the physician				
						Unable to perform at all (1 point)	Can perform under supervision (2 points)	Can perform independently (3 points)	Can guide junior physicians (4 points)	Deep understanding and personal insight (5 points)
		P1S8	Possesses cross-disciplinary analytical skills to design personalized chronic disease management strategies—such as for hypertension and secondary prevention of coronary artery disease—based on the sociocultural and psychological context of Chinese patients.	0.0553	0.0108					
		P1S9	Able to integrate the latest cardiovascular research findings into clinical practice, enhancing diagnostic and therapeutic outcomes, including the application of cardiac rehabilitation, remote monitoring, and AI-assisted diagnostics.	0.0553	0.0108					
		P1S10	Proficient in the use and safe handling of commonly used cardiovascular equipment and medications, including monitors, temporary pacemakers, coronary angiography tools, vascular stents, and cardiovascular drugs, with the ability to identify and manage associated complications.	0.0599	0.0117					
		P1S11	Skilled in comprehensive and compliant medical documentation, ensuring completeness, traceability, and legal soundness of clinical records, with accurate recording of key decision points, especially in multidisciplinary contexts.	0.0599	0.0117					
		P1S12	Able to independently assess and manage complex cardiovascular conditions (e.g., multivessel coronary disease, severe valvular heart disease, refractory hypertension, adult congenital heart disease, chronic heart failure), incorporating Chinese population characteristics and local clinical experience.	0.0599	0.0117					
		P1S13	Knowledgeable in commonly used diagnostic and therapeutic techniques within the Chinese healthcare context, including percutaneous coronary interventions, radiofrequency ablation, device implantation (e.g., pacemakers, ICDs), and transcatheter valve procedures, with basic technical and perioperative management competencies.	0.0556	0.0108					
		P1S14	Demonstrates cultural competence and effective communication, establishing trust with patients and families, explaining disease conditions, treatment options, and prognosis clearly, and providing psychological support, health education, and guidance for long-term care.	0.0599	0.0117					
		P1S15	Able to explain medical concepts in lay terms, engage patients in shared decision-making, and enhance their adherence to pharmacologic and lifestyle interventions (e.g., diet, exercise, smoking cessation).	0.0596	0.0116					

Continued

Primary indicators	Weights of primary indicators	No.	Secondary indicators	Weights of secondary indicators	Integrated weights	Familiarity of the physician				
						Unable to perform at all (1 point)	Can perform under supervision (2 points)	Can perform independently (3 points)	Can guide junior physicians (4 points)	Deep understanding and personal insight (5 points)
		P1S16	Possesses a comprehensive understanding of the procedural workflow and technical nuances of cardiovascular interventions and minimally invasive procedures, with the ability to optimize technique, anticipate intraoperative challenges, and coordinate effectively within multidisciplinary teams to ensure procedural safety and efficacy.	0.0553	0.0108					
		P1S17	Able to select cardiovascular medications rationally in the context of common comorbidities in the Chinese population (e.g., diabetes, renal impairment), and well-versed in indications, contraindications, adverse effects, and drug interactions to optimize therapeutic outcomes and minimize risk.	0.0605	0.0118					
P2.Disease prevention and health promotion	0.1115	P2S1	Provide personalized prevention measures and health promotion plans for cardiovascular diseases in Chinese patients, including lifestyle changes, dietary recommendations, exercise programs, and cardiovascular disease screening.	0.3358	0.0374					
		P2S2	Collaborate with other medical teams and public health departments to develop comprehensive cardiovascular disease prevention and control strategies, including rehabilitation programs tailored to China's context.	0.3321	0.037					
		P2S3	Familiarize with the structure and operational mechanisms of the Chinese cardiovascular healthcare system, and make effective use of medical resources in the cardiovascular field in China to ensure the implementation of disease prevention and health promotion efforts.	0.3321	0.037					
P3.Information and management skills	0.0611	P3S1	Utilize specialized databases and literature search tools in the field of cardiovascular diseases to obtain the latest medical information and research findings.	0.1787	0.0109					
		P3S2	Employ information technology to communicate effectively with other healthcare professionals, including through medical conferences, academic discussions, and telemedicine consultations, to promote comprehensive patient management.	0.1622	0.0099					
		P3S3	Ensure the rationality and cost-effectiveness of cardiovascular treatment and medication plans, effectively control medical expenses, and enhance the efficiency of medical resource utilization.	0.1659	0.0101					
		P3S4	Strictly adhere to China's medical information management regulations and standards, managing cardiovascular patient records and related information to ensure completeness, accuracy, and confidentiality.	0.165	0.0101					

Continued

Primary indicators	Weights of primary indicators	No.	Secondary indicators	Weights of secondary indicators	Integrated weights	Familiarity of the physician				
						Unable to perform at all (1 point)	Can perform under supervision (2 points)	Can perform independently (3 points)	Can guide junior physicians (4 points)	Deep understanding and personal insight (5 points)
		P3S5	Conduct comprehensive health assessments and management of cardiovascular patients, including diagnosis, treatment, and rehabilitation guidance, considering the unique epidemiological and cultural characteristics of cardiovascular diseases in China.	0.1641	0.01					
		P3S6	Utilize modern information technology to conduct cardiovascular health education and publicity activities with Chinese characteristics, raising public awareness and prevention of cardiovascular diseases.	0.1641	0.01					
P4.Medical knowledge and lifelong learning ability	0.1066	P4S1	Master the fundamental biomedical knowledge of cardiovascular diseases, including cardiovascular anatomy, physiology, and pathology, with particular attention to the characteristics of the Chinese population.	0.1996	0.0213					
		P4S2	Possess knowledge in behavioral and social sciences, medical ethics, and law, and be able to integrate the Chinese cultural background into clinical practice, considering patients' psychological, social, and legal factors.	0.2007	0.0214					
		P4S3	Proficiently apply basic clinical medical knowledge, including the diagnosis, treatment, and prevention of cardiovascular diseases, and develop personalized treatment plans based on the characteristics of the Chinese population.	0.2007	0.0214					
		P4S4	Stay informed about the latest advancements in the field of cardiovascular medicine, including the application of new materials and technologies, with a particular focus on key areas such as imaging, coronary artery disease, valvular heart disease, heart failure, arrhythmias, acute cardiovascular settings, prevention and rehabilitation, as well as basic knowledge of aortic diseases, trauma to the aorta or heart, peripheral artery disease, thromboembolic venous disease, pulmonary thromboembolism, pulmonary hypertension, and adult congenital heart disease, in order to continuously enhance knowledge and professional skills.	0.2018	0.0215					
		P4S5	Actively participate in continuing education and academic exchange activities in the field of cardiovascular medicine, such as conferences, seminars, and training courses, to continuously improve professional capabilities and clinical practice.	0.1973	0.021					
P5. Interpersonal communication skills	0.0643	P5S1	Listen to patients' opinions and concerns, understand their condition and psychological state, to provide better medical services.	0.1116	0.0072					
		P5S2	Respect patients' choices and opinions, build a trustful relationship with them, and especially consider the cultural context of China to ensure patients feel respected and cared for.	0.1116	0.0072					

Continued

Primary indicators	Weights of primary indicators	No.	Secondary indicators	Weights of secondary indicators	Integrated weights	Familiarity of the physician				
						Unable to perform at all (1 point)	Can perform under supervision (2 points)	Can perform independently (3 points)	Can guide junior physicians (4 points)	Deep understanding and personal insight (5 points)
		P5S3	Safeguard patients' privacy and the right to informed consent, ensuring that their personal and medical information is kept confidential and respected.	0.1116	0.0072					
		P5S4	Handle ethical issues in medical practice, such as patient rights protection and medical decision-making, in accordance with Chinese ethical traditions and values, respecting patients' personal wishes and family concepts, and protecting their legal rights.	0.1116	0.0072					
		P5S5	Actively prevent and resolve conflicts and misunderstandings between patients and healthcare providers through effective communication and explanation, alleviating patients' anxiety and concerns.	0.1104	0.0071					
		P5S6	Deliver negative news, such as disease diagnoses or treatment plans, to patients in a sensitive manner, balancing honesty with compassion to minimize emotional distress.	0.111	0.0071					
		P5S7	Engage with patients and their families in clinical decision-making, respecting patients' wishes and reaching consensus, while considering the Chinese cultural environment.	0.1104	0.0071					
		P5S8	Clearly and accurately convey medical information and treatment plans to patients and their families, ensuring they understand and comply with medical procedures.	0.1116	0.0072					
		P5S9	Communicate and collaborate effectively with patients, families, medical team members, and other healthcare professionals to ensure the smooth delivery of medical services.	0.1104	0.0071					
P6.Teamwork skills	0.0581	P6S1	Actively collaborate with team members, respecting their professional abilities and contributions, jointly develop patient treatment plans, and coordinate resources to ensure smooth medical services.	0.3243	0.0188					
		P6S2	Demonstrate good communication and coordination skills, emphasize harmony and stability, promptly resolve internal conflicts and disputes, and maintain team harmony and stability.	0.3243	0.0188					
		P6S3	Follow and execute the orders and clinical treatment decisions of senior physicians to ensure patients receive standardized and timely medical services, maintaining their health and safety.	0.3514	0.0204					
P7.Scientific research skills	0.1734	P7S1	Exhibit critical thinking abilities, applying China's cultural emphasis on practical and thoughtful analysis to make appropriate medical decisions, providing high-quality medical services, and enhancing patient trust and satisfaction.	0.334	0.0579					
		P7S2	Possess the ability to read and review academic literature, conduct systematic literature reviews, stay updated on the latest medical advancements, and actively disseminate and share medical knowledge.	0.334	0.0579					

Continued

Primary indicators	Weights of primary indicators	No.	Secondary indicators	Weights of secondary indicators	Integrated weights	Familiarity of the physician				
						Unable to perform at all (1 point)	Can perform under supervision (2 points)	Can perform independently (3 points)	Can guide junior physicians (4 points)	Deep understanding and personal insight (5 points)
		P7S3	Actively participate in research activities in cardiovascular diseases, especially in high-priority areas such as coronary artery disease, heart failure, and arrhythmias, to contribute to evidence-based practice in China's evolving healthcare system.	0.3321	0.0576					
P8.Core values and professionalism	0.23	P8S1	Adhere to the principle of serving the health of the people throughout one's career, prioritize patients' health, provide high-quality medical services, and uphold the original intentions of being a physician.	0.0767	0.0176					
		P8S2	Foster an altruistic mindset, strive for medical excellence, actively contribute to the development of China's healthcare system, avoid temptations of fame and fortune, and practice compassion through tangible actions.	0.0708	0.0163					
		P8S3	Possess sincere and trustworthy qualities, strong sense of responsibility, and proactively fulfill the duties of a physician, addressing issues of trust between doctors and patients in China with a professional attitude and dedication.	0.0708	0.0163					
		P8S4	Show love and empathy, care for patients' physical and mental health, protect their rights, privacy, and interests, and provide warmth and concern.	0.0708	0.0163					
		P8S5	Abide by industry standards, insurance policies, and ethical guidelines, putting patients at the center, and wholeheartedly pursue the greatest benefit for patients, safeguarding their rights and interests.	0.0705	0.0162					
		P8S6	Exhibit meticulous, detailed, and keen medical observation and analysis skills, and accurately assess patients' conditions and needs, considering the characteristics of cardiovascular patients in China.	0.0705	0.0162					
		P8S7	Maintain physical and mental health, possess good psychological qualities and stress resilience, effectively handle various pressures and challenges in work and life, and maintain a healthy working state.	0.0705	0.0162					
		P8S8	Utilize medical resources fairly and reasonably in medical services, be mindful of the uneven distribution of healthcare resources in China, ensure effective use of resources, provide equitable medical services, and promote sustainable development in healthcare.	0.0701	0.0161					
		P8S9	Have awareness of occupational health and protection, take effective measures to reduce occupational hazards in medical work, and ensure the health and safety of healthcare professionals.	0.0767	0.0176					
		P8S10	Be capable of responding to emergencies, focus on the handling of medical disasters and public health emergencies in China, and be able to react quickly and decisively to ensure patient safety and interests.	0.0705	0.0162					

Continued

Primary indicators	Weights of primary indicators	No.	Secondary indicators	Weights of secondary indicators	Integrated weights	Familiarity of the physician				
						Unable to perform at all (1 point)	Can perform under supervision (2 points)	Can perform independently (3 points)	Can guide junior physicians (4 points)	Deep understanding and personal insight (5 points)
		P8S11	Maintain a clean and professional appearance, reflecting the image of a physician and showcasing the demeanor of a medical professional.	0.0705	0.0162					
		P8S12	Objectively assess one's clinical abilities, recognize personal limitations, and seek advice or assistance from others in a timely manner to enhance medical skills and service quality.	0.0708	0.0163					
		P8S13	Respect the professional opinions and advice of colleagues, maintain good relationships with peers, and jointly promote the development of the healthcare industry.	0.0705	0.0162					
		P8S14	Be aware of the risks of medical disputes, understand the occurrence and handling of such disputes in China, anticipate potential disputes, and take measures to prevent or resolve them.	0.0705	0.0162					

Table 3. Competency model for cardiovascular physicians in accordance with the Chinese context.

Chinese cardiovascular physicians must possess, such as "Medical Knowledge and Lifelong Learning Ability" ,"Interpersonal Communication Skills" ,"Teamwork Skills" and "scientific Research Skills". These competencies are usually acquired through practical experience or systematic training. The innermost layer is "Core Values and Professionalism", which reflects the motivational traits and values of Chinese cardiovascular physicians. This layer represents the driving force behind their commitment to their work.

Since the establishment of The American College of Cardiology/American Heart Association/American College of Physicians–American Society of Internal Medicine (ACC/AHA/ACP–ASIM) in 1998, the Core Cardiology Training Statement (COCATS) has been formulated[6,77–80]. COCATS primarily covers six dimensions: Medical Knowledge, Patient Care and Procedural Skills, Systems-Based Practice, Practice-Based Learning and Improvement, Professionalism, and Interpersonal and Communication Skills. In comparison, our research team developed a cardiovascular physician competency model tailored to the Chinese context, addressing specific needs within China's medical environment. This model includes eight dimensions: Clinical Skills and Medical Services, Disease Prevention and Health Promotion, Information and Management Skills, Medical Knowledge and Lifelong Learning Ability, Interpersonal Communication Skills, Teamwork Skills, Scientific Research Skills, and Core Values and Professionalism. This model not only encompasses the dimensions emphasized by COCATS—such as medical knowledge, clinical skills, continuous learning, professionalism, and communication skills—but also adds a focus on teamwork, information management, scientific research abilities, and core values. These additions reflect the importance of team collaboration, information technology application, scientific research capabilities, and core values within the Chinese medical environment.

The cardiovascular education roadmap proposed by the European Society of Cardiology (ESC) emphasizes the humanistic aspects of medical training, including medical ethics, communication skills, and attention to patient-related outcomes. It also highlights the impact of new technologies on cardiology training and continued medical education. These recommendations support ESC's goal of providing comprehensive and high-quality cardiovascular education for the next generation of specialists[81]. These aspects align well with our model's emphasis on information management, core values, and physician professionalism. However, unlike the ESC's broader recommendations, our model is specifically designed to address the unique characteristics of China's healthcare system. In China, there is a significant focus on the efficient management of information due to the large population and the need for streamlined healthcare services. Additionally, there is an increasing emphasis on research innovation to tackle prevalent local health issues and to advance medical practices. Furthermore, the core values and professional standards for physicians in China are tailored to align with the cultural context and healthcare policies of the country. Therefore, our model more effectively meets the specific demands for information management, research innovation, and physician professionalism in the Chinese medical environment.

The Canadian Medical Education Directions for Specialists (CanMEDS) framework requires residents to achieve proficiency in seven roles: medical expert (central role), professional, health advocate, scholar, manager, collaborator, and communicator. This comprehensive description offers trainees guidance on the cognitive knowledge, technical skills, and personal qualities necessary for their profession[9]. In comparison, our model is specifically designed for the Chinese healthcare environment, utilizing two levels of indicators that provide more detailed descriptions of competencies. This approach offers a more concrete and practical framework for evaluating the capabilities of Chinese cardiovascular physicians, delivering a more targeted and operational tool.

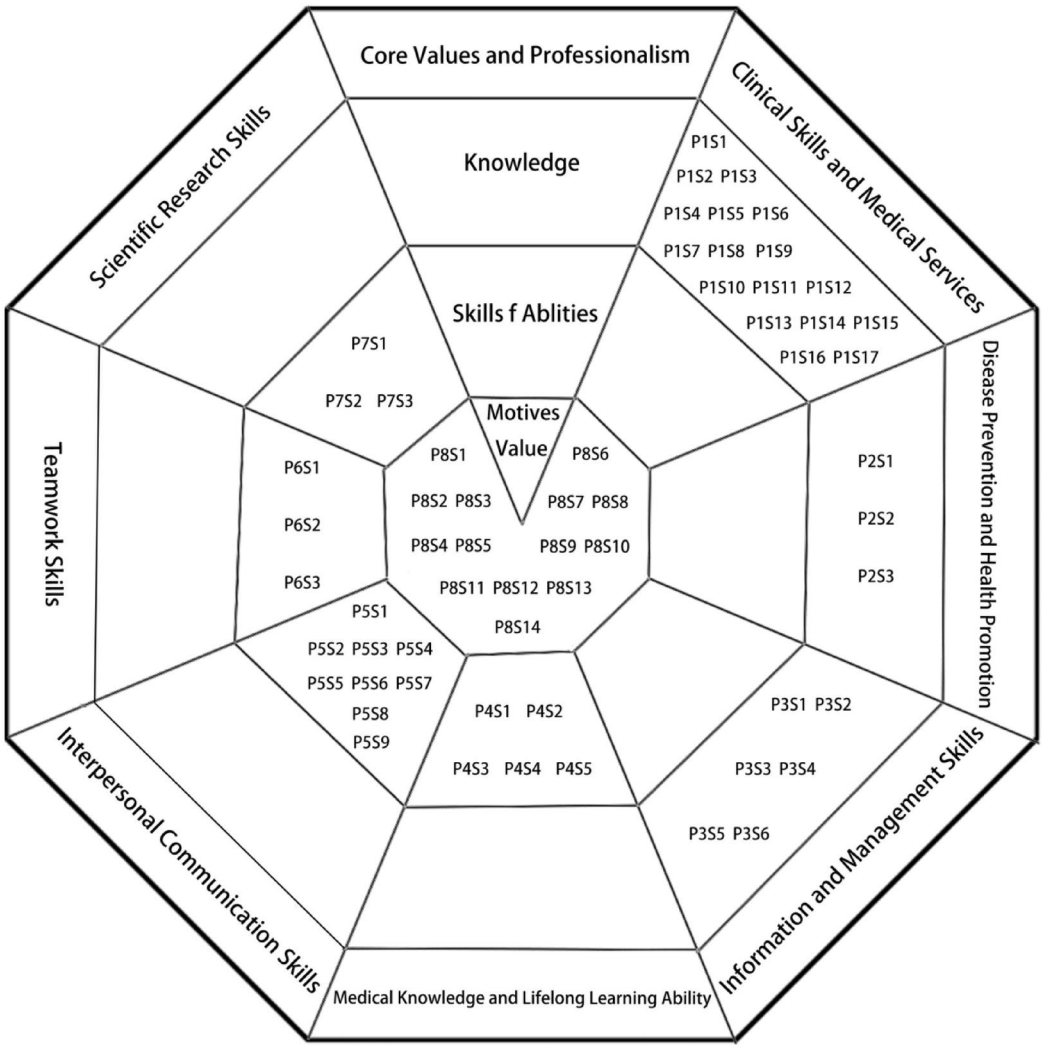

Fig. 2. Chinese cardiovascular physician competency model diagram. Codes represent the meanings of the items in Table 3.

In constructing the competency model for cardiovascular physicians, our research team has fully taken into account various factors unique to China, including its culture, distribution of medical resources, medical education system, policies and regulations, as well as patient needs. These considerations are reflected in the following aspects:

(1) In terms of clinical skills and medical services, we focus on the characteristics of common cardiovascular diseases among the Chinese population. By integrating China's unique cultural and social background, as well as considering the country's medical resources and technological capabilities, we are committed to selecting appropriate medications tailored to the characteristics and needs of Chinese patients.
(2) In terms of disease prevention and health promotion, we emphasize analyzing the epidemiological trends of cardiovascular diseases in China. By tailoring personalized prevention measures and health promotion programs for Chinese patients, we aim to optimize the utilization of cardiovascular medical resources in China. We actively promote cardiovascular health education initiatives and public awareness campaigns tailored to the Chinese context, aiming to implement infection control measures for cardiovascular diseases and advance the implementation of cardiovascular health policies and strategies in China.
(3) In terms of information and management capabilities, we emphasize the utilization of professional databases and literature retrieval tools in the field of cardiovascular diseases to conduct cardiovascular health education and promotional activities tailored to the Chinese context. We advocate for effective communication with other healthcare professionals, considering the unique epidemiological characteristics and cultural background of cardiovascular diseases in China, to promote comprehensive patient management.
(4) In terms of medical knowledge and lifelong learning abilities, we focus on cardiovascular biomedical fundamentals tailored to the characteristics of the Chinese population. We emphasize the importance of integrating Chinese cultural backgrounds and considering patients' psychological, social, and legal factors to develop personalized diagnosis and treatment plans. Additionally, we advocate for staying updated on the

latest advancements in the field of Chinese cardiovascular medicine to continuously enhance our professional expertise.
(5) In terms of interpersonal communication skills, we particularly emphasize the Chinese cultural background. Integrating Chinese ethical traditions, values, and cultural atmosphere, we are committed to establishing trust with patients.
(6) In terms of teamwork ability, we integrate the Chinese cultural atmosphere and emphasize the work and life of team members. We emphasize harmony and stability, timely resolution of internal conflicts and disputes within the team, to reflect the importance of teamwork cooperation in the Chinese medical context.
(7) In terms of scientific research ability, we integrate the traditional Chinese values of seeking truth and cautious deliberation. Within the Chinese medical environment, we foster an atmosphere of innovation and exploration, nurturing creative thinking and innovative capabilities. Moreover, grounded in the Chinese emphasis on academic exchange and collaboration, we advocate active participation in academic exchanges and conferences.
(8) In terms of core values and professional ethics, we prioritize patient health and uphold the original intention of being a doctor. We pay special attention to the issue of trust between Chinese doctors and patients, providing warmth and care to patients. Regarding the allocation of medical resources, we adhere to principles of fairness and reasonableness, promoting the sustainable development of healthcare services.

Furthermore, to better align with practical clinical application, our research team proposed an improved Likert scale method for the physician competency model based on a hierarchical approach. In this scale, the familiarity of physicians is subdivided into the following five levels:

(1) Unable to perform at all (1 point): The physician has no understanding of the competency or is unable to complete related tasks.
(2) Can perform under supervision (2 points): The physician requires guidance from a superior to complete the tasks.
(3) Can perform independently (3 points): The physician can complete the tasks independently without additional guidance.
(4) Can guide junior physicians (4 points): The physician can not only complete the tasks independently but can also guide junior physicians.
(5) Deep understanding and personal insight (5 points): The physician has a profound understanding of the competency, can think independently, and can provide insightful evaluations and decisions based on personal insights.

Compared to the typical competency models that only categorize physicians' familiarity levels using Likert scales as very familiar, quite familiar, moderately familiar, somewhat familiar, and unfamiliar, this improved approach is more aligned with real clinical application, exhibiting greater specificity and differentiation. It emphasizes physicians' autonomy and reflective awareness and enhances the flexibility and adaptability of the scale. Consequently, it can more effectively assess physicians' competency levels, provide more targeted guidance for their training and development and offer greater advantages.

Although we employed the modified Delphi method and integrated various approaches**—such as literature review, behavioral event interviews, and expert consultations—**in our study, including two rounds of Delphi surveys with experts in cardiovascular medicine to develop a competency model tailored to the Chinese context, we must acknowledge several limitations that may impact the interpretation and generalizability of our findings. Firstly, the Delphi method itself has inherent limitations. It relies on the subjective judgments and experiences of experts. Although we strengthened the rigor and scientific validity of our study through measures such as expert positive coefficients, authority coefficients, and coordination coefficients, the process may still be susceptible to biases stemming from expert selection and participation levels. Additionally, during the process of expert communication and consensus-building, there is a potential risk of information imbalance or opinion dominance. Secondly, the literature review component may have been affected by selection bias. Some relevant studies may not have been included in the analysis, which could compromise the comprehensiveness and accuracy of the resulting competency model. Thirdly, the behavioral event interviews and expert consultations may have been influenced by the respondents' subjective memory and personal biases, potentially leading to incomplete or inaccurate data. Fourthly, our study focused on cardiovascular physicians and experts from Guangdong Province. While Guangdong exhibits typical geographical, economic, and demographic features and holds a leading role in China's healthcare development, it may not fully represent the diversity of medical environments across the country—particularly in rural or economically underdeveloped regions. These areas may differ significantly in terms of healthcare resources, physician responsibilities, training access, and population health needs. As such, the competency requirements for cardiovascular physicians in these settings may differ from those in tertiary, high-resource centers. This could limit the generalizability of our model. In future work, we plan to expand the sampling scope to include experts from multiple regions and healthcare settings to further validate and refine the model. Moreover, considering the substantial variation in healthcare systems and physician roles across China, it may be necessary to develop a stratified competency framework—for example, a basic tier (e.g., level 1–2 in the ESC Core Curriculum or CanMEDS framework) for general cardiovascular care in primary or resource-limited settings, and an advanced tier (e.g., level 4–5) for subspecialist physicians in high-income or tertiary institutions. Finally, we also intend to disseminate the research findings through follow-up surveys aimed at assessing the actual competency levels of cardiovascular physicians in China. This will further enhance the model's generalizability and provide more effective guidance for physician recruitment, evaluation, and training.

Conclusion

Based on the consensus process using the modified Delphi method, the research team has developed a competency model for cardiovascular physicians tailored to the Chinese context. This model consists of 8 primary indicators and 60 secondary indicators, covering various aspects of clinical performance and professional behaviors of cardiovascular physicians. This model can provide effective guidance for the recruitment, assessment, and training of cardiovascular physicians in China. However, further research validation is still needed before applying this competency model to general practice.

Data availability

The raw data and code is available from the corresponding author (weiweiquan1980@126.com) on reasonable request.

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Author contributions

Data analysis and manuscript composition were performed by S.S. M.L. and H.L. contributed to data collection and data interpretation. W.H., Y.Z. and B.Z. were responsible for data collection.W.Q. designed the study and critically reviewed the manuscript. All authors participated in the preparation of the article and gave their approval for the final version.

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Declarations

Competing interests

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