

Perceived Importance of Core Competencies Among Chinese Epidemiological Practitioners: A Network Analysis and Implications for Targeted Training

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Abstract

Background

Epidemiology is the core supporting discipline of public health prevention and control. Against the background of the Healthy China initiative and normalized public health risks, the core competence of practitioners directly affects the efficiency of disease prevention and control and emergency response. At present, the workforce is confronted with problems such as unbalanced competence structure and insufficient reserve of emerging skills. It is urgent to clarify the current status and influencing factors of the perception of core competence importance, so as to provide a basis for optimizing talent training.

Methods

A total of 1,150 epidemiological practitioners from disease control and prevention (CDCs), medical institutions, universities and other institutions at all levels in multiple provinces of China were selected by convenience sampling. An online survey was conducted using a validated scale with good reliability and validity. Data were processed by descriptive statistics, one-way ANOVA and network analysis.

Results

Practitioners' overall perception of the importance of 34 core competencies was high, with a total mean score of 150.27 ± 21.99 . The mean score per item of the 6 dimensions ranged from 4.28 to 4.53, showing an overall characteristic of "valuing basic practical operation while neglecting emerging cross-domain competence". Gender, age, education, working years and unit level had significant effects on the perception of some dimensions ($P < 0.05$), while professional title had no significant effect ($P > 0.05$). Network analysis showed that competence perception presented a structure of "intra-dimensional cohesion and inter-dimensional linkage", with professional skills (practical application) as the hub of the perception network. The most urgent demands for competence improvement were investigation and analysis, practical application and data processing. Practitioners preferred practical training forms such as offline practical operation, practical drills and case discussions.

Conclusion

The competence perception of Chinese epidemiological practitioners is basically consistent with the needs of grassroots posts, but there are shortcomings in the perception of emerging competencies such as digitalization and cross-domain collaboration. It is suggested to take practical application as the core, implement hierarchical and classified precise training, make up for the shortcomings of emerging competencies, and build a practical public health talent training system.

1. Background

Epidemiology is the methodological cornerstone and practical core of the public health system, undertaking key functions such as disease surveillance, etiological exploration, risk assessment, prevention and control decision-making, and effect evaluation; It is the core force in responding to public health emergencies and protecting population health[1–4]. The professional literacy, technical level and comprehensive abilities of epidemiological practitioners are directly related to the effectiveness of major disease prevention and control, emergency response efficiency, and the scientificity and feasibility of health policy formulation[5].

Against the background of the comprehensive advancement of the Healthy China 2030 strategy and the normalization and complexity of global public health risks, the demand for epidemiological talents in the public health system has shifted from the traditional "basic practical type" to the "comprehensive and innovative type". Practitioners are required not only to have solid basic capabilities such as on-site epidemiological investigation, data statistics and prevention and control implementation, but also to master emerging capabilities such as big data analysis, artificial intelligence (AI) application, cross-regional and cross-departmental collaboration, and global health governance[6, 7].

In recent years, the construction of China's public health system has been continuously strengthened, and the capacity for disease prevention and control has been steadily improved. However, in the process of responding to major public health emergencies, problems such as unbalanced competency structure of epidemiological talent teams, insufficient reserve of emerging skills, and weak interdisciplinary collaboration capabilities are still exposed[7, 8]. Behind these problems are not only the lag of the talent training system behind the development needs of the industry, but also the insufficient perception of the importance of core competencies and unclear direction of competency improvement among practitioners.

The perceived importance of core competencies among practitioners is the internal driving force for them to take the initiative to improve their abilities, optimize work behaviors and adapt to post demands, and is also an important basis for the design of talent training programs, construction of curriculum systems and setting of training content. The level of cognition and rationality of cognitive structure directly affect the direction and final effect of competency development[9, 10].

At present, domestic scholars have carried out a large number of studies on the core competencies of public health personnel, but most studies focus on the description of competency status, single-dimensional demand analysis or simple exploration of influencing factors, with three obvious deficiencies: first, the lack of research on the internal structure and dimensional correlation of the perceived importance of competencies, making it difficult to reveal the formation mechanism and core logic of competency cognition; second, the lack of accurate identification of cognitive shortcomings, and most training strategies are macro suggestions with low pertinence and operability; third, the relatively traditional research methods, with few quantitative structural methods such as network analysis, which cannot realize the visualization and in-depth deconstruction of the competency cognitive system.

In this context, systematically conducting research on the perceived importance of core competencies among epidemiological practitioners, exploring cognitive characteristics, influencing factors and internal structure, is of great practical significance for improving the talent training system, enhancing the core competencies of the team, and building a strong line of defense for public health security.

2. Objects and Methods

2.1 Research Objects

A convenience sampling method was adopted to select personnel engaged in epidemiological surveillance, on-site investigation, emergency response, teaching and research from CDCs, medical institutions, universities and research institutes at all levels in Jilin, Shandong, Jiangxi, Jiangsu, Henan and other provinces in China in November 2025 as survey objects. Inclusion criteria: ☐ Engaged in epidemiological related work for 1 year or more and familiar with the core competency requirements of the post; ☐ Informed consent, voluntarily participated in the study and completed the questionnaire; ☐ No cognitive dysfunction, able to accurately understand the meaning of questionnaire items and scoring standards. Exclusion criteria: ☐ Invalid questionnaires with filling time less than 45 seconds, missing key information or obvious logical contradictions; ☐ Non-epidemiological related posts, unable to accurately judge the importance of competencies; ☐ Refused to participate or withdrew midway. This study has been approved by the Ethics Committee of Xuzhou Medical University (Ethics Approval No. : XZHMU-25J1101), and all survey subjects signed electronic informed consent.

2.2 Survey Tools

The survey tool was the self-developed *Questionnaire on Perceived Importance of Epidemiological Core Competencies* by the research group (Supplementary Material), which has good scientificity, reliability and applicability after two rounds of Delphi expert consultation, item analysis and strict reliability and validity tests. (1) Expert consultation results: 24 senior experts engaged in epidemiological teaching, scientific research, CDC management and emergency response were selected for Delphi consultation. The mean importance of items was ≥ 3.5 , coefficient of variation ≤ 0.2 , Kendall's $W = 0.30$, $P < 0.001$, indicating good coordination of expert opinions. (2) Reliability and validity test results: The KMO value of the scale was 0.983, Bartlett sphericity test $P < 0.001$; the overall Cronbach's α coefficient was 0.987, and the Cronbach's α coefficient of each dimension ranged from 0.95 to 0.97, indicating excellent reliability (detailed process and results have been reported in another paper).

The questionnaire included two parts: (1) Demographics and job characteristics: 6 items including gender, age, highest education, professional title, working years, and institutional level/type, used to analyze cognitive differences among people with different characteristics; (2) Evaluation of the importance of core competencies: 6 dimensions (D1-D6) and 34 specific competency indicators were set, adopting a 5-point Likert scale (1 = extremely unimportant, 2 = unimportant, 3 = neutral, 4 = important, 5 = extremely important). Higher scores indicated higher perceived importance of the competency. D1 Professional Knowledge (6 items): Basic epidemiological theories and application

scenarios; epidemic laws and epidemiological characteristics of diseases; emergency epidemiological knowledge of emerging and sudden infectious diseases; public health-related laws, regulations and work specifications; core knowledge of branch disciplines such as molecular epidemiology and environmental epidemiology; operation mechanism of national/local public health surveillance networks. D2 Professional Skills (Investigation and Analysis) (5 items): Formulating epidemiological investigation plans; conducting on-site epidemiological investigation practice; identifying disease transmission risks and weak links in prevention and control; tracing outbreaks and mapping transmission chains; rapid epidemiological investigation and response to public health emergencies. D3 Professional Skills (Data Processing) (6 items): Data cleaning and statistical analysis using SPSS, R and other software; integrating surveillance data and identifying abnormal signals; constructing disease prediction and epidemic trend analysis models; big data technology correlation analysis; verifying prediction results with AI-assisted tools; writing high-quality epidemiological investigation reports. D4 Professional Skills (Practical Application) (7 items): Evaluating the effect of prevention and control interventions; formulating disease prevention and control strategies and surveillance and early warning plans; transforming data and analysis results into policy recommendations; providing technical guidance and science popularization; comprehensive analysis of multi-source data; formulating phased priorities for prevention and control work; cross-regional information exchange and collaboration. D5 Personal Literacy (5 items): Emergency response and stress resistance in public health emergencies; logical thinking and problem-solving ability; cross-departmental and interdisciplinary communication and collaboration; learning, research and application of new epidemiological theories and technologies; innovative thinking and practical ability. D6 Professional Literacy (5 items): Scientific rigor and data authenticity; privacy protection and information security; public health responsibility and service awareness; professional dedication and on-site adherence in emergencies; ethical compliance in research and investigation.

2.3 Statistical Methods

Data analysis was performed using SPSS 26.0 statistical software and R 4.3.1 software, with a test level of $\alpha = 0.05$. Among them, descriptive statistics were used to calculate frequency, constituent ratio, mean and standard deviation, so as to describe the baseline characteristics of the respondents and the distribution of cognitive scores on the importance of core competencies; one-way analysis of variance (ANOVA) was used to compare the differences in cognitive scores of each competence dimension among groups with different genders, ages, educational backgrounds, professional titles, working years and unit levels, and $P < 0.05$ was considered statistically significant; for network analysis, a competence cognitive network model was constructed based on the igraph package of R language, and the qqgraph package was used to calculate centrality indicators (mainly including Strength, Closeness and Expected influence) to identify core nodes. Strength reflects the total connection strength of a certain competence in the network, and a higher value indicates a higher correlation with other competencies; a higher centrality value indicates that the competence is more likely to be in the central position of the network, and a higher Expected influence value also indicates higher centrality. Meanwhile, the bootnet package was used to calculate the 95% confidence interval of the edge weight stability coefficient through the

non-parametric Bootstrap method (1000 samplings) to test the network stability, ensuring that the analysis results are stable and reliable.

3. Results

3.1 General Information of Survey Subjects

A total of 1,150 valid questionnaires were collected, and the baseline characteristics of the survey subjects were analyzed (Table 1). In terms of gender, there were 507 males (44.10%) and 643 females (55.90%), with slightly more females, consistent with the gender distribution characteristics of public health practitioners in China. In terms of age, 423 people (36.80%) were under 35 years old, 400 people (34.80%) were 36–45 years old, 279 people (24.20%) were 46–55 years old, and 48 people (4.20%) were over 56 years old. Young and middle-aged groups accounted for 71.60%, being the main force of epidemiological practitioners. In terms of education, 188 people (16.30%) had junior college or below, 718 people (62.40%) had bachelor's degree, 233 people (20.30%) had master's degree, and 11 people (1.00%) had doctorate degree. Bachelor's degree was the main body, and the proportion of highly educated talents was low, in line with the current educational structure of grassroots epidemiological teams. In terms of professional title, 191 people (16.61%) had no professional title, 344 people (29.91%) had primary title, 311 people (27.04%) had intermediate title, 229 people (19.92%) had associate senior title, and 75 people (6.52%) had senior title. Primary and intermediate titles accounted for more than 57%, and the professional title structure of the team was pyramid-shaped. In terms of working years, 179 people (15.57%) had 3 years or less, 274 people (23.82%) had 4–10 years, 333 people (28.96%) had 11–20 years, and 364 people (31.65%) had 21 years or more. Senior practitioners with 11 years or more accounted for more than 60%, and the team had rich working experience as a whole. In terms of institutional level, 7 people (0.60%) were from national CDCs, 12 people (1.10%) from provincial CDCs, 330 people (28.70%) from municipal CDCs, 780 people (67.80%) from county/district CDCs, 5 people (0.40%) from universities/research institutes, and 16 people (1.40%) from medical institutions, mainly grassroots county/district CDCs. The sample structure was consistent with the actual situation that epidemiological practitioners in China are concentrated at the grassroots level.

Table 1
Baseline Characteristics of 1150 Respondents

Variable	Category	Frequency (n)	Percentage (%)	Cumulative Percentage (%)
Gender	Male	507	44.10	44.10
	Female	643	55.90	100.00
Age (years)	≤ 35	423	36.80	36.80
	36–45	400	34.80	71.60
	46–55	279	24.20	95.80
	≥ 56	48	4.20	100.00
Highest Education	Junior college or below	188	16.30	16.30
	Bachelor's degree	718	62.40	78.70
	Master's degree	233	20.30	99.00
	Doctoral degree	11	1.00	100.00
Professional Title	No title	191	16.61	16.60
	Primary	344	29.91	46.52
	Intermediate	311	27.04	73.56
	Associate senior	229	19.92	93.48
	Senior	75	6.52	100.00
Working Years	≤ 3	179	15.57	15.57
	4–10	274	23.82	39.39
	11–20	333	28.96	68.35
	≥ 21	364	31.65	100.00
Institutional Level	National CDC	7	0.60	0.60
	Provincial CDC	12	1.10	1.70
	Municipal CDC	330	28.70	30.40
	County/District CDC	780	67.80	98.20
	University/Research Inst	5	0.40	98.60

Note: CDC = Center for Disease Control and Prevention

Variable	Category	Frequency (n)	Percentage (%)	Cumulative Percentage (%)
	Medical institution	16	1.40	100.00
<i>Note: CDC = Center for Disease Control and Prevention</i>				

3.2 Current Status of Perceived Importance of Core Competencies Among Epidemiological Practitioners

3.2.1 Overall Cognitive Level

The overall perceived importance of the 34 core competencies among practitioners was high, with a total mean score of 150.27 ± 21.99 (full score 170), close to the full score, indicating that practitioners generally recognized the importance of epidemiological core competencies and had a strong awareness of competency improvement. The single-item mean scores of the 6 dimensions ranged from 4.28 to 4.53, all in the range of "important" to "extremely important". The order of importance from high to low was: professional literacy (4.53 ± 0.66), professional skills (investigation and analysis) (4.52 ± 0.70), personal literacy (4.47 ± 0.68), professional knowledge (4.43 ± 0.72), professional skills (practical application) (4.36 ± 0.72), professional skills (data processing) (4.28 ± 0.76) (Table 2).

Table 2

Scores of Six Core Competency Dimensions ($\bar{x} \pm s$, points)

Dimension ID	Core Competency Dimension	Number of Indicators	Full Score	Min Score	Max Score	$\bar{x} \pm s$	Single-item Mean
D1	Professional Knowledge	6	30	6.00	30.00	26.55 $\pm$ 4.32	4.43
D2	Professional Skills (Investigation & Analysis)	5	25	5.00	25.00	22.58 $\pm$ 3.49	4.52
D3	Professional Skills (Data Processing)	6	30	6.00	30.00	25.66 $\pm$ 4.54	4.28
D4	Professional Skills (Practical Application)	7	35	7.00	35.00	30.53 $\pm$ 5.04	4.36
D5	Personal Literacy	5	25	5.00	25.00	22.34 $\pm$ 3.38	4.47
D6	Professional Literacy	5	25	5.00	25.00	22.63 $\pm$ 3.28	4.53
—	Total Score	34	170	34.00	170.00	150.27 $\pm$ 21.99	4.42

3.2.2 Internal Cognitive Characteristics of Dimensions and Single Competency Scores

Each dimension presented an obvious characteristic of "valuing basics over frontiers; valuing practice over interdisciplinary collaboration" (Table S1). (1) Professional knowledge dimension: Basic epidemiological theories and disease epidemic laws had the highest scores (both 4.54), while frontier and systematic knowledge such as molecular epidemiology and surveillance network operation mechanism had low scores (4.21–4.34). Practitioners paid more attention to basic theoretical knowledge directly applied to posts, and had insufficient cognition of branch disciplines and systematic knowledge. (2) Investigation and analysis skills dimension: On-site investigation practice and rapid response to public health emergencies had the highest scores (both 4.56), while investigation plan formulation had a relatively low score (4.43), highlighting the core status of on-site practical ability and slightly weak cognition of the importance of early plan design. (3) Data processing skills dimension: Traditional statistical software application and investigation report writing had high scores (4.25, 4.41), while digital frontier skills such as AI-assisted tool application and prediction model construction had the lowest scores (4.19, 4.21), showing a cognitive bias of "valuing tradition over digitalization". (4) Practical application skills dimension: Prevention and control strategy formulation and science popularization had

high scores (4.39), while cross-regional/cross-border information exchange and collaboration had the lowest score (4.29), attaching importance to local prevention and control practice and insufficient cognition of the importance of cross-regional collaboration.

The top 5 competencies with the highest scores were all core rigid demands of grassroots posts, in order: C31 Protecting the privacy and information security of respondents (4.57), C8 Conducting on-site epidemiological investigation practice (4.56), C10 Rapid epidemiological investigation and response to public health emergencies (4.56), C30 Adhering to scientific rigor and data authenticity in epidemiological work (4.56), C33 Professional dedication and on-site adherence in public health emergencies (4.56).

The bottom 5 competencies with the lowest scores were all emerging interdisciplinary competencies, in order: C17 Verifying epidemiological prediction results with AI-assisted tools (4.19), C14 Constructing disease prediction and epidemic trend analysis models (4.21), C3 Understanding the operation mechanism of surveillance networks (4.21), C16 Correlation analysis of epidemiological data with big data technology (4.28), C24 Cross-regional epidemiological information exchange and collaboration (4.29), further confirming the cognitive pattern of "valuing basic practical operation while neglecting emerging interdisciplinary collaboration".

3.3 Analysis of Differences in Core Competency Cognition Among People with Different Characteristics

One-way ANOVA showed that gender, age, education, working years and institutional level had significant effects on the cognition of some dimensions ($P < 0.05$), while professional title had no significant effect ($P > 0.05$) (Table S2).

3.3.1 Gender Difference

Females had a significantly higher cognitive score in the professional knowledge dimension (26.98 ± 3.97) than males (26.01 ± 4.68) ($F = 6.473$, $P = 0.011$), with no significant differences in other dimensions ($P > 0.05$). The possible reason is that female practitioners pay more attention to the learning of theoretical knowledge and have advantages in the accumulation and cognition of professional knowledge.

3.3.2 Age Difference

Cognitive scores in data processing ($F = 2.640$, $P = 0.048$) and personal literacy ($F = 2.648$, $P = 0.048$) dimensions showed a significant downward trend with age. Young people under 35 years old had the highest scores, and those over 56 years old had the lowest scores. Young groups grew up in the digital era, have higher acceptance of new technologies such as data processing, and pay more attention to the improvement of personal comprehensive literacy; senior practitioners are affected by traditional work modes and have relatively lagging cognition of emerging technologies and personal literacy improvement.

3.3.3 Educational Difference

There were significant educational differences in the cognition of professional skills (investigation and analysis) ($F = 3.156$, $P = 0.024$), personal literacy ($F = 2.673$, $P = 0.046$) and professional literacy ($F = 3.081$, $P = 0.027$) dimensions. The scores of bachelor and master groups were significantly higher than those of junior college/below and doctorate groups. Doctorate training focuses on theoretical research, which is not well matched with the practical needs of grassroots posts, leading to low cognition of relevant dimensions; junior college/below groups have weak theoretical foundation and comprehensive literacy cognition, while bachelor and master groups balance theory and practice, and their cognition is more in line with post demands.

3.3.4 Working Years Difference

Only the personal literacy dimension had significant working years difference in cognition ($F = 3.822$, $P = 0.010$). New practitioners with 3 years or less of working experience had a significantly higher score (22.88 ± 3.19) than senior practitioners with 21 years or more (21.91 ± 3.46). New practitioners have just entered the post and pay more attention to the cultivation of personal literacy such as emergency stress resistance and communication collaboration; senior practitioners have formed a fixed work mode and pay insufficient attention to the continuous improvement of personal literacy.

3.3.5 Institutional Level Difference

Institutional level had a significant effect on the total score and cognition of each dimension ($P < 0.05$): medical institutions had the highest scores in professional knowledge, investigation and analysis, and practical application dimensions, as the first diagnosis and discovery end of public health emergencies, with more urgent demand for professional capabilities; county/district CDCs had the highest scores in personal literacy and professional literacy dimensions, as the "last mile" of prevention and control, paying more attention to professional ethics and comprehensive literacy; some dimensions of national and provincial CDCs had low scores, disconnected from grassroots practical scenarios, with cognition biased towards theoretical research.

3.3.6 Professional Title Difference

There was no significant professional title difference in cognitive scores of each dimension ($P > 0.05$), only the data processing dimension was close to significant level ($P = 0.078$). It indicates that the core competency cognition of practitioners is not directly related to professional title promotion, and the current professional title evaluation system does not fully reflect the guiding role of core competency cultivation and cognition.

3.4 Network Structural Characteristics of Perceived Importance of Core Competencies

3.4.1 Overall Network Characteristics

The competency cognitive network presented a structural feature of "high cohesion within dimensions and close linkage between dimensions". Competency nodes in the same dimension had higher correlation strength, and there were extensive and significant correlations between different dimensions ($P < 0.05$), indicating that competency cognition is not an isolated existence but an organic whole that influences and supports each other (Fig. 1).

3.4.2 Dimensional and Node Centrality Analysis

Centrality analysis grouped by 6 core competence dimensions (based on strength, closeness centrality and expected influence) showed that Professional Skills (Practical Application) ranked first in both closeness centrality and expected influence indicators (Fig. 2A–C). This result further confirms that the internal competence items of the practical application dimension are not only closely connected with each other, but also play a significant driving role in the overall competence perception network structure, occupying an irreplaceable core hub position in the core competence system of epidemiological practitioners.

Node centrality analysis showed that the core nodes were C19 Formulating targeted disease prevention and control strategies and surveillance and early warning plans, C23 Formulating phased epidemiological work priorities, and C21 Comprehensive analysis of multi-source data, all belonging to D4 Professional Skills (Practical Application) (Fig. 2D–F). These nodes performed prominently in the two key indicators of closeness centrality and expected influence, indicating that they have stronger information transmission efficiency and structural influence in the competence perception network, and are the key starting points supporting the implementation of practical application competence.

3.4.3 Network Stability Test (Bootstrap Test)

Bootstrap test was performed on network edge weights to verify model stability (Fig. 3). The test showed that the 95% confidence intervals of most edge weights were relatively concentrated, and the original values were highly consistent with the mean values, indicating that the parameters of the competence perception network model constructed in this study were accurately estimated, the structure was stable, and the analysis results were reliable and effective.

3.4.4 Core Nodes of Practical Application Dimension

Among the 7 competencies in practical application, C22 Transforming data and analysis results into policy recommendations and C23 Formulating phased priorities for prevention and control work were core nodes, with total correlation strength and average correlation strength significantly higher than other nodes. The correlation strength between the two was 0.894, the strongest correlation pair in the dimension, being the key starting point for the implementation of practical application competencies (Table 3).

Table 3
Correlation Strength and Centrality of Core Nodes in Practical Application Dimension

Item ID	Competency Description (Abbreviated)	Total Correlation Strength	Average Correlation Strength	Centrality Rank
C22	Transform data/analysis into policy recommendations	6.088394	0.897706	1
C23	Formulate phased priorities for prevention & control	6.086630	0.895185	2
C19	Develop disease control strategies & surveillance plans	6.079296	0.865185	3
C21	Comprehensive analysis of multi-source data	6.057124	0.868589	4
C24	Cross-regional epidemiological information exchange & collaboration	5.988845	0.855549	5
C18	Evaluate effectiveness of prevention & control interventions	5.939825	0.845465	6
C20	Provide technical guidance & health education	5.852373	0.836053	7

3.5 Competency Improvement Demand and Training Preference

3.5.1 Competency Improvement Demand

A total of 3,914 valid demand responses were obtained. The demand for competency improvement among practitioners was highly consistent with the perceived importance, with the demand rate from high to low: investigation and analysis (73.9%), practical application (71.8%), data processing (68.9%), professional knowledge (67.0%), professional literacy (30.6%), personal literacy (28.1%) (Table 4). The three skill dimensions accounted for more than 63% of the demand, while the demand for literacy was low, showing a cognitive bias of "basic competencies do not need improvement" and ignoring the continuous cultivation of literacy competencies.

Table 4
Demand for Core Competency Improvement Among Epidemiological Practitioners

Dimension ID	Core Competency Dimension	Number of Responses	Demand Rate (%)	Constituent Ratio (%)
D2	Professional Skills (Investigation & Analysis)	850	73.9	21.7
D4	Professional Skills (Practical Application)	826	71.8	21.1
D3	Professional Skills (Data Processing)	792	68.9	20.2
D1	Professional Knowledge	771	67.0	19.7
D6	Professional Literacy	352	30.6	9.0
D5	Personal Literacy	323	28.1	8.3
—	Total	3914	—	100.0

3.5.2 Training Method Preference

A total of 3,741 valid responses were obtained. Training preferences showed distinct practical and situational characteristics, with the response rate from high to low: offline centralized training (75.9%), practical drills (72.9%), case discussions (68.9%), online courses (53.7%), mentor guidance (51.1%), others (2.9%) (Table 5). Practitioners preferred practical training that can be directly applied to posts, rejecting pure theoretical indoctrination training, which is highly consistent with the cognitive characteristic of "valuing basic practical operation".

Table 5
Preferences for Training Methods Among Epidemiological Practitioners

Training Method	Number of Responses	Response Rate (%)	Constituent Ratio (%)
Offline centralized training	873	75.9	23.3
Practical drills	838	72.9	22.4
Case discussions	792	68.9	21.2
Online courses	617	53.7	16.5
Mentor guidance	588	51.1	15.7
Others	33	2.9	0.9
Total	3741	—	100.0

4. Discussion

4.1 Overall Characteristics of Core Competency Cognition: Distinct Grassroots Orientation, Insufficient Forward-looking Competencies

This study shows that the overall perceived importance of core competencies among epidemiological practitioners in China is high, highly in line with the actual needs of grassroots CDC posts, showing distinct characteristics of "valuing basic practical operation, professional bottom line and on-site application". The top-scoring competencies are all core skills necessary for daily grassroots work, such as on-site epidemiological investigation, privacy protection, scientific rigor and basic theories, reflecting the pragmatic cognitive logic of practitioners "oriented by post demands", which is highly consistent with the structural characteristics that China's epidemiological team is mainly composed of grassroots CDC personnel[11]. The formation of this cognitive pattern stems from the fact that grassroots practitioners' daily work focuses on practical operations such as routine epidemic response, on-site investigation and basic data statistics, and the actual demand for basic competencies is much higher than that for frontier and interdisciplinary competencies, thus forming a cognitive closed loop of "what the post needs, what is valued".

At the same time, obvious cognitive shortcomings are found in the study: practitioners' perceived importance of frontier and interdisciplinary competencies such as big data analysis, AI-assisted application, cross-regional collaboration and molecular epidemiology is significantly low. In the context of rapid development of digital public health and increasingly close global health collaboration, this cognitive shortcoming will directly restrict practitioners' ability to respond to complex public health emergencies, affect the scientificity and foresight of prevention and control decisions, and is not compatible with the requirements of compound and innovative talents for the high-quality development of public health in the new era[12–14]. With the increasing demand for normalized prevention and control of emerging and sudden infectious diseases, refined prevention and control of chronic diseases and efficient public health emergency response, epidemiological practitioners must have composite capabilities of "basic practical operation & digital skills & cross-regional collaboration". Therefore, future talent training must strengthen the guidance of emerging competency cognition while consolidating basic practical competencies, and promote the transformation of cognitive structure from "post adaptation" to "forward-looking leadership".

4.2 Influence of Demographic and Job Characteristics: Significant Differences, Providing Basis for Precise Training

This study confirms that gender, age, education, working years and institutional level have significant differentiated effects on competency cognition, providing an important basis for implementing hierarchical, classified, precise and efficient talent training and breaking the limitations of the traditional "one-size-fits-all" training model.

4.2.1 Age and Generational Differences

Young groups pay more attention to data processing and personal literacy, and are more receptive to new technologies and methods, while senior practitioners have low cognition of emerging technologies. This generational difference suggests that talent training needs to implement hierarchical training: for young practitioners, focus on strengthening the standardization of basic practical operation and cultivation of professional literacy, while giving play to their digital advantages and encouraging participation in frontier technology application; for senior practitioners, carry out adaptive digital skill improvement training, simplify operation processes, explain application methods combined with actual work scenarios, lower the learning threshold, and promote the renewal of their knowledge system.

4.2.2 Educational Differences

The cognition of bachelor and master groups is more in line with grassroots needs, doctorate groups focus on theory, and junior college/below groups have weak theoretical foundation. This result suggests that the educational training system needs to be optimized: universities offering epidemiology should strengthen grassroots practical teaching at bachelor and master stages, increase practical courses such as on-site epidemiological investigation and emergency response; doctorate stage should add grassroots practice links to promote the in-depth integration of theoretical research and practical needs; for practitioners with junior college or below, carry out systematic training of professional knowledge to consolidate the theoretical foundation and improve comprehensive cognition.

4.2.3 Institutional Level Differences

Medical institutions, municipal/county CDCs and provincial CDCs have different functional positioning, with obvious differentiation in competency cognition. It is suggested to establish a hierarchical competency standard: medical institutions focus on improving first diagnosis discovery, rapid epidemiological investigation and risk identification capabilities; county/district CDCs consolidate on-site practical operation, prevention and control implementation and science popularization capabilities, and make up for shortcomings in cross-regional collaboration; municipal CDCs strengthen data analysis, emergency command and technical guidance capabilities; provincial and national CDCs focus on policy transformation, frontier research and cross-regional coordination capabilities to achieve precise matching of competencies at all levels with functional positioning.

4.2.4 Disconnection Between Professional Title and Cognition

Professional title has no significant effect on the cognition of each dimension, indicating that the current professional title evaluation system has insufficient guiding role for core competencies. It is suggested to include epidemiological core competencies into professional title evaluation indicators, add evaluation contents such as practical operation ability, emergency response and technical application, change the evaluation tendency of "valuing papers over practice", take professional title evaluation as a

lever to strengthen the external incentive for practitioners to improve competencies, and promote the in-depth binding of competency cognition and career development.

4.3 Competence Perception Network Structure: Practical Application as the Hub, Significant Systematic Linkage Characteristics

Network analysis results show that the perception of core competence importance among epidemiological practitioners presents a structural feature of “high intra-dimensional cohesion and close inter-dimensional linkage”. Each dimension is directly connected to the other 5 dimensions, forming a complete and stable cognitive network system, indicating that competence perception is not isolated but an organic whole that supports and collaborates with each other.

Professional Skills (Practical Application, D4) is the core hub dimension of the cognitive network, ranking first in both closeness centrality and expected influence indicators, and most closely related to data processing and personal literacy. It is a key bridge connecting professional knowledge, investigation and analysis, personal literacy and professional literacy, and all competencies ultimately point to the implementation of practical application.

In terms of core nodes, C19 Formulating disease prevention and control strategies and surveillance and early warning plans, C23 Formulating phased prevention and control work priorities, and C21 Comprehensive analysis of multi-source data are at the center of the network, all belonging to the practical application dimension, and are the key starting points supporting the implementation of competencies. Meanwhile, the network Bootstrap stability test results are reliable, indicating that the network structure of this study is stable and the results are credible.

Based on the above findings, talent training should avoid fragmented and single training, and build an integrated and collaborative training model of “knowledge – skills – literacy” with practical application as the core hub.

4.4 Competence Improvement Needs and Training Preferences: Highly Consistent Practical Orientation

This study shows that practitioners’ competence improvement needs are highly consistent with importance perception. The demand rates in descending order are Investigation and Analysis (73.9%), Practical Application (71.8%), Data Processing (68.9%), Professional Knowledge (67.0%), Professional Literacy (30.6%), Personal Literacy (28.1%). The three skill dimensions rank top in demand, while literacy demand is low, showing a cognitive bias of “valuing skill improvement over literacy cultivation”.

In terms of training method preferences, it shows distinct practical and scenario-based characteristics. The response rates in descending order are offline centralized training (75.9%), practical drills (72.9%), case discussions (68.9%), online courses (53.7%), mentor guidance (51.1%). Practitioners obviously

prefer practical training that can be directly applied to posts, rejecting pure theoretical indoctrination teaching.

Based on demand and preference characteristics, a closed-loop training system of “cognitive evaluation – demand diagnosis – practical training – effect evaluation” should be constructed, focusing on the three core needs of investigation and analysis, practical application and data processing, strengthening the supply of emerging competencies such as AI, big data and cross-domain collaboration, and adopting practical forms such as offline practical operation, case discussions and on-site drills to comprehensively improve the pertinence and effectiveness of training.

4.5 Research Limitations

This study has certain limitations: ☐ Convenience sampling was adopted, with a small sample size of national/provincial CDCs and research institutes, and the representativeness of the results in high-level institutions is limited; ☐ Only the perceived importance of competencies was analyzed, and no actual competency level evaluation was carried out, so the “knowledge-practice gap” between cognition and competency cannot be revealed; ☐ No comparative analysis of practitioners in different regions and professional fields was carried out, and regional adaptability research is insufficient; ☐ Macro factors such as economic level and policy environment were not included, and the analysis of influencing factors is not comprehensive enough.

5. Conclusion

The overall perception of core competence importance among Chinese epidemiological practitioners is high, showing the characteristic of “valuing basic practical operation while neglecting emerging cross-domains”, which is highly matched with grassroots post needs, but there are insufficient perceptions of forward-looking competencies such as digitalization and cross-domain collaboration. Competence perception is significantly affected by gender, age, education, working years and unit level, while professional title has no significant effect. Core competence perception is network-structured, with practical application as the core hub. Practitioners’ competence improvement needs focus on investigation and analysis, practical application and data processing, with a preference for practical training. It is recommended to implement a precise training model of hierarchical classification, hub leadership and shortcoming supplementation, optimize the professional title evaluation orientation, build a practical training system, and comprehensively improve the core competence of the epidemiological talent team.

Abbreviations

disease control and prevention (CDCs); artificial intelligence (AI).

Declarations

Ethics approval and consent to participate

This study has been approved by the Ethics Committee of Xuzhou Medical University (Ethics Approval Number: XZMU-25J1101). All procedures involving human participants in this study comply with the Declaration of Helsinki and its subsequent amendments, or comparable ethical guidelines and regulations.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analyzed in this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Yansu Chen prepared the final version of the manuscript, participated in data interpretation and manuscript revision. Hongyu Bi analyzed the data. Binghua Wang and Meixue Yao collected and completed data verification and sorting. Dehui Yin and Guixiang Sun designed the study, provided critical comments on the manuscript, and were responsible for correspondence. All authors have read and approved the final manuscript.

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Figures

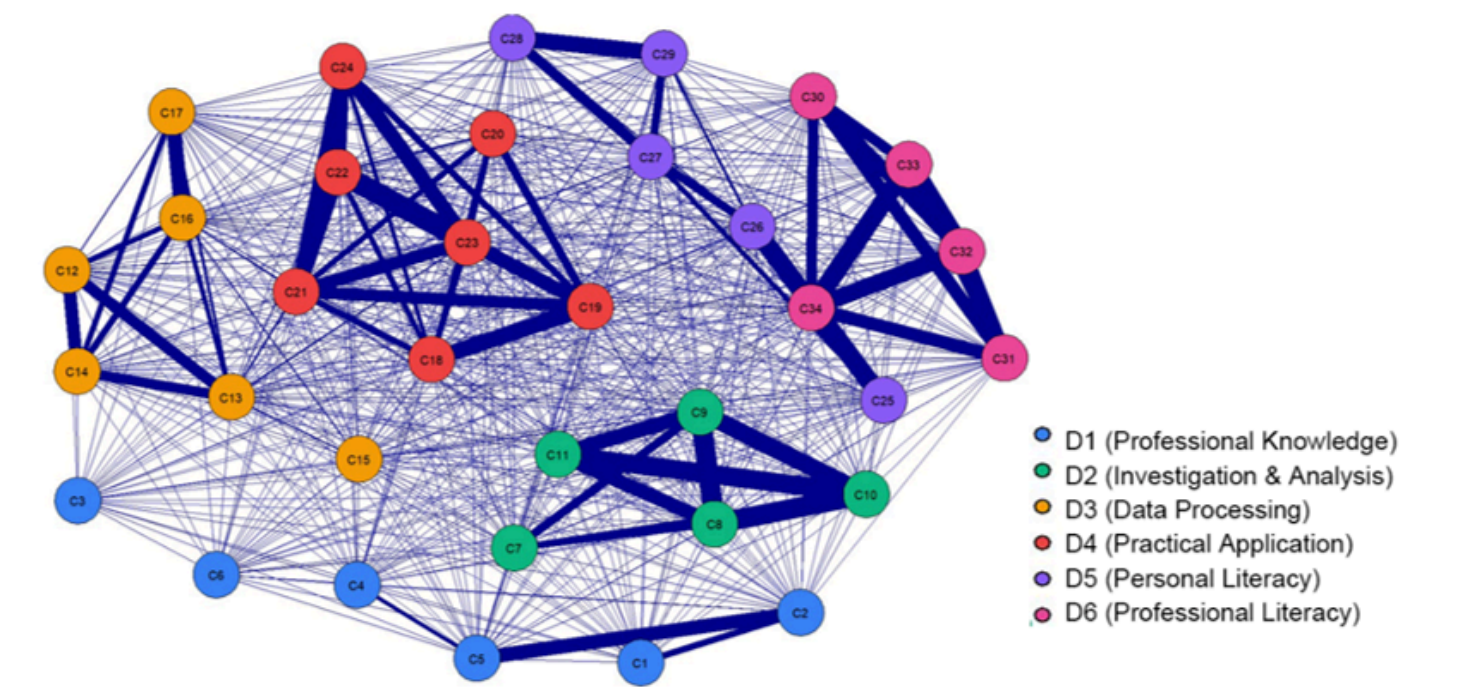


Figure 1

Cognitive Network Analysis of the Importance of Six Core Competencies for Epidemiological Practitioners. The nodes correspond to the 34 specific competency indicators in the questionnaire. The lines connecting the nodes represent statistically significant cognitive correlations ($P < 0.05$), and the thickness of the lines indicates the magnitude of the correlation strength.

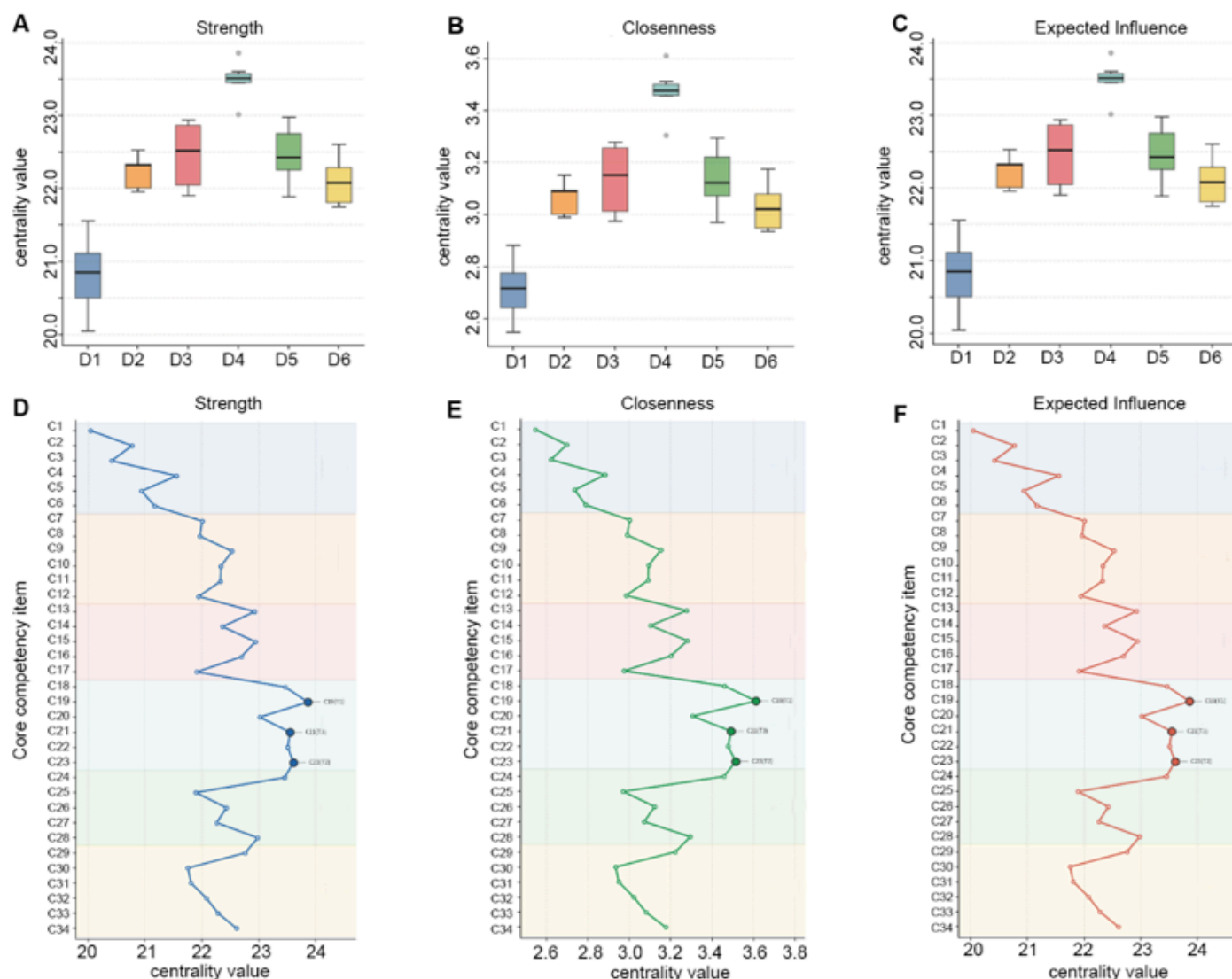


Figure 2

Results of centrality analysis at the dimension and node levels of core competencies among epidemiological practitioners. (A-C) Centrality analysis grouped by the 6 core competence dimensions (D1-D6), namely Strength, Closeness, and Expected Influence, where D4 is the Professional Skills (Practical Application) dimension; (D-F) Node centrality analysis of each core competence item (C1-C34), namely Strength, Closeness, and Expected Influence, with the top three core nodes (C19, C23, C21) labeled, all belonging to the D4 dimension.

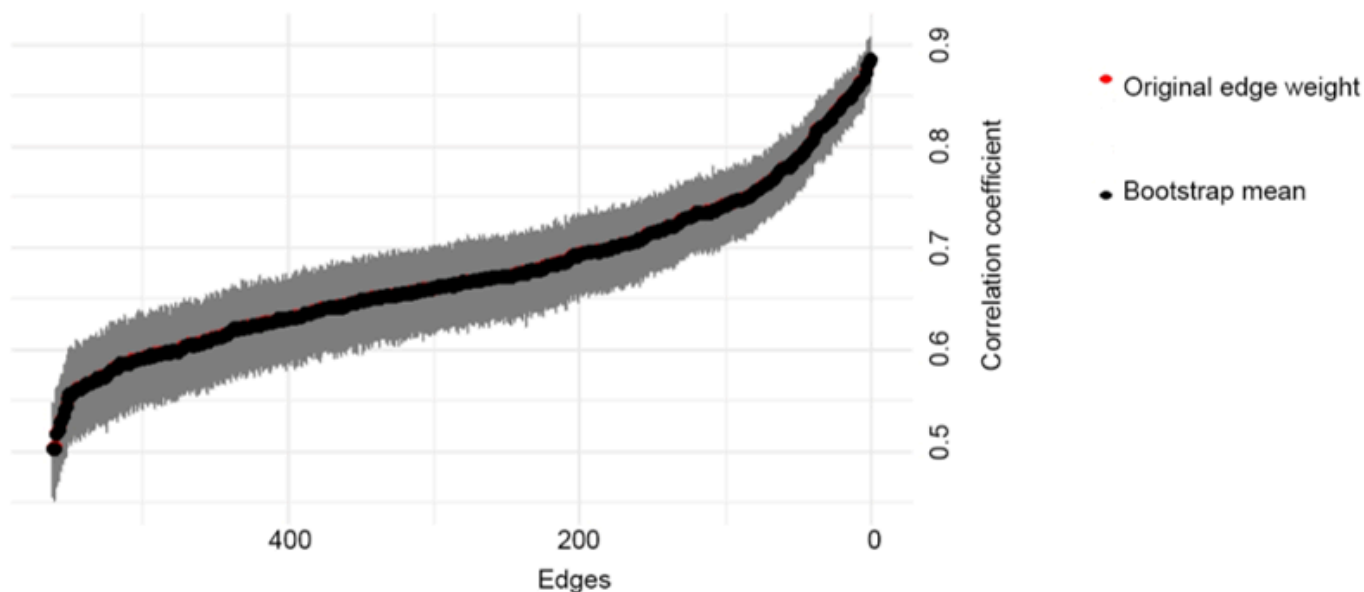


Figure 3

Accuracy estimation graph of network edge weights. The red line in the figure represents the original edge weight value, the black line represents the Bootstrap mean, and the gray area represents the 95% confidence interval. The narrower the gray interval and the closer the red line is to the black line, the more stable the edge weight estimation and the more reliable the results.

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