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Formation and influencing factors of health communication competence among Chinese physical education teachers based on the ecological systems theory

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Health communication is of paramount importance in promoting physical activity participation and reducing sedentary behavior. However, limited research has been conducted on the health communication competence (HCC) of physical education (PE) teachers. Thus, this study aims to investigate the factors and mechanism influencing the development of HCC among PE teachers base on Ecological System Theory (EST). The interview method was first used to collect influencing factors and form theoretical models. An online survey questionnaire was used to collect data from 394 PE teachers in primary and secondary schools in China. The data were randomly divided into two subsamples and subjected to exploratory ($n = 184$) and confirmatory factor analyses ($n = 210$). The hypothesis was verified using a structural equation model approach. (1) The formation of HCC among PE teachers is influenced by multiple factors, including social factors (0.396), school factors (0.379), and individual factors (0.210), encompassing a total of 13 sub-factors. (2) Physical education teachers' HCC is primarily shaped by external factors, and aligns with the EST's hierarchy. This study could help PE teachers identify the factors and mechanism that affect the formation of their HCC. As primary influencing factors, the government and relevant stakeholders should clarify the specific roles and provide policy support for PE teachers when formulating health-related policies.

Keywords Health communication competence, Physical education teacher, Ecological system theory

The health crisis and economic expenditure caused by sedentary behavior (SB) and physical inactivity have garnered widespread attention worldwide[1]. Physical inactivity represents the fourth leading cause of mortality worldwide. It and SB can lead to a number of health problems, including chronic disease, obesity, and type 2 diabetes[1,2]. To address these risks, various versions of physical activity and sedentary behavior guidelines published by WHO or local governments recommend that individuals move more and sit less[3]. These guidelines also emphasize meeting at least the minimum recommended levels of physical activity. However, some researchers have argued that these standards may no longer be sufficient under current health conditions[1]. Furthermore, Santos (2023)[4] revealed that the annual global economic losses resulting from inadequate physical activity amount to approximately 47.6 billion US dollars.

Addressing such public health concerns requires strategic health communication. Health communication plays a vital role in promoting physical activity and reducing sedentary behavior, serving as an indispensable instrument in both health education and health promotion. However, despite decades of research on physical activity promotion, policy planning, infrastructure, and health communication efforts remain underdeveloped[5]. Kohl (2012)[5] further identified health communication as a critical yet often overlooked component in this area. Nevertheless, in the current field of health communication and health promotion, there remains a paucity of

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research focusing specifically on physical activity and sedentary behavior. Moreover, given the interdisciplinary nature of health communication, the development of such competence is inevitably influenced by multiple contextual and individual factors.

As defined by Rogers, health communication is any form of human interaction that pertains to health-related content[6]. Extensive research has been conducted in this field, contributing to the development of effective strategies and practices that improve public health outcomes. Existing studies primarily focus on two key elements: health communication receivers and health communication senders. Research on receivers often targets specific populations—such as adolescents[7], older adults[8], or minority ethnic groups[9]—to identify their unique communication needs and challenges, thereby informing tailored health communication strategies.

In contrast, research on health communication senders typically examines healthcare professionals and institutions responsible for delivering health information. For instance, Lawati (2018)[10] conducted a systematic review on health promotion in primary healthcare, with a focus on the health communication strategies and practices employed by healthcare senders and relatable organizations. Similarly, Javier (2018)[11] explored communication-based strategies used in clinic- and community-based HIV prevention interventions among African American women, illustrating how sender-oriented approaches can enhance health outcomes within specific social contexts.

Except for research focusing on health communication receivers and senders, theory-oriented studies also represent an important area of inquiry in this field. Haardörfer (2019)[12] emphasized the significance of theory-driven and data-informed analysis in social science research, highlighting the importance of introducing theoretical priorities as the foundation of inquiry. Among the theories frequently applied in health education and health promotion, Ecological Systems Theory (EST) has been particularly influential. Wold (2018)[13] reviewed three decades of research utilizing the social-ecological model for health promotion and identified the lack of interdisciplinary collaboration and systems thinking as major barriers to progress. Stokols (1996)[14] translated Social Ecological Theory into practical guidelines aimed at advancing community health promotion.

Although existing research has provided valuable guidance on the methodology of health communication HCC, the research objectives in the field primarily revolve around healthcare professional in medical setting, such as doctors or nurses, with limited attention given to a specific group who has expertise in promoting physical activity scientifically: PE teachers. Given the interdisciplinary background of health communication, it should span across more relevant disciplines and groups. PE teacher plays a significant role in school health communication and school setting is an essential component in the comprehensive health system. These teachers undergo pre-service education programs and receive relevant in-service training such as sports health science, exercise physiology, and sports anatomy[15]. In comparison to medical professionals, PE teachers possess specialized knowledge in the subfield of sport health communication. As active participants in both physical education and health communication, PE teachers hold the potential to nurture a nationwide culture of active healthy lifestyle, addressing prevalent health concerns like increasing rates of public sedentary behavior.

In this regard, enhancing PE teachers' competence in health communication offers a practical and cost-effective means to promote public health and reduce health inequities. While not a universal remedy, school-based health communication led by PE teachers capitalizes on existing educational structures, yielding high efficiency under limited health budgets[16,17]. Embedded within daily teaching, it ensures sustained exposure, behavioural reinforcement, and strong external validity, as educators in school settings are uniquely positioned to influence students through regular, trust-based interactions[18]. By integrating health communication into PE practice, this approach bridges the gap between health knowledge and behaviour, advancing both equity and efficiency in national and global health promotion. Moreover, the cost-effectiveness and scalability of communication interventions have been widely recognized in the literature[16].

Although certain aspects of health communication research within the field of PE teachers have been explored—such as teachers' perceptions of digital communication via social media[19], the definition and theoretical model of sport health communication[15], and participation in health communication volunteering programs[20]—gaps remain. Martínez-Rico et al. (2021)[21] surveyed in-service secondary PE teachers and reported high self-confidence in operating hardware, but significantly lower confidence in designing online collaborative tasks or using networks to foster pupils' health-oriented inquiry, indicating that health communication functions remain peripheral to their digital practice. Wallace, Scanlon and Calderón (2023)[22] showed that when teachers did share fitness videos or performance clips, students valued the clarity of the health cues but stressed that one-way posting was insufficient; they expected dialogue and contextual follow-up that most teachers felt unprepared to provide. However, clarification on the factors influencing the development of teachers' health communication competence—and verification of whether these factors genuinely impact their proficiency—remain unclear.

Against this backdrop, the primary goal of this study is to investigate the factors contributing to the development of health communication competence (HCC) in PE teachers. Three central questions guide this exploration:

- RQ1: How do PE teachers perceive and experience the factors that shape their health communication competence?
- RQ2: To what extent do these factors genuinely contribute to the development of health communication competence in PE teachers, and which factors exhibit varying degrees of influence?
- RQ3: What are the characteristics and mechanisms of PE teachers' health communication competencies when they are formed? Do these align with the EST theory?

By addressing these questions, we used EST as our theoretical foundation and used focus group and individual interview as the research method to firstly explore and form the factors that influence the formation of HCC of PE teachers. Secondly, a questionnaire was designed based on the interview results and the theoretical model

and research hypothesis were formed, which were combined with EST. Finally, a survey was conducted of 394 PE teachers, and the structural equation model method was employed to verify the hypotheses and to ascertain whether the formation mechanism of PE teachers' HCC aligns with the EST theory. This research will provide valuable insights to support the development of HCC of PE teachers both theoretically and practically. Secondly, the research will expand the research scope of health communication.

Theoretical framework

Ecological Systems Theory first proposed by Bronfenbrenner and aim to explain the interactions between individuals and their environment. The theory argues that an individual's development and behavior are influenced by the environment in which he or she lives, and divides the environment into four different levels: Marcosystem, Exosystem, Mesosystem, Microsystem, each of which has a unique impact on an individual's development (see Fig. 1 for details)[23].

Macrosystem: Macrosystems are broader cultural and social structures such as culture, social institutions and values. Macrosystems have a profound and long-term impact on an individual's development because they shape the social and cultural environment in which the individual lives.

Exosystem: Exosystems are environments in which the individual is not directly involved but which have an impact on his or her development, e.g. community resources. These environmental factors can indirectly influence an individual's development by influencing the microsystem in which he or she lives.

Mesosystem: Mesosystems refer to the interactions and connections between microsystems, such as family, school, colleague. The interactions in mesosystems influence the individual's experience and development in the different microsystems.

Microsystem: In EST, Microsystem can be conceptualized as face-to-face influence, it can refer to the environment in which individuals are directly involved.

Methods
Sample, sampling, and data collection

The initial interview phase involved 31 health professionals, including both PE teachers and health educators, each with at least two years of experience or formal training in health communication (see Table 1 for details). To ensure diversity and applicability of the findings, participants were selected across different regions, age
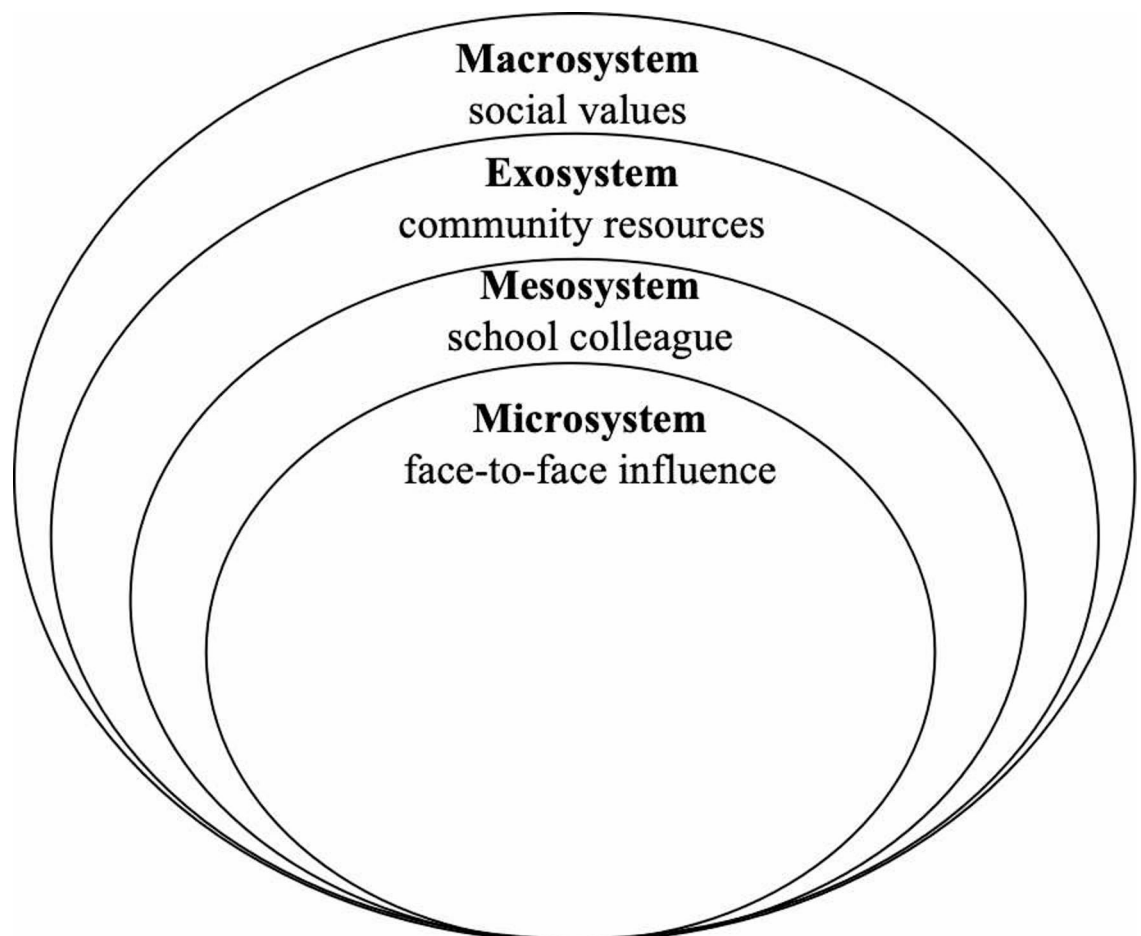

Fig. 1. Bronfenbrenner's ecological system theory.

Demographic information		n (%)
Teaching experience (years)	0–10 10–20 20–30 30–40	20(65%) 2(6%) 4(13%) 5(16%)
Degree	College diploma BEd MEd PhD	1(3%) 9(29%) 16(52%) 5(16%)
Title	Second-level teacher First-level teacher/Assistant Professor Associate Senior teacher/Associate chief nurse/Associate Professor Professor	15(49%) 4(13%) 10(32%) 2(6%)
Region	Northern of China Eastern of China Central of China Southwest of China Northwest of China	2(6%) 19(61%) 1(3%) 6(20%) 3(10%)
Interview method	Individual interview Focus group interview	16(52%) 15(48%)

Table 1. Demographic characteristics of qualitative participants ($N = 31$).

groups, years of teaching experience, and professional titles. All interviews were audio-recorded and transcribed verbatim, followed by systematic coding using Nvivo 19.0. Based on the qualitative analysis, a set of key influencing factors related to the development of PE teachers' health communication competence was identified, laying the foundation for the subsequent conceptual framework and quantitative model construction.

Secondly, in the quantitative part of the study, we used purposive sampling via an online questionnaire (using the Questionnaire Star platform) to survey 394 Chinese primary and secondary school PE teachers. This survey was conducted across four major regions of mainland China (see Table 2 for details).

As shown in Table 2, a total of 394 PE teachers participated in the study. Most participants were male (67%), aged 26–35 years (62%), and held a bachelor's degree (60%). Nearly half were second-level teachers (46%), and 43% had 5–10 years of teaching experience. Participants were mainly from western (34%) and eastern (33%) regions, working primarily in urban (32%) and rural (29%) schools.

Factor influencing the formation of PE teacher' HCC

The framework was developed using qualitative data guided by EST to ensure closer alignment with the research focus. A core interview question was set: what factors do you believe influence the HCC of PE teachers when they are forming? During the interview process, further questions were asked in response to the valuable responses of the interviewees in order to identify the relevant influencing factors.

Social factors
In this study, four observed variables were identified under the dimension of social factors: A1 Social Recognition Degree, A2 Policy Support, A3 Availability of Public Facilities, and A4 Adequacy of the Educational System. These categories were derived through inductive coding, reflecting the broader social environment that influences PE teachers' HCC. For example, social recognition was frequently mentioned by participants as a key facilitator: "when colleagues and the community value and recognize the concept of health communication, PE teachers are more likely to align with these shared beliefs and actively participate in related practices". Illustrative excerpts supporting this category are presented in Table 3.

School factors
Four observed variables were identified under the dimension of school factors: B1 Support and Importance by the School, B2 Implementation of Relevant Training Programs, B3 Availability of Facility Support in School, and B4 Working Environment. These categories reflect how institutional and environmental conditions within schools influence PE teachers' engagement in health communication practices. In some schools where academic achievement is prioritized over holistic education, PE is often marginalized, with its primary focus limited to teaching motor skills rather than promoting broader health literacy. Under such circumstances, PE teachers may find it difficult to obtain support from school administrators and colleagues when implementing health communication activities, and may even face resistance or skepticism about the legitimacy of their work. Representative excerpts illustrating this category are presented in Table 4.

Individual factors
Five observed variables were identified under the dimension of individual factors: C1 Personal Awareness, C2 Education Background, C3 Health Communication Knowledge and Skills, C4 Willingness to Learn, and C5 Personal Characteristics. These variables reflect the personal capacities and attributes that shape PE teachers' engagement in health communication. For instance, personal awareness (C1) refers to teachers' self-recognition of their educational responsibilities and their willingness to contribute voluntarily to health promotion within the school context. As one participant explained, "If you want to access some health-related information, it is common that you need to pay for a reliable one. In contrast, as an educator, promoting health communication,

Demographic information		n (%)
Age	20–25	22% (87)
	26–30	33% (130)
	31–35	29% (115)
	36 and above	16% (62)
Gender	Male	67% (264)
	Female	33% (130)
Teaching experience	3–5 years	40% (158)
	5–10 years	43% (170)
	More than 10 years	17% (66)
Education background	College degree or below	30% (118)
	Bachelor's degree	60% (236)
	Master's degree	10% (40)
Professional title	Third-level teacher	20% (79)
	Second-level teacher	46% (182)
	First-level teacher	26% (102)
	Associate senior teacher	8% (31)
	Senior teacher	0% (0)
Weekly teaching workload	≤10	28% (110)
	10–14	34% (134)
	15–19	25% (98)
	≥20	13% (52)
Teaching region	Western	34% (134)
	Eastern	33% (130)
	Central	18% (71)
	Northeast	15% (59)
School type	Urban schools	32% (126)
	Rural schools	29% (114)
	Urban-rural mixed schools	24% (94)
	Others (special education, etc.)	15% (60)

Table 2. Demographic characteristics of quantitative participants (N = 394). The Chinese government uses a professional title system to guide primary and secondary school teachers' career development. The system consists of five primary levels: third level teachers, second level teachers, first level teachers, associate senior teachers, and senior teacher.

Categories	Illustrative excerpt	Participants (no.)
A1. Social recognition degree	If your colleagues embrace the concept of health communication, it becomes easier for PE teachers to align with them and become actively involved in health communication practices. They are more likely to follow suit and actively participate in promoting health communication.	1, 5, 9, 10
A2. Policy support	I think the educational policies and regulations set by school principals have a significant impact on guiding PE teachers in their approach to health communication practices. For example, if there is a strong policy encouraging PE teachers to actively engage in health communication, it provides them with more opportunities to learn and develop their health communication skills.	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12
A3. Availability of public facilities	The character of PE teachers' health communication should be highly related to physical activity. Physical activity often involves specific infrastructures, such as outdoor spaces dedicated to soccer, rugby, track and field events, and baseball. These spaces typically have distinct markings and goalposts designed for each sport. However, there are challenges for PE teachers when it comes to conducting health communication if ideal locations for physical activity are not readily available.	1, 2, 3, 7, 10
A4. Adequacy of the education system	Another factor is the constraints imposed by the curriculum. For example, issues such as physical injuries or a lack of widespread dissemination of educational knowledge often result from inadequate previous education, leaving teachers deficient in relevant knowledge.	4, 7, 9, 10

Table 3. Illustrative examples for the category of social factors. No. refers to the numbered interview materials.

especially in school settings, is unpaid, which requires strong self-awareness and a sense of dedication." Representative excerpts for each subcategory are provided in Table 5.

Based on the qualitative data analysis, three overarching factors were identified as central to the formation of PE teachers' health communication competence: social factors, school factors, and individual factors. Each factor consists of several interrelated subcategories that collectively reflect the contextual, institutional, and personal conditions shaping teachers' competence. Specifically, social factors capture the external environment and policy context that influence teachers' engagement in health communication; school factors reflect institutional support, resources, and professional development opportunities within schools; and individual

Categories	Illustrative excerpt	Participants (no.)
B1. Support and importance by the school	In some schools, the main task of PE is to teach motor skills. Especially in schools emphasizing academic achievement, PE is often marginalized. Under such circumstances, PE teachers receive little support for health communication and may even be criticized for doing work considered irrelevant."	1, 2, 3, 4, 5, 6, 7, 9, 11, 12
B2. Implementation of relevant training programs	Formal learning and informal learning are distinct in nature. Informal learning, such as through social media, involves randomly acquiring information on health communication, often without assurance of its accuracy. On the other hand, formal learning through school training programs follows a systematic approach and provides more reliable information. Therefore, I believe that to enhance health communication competence, schools and institutions should prioritize providing PE teachers with relevant formal training opportunities.	4, 6, 7, 9, 11, 12
B3. Availability of facility support in school	PE teachers to implement health communication must need related infrastructure, if local school does not put money in it, it is nearly impossible for PE teachers themselves to pay all the devices or equipment.	1, 2, 3, 4, 5, 6, 7, 9, 11, 12
B4. Working Environment	If the colleagues around you consistently express dissatisfaction with health communication and do not acknowledge their responsibility in this aspect of their job, it's easy to become influenced by their negative mindset. This effect becomes even stronger when the institution as a whole or the principals ignore or undervalue the importance of health communication practices. In such situations, it can be challenging to assert your influence or advocate for health communication effectively.	9, 11, 12

Table 4. Illustrative examples for the category of school factors. No. refers to the numbered interview materials.

Categories	Illustrative excerpt	Participants (no.)
C1. Personal awareness	If you want to access some health-related information, it is common that you need to pay for a reliable one. As a PE teacher, promoting health communication, especially in the school setting, is unpaid, which requires strong self-awareness and a spirit of dedication.	1, 3, 6, 7
C2. Education background	As a PE teacher, if you want to help others with health issues, you need to have systematic knowledge and practice over a long period of time, which depends on your educational background and requires professional learning in physiology, health education, etc., instead of amateur learning as a hobby.	1, 3, 8
C3. Health communication knowledge and skills	Communication is about to give targeted audience related information; it means teacher should have not only know enough health knowledge but also knows how to communicate effectively. Meanwhile, have a clear mind about different health promotion needs from different groups of people.	3, 4, 8, 9
C4. Willing to learn	The idea related to health promotion keep updating, formal learning in a certain time such as PE teacher education program or in-service training for beginning teachers are obviously not enough. Health communication needs to learn step by step, day by day. PE teachers should make a commitment to actively learn health communication sustainably.	1, 3, 6
C5. Personal characteristics	To promote health communication, especially in PE, you must be able to express clearly and serve as a role model. This requires certain personality traits. For introverted teachers, this can be a great challenge.	1, 3, 5

Table 5. Illustrative examples for the category of individual factors. No. refers to the numbered interview materials.

Latent variable	Observed variable
A. Social factors	A1 social recognition degree
	A2 policy support
	A3 availability of public facilities
	A4 adequacy of the education system
B. School factors	B1 support and importance by the school
	B2 implementation of relevant training programs
	B3 availability of facility support in school
	B4 working environment
C. Individual factors	C1 personal awareness
	C2 education background
	C3 health communication knowledge and skills
	C4 willing to learn
	C5 personal characteristics

Table 6. Summary of three major factors and their subcategories identified from qualitative analysis. Based on EST, the formation of PE teachers' HCC is the result of dynamic and reciprocal interactions across macro, meso, and micro ecological levels.

factors emphasize teachers' personal awareness, professional knowledge, and intrinsic motivation for continuous learning. These three major factors and their corresponding subcategories, as derived from inductive coding and constant comparison, are summarized in Table 6.

At the macrosystem, social factors such as social recognition degree, policy support, adequacy of the educational system, and availability of public facilities constitute the broader social context. These factors

not only directly shape the external environment in which health communication occurs, but also indirectly influence teachers' competence by affecting the school system—for example, through policy implementation, institutional resource allocation, and cultural recognition of health education. Moreover, social contexts may also shape individual-level attitudes and motivation, determining teachers' value orientation and willingness to engage in health communication.

At the mesosystem, school factors serve as a bridge linking the macro and micro systems. School support and importance, working environment, implementation of training programs, and facility availability mediate the impact of social contexts and translate macro-level policies into concrete practices. Meanwhile, they exert direct effects on teachers' professional development, knowledge acquisition, and behavioral engagement in health communication.

At the microsystem, individual factors—including personal awareness, educational background, health communication knowledge and skills, willingness to learn, and personal characteristics—represent the most proximal determinants of competence. These characteristics not only influence teachers' capacity and motivation to conduct health communication, but also interact with contextual factors. Teachers with strong awareness and motivation are more likely to utilize school resources and respond positively to social support.

In summary, social factors influence school environments and individual characteristics, while school factors mediate and reinforce these influences on teachers' HCC. The interplay across these three ecological levels highlights that the formation of HCC is not a linear process, but rather an outcome of multi-level interactions within a nested ecological system (see Fig. 2).

HCC of PE teacher

Health communication competence of PE teachers was measured using a five-point Likert scale ranging from 1 (Not Important) to 5 (Very Important). The items were developed based on the theoretical model established in our previous research, which was constructed using grounded theory (Chen et al., 2023). Ten items were used to measure the HCC of PE teachers.

Study hypothesis

Under the theoretical model above, we propose the hypotheses for this study (see Fig. 3 for details).

Social factors

The participants from interviews frequently discussed how their health communication beliefs were influenced by society. While some participants highlighted the positive influence of social factors on their values, others pointed out that although social factors may not directly impact their beliefs or values regarding health communication, they believe society could gradually shape their beliefs and behaviors in this area. Based on the above, the hypotheses related to SOF as follows:

- H1a: Social factors have a positive impact on schools.
- H1b: Social factors have a positive impact on individuals.
- H1c: Social factors have a positive impact on PE teachers' health communication competence.
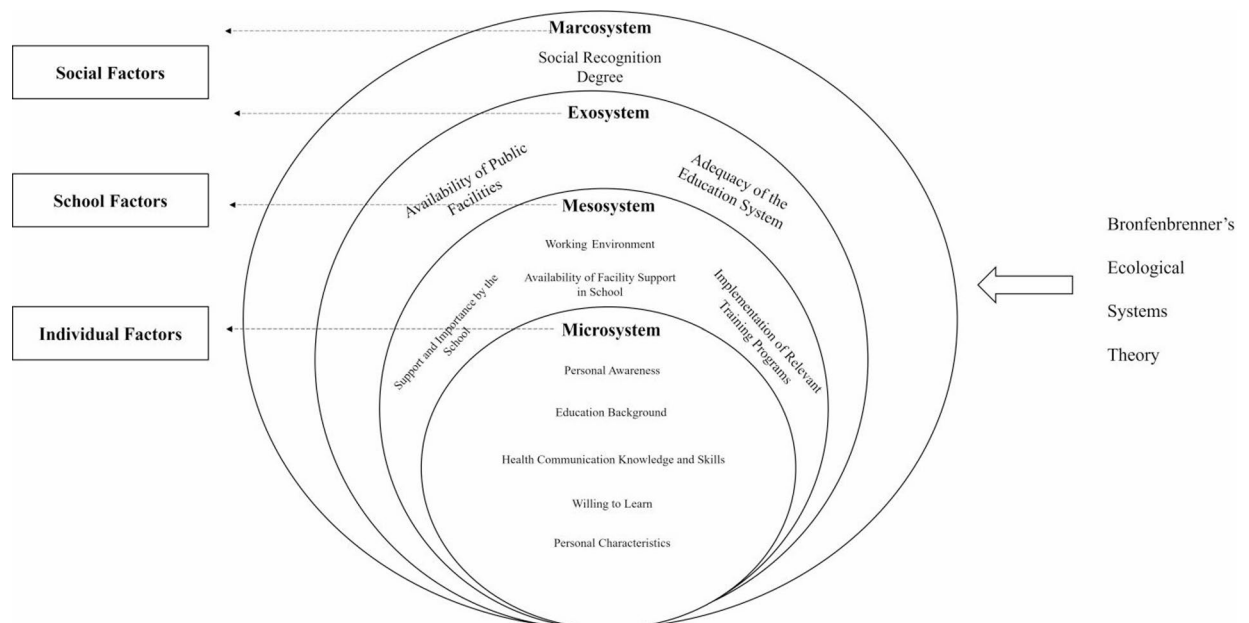

Fig. 2. Theoretical model of the factors influencing the formation of PE teacher's health communication competence.
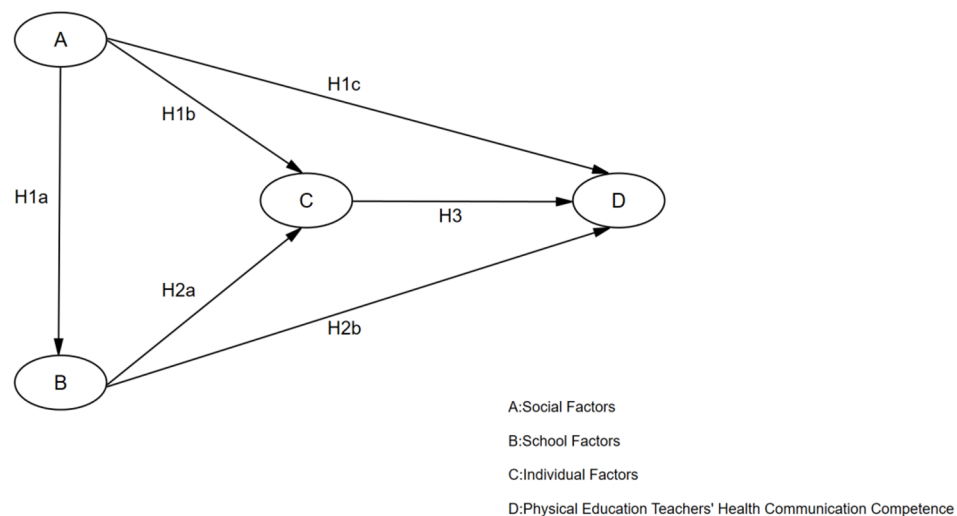
Fig. 3. Research hypothesis (Structural Model).

School factors
In contrast to the roles of hospital and health organization personnel, PE teachers are tasked with the dual responsibility of both teaching and health communication within the context of the school environment. Based on the above, the relevant research hypotheses are as follows:

- H2a: School factors have a positive impact on individuals.
- H2b: School factors have a positive impact on PE teachers' health communication.

Individual factors
In our study, participants highlighted that the desire to develop health communication competence is not only tied to professional growth but also to personal development. Based on the above, the hypotheses related to IDF as follows.

- H3: Individual factors have a positive impact on PE teachers' health communication competence.

Based on the aforementioned points, the following research hypotheses have been formulated, see Fig. 3 in details:

Statistical analysis and validation
In the quantitative part of the study, we using the SEM approach. Structural Equation Modelling is a powerful tool for explaining complex relationships, validating theoretical hypotheses, assessing intervention effects[24]. There are numerous algorithms for conducting SEM, with the most widely used methods being Covariance-based Structural Equation Modelling (CB-SEM) and Partial Least Squares Structural Equation Modelling (PLS-SEM)[25,26]. For the purpose of this study, CB-SEM was chosen. CB-SEM is a parameter estimation method that utilises either covariance matrices or correlation coefficient matrices as input data and typically employs Maximum Likelihood (ML) estimation to estimate model parameters. It assumes that the observed variables follow a multivariate normal distribution[26]. CB-SEM is commonly employed to validate existing theoretical models, test causal relationships, and explore hierarchical structures[25]. Therefore, CB-SEM was selected to examine the causal relationships within the theoretical model we constructed, with the aim of elucidating the mechanisms which influencing the formation of HCC among PE teachers.

Before conducting CB-SEM, preliminary analyses were performed to ensure the adequacy of the data. Reliability was assessed using Cronbach's α coefficients to examine internal consistency across all constructs. Validity was evaluated through both exploratory and confirmatory factor analyses: exploratory factor analysis (EFA) was first conducted to explore the underlying factor structure, including the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, Bartlett's test of sphericity, and principal component analysis (PCA); subsequently, confirmatory factor analysis (CFA) was employed to validate the measurement model and assess convergent and discriminant validity. In addition, multicollinearity diagnostics were carried out by calculating the variance inflation factor (VIF) and tolerance values, confirming that no severe multicollinearity existed among the observed variables.

Ethics approval
This study has been approved by Ethics Board at East China Normal University (HR 608–2021, 5 November 2021). All methods were performed in accordance with the relevant guidelines and regulations as outlined by the Ethics Board at East China Normal University and in compliance with the Declaration of Helsinki.

Informed consent

The researchers obtained informed consent after explaining the purposes, procedures, and voluntary nature. Confidentiality and anonymity in the collection and presentation of results were maintained.

Results

To ensure the independence of exploratory and confirmatory analyses, the dataset was randomly split into two subsamples. The first subsample ($n = 184$) was used for PCA to explore the underlying factor structure, while the second subsample ($n = 210$) was used for CFA and subsequent SEM to validate the measurement model and test the hypothesized structural relationships

Reliability and validity analysis

Principal component analysis results
In the PCA, data collected from 184 PE teachers were analyzed. The Cronbach's alpha coefficients for the subscales and the overall questionnaire ranged from 0.895 to 0.926, demonstrating excellent internal consistency reliability. The KMO measure of sampling adequacy was 0.894, indicating that the correlations among the items were sufficiently high to justify factor analysis. Bartlett's test of sphericity was significant ($\chi^2 = 3386.359$, df $= 253$, $p < 0.001$), suggesting that the data were appropriate for PCA.

In the PCA, a two-step procedure was adopted because the study included two distinct measurement parts: "PE Teachers' HCC" and "Influencing Factors."

Step 1, a separate PCA was conducted for the Health Communication Competence scale. The results indicated that one component could be extracted, with an eigenvalue of 6.125, explaining 61.3% of the total variance. All items loaded strongly on this component (loadings ≥ 0.50), demonstrating good convergent validity and uniqueness.

Step 2, a separate PCA was conducted for the Influencing Factors scale. The analysis extracted three components with eigenvalues of 6.453, 2.944, and 1.120, cumulatively explaining 80.2% of the total variance. In the rotated component matrix, F1 consisted of items 3, 1, 4, 5, and 2; F2 consisted of items 8, 9, 7, and 6; and F3 consisted of items 11, 10, 12, and 13. All items had substantial loadings (≥ 0.79) on their respective factors, indicating clear factor structures (see Table 7 for details).

Confirmatory factor analysis results
In the SEM analysis, the influencing factors and HCC were integrated into a unified structural model. Accordingly, a CFA was conducted to validate a measurement model consisting of four latent constructs: Social Factors, School Factors, Individual Factors, and HCC.

The model fit indices indicated an acceptable model fit (χ^2/df $= 2.47$, CFI $= 0.90$, TLI $= 0.89$, RMSEA $= 0.08$). All standardized factor loadings exceeded 0.50 and were statistically significant ($p < 0.001$), suggesting that each observed variable effectively represented its respective latent construct (see Table 8 for details). The Cronbach's alpha coefficients ranged from 0.859 to 0.926, demonstrating satisfactory internal consistency reliability across all constructs.

Furthermore, the composite reliability (CR) values ranged from 0.861 to 0.921, all exceeding the recommended threshold of 0.70, and the average variance extracted (AVE) values ranged from 0.538 to 0.669, all greater than 0.50, indicating adequate convergent validity. In addition, the square roots of the AVE values were greater than the inter-factor correlations, providing evidence for satisfactory discriminant validity. Overall, these results suggest that the measurement model demonstrated good reliability and validity, supporting its use in subsequent SEM analysis.

Structural equation model (SEM)

Descriptive analysis
The normality of the data was assessed using skewness and kurtosis statistics. All variables exhibited skewness values below 2 and kurtosis values below 5, indicating approximate univariate normality[27]. Thus, the assumption of normality was met for subsequent SEM analyses.

Multicollinearity test results
A multicollinearity test was conducted for all measurement items. The results showed that the VIF values ranged from 2.27 to 3.89 (all < 5), and the tolerance values ranged from 0.26 to 0.44 (all > 0.2), indicating that there were no serious multicollinearity problem and the data were suitable for subsequent SEM analysis (see Table 9 for details).

Model fit
Based on the hypothesized model, four latent factors were identified and denoted as A, B, C, and D for clarity. Specifically, Factor A represented Social Factors, Factor B represented School Factors, Factor C represented Individual Factors, and Factor D represented PE Teachers' HCC. The corresponding observed variables were labeled as A1–A4, B1–B4, C1–C5, D1a–D1c, D2a–D2b, and D3a–D3e. The standardized path coefficients and model fit results are presented in Fig. 4.

The CFI has a value of 0.916, the NNFI is 0.905, the RMR is 0.097, the RMSEA is 0.076, the DF is 2.124, and the IFI is 0.917. These indicators provide information about how well the model fits the observed data. In this case, all of these indicators meet the standard criteria, suggesting a good fit of the model.

Model results
According to the structural equation model, the hypothesis testing results are summarized in Table 10:

Step 1		
Items	F1	Uniqueness
16	0.829	0.313
23	0.818	0.33
20	0.8	0.359
22	0.796	0.366
21	0.795	0.368
15	0.792	0.373
18	0.775	0.4
17	0.75	0.438
14	0.738	0.456
19	0.727	0.471

Step 2			
Items	F1	F2	F3	Uniqueness
3	0.875			0.235
1	0.868			0.258
4	0.867			0.269
5	0.841			0.246
2	0.789			0.352
8		0.907		0.176
9		0.884		0.191
7		0.847		0.176
6		0.836		0.171
11			0.915	0.205
10			0.896	0.151
12			0.861	0.166
13			0.819	0.149

Table 7. Rotated component matrix and uniqueness values (two independent steps). Based on both the statistical outcomes and the conceptual meanings of the items, the single component extracted in Step 1 was labeled as PE Teachers' HCC. The three components extracted in Step 2 were labeled as Social Factors (F1), School Factors (F2), and Individual Factors (F3), respectively.

It can be observed that all three factors have a positive influence on the HCC of PE teachers, in accordance with the theoretical hypothesis model presented in this study. In terms of the magnitude of influence, the total effect value of social factors is 0.396, ranking first, followed by the total effect value of school factors at 0.379, ranking second, and the total effect value of individual factors at 0.210, ranking third.

Rank of observation variables for influential factors
A composite weighting approach was employed to evaluate and rank the influencing factors of PE teachers' HCC. By multiplying the path coefficients of each observed variable by the total effect of its corresponding latent variable, a comprehensive index for each factor was obtained and ranked in descending order. As shown in Table 11, the results suggest that PE teachers tend to attribute the formation of HCC more to external factors, with A2 Policy Support, A1 Social Recognition Degree, and B2 Implementation of Relevant Training Programs ranking first, second, and third, respectively.

Discussion
This study aims to explore the factors influencing the development of HCC in PE teachers, guided by three central questions: (1) How do PE teachers perceive and experience the factors that shape their health communication competence? (2) To what extent do these factors genuinely contribute to the competence development, and how do they vary in influence? (3) What are the characteristics of PE teachers' HCC when they are formed? Do these align with the EST theory? The findings reveal that (1) HCC among PE teachers is influenced by multiple factors, with social factors (0.396), school factors (0.379), and individual factors (0.210) playing significant roles. Thirteen sub-factors contribute to these influences. (2) The top three contributing factors include policy support, social recognition degree, and the implementation of relevant training programs. (3) The formation of PE teachers' HCC is influenced by the hierarchical structure of Macro, Exo, Meso, and Microsystems in the EST, with interactions among these levels. However, among them, the Macro and Exo levels, namely social factors, have the most significant impact on the HCC of PE teachers.

Structural determinants and institutional integration of HCC
The cultivation of HCC among PE teachers is deeply embedded in a broader structural ecology shaped by policy, social perception, and institutional capacity. As this study indicates, policy support and social recognition

Factor	Items	Std. estimate	Std. error	p
Social factor	SOF1	0.855	0.022	< 0.001
	SOF2	0.783	0.03	< 0.001
	SOF3	0.885	0.019	< 0.001
	SOF4	0.757	0.032	< 0.001
	SOF5	0.801	0.028	< 0.001
School factor	SCF1	0.766	0.033	< 0.001
	SCF2	0.808	0.029	< 0.001
	SCF3	0.779	0.032	< 0.001
	SCF4	0.765	0.033	< 0.001
Individual factor	IDF1	0.802	0.028	< 0.001
	IDF2	0.843	0.024	< 0.001
	IDF3	0.809	0.028	< 0.001
	IDF4	0.821	0.026	< 0.001
Health communication competence	HCC1	0.685	0.04	< 0.001
	HCC2	0.715	0.037	< 0.001
	HCC3	0.819	0.026	< 0.001
	HCC4	0.717	0.037	< 0.001
	HCC5	0.724	0.036	< 0.001
	HCC6	0.72	0.036	< 0.001
	HCC7	0.762	0.032	< 0.001
	HCC8	0.724	0.036	< 0.001
	HCC9	0.722	0.036	< 0.001
	HCC10	0.74	0.034	< 0.001

Table 8. Standardized factor loadings, standard errors, and significance levels from the CFA. *SOF* social factor, *SCF* school factors, *HCC* Health communication competence.

Items	VIF value	Tolerance
1	3.398	0.294
2	2.753	0.363
3	3.889	0.257
4	2.778	0.36
5	3.134	0.319
6	2.981	0.335
7	3.022	0.331
8	2.677	0.374
9	2.362	0.423
10	2.818	0.355
11	3.331	0.3
12	2.763	0.362
13	3.028	0.33
14	2.43	0.412
15	2.541	0.394
16	3.532	0.283
17	2.275	0.44
18	2.799	0.357
19	2.378	0.42
20	2.949	0.339
21	2.713	0.369
22	2.724	0.367
23	2.756	0.363

Table 9. Multicollinearity test results for measurement items.

A: Social Factors
B: School Factors
C: Individual Factors
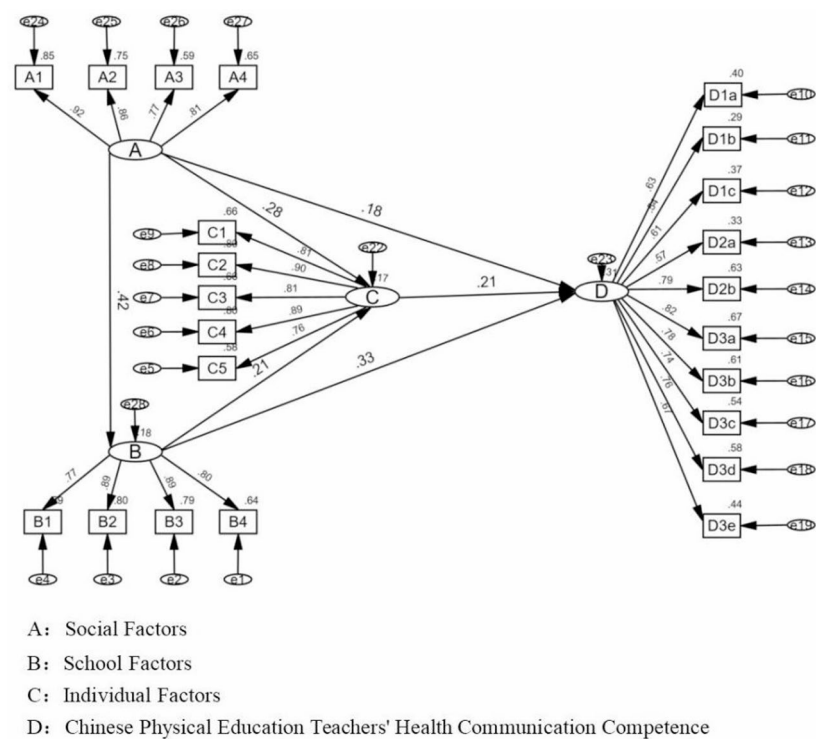D: Chinese Physical Education Teachers' Health Communication Competence

Fig. 4. Structural equation model results.

Hypothesis no.	Research hypothesis	Path coefficient	Significance level	Test results
H1a	SOF→SCF	0.42	***	Positive
H1b	SOF→IDF	0.28	***	Positive
H1c	SOF→HCC of PE teachers	0.18	*	Positive
H2a	SCF→IDF	0.21	**	Positive
H2b	SCF→HCC of PE teachers	0.33	**	Positive
H3	IDF→HCC of PE teachers	0.21	**	Positive

Table 10. Model verification results. *** indicates $P < 0.001$, ** indicates $P < 0.01$, * indicates $P < 0.05$. .

Observed variable indicators		Comprehensive index	Ranking
Code	Name		
A2	Policy support	0.341	1
A1	Social recognition degree	0.337	2
B2	Implementation of relevant training programs	0.337	2
B3	Availability of facility support in school	0.337	2
A4	Adequacy of the educational system	0.321	3
A3	Availability of public facilities	0.304	4
B4	Working environment	0.301	5
B1	Support and importance by the school	0.289	6
C2	Education background	0.189	7
C4	Willing to learn	0.187	8
C3	Health communication knowledge and skills	0.170	9
C1	Personal awareness	0.170	9
C5	Personal characteristics	0.159	10

Table 11. Ranking of comprehensive index of influencing factors in the formation of HCC.

jointly constitute the most influential drivers, demonstrating that health communication cannot be effectively strengthened without systemic legitimacy and public endorsement. Consistent with the principles of the social determinants of health[28], the social and political environment provides both enabling and constraining conditions for teachers' professional enactment. The blurred and sometimes contradictory policy boundaries between education and health domains further complicate the implementation of communication initiatives. Although the National K12 PE and Health Curriculum Standards (2022 Edition) designate PE teachers as essential actors in school health education[29], their roles and responsibilities in health communication remain vaguely defined. This ambiguity limits teachers' confidence and creates inconsistencies in practice. Clarifying the national policy framework, aligning educational and health agendas, and establishing evaluation mechanisms would therefore provide both clarity and incentive for teachers' engagement in systematic, evidence-based communication activities.

This policy-practice gap is rooted in a structural disconnect between education and health systems, where the formal recognition of PE teachers' roles often lacks institutional alignment and operational clarity. Although national policies acknowledge PE teachers as key agents of health education, weak inter-system coordination limits their capacity to implement communication tasks effectively. This misalignment reflects broader global concerns about the divide between health and education governance. The unclear delineation of communication responsibilities and the absence of coordinated support mechanisms further reinforce this institutional gap.

Furthermore, the current professional training environment appears to reinforce this fragmentation. Despite the recognized importance of teacher development, many training programs remain narrowly oriented toward sports pedagogy rather than integrative health communication, limiting their relevance and practical transferability. Similar challenges have been documented internationally, where professional preparation often fails to bridge disciplinary divides[30,31]. As a result, PE teachers frequently face inadequate institutional capacity—uneven access to health-related teaching materials, fitness facilities, and communication resources—which constrains their ability to engage students effectively. Addressing these issues requires a multilevel strategy that not only enhances resource allocation but also redefines training systems to embed health communication as a central component of professional identity. By positioning PE teachers as credible and competent health communicators, school-based health education can simultaneously advance equity and cost-effectiveness, reinforcing its role as a sustainable pathway for public health promotion[32].

Contextual constraints and the lag in policy implementation

The limited development of HCC among PE teachers is further compounded by contextual constraints arising from delayed policy implementation and insufficient health awareness. Although numerous national policies have been issued to promote physical activity and school-based health initiatives, the translation of these policies into practice remains slow and uneven across regions[33]. The fragmented pre-service and in-service training systems for PE teachers lack an integrated framework for health communication, leaving educators without systematic guidance or institutional support. Moreover, the absence of detailed national physical activity guidelines and clear role definitions within the education sector contributes to weak compliance and inconsistent delivery[34]. Such policy–practice gaps are not unique to China; comparable challenges have been observed in other countries where limited enforcement and resource disparities hinder teachers' engagement in school-based health promotion[35]. This phenomenon aligns with the observed deficiencies in facility availability (B3) and educational system adequacy (A4), revealing that institutional and infrastructural shortcomings significantly impede the operationalization of teachers' communicative functions.

Societal attitudes further intensify these systemic challenges. Despite increasing public awareness of the consequences of sedentary behaviour and physical inactivity, preventive health consciousness remains low[36,37]. The cultural hierarchy of authority in health discourse—where physicians and nurses are traditionally regarded as the primary opinion leaders—also undermines the legitimacy of PE teachers' health-related communication efforts[38]. Consequently, even when PE teachers disseminate accurate information, students and parents may question its validity. To address these challenges, both top-down policy reinforcement and bottom-up cultural recognition are essential. Strengthening policy mandates, improving interdepartmental coordination, and enhancing public trust would together position PE teachers as legitimate, trusted, and sustainable agents of health communication. Comparative research across different cultural and institutional contexts could further clarify how national education systems can mobilize PE teachers to promote health equity and long-term behavioural change.

Limitations and future research

This study employed a cross-sectional design to explore predictive relationships derived from theoretical frameworks and previous empirical findings. While this design provided valuable insights into the factors influencing PE teachers' HCC, it cannot capture causal or temporal dynamics among variables. Future studies should therefore adopt longitudinal or intervention-based designs to examine how HCC evolves over time and how targeted strategies may enhance it. Additionally, the context-specific nature of the current measurement instrument—developed within a particular educational and cultural environment—may limit its applicability to other regions or educational settings. Potential social desirability bias should also be acknowledged, as participants may have overreported positive attitudes or competencies related to health communication.

The relatively limited sample size further constrains the generalizability of the results. To strengthen the external validity and robustness of future findings, subsequent studies should expand sample coverage across diverse geographic regions and school contexts. In addition to increasing sample size, future research could advance by developing standardized and context-sensitive evaluation scales tailored to assess PE teachers' HCC more precisely.Moreover, insights from comparative research across diverse cultural and institutional contexts

could provide valuable guidance for advancing the health communication practices of PE teachers in China and other countries, contributing to more equitable and sustainable health promotion efforts.

Conclusions

This study is based on the EST and uses CB-SEM to verify the influencing mechanism in the formation process of PE teachers' HCC. The results show that EST is a powerful theory to understand the forming mechanism of the HCC of PE teachers. In addition, the influence of external factors (social factors, school factors) is greater than that of internal factors (individual factors).

The implications of this study are twofold: (1) It helps PE teachers identify the factors and mechanism that may affect the formation of their HCC, allowing them to address these factors and improve their deficiencies in HCC. (2) As primary influencing factors, in order to facilitate the development of HCC among PE teachers, it is essential that both governmental and societal levels provide policy and public opinion support.

Data availability

Data/materials can be shared upon reasonable request to the corresponding author.

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Conceptualization, L.C. and Y.X.; methodology, M.Z. and Z.Y.; software, L.C.; formal analysis, L.C and M.S.; writing—original draft preparation: L.C. and Y.X.; writing—review and editing, L.C., Y.X., and M.Z.; funding acquisition, Z.Y., Z.G. and B.L. All authors have read and agreed to the published version of the manuscript.

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