

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

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Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study

Percepciones de los estudiantes universitarios chinos sobre los factores relacionados con la participación en la actividad física: un estudio de mapeo cognitivo difuso

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Abstract

Student engagement in physical activities has been associated with personal, social, instructional, and environmental factors; however, these factors are often examined as isolated predictors rather than as an interconnected system. This study applied fuzzy cognitive mapping (FCM) to examine how university students perceived engagement-related factors and the directional relationships among them. A total of 437 second-year undergraduate students from

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a public university in Anhui Province, China, participated. Candidate factors were identified through a literature review and focus group interviews, organised according to Bronfenbrenner's ecological model, and assessed through an FCM questionnaire. The aggregated Student FCM was analysed to identify the most strongly weighted perceived factors and their perceived interrelationships. Peer support and interaction, facilities, peer collaboration, body mass index, motivation, parental support, well-being, extracurricular physical activity, inclusive school policy, and coaching styles received the highest weights. The strongest perceived pathways were concentrated mainly within the microsystem, particularly those involving peers, family, coaching, and extracurricular participation. These findings represent students' perceived relationships rather than empirically verified causal effects and demonstrate the value of FCM for revealing interconnected engagement structures that may be overlooked when factors are examined independently.

Keywords: student engagement; physical activity; fuzzy cognitive mapping; ecological model; university students

Resumen

La participación de los estudiantes en actividades físicas se ha asociado con factores personales, sociales, educativos y ambientales; sin embargo, estos factores suelen examinarse como predictores aislados en lugar de como un sistema interconectado. Este estudio aplicó el mapeo cognitivo difuso (FCM, por sus siglas en inglés) para examinar cómo los estudiantes universitarios perciben los factores relacionados con la participación en actividades físicas y las relaciones direccionales entre ellos. Participaron un total de 437 estudiantes de segundo año de pregrado de una universidad pública de la provincia de Anhui, China. Los factores potenciales se identificaron mediante una revisión de la literatura y entrevistas con grupos focales, se organizaron según el modelo ecológico de Bronfenbrenner y se evaluaron mediante un cuestionario de FCM. Se analizó el mapa cognitivo difuso agregado de los estudiantes para identificar los factores percibidos con mayor peso y las interrelaciones percibidas entre ellos. El apoyo y la interacción entre compañeros, las instalaciones, la colaboración entre compañeros, el índice de masa corporal, la motivación, el apoyo parental, el bienestar, la actividad física extracurricular, las políticas escolares inclusivas y los estilos de entrenamiento recibieron las ponderaciones más altas. Las relaciones direccionales percibidas más fuertes se concentraron principalmente en el microsistema, en particular aquellas relacionadas con los compañeros, la familia, los entrenadores y la participación en actividades extracurriculares. Estos hallazgos representan las relaciones percibidas por los estudiantes, y no efectos causales verificados empíricamente, y demuestran el valor del mapeo cognitivo difuso para revelar estructuras interconectadas de participación que pueden pasar desapercibidas cuando los factores se examinan de manera independiente.

Palabras clave: compromiso estudiantil; actividad física; mapas cognitivos difusos; modelo ecológico; estudiantes universitarios

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

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Introduction

Student engagement in physical activities has become an important concern in higher education because regular physical activity contributes to physical health, psychological well-being, social development, and students' wider educational experience (Singh et al., 2023). According to the latest WHO-led global analysis, nearly one-third of adults worldwide were insufficiently physically active in 2022, indicating that physical inactivity continues to be a major public health concern (Strain et al., 2024). For university students, promoting physical activity is particularly important because the transition to university is accompanied by greater independence, changing social networks, and the establishment of health behaviors that often track into adulthood (Arnett, 2000; Arnett et al., 2014). Although regular physical activity is widely recognized as essential for physical and mental health, university students often encounter barriers that limit their participation, including competing academic demands, lack of time, sedentary study routines, and limited access to suitable opportunities for exercise. These challenges contribute to insufficient physical activity among university students and reflect a broader global public health concern regarding physical inactivity (Brown et al., 2024; Silva et al., 2022; Strain et al., 2024).

Student engagement is commonly conceptualized as a multidimensional construct involving behavioral participation, emotional connection, and cognitive investment (Appleton et al., 2006; Fredricks et al., 2004; Wong & Liem, 2022). In physical activity contexts, engagement therefore refers not only to taking part in sport, exercise, or physical education, but also to the quality, persistence, and meaning of that involvement. Students may participate because of curricular requirements or external encouragement, but sustained engagement depends on motivation, perceived value, enjoyment, confidence, social support, and willingness to continue despite competing demands.

Previous research has identified multiple influences associated with student physical activity engagement. These include individual factors such as motivation, self-regulation, self-efficacy, body-related perceptions, and perceived competence, as well as interpersonal and environmental factors such as peer support, parental encouragement, teacher support, coaching climate, facilities, and participation opportunities (Keegan et al., 2009; Ornelas et al., 2007;

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

Teixeira et al., 2012; Vazou et al., 2006). Recent studies have further highlighted the importance of peer influence, teacher support, and university activity environments in shaping participation and engagement (Coteron et al., 2024; Kirby et al., 2024; Miao et al., 2024; Sayyd et al., 2021; Sheng et al., 2023; Zhang et al., 2024; Zhou et al., 2023).

However, much of the existing literature examines these influences as separate predictors or correlates. Such approaches are useful for identifying variables associated with participation, but they provide limited insight into how students perceive these factors as influencing one another within a broader engagement system. In practice, engagement may emerge through indirect, reciprocal, and interconnected pathways. For example, peer support may encourage collaborative participation, collaborative activity may strengthen peer support, and supportive coaching may increase students' willingness to participate in extracurricular physical activities. These causal pathways are difficult to capture when factors are analyzed only as isolated variables.

Bronfenbrenner's ecological model provides a useful framework for organizing this complexity because it explains development through reciprocal interactions between individuals and their surrounding environments (Bronfenbrenner, 1979, 1986). Its later bioecological perspective emphasizes proximal processes, namely regular interactions between individuals and their immediate environments, as important mechanisms shaping development and behavior (Bronfenbrenner & Morris, 2006). Ecological approaches to health behavior similarly emphasise that behavior is influenced by individual, interpersonal, organizational, community, and policy-level conditions (McLeroy et al., 1988). Applied to university physical activity, this perspective suggests that engagement should be understood as a system involving personal characteristics, peer relationships, family support, teachers, coaches, facilities, policies, and activity opportunities.

Ecological classification alone, however, does not explain how students perceive these factors as causally connected. A factor may belong to a particular ecological level, but the key question is how it operates within a network of influence. Fuzzy Cognitive Mapping (FCM) is suited to this purpose because it represents complex systems through concepts and weighted causal relationships (Kosko, 1986; Özesmi & Özesmi, 2004). Unlike conventional statistical

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Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

approaches that primarily estimate linear associations among variables, FCM can model perceived reciprocal, indirect, and interconnected relationships within a single system. It has been applied in education and systems research to capture participants' mental models and perceived causal structures (Barbrook-Johnson & Penn, 2022; Papageorgiou & Salmeron, 2013).

The present study adopts Bronfenbrenner's ecological model to classify engagement-related factors and applies FCM to examine how university students perceive the causal interrelationships among these factors. The article focuses specifically on the student perspective. This boundary is deliberate because students are the direct participants whose engagement is being studied, and their perceived causal logic should be examined independently before comparison with teachers, coaches, or administrators. Focusing on the Student FCM also helps reveal the distinctive structure of students' engagement system without diluting it through multi-stakeholder aggregation.

The study addresses three research questions. First, what are the strongest factors perceived by students as influencing their engagement in physical activities? Second, what are the strongest perceived causal interrelationships among these factors in the Student FCM? Third, how can the Student FCM be interpreted as a network explaining students' engagement in physical activities? By answering these questions, the study extends ecological perspectives on physical activity engagement, demonstrates the usefulness of FCM for analyzing perceived causal structures, and identifies potential leverage points for universities seeking to strengthen student engagement in physical activities.

Method

This study used fuzzy cognitive mapping (FCM) to examine university students' perceptions of the factors associated with engagement in physical activity and the perceived directional relationships among these factors. FCM is suitable for representing complex systems because it captures both the direction and strength of perceived causal relationships among factors (Kosko, 1986; Özesmi & Özesmi, 2004). The study was conducted at a public university in Anhui Province, China. A total of 437 second-year undergraduate students

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Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

participated voluntarily. Second-year students were selected because they had completed their initial transition to university and had sufficient experience of campus-based physical activity. This selection was intended to provide a contextually relevant cohort rather than a representative sample of Chinese university students as a whole. Because participation was voluntary, the possibility of self-selection bias cannot be excluded.

The FCM questionnaire did not collect participant-level sociodemographic characteristics such as sex, exact age, academic programme, place of residence, socioeconomic status, or previous physical activity experience. Age, gender, and physical activity participation frequency were included as predefined concepts within the FCM rather than as descriptive characteristics of individual respondents. Consequently, subgroup-specific descriptive statistics were not available for the present analysis. Before data collection, participants were informed about the purpose and procedures of the study. Written informed consent was obtained from all participants through a consent form before they completed the FCM questionnaire. Participation was voluntary and anonymous, and no personally identifying information was collected. Participants were informed that they could withdraw from the study at any time without penalty or adverse consequences. Ethical approval was granted by the Human Research Ethics Committee (Non Medical) of the authors' institution (Approval No. HREC(NM)/2023 (3)/16). The application was approved at the committee meeting held on 2 September 2025, and the formal approval memorandum was issued on 30 October 2025.

Candidate factors were identified through a two-stage process combining literature review and stakeholder input. First, relevant studies were searched through Google Scholar, Scopus, and Web of Science to develop an initial pool of factors associated with university students' engagement in physical activities. The literature-derived factors covered individual, social, instructional, environmental, institutional, and temporal influences.

Second, one focus-group interview was conducted as a contextual validation step. The participants comprised ten third-year students from the Social Sports Guidance and Management programme (S1–S10), one professor with more than ten years of experience in physical activity and management, and one representative from the administrative management team. The students were selected because their programme and year of study provided them

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

with relatively extensive exposure to sport and physical activity knowledge and practice. The discussion focused on factors that participants perceived as facilitating or constraining students' engagement in physical activities within the university environment. The focus-group findings were reviewed descriptively by identifying recurrently mentioned factors and comparing them with the literature-derived factor pool; no separate formal thematic coding procedure was undertaken.

Factor retention was based on two considerations: support in the existing literature and recurrence during the focus-group discussion. Factors that were repeatedly identified by participants and were supported by previous research were prioritised for inclusion, while factors with limited support from either source were reviewed and, where appropriate, excluded or merged with conceptually overlapping factors. The final decisions were made by comparing the interview findings with the literature-derived factor pool to ensure both empirical relevance and conceptual coverage. The retained factors were subsequently integrated and organised according to the adapted Bronfenbrenner ecological framework, comprising the Self, Microsystem, Mesosystem, Exosystem, Macrosystem, and Chronosystem. This process resulted in 44 candidate factors.

The ecological classification followed the conceptual boundaries of the adapted Bronfenbrenner framework. Self factors represented individual biological and psychological characteristics; Microsystem factors represented students' direct interpersonal relationships and immediate participation environments; Mesosystem factors represented interconnections between immediate settings; Exosystem factors represented social and institutional contexts that could influence students indirectly; Macrosystem factors represented broader cultural, socioeconomic, and societal contexts; and Chronosystem factors represented temporal changes, life transitions, and historical events. The classification resulted in 12 Self factors, 15 Microsystem factors, 2 Mesosystem factors, 3 Exosystem factors, 5 Macrosystem factors, and 7 Chronosystem factors. The complete distribution of the 44 candidate factors is provided in Table 1.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

TABLE 1. Distribution and Operational Definitions of the 44 Candidate Factors Across the Six Ecological Levels

No.	Ecological level	Original questionnaire factor	Operational definition
1	Self	Age	Chronological age is considered an individual characteristic that may shape students' perceived engagement in physical activity.
2	Self	Body Mass Index	Body mass index is a predefined body-related concept in the FCM. It was not calculated from measured height and weight in this study.
3	Self	Gender	Gender as an individual characteristic that participants may perceive as relevant to physical activity engagement.
4	Self	Ethnicity	Ethnic background as an individual characteristic that may be perceived as shaping physical activity engagement.
5	Self	Motivation	The psychological drive to initiate and sustain participation in physical activity.
6	Self	Frequency of physical activities participation	Regularity of student participation in physical activity.
7	Self	Regulate anxiety and stress via physical activities	The perceived role of physical activity in managing or reducing anxiety and stress.
8	Self	Build resilience (mental toughness) via physical activities participation	The perceived development of resilience or mental toughness through participation in physical activity.
9	Self	Self-efficacy (judgments of own capabilities) for engaging in physical activities	Students' judgements of their own capability to participate successfully in physical activity.
10	Self	Self-esteem on engagement in physical activities (individual's overall subjective emotional evaluation of their own worth)	Students' overall subjective evaluation of self-worth as it relates to engagement in physical activity.
11	Self	Physical activities for well-being	Perceived physical or psychological well-being benefits associated with participation in physical activity.
12	Self	Regulate emotion via physical activities participation	The perceived role of physical activity participation in managing or regulating emotions.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

No.	Ecological level	Original questionnaire factor	Operational definition
13	Microsystem	Parental active participation and modeling behavior on physical activities	Parents' own participation in physical activity and the behavioral example they provide to the student.
14	Microsystem	Parental support and encouragement for physical activities	Parents' encouragement and practical or emotional support for the student's physical activity participation.
15	Microsystem	Parental educational level	Parents' level of education as an immediate family-context characteristic potentially related to students' engagement.
16	Microsystem	Parental economic income	Family economic resources, represented by parental income, as an immediate contextual condition related to participation opportunities.
17	Microsystem	Peer support and interaction	General encouragement, companionship, and social interaction with peers in relation to physical activity.
18	Microsystem	Supportive and caring teachers or coaches	The relational and emotional climate created by teachers or coaches through supportive and caring interactions.
19	Microsystem	Peer collaboration physical activities	Joint or cooperative participation with peers in physical activity.
20	Microsystem	Coach's or teacher's support strategies	Specific supportive actions used by coaches or teachers, such as autonomy support, structured guidance, encouragement, or individualized assistance.
21	Microsystem	Coach's or teacher's coaching styles	Broader instructional or leadership approaches adopted by coaches or teachers when organizing and supporting physical activity participation.
22	Microsystem	Physical activities as extracurricular activities (e.g. sports club)	Participation opportunities outside regular curricular activity, such as sports clubs and other organized extracurricular physical activities.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

No.	Ecological level	Original questionnaire factor	Operational definition
23	Microsystem	Facilities for physical activities	The availability and accessibility of physical infrastructure for students' physical activity participation.
24	Microsystem	Community sport facilities	Sport and physical activity facilities available in the surrounding community.
25	Microsystem	Attractive, safe, and accessible facilities	The perceived attractiveness, safety, and accessibility of facilities used for physical activity.
26	Microsystem	Financial support for physical activity programs	Financial resources or funding available to support physical activity programs and participation opportunities.
27	Microsystem	School policy for inclusive physical activities participation	The original questionnaire label for institutional policies and organizational arrangements that support equitable access to physical activity participation in the university context.
28	Mesosystem	Family-school interactions	Interactions and coordination between the student's family and educational setting that may shape physical activity engagement.
29	Mesosystem	Family-peer group interactions	Interactions between family and peer contexts that may jointly shape the student's physical activity engagement.
30	Exosystem	Digital technologies for physical activities (e.g. mobile applications, wearable devices (fitness bands, smartwatches), online fitness classes and virtual workout videos)	Digital tools and technology-based resources that can support, guide, track, or facilitate physical activity.
31	Exosystem	Mass media and social media	Media and social-media content or environments that may indirectly shape physical activity attitudes, information, and participation.
32	Exosystem	Local government policies	Policies and decisions of local government that may indirectly affect physical activity opportunities, resources, or environments.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

No.	Ecological level	Original questionnaire factor	Operational definition
33	Macrosystem	Local socioeconomic	The broader local socioeconomic context, including economic conditions and resource availability that may shape opportunities for physical activity.
34	Macrosystem	Injury Prevention and Health Monitoring Supports	Broader systems and supports for preventing physical activity-related injury and monitoring health during participation.
35	Macrosystem	Cultural Norms and Values	Broader cultural beliefs, expectations, and values that shape attitudes towards physical activity and sport.
36	Macrosystem	Global collaborative physical activities	Physical activity experiences or initiatives involving international or cross-cultural collaboration and participation.
37	Macrosystem	Public health system	The wider public-health structures, priorities, and supports that shape physical activity promotion and health-related participation.
38	Chronosystem	Changes in family structure (parental divorce, single-parent family)	Changes in family composition over time, such as parental divorce or transition to a single-parent family.
39	Chronosystem	Historical Events (Educational reform)	Educational reforms or policy changes occur over time that may alter students' physical activity environments or opportunities.
40	Chronosystem	Historical Events (COVID-19 Pandemic)	The COVID-19 pandemic as a historical event that changed access to, patterns of, and opportunities for physical activity.
41	Chronosystem	Historical Events (Life Events and Transitions - entering adulthood, changing employment status, or experiencing health setbacks)	Major personal life events and transitions over time, including entering adulthood, changes in employment status, or health setbacks.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

No.	Ecological level	Original questionnaire factor	Operational definition
42	Chronosystem	Historical Events (Major event - Olympic Games)	Major sporting events, represented by the Olympic Games, as temporal societal events that may influence physical activity perceptions or participation.
43	Chronosystem	Changes in educational stages (primary school to middle school, middle school to university)	Transitions between educational stages that may change physical activity routines, environments, and participation opportunities.
44	Chronosystem	Climate change	Long-term environmental and climatic change that may alter conditions and opportunities for physical activity over time.

NOTE. Factor labels are reproduced from the FCM questionnaire used for data collection and are retained to preserve consistency with the instrument. Operational definitions provide concise clarification of their intended meaning in the present study.

Although several retained factors were conceptually related, they were not treated as interchangeable. They were retained as separate FCM concepts when the literature and focus-group discussion indicated distinct functional meanings within the engagement system. Peer support and interaction referred primarily to general encouragement, companionship, and social interaction with peers, whereas peer collaboration in physical activities referred to joint or cooperative participation in physical activity. Supportive and caring teachers or coaches represented the relational and emotional climate created by instructional staff; support strategies referred to specific supportive actions, such as autonomy support, structured guidance, and individualised assistance; and “Coach’s or teacher’s coaching styles” referred to broader instructional or leadership approaches adopted by coaches or teachers.

Motivation referred to the psychological drive to initiate or sustain participation, whereas physical activity for well-being represented perceived physical or psychological benefits associated with participation. Facilities for physical activities referred to the availability and accessibility of physical infrastructure, whereas “School policy for inclusive physical activities participation” referred, in the present university context, to institutional policies and organisational arrangements intended to support equitable access to physical activity participation. These original questionnaire labels were retained throughout the

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

manuscript to maintain consistency with the instrument used for data collection. These distinctions are conceptual and should not be interpreted as evidence of empirically established discriminant validity among the factors.

BMI was included as a predefined Self-level concept in the FCM questionnaire rather than as an anthropometrically measured participant variable. Participants' height and weight were not collected for the calculation of individual BMI; instead, students evaluated the perceived directional relationships involving the BMI concept in the same way as the other FCM concepts. The instrument required students to assess perceived causal relationships among the factors using a fuzzy weighting scale from -1 to $+1$, where positive values indicated a strengthening effect, negative values indicated a reducing effect, and zero indicated no perceived relationship. Importantly, these directional weights represent participants' perceived influence between factors within the FCM and should not be interpreted as empirically verified causal effects.

Before the main survey, the questionnaire was reviewed by ten third-year students and an experienced physical education academic to assess the clarity, relevance, and comprehensibility of the questionnaire instructions, factor descriptions, and causal-rating procedure. These participants were not included in the main study. The expert and student review was used to assess the relevance and comprehensibility of the questionnaire content; however, no separate factor-analytic assessment of construct validity was conducted. Accordingly, Cronbach's alpha was treated as a preliminary reliability indicator and not as evidence of construct validity or causal validity.

A separate reliability assessment was subsequently conducted with 27 second-year students who were also excluded from the final sample. Cronbach's alpha was calculated using IBM SPSS Statistics across 456 predefined pairwise causal-relationship ratings, with each rated relationship treated as an item. The resulting coefficient was .991. Given the large number of relationship ratings included in the analysis, this very high coefficient was interpreted cautiously as an indicator of consistency across the ratings rather than as evidence of the validity of the perceived causal relationships represented in the FCM. The very high coefficient may also partly reflect the large number of relationship ratings and the conceptual proximity of some

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

predefined factors; therefore, it was not interpreted as evidence that the factors were empirically distinct or that the proposed relationships were valid.

The main student data collection was conducted between 16 and 30 November 2025 in a closed laboratory setting to provide a consistent environment and minimise external distractions. The FCM questionnaire was administered in person. Before completing the questionnaire, students received a detailed briefing on the purpose of the study, the meaning of student engagement in physical activity, the definitions of the candidate factors, and the FCM rating procedure. The -1 to $+1$ scale was explained using its three reference points: -1 represented a strong negative perceived influence, 0 represented no perceived influence, and $+1$ represented a strong positive perceived influence. Participants' understanding was supported through this pre-administration briefing, while the clarity of the questionnaire instructions and factor descriptions had previously been checked during the pilot study. Participants completed the questionnaire independently, and discussion among students was not permitted during the evaluation to minimise potential influence from other participants. Completion of the questionnaire typically required approximately 50–70 minutes. Although the standardised setting, prior briefing, and pilot testing were intended to reduce procedural difficulty and unnecessary burden, the large number of relationship ratings meant that respondent fatigue could not be completely excluded.

Each completed questionnaire generated an individual FCM matrix. The 437 individual Student FCM matrices were aggregated by calculating the arithmetic mean of the corresponding weights across participants. All participants were assigned equal credibility weights ($w = 1$); therefore, for each directed relationship from factor j to factor k , the aggregated weight was calculated as the sum of the corresponding individual weights divided by the number of student matrices ($N = 437$). This procedure produced a collective map representing the average pattern of students' perceived relationships. For terminological clarity, throughout this article, “Student FCM” and “aggregated Student FCM” refer to the same collective map obtained by averaging the corresponding weights across the 437 individual student FCMs. An “individual student FCM” refers to the map generated from one participant's ratings, whereas the “physical activity

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

engagement system” refers to the conceptual network of engagement-related factors represented by the FCM rather than to a separate map.

In this study, the term “factor weight” refers to the aggregated mean direct-influence weight from a candidate factor to the target concept, student engagement in physical activities. It does not represent FCM centrality, the sum of incoming and outgoing connections, or an indicator automatically generated by Mental Modeler. For each candidate factor, the corresponding factor-to-engagement weights were averaged across the 437 individual Student FCMs. The resulting aggregated mean factor weights were ranked in descending order, and the ten highest-ranked factors were retained for presentation.

Relationship weights were calculated separately from factor weights. For each directed factor-to-factor relationship, the corresponding weights were averaged across the 437 individual Student FCMs to obtain an aggregated mean relationship weight. These aggregated mean relationship weights were ranked in descending order, and the fifteen highest-ranked perceived interrelationships were retained for presentation. Mental Modeler was used to construct and visualise the aggregated Student FCM rather than to generate the factor-ranking statistic.

The present analysis focused on the aggregated Student FCM. Between-student variability, confidence intervals around the mean weights, and formal sensitivity analyses were not calculated. Accordingly, the aggregated map should be interpreted as a summary of the average pattern of perceptions across the participating students rather than as a representation of every individual student or subgroup.

Questionnaires with incomplete FCM evaluations were excluded before matrix construction; consequently, only complete student matrices ($N = 437$) were included in the aggregation, and no missing values were imputed.

Results

The aggregated Student FCM was constructed from the responses of 437 second-year university students. The analysis examined the overall network structure, the ten highest-ranked engagement factors, and the fifteen strongest perceived interrelationships. All directional

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

relationships reported below represent students' aggregated perceptions within the FCM and should not be interpreted as empirically verified causal effects.

Student FCM Overview

Figure 1 presents the FCM constructed using the Mental Modeler tool (Gray et al., 2013) from the aggregated perceptions of 437 students. The factor-to-factor arrows correspond to the relationships reported in Table 3. Figure 1 shows that the strongest factors and perceived interrelationships were concentrated mainly in the Microsystem and Self dimensions. Seven of the top ten factors belonged to the Microsystem and three to the Self dimension. Similarly, fourteen of the top fifteen perceived interrelationships were located within the Microsystem, while only one was located within the Self dimension. No Mesosystem, Exosystem, Macrosystem, or Chronosystem factor appeared among the highest-ranked results. This absence should not be interpreted as evidence that factors at these ecological levels are unimportant; rather, it indicates that they did not receive sufficiently high aggregated mean weights to be included among the ten highest-ranked factors or fifteen highest-ranked interrelationships in this sample. This indicates that students perceived engagement in physical activity mainly through immediate social relationships, participation opportunities, instructional support, and personal conditions.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

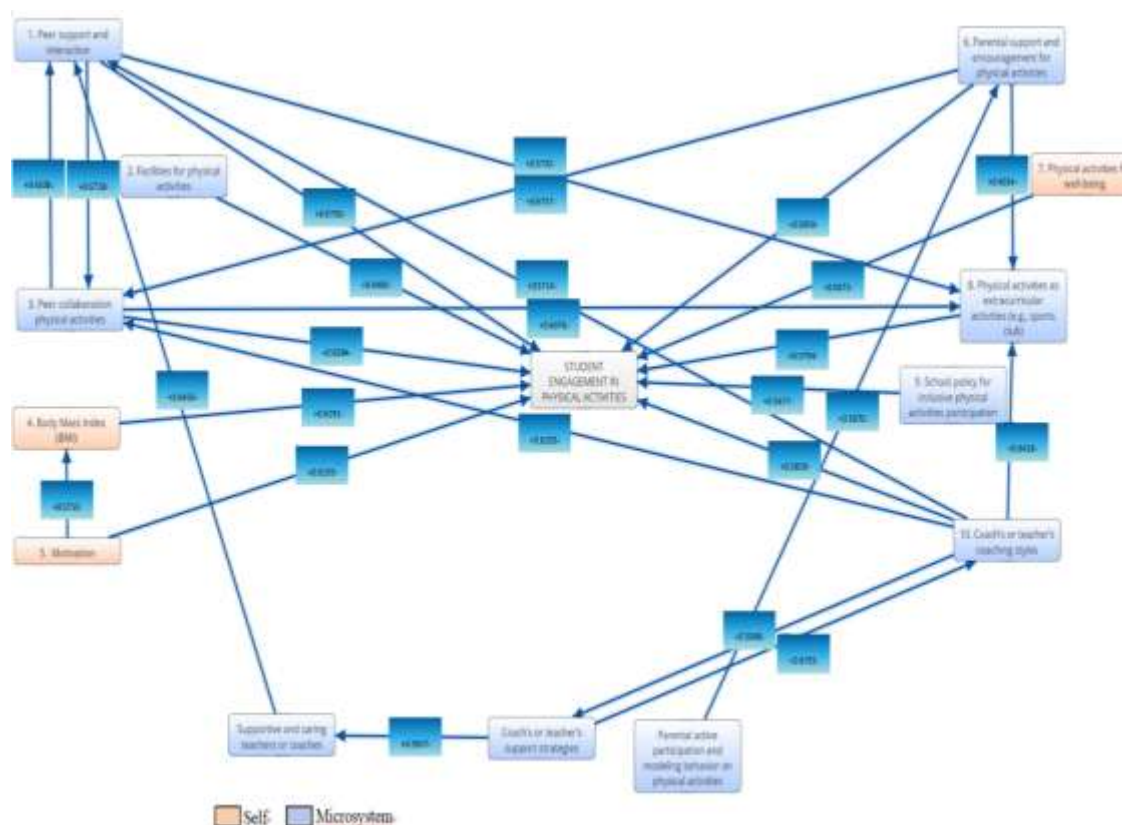


FIGURE 1. Student FCM showing the ten highest-ranked factor-to-engagement links and the fifteen highest-ranked perceived factor-to-factor interrelationships.

Top Ten Engagement Factors

Table 2 presents the ten highest-ranked engagement factors based on their aggregated mean factor-to-engagement weights. Peer support and interaction had the highest aggregated mean weight (+0.6700), followed by facilities for physical activities (+0.6483), peer collaboration in physical activities (+0.6384), body mass index (BMI) (+0.6291), motivation (+0.6195), parental support and encouragement (+0.5959), physical activities for well-being (+0.5872), extracurricular physical activities such as sports clubs (+0.5794), inclusive school policy (+0.5677), and coaching styles (+0.5659). These results show that students associated engagement with a combination of social support, accessible facilities, organised participation opportunities, and individual motivational or physical conditions.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

Peer-related influences were especially prominent. Peer support and interaction ranked first, while peer collaboration ranked third. These factors suggest that encouragement, companionship, and collaborative participation are central to students' physical activity engagement. Environmental and organizational factors were also important, particularly facilities, extracurricular activities, and inclusive school policy. The presence of BMI, motivation, and well-being among the top factors further indicates that students also recognized the importance of personal condition, internal drive, and perceived benefits of participation.

TABLE 2. Top Ten Engagement Factors Ranked by Aggregated Mean Factor Weight

Factor	Dimension	Aggregated Mean Factor Weight
Peer support and interaction	Microsystem	+0.6700
Facilities for physical activities	Microsystem	+0.6483
Peer collaboration in physical activities	Microsystem	+0.6384
Body mass index (BMI)	Self	+0.6291
Motivation	Self	+0.6195
Parental support and encouragement for physical activities	Microsystem	+0.5959
Physical activities for well-being	Self	+0.5872
Physical activities as extracurricular activities (e.g. sports club)	Microsystem	+0.5794
School policy for inclusive participation in physical activities	Microsystem	+0.5677
Coach's or teacher's coaching styles	Microsystem	+0.5659

Top 15 Interrelationships Among Engagement Factors

Table 3 presents the fifteen highest-ranked perceived interrelationships based on their aggregated mean relationship weights. The highest-ranked relationship was parental support and encouragement → peer collaboration in physical activities (+0.6737), followed closely by coach's or teacher's support strategies → coaching styles (+0.6735) and peer support and interaction → peer collaboration in physical activities (+0.6728). Peer support and peer collaboration also formed a reciprocal perceived relationship, with peer collaboration → peer support and interaction (+0.6538). Students also perceived peer collaboration (+0.6076) and

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

peer support (+0.5732) as positively influencing extracurricular physical activities, showing that peer-related pathways were closely connected with organised participation in the Student FCM.

TABLE 3. Top 15 Perceived Interrelationships Ranked by Aggregated Mean Relationship Weight

Top 15 Causal Interrelationships	Dimension	Aggregated Mean Relationship Weight
Parental support and encouragement for physical activities → Peer collaboration in physical activities	Microsystem	+0.6737
Coach's or teacher's support strategies → Coach's or teacher's coaching styles	Microsystem	+0.6735
Peer support and interaction → Peer collaboration in physical activities	Microsystem	+0.6728
Peer collaboration in physical activities → Peer support and interaction	Microsystem	+0.6538
Supportive and caring teachers or coaches → Peer support and interaction	Microsystem	+0.6426
Coach's or teacher's coaching styles → Physical activities as extracurricular activities (e.g. sports club)	Microsystem	+0.6416
Coach's or teacher's coaching styles → Peer collaboration in physical activities	Microsystem	+0.6103
Peer collaboration in physical activities → Physical activities as extracurricular activities (e.g. sports club)	Microsystem	+0.6076
Parental support and encouragement for physical activities → Physical activities as extracurricular activities (e.g. sports club)	Microsystem	+0.6014
Coach's or teacher's coaching styles → Coach's or teacher's support strategies	Microsystem	+0.5998
Coach's or teacher's support strategies → Supportive and caring teachers or coaches	Microsystem	+0.5927
Parental active participation and modeling behavior on physical activities → Parental support and encouragement for physical activities	Microsystem	+0.5870
Motivation → Body mass index (BMI)	Self	+0.5753
14. Peer support and interaction → Physical activities as extracurricular activities (e.g. sports club)	Microsystem	+0.5732
15. Coach's or teacher's coaching styles → Peer support and interaction	Microsystem	+0.5714

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

Family-related pathways were also evident. Students perceived parental support as positively influencing peer collaboration (+0.6737) and extracurricular physical activities (+0.6014), while parental modelling was perceived as positively influencing parental support (+0.5870). These perceived relationships suggest that students connected family encouragement and modelling with participation through peer and extracurricular pathways.

Coaching and instructional factors formed another important cluster. Students perceived support strategies as positively influencing coaching styles (+0.6735), while coaching styles were also perceived as positively influencing support strategies (+0.5998), indicating a reciprocal perceived relationship. Coaching styles were further perceived as positively influencing extracurricular physical activities (+0.6416), peer collaboration (+0.6103), and peer support and interaction (+0.5714). Supportive and caring teachers or coaches were also perceived as positively influencing peer support and interaction (+0.6426). These relationships show how students connected teacher and coach practices with their social and extracurricular participation environment.

Only one Self-related perceived causal relationship appeared among the top fifteen: motivation → BMI (+0.5753). Within the FCM, this arrow represents the aggregated direction and weight that students assigned to the perceived relationship between the two predefined concepts. It does not represent an observed change in BMI, demonstrate that motivation causes BMI to change, or identify any behavioural or physiological mechanism linking the two concepts. Although Self factors were represented among the top ten engagement factors, the strongest perceived causal pathways were concentrated mainly within the Microsystem.

Overall, the findings indicate that students perceived physical activity engagement as an interconnected system rather than as a set of isolated factors. The strongest perceived causal pathways centred on peers, family support, coaching practices, and extracurricular opportunities. Figure 2 integrates these perceived relationships into a model of student engagement in physical activities across ecological levels within the university environment. Figure 2 provides a conceptual summary of the highest-ranked engagement factors and selected perceived interrelationships discussed in the main analysis; it does not represent all 44 candidate factors or the complete Student FCM.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

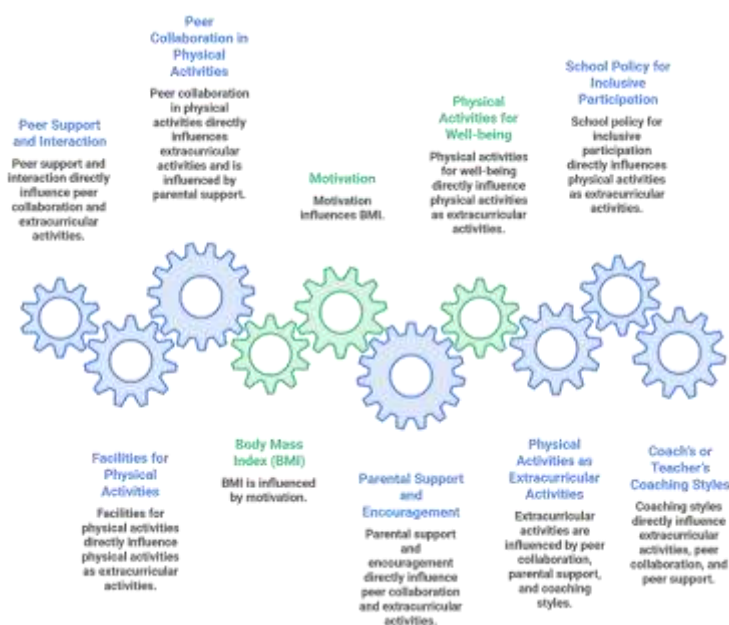


FIGURE 2. Conceptual Summary of the Highest-Ranked Engagement Factors and Selected Perceived Interrelationships in the Student FCM

Discussion

Microsystem factors were the most prominent among the highest-ranked results in the aggregated Student FCM. Seven of the ten highest-ranked factors and fourteen of the fifteen highest-ranked perceived interrelationships were classified within the Microsystem, whereas factors from the Mesosystem, Exosystem, Macrosystem, and Chronosystem did not appear among these selected rankings. This pattern is consistent with Bronfenbrenner's ecological systems theory, which emphasises the importance of proximal processes within the individual's immediate environment (Bronfenbrenner, 1979; Bronfenbrenner & Morris, 2006). In the university context, these proximal influences include peers, teachers, coaches, family members, facilities, and organised participation opportunities. The present pattern indicates that immediate social and participation contexts received comparatively high aggregated weights in this sample. It should not, however, be interpreted as evidence that the broader ecological levels are unimportant to physical activity engagement. Factors from these levels were included in the full 44-factor FCM questionnaire but did not reach the thresholds for inclusion in the top ten

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

factors or top fifteen interrelationships. Broader ecological influences may therefore remain relevant even when they are less prominent in students' aggregated perceptions.

This result is also consistent with previous physical activity research showing that peer support, parental encouragement, teacher support, coaching practices, and participation opportunities are important determinants of engagement among adolescents and young adults (Keegan et al., 2009; Ornelas et al., 2007; Vazou et al., 2006; Zhang et al., 2022). The present study extends this evidence by showing that these factors were not only individually important, but also centrally positioned within the strongest perceived causal pathways of the Student FCM. This highlights the value of FCM in identifying both direct and indirect relationships among engagement-related factors.

Peer support and collaborative participation formed a prominent perceived pathway within the Student FCM. Students perceived peer support and interaction as positively influencing peer collaboration in physical activities, while peer collaboration was also perceived as positively influencing peer support and interaction. This reciprocal perceived relationship suggests that students viewed peer encouragement, companionship, and collaborative participation as mutually reinforcing. At the same time, peer support and peer collaboration are conceptually adjacent constructs. The reciprocal relationship may therefore partly reflect the close cognitive association students made between general peer support and cooperative participation, rather than demonstrating two empirically distinct causal mechanisms. These findings support previous studies showing that peers are associated with motivation, enjoyment, and continued involvement in sport and physical activity (Keegan et al., 2009; Vazou et al., 2006). In addition, students perceived both peer support and peer collaboration as positively influencing extracurricular physical activities, suggesting that they associated supportive peer relationships with participation in organised activities such as sports clubs.

Family and coaching support networks were also prominent within students' perceived engagement system. Students perceived parental support and encouragement as positively influencing peer collaboration and extracurricular participation, while parental active participation and modelling behaviour was perceived as positively influencing parental support.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

Rather than demonstrating causal effects, these pathways indicate how students connected family support with social and organised participation. This interpretation is consistent with research showing that parental encouragement, emotional support, and practical assistance are associated with young people's physical activity participation (Ornelas et al., 2007).

Coaching and instructional factors formed another prominent perceived pathway. Coach or teacher support strategies and coaching styles showed a reciprocal relationship within the Student FCM, while coaching styles were also perceived as influencing peer support, peer collaboration, and extracurricular participation. Supportive and caring teachers or coaches were similarly perceived as influencing peer support and interaction. These findings indicate that students connected teachers' and coaches' practices with both instructional experiences and the wider social context of participation. This interpretation is consistent with previous studies showing that coaches, parents, and peers are associated with motivation and continued sport involvement (Keegan et al., 2009; Vazou et al., 2006), while more recent research has reported associations between teaching styles, perceived support, motivation, and engagement in physical education (Coteron et al., 2024; Miao et al., 2024). This reciprocal pattern should also be interpreted cautiously because the two concepts are related but were operationally distinguished: support strategies referred to specific supportive actions, whereas coaching styles referred to the broader instructional or leadership approach within which those actions occurred.

The Student FCM also highlighted the role of participation environments and opportunity structures. Facilities for physical activities emerged as an important engagement factor, indicating that students regarded access to suitable facilities as a condition for sustained participation. This is consistent with evidence that supportive physical environments reduce participation barriers and increase opportunities for exercise and recreation (Sayyid et al., 2021). Extracurricular physical activities also served as a key connecting factor because they were influenced by peers, parental support, and coaching styles. Similarly, university policy for inclusive physical activity participation inclusive school policy appeared among the top engagement factors, suggesting that students valued institutional support for accessible and inclusive participation. This finding aligns with broader physical activity promotion strategies

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

that emphasize coordinated investment in school, sport, recreation, and community settings (Milton et al., 2021).

Although Microsystem factors were the most prominent in the aggregated Student FCM, Self-related factors also remained important. BMI, motivation, and physical activities for well-being appeared among the ten highest-ranked engagement factors. Motivation was involved in the only Self-related relationship among the top fifteen perceived interrelationship pathways, with students perceiving motivation as positively influencing BMI. Motivation has been widely recognised as an important factor in behavioural engagement and sustained participation, consistent with Self-Determination Theory (Ryan & Deci, 2020). Previous studies have also reported associations between motivation, physical activity, and BMI among university students (Alecú et al., 2025; Teixeira et al., 2012). However, the motivation → BMI relationship identified in the present FCM should not be interpreted as evidence that motivation directly changes BMI; rather, it reflects how students cognitively connected motivational and body-related conditions within the engagement system. The present FCM does not establish the behavioural or physiological mechanisms underlying this perceived relationship. The prominence of BMI suggests that students perceived physical condition as relevant to participation, while the inclusion of well-being indicates that students associated physical activity with physical and psychological benefits. This is consistent with evidence that physical activity contributes to mental health, emotional regulation, and overall well-being (Singh et al., 2023; Zhang et al., 2025).

Overall, the findings suggest that students perceived physical activity engagement as an interconnected system of personal, social, instructional, and environmental factors. The strongest perceived factors and causal pathways were concentrated within the Microsystem, especially those involving peers, family, coaching, and extracurricular participation. These patterns identify peer relationships, coaching and teaching practices, extracurricular opportunities, facilities, and family encouragement as potential areas for future intervention design and evaluation, rather than demonstrating the effectiveness of any specific intervention.

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

Conclusion

This study used fuzzy cognitive mapping (FCM) to examine university students' perceived causal structure of engagement in physical activities. The aggregated Student FCM showed that students represented engagement through an interconnected network of peer, family, coaching, facility, and Self-related factors, with the strongest factors and perceived causal pathways concentrated within the Microsystem. Peer support and collaborative participation formed a prominent perceived pathway, while parental encouragement, coaching practices, and extracurricular opportunities occupied important positions within students' cognitive representations. These findings describe perceived direct, indirect, and reciprocal relationships among engagement-related factors and should not be interpreted as empirically verified causal effects. The study therefore demonstrates the value of FCM as a systems-based approach for representing how students perceive interconnected conditions associated with their engagement in physical activities. Accordingly, the findings should be interpreted as reflecting the perceptions of second-year students at one public university in Anhui Province rather than as representative of Chinese university students as a whole. The findings identify perceived areas of importance within students' engagement system but do not demonstrate that interventions targeting these areas will improve physical activity engagement. They should therefore be regarded as a basis for generating and testing future intervention hypotheses.

Practical Implications

Within similar university contexts, the perceived patterns identified in the aggregated Student FCM may help identify areas for future intervention development and evaluation. Peer-supported and collaborative approaches, such as buddy systems, student-led activity groups, recreational sport clubs, and peer ambassador schemes, represent possible options for intervention design because peer support and peer collaboration were prominent in students' cognitive representations. These approaches should be regarded as potential courses of action rather than interventions whose effectiveness was demonstrated by the present study. Extracurricular physical activity opportunities may also provide a context in which peer, family, and coaching-related influences can be examined in future intervention research. This is

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

consistent with evidence on peer-led campus recreation programmes, which highlights the value of structured participation opportunities for student well-being (Kirby et al., 2024).

Facilities, inclusive participation policies, supportive coaching and teaching practices, and family encouragement may also be considered candidate areas for future intervention development. Future studies could examine whether improving access to physical activity facilities, strengthening supportive coaching practices, or increasing opportunities for peer-supported participation leads to measurable changes in students' engagement. Such interventions should be evaluated prospectively before conclusions are drawn about their effectiveness.

Limitations and Future Research

Several limitations should be noted. First, the participants were 437 second-year students from a single public university in Anhui Province, China, and participation was voluntary. The sample should therefore not be regarded as representative of Chinese university students as a whole. Voluntary participation may also have introduced self-selection bias, as students with greater interest in physical activity may have been more willing to participate. In addition, restricting the sample to second-year students means that the findings may not reflect students' perceptions at other stages of university study. The findings should therefore be interpreted within this specific institutional and cohort context. In addition, the present analysis focused on aggregated mean weights. Between-student variability, measures of dispersion, confidence intervals around the mean weights, and formal sensitivity analyses were not calculated. Accordingly, the aggregated Student FCM should be interpreted as a summary of average perceptions rather than as a representation of every individual student or subgroup.

Future research should include students from multiple universities, regions, years of study, and physical activity backgrounds to examine the extent to which the observed patterns are reproduced across different student populations. In addition, participant-level sociodemographic information was not collected in the original FCM survey. It was therefore not possible to examine whether differences in sex, exact age, academic programme, place of residence, socioeconomic background, or previous physical activity experience were associated

Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

Vol. 12, n.º 6; p. 1-31, October 2026. <https://doi.org/10.55040/hz6adn42>

with variations in students' FCM ratings. Future studies should collect these characteristics and examine both overall and subgroup-specific FCMs. Second, the FCM represents students' perceived interrelationships rather than objectively verified causal effects. Third, the cross-sectional design captured perceptions at one point in time and did not examine how engagement pathways may change across university study stages. A further limitation concerns the length and cognitive demands of the FCM questionnaire. Participants were required to evaluate a large number of predefined relationships, and completion typically required approximately 50–70 minutes. Although the questionnaire was piloted for clarity and completion time and administered under standardised conditions, the possibility of respondent fatigue cannot be excluded and may have affected some of the ratings.

The absence of broader ecological factors among the strongest pathways does not mean that institutional, social, or temporal influences are unimportant. Rather, these factors may have been less visible in students' immediate cognitive representations of engagement. Broader influences may operate indirectly through facilities, policies, teachers, coaches, or participation opportunities. Future research could compare student FCMs with teacher, coach, and administrator FCMs to examine stakeholder agreement and differences. Longitudinal studies could assess whether Microsystem pathways remain stable over time. Future studies may also combine FCM with qualitative interviews or intervention designs to examine how changes in peer support, coaching practices, and participation opportunities influence engagement outcomes.

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Original article. Chinese university students' perceptions of factors related to physical activity engagement: a fuzzy cognitive mapping study.

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