

Research Hotspots and Development Trends of Adolescent Physical Exercise in China: A CiteSpace-Based Knowledge Mapping Study

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Abstract

Objective: Adolescent physical exercise is a key component of China's strategies to build a leading sporting nation, advance the Healthy China initiative, and strengthen the education system. It has therefore remained an important issue of sustained concern for the Party and the state. This study aims to examine the current research landscape, hotspots, and future trends in studies on adolescent physical exercise in China. **Methods:** A total of 185 articles on adolescent physical exercise published between 1993 and 2025 in Peking University Core Journals and indexed in the China National Knowledge Infrastructure (CNKI) database were selected as research samples. Bibliometric methods and CiteSpace-based knowledge mapping were used to conduct a systematic analysis of the field. **Results:** Research on adolescent physical exercise in China shows three main characteristics. First, its development can be divided into several stages: an initial stage focused on basic physical fitness and institutional exploration; an intermediate stage in which an integrated framework linking physical fitness, psychological factors, and practical mechanisms gradually took shape; and a recent stage characterized by technology-enabled precision and specialization. Second, the collaboration network shows a pattern of strong core concentration but loose overall connections, with insufficient cooperation among leading institutions and limited participation from peripheral universities. Third, high-frequency research themes include adolescents, physical exercise, and school sports. However, several problems remain, including insufficient interdisciplinary integration, limited attention to vulnerable groups, and inadequate application of emerging technologies. **Conclusion:** Future research on adolescent physical exercise in China should strengthen interdisciplinary collaboration and promote coordinated efforts among families, schools, and communities. It should also advance personalized exercise interventions empowered by intelligent technologies, facilitate the translation of research findings into policy and practice, and improve the equitable allocation of sports facilities, thereby consolidating the foundation for building a leading sporting nation.

Keywords

Adolescent physical exercise; CiteSpace; integration of sports and education; mental health; personalized exercise.

1. Introduction

Since the 18th National Congress of the Communist Party of China (CPC), the CPC Central Committee with Comrade Xi Jinping at its core has strategically planned and systematically advanced the development of a leading sporting nation from the perspective of national prosperity and national rejuvenation. These efforts have promoted the high-quality development of China's sports sector and opened new prospects for sports development in the

new era. Adolescent sports are no longer merely an issue of individual growth and development; they have become an important foundation for improving population health and advancing the Healthy China initiative. Their strategic value and social significance have therefore received unprecedented attention. The National Fitness Program (2021-2025) explicitly identifies adolescents as a priority group in sports development and emphasizes the establishment of a systematic and sustainable mechanism for promoting youth physical activity, providing clear policy guidance for the field. Despite these efforts, the physical health of Chinese adolescents faces multiple challenges. High and increasingly younger rates of myopia, the growing prevalence of obesity, a significant increase in postural problems such as scoliosis, and the rising incidence of mental health problems such as anxiety and depression have become major concerns. In addition, key indicators of physical fitness, including speed, strength, and endurance, have shown structural declines. These problems not only threaten the holistic development of adolescents but also constitute major obstacles to the implementation of the Healthy China strategy. According to Li Qiang, governmental attention to adolescent sports has deepened continuously since China's reform and opening-up in 1978. During the early reform period, relevant policies mainly focused on restoring educational order and improving adolescents' physical health. In the 1990s, school sports gradually became institutionalized. In the new century, adolescent health was elevated to the level of national strategy under the guiding principle of "Health First", and policy and research concerns expanded to include psychological well-being, scientific training, and other dimensions of adolescent development. This evolution reflects a transition from an emphasis on physical fitness alone to a comprehensive strategic framework related to the future of the nation. Against the background of socialism with Chinese characteristics in the new era, it is necessary and timely to systematically review research on adolescent sports in China. Such a review can help identify major research themes, developmental trajectories, and emerging trends, clarify the internal logic of the high-quality development of adolescent sports, refine theoretical frameworks, provide evidence-based support for policymaking, and guide collaborative practices among families, schools, and communities. Therefore, this study reviews the literature on adolescent sports in China with the aim of identifying research hotspots and frontier trends in the field. It also reflects on the limitations of existing studies in terms of theoretical depth, research perspectives, methodological approaches, and practical orientation. In particular, this study addresses three key questions: What are the main constraints on the development of adolescent sports under the Healthy China strategy? To what extent have existing studies responded to these constraints? How can an innovative and operational governance system and development pathway for adolescent sports be established? By answering these questions, this study seeks to provide theoretical support for the modernization of China's adolescent sports governance system and governance capacity.

2. Data Sources and Research Methods

2.1. Data Sources

The data used in this study were retrieved from the China National Knowledge Infrastructure (CNKI) database. Literature related to adolescent sports was identified through a topic search, with "adolescent physical exercise" used as the primary search term. The retrieval period covered publications from January 1, 1993, to 2025. To ensure the academic quality and representativeness of the sample, only articles published in Peking University Core Journals were included. After screening and removing irrelevant records, 185 valid articles were retained as the data source for subsequent analysis.

Table 1. Data Source Information

Item	Description
Data Source	China National Knowledge Infrastructure (CNKI)
Search Term	Adolescent Physical Activity
Language	Chinese
Document Type	Peking University Core Journals
Time Span	1993–2025 (33 Years)
Final Sample Size	185 Articles

2.2. Research Methods

2.2.1. Literature Review Method

This study retrieved core literature on adolescent physical exercise published between 1993 and 2025 from the CNKI database. The review focused on key themes such as determinants of physical exercise behavior, practical pathways for the integration of sports and education, and mechanisms of health promotion. The selected literature was systematically organized, summarized, and analyzed to clarify the developmental trajectory, major viewpoints, and existing debates in the field of adolescent physical exercise research in China. This process provided a theoretical foundation for constructing the analytical framework and deriving research conclusions.

2.2.2. Bibliometric Analysis Method

Bibliometric analysis was conducted using CiteSpace. CiteSpace enables dynamic complex network analysis and visualization, making it possible to construct knowledge maps such as keyword co-occurrence networks, author collaboration networks, and institutional publication clusters. These visualizations provide an intuitive representation of research distributions, thematic clusters, and frontier trends in the field of adolescent physical exercise. The method also supports quantitative analysis of the academic influence and collaboration patterns of core authors and key institutions, thereby providing empirical evidence for evaluating the current state and future direction of the field.

3. Results and Analysis

3.1. Research Status of Adolescent Physical Exercise

3.1.1. Publication Output Analysis

Based on the CiteSpace bibliometric framework, this study selected 185 core journal articles on adolescent physical exercise published between 1993 and 2025 as the research sample. Annual publication output was statistically analyzed, and stage-based characteristics were identified to reveal the developmental trajectory and influencing factors of research in this field. During the study period, the average annual publication output was 5.6 articles. Publication output showed clear stage characteristics, including an initial exploratory phase with a low baseline, a policy-driven growth phase, and a recent phase characterized by multidisciplinary expansion.

Table 2. Annual Publication Output of Adolescent Physical Exercise Research (1993-2025)

Year	Articles	Year	Articles
1993	1	2010	4
1994	1	2011	8
1995	1	2012	6
1996	1	2013	6
1997	0	2014	5
1998	0	2015	5
1999	1	2016	13
2000	0	2017	12
2001	0	2018	10
2002	1	2019	10
2003	1	2020	13
2004	0	2021	11
2005	3	2022	21
2006	1	2023	24
2007	5	2024	5
2008	4	2025	9
2009	3		
Total:	185 publications		
Average annual output:	5.6 publications		

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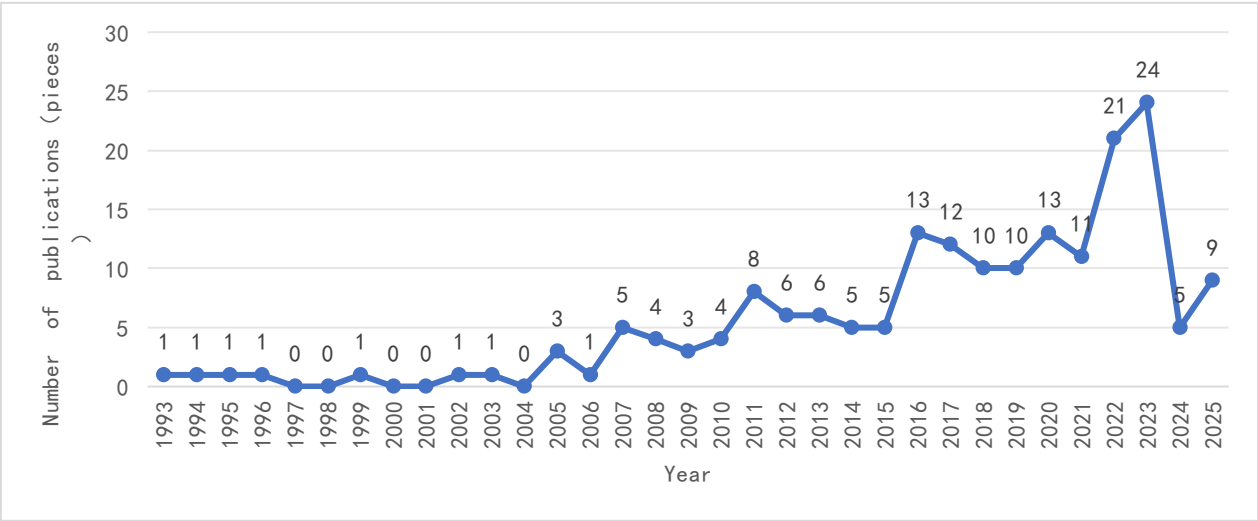


Figure 1. Annual Publication Trends of Adolescent Physical Activity Research (1993–2025)
(1) Initial Exploratory Stage (1993-2005)

The Party and the state have consistently attached great importance to youth sports development. Strengthening adolescent physical exercise is a key measure for accelerating the construction of a leading sporting nation, a strong education system, and a Healthy China. The period from 1993 to 2005 represents the initial exploratory stage of research on adolescent physical exercise in China. During this 13-year period, only 10 articles were published, with an average of approximately one article per year, accounting for 5.4% of the total sample. Publication gaps occurred in several years, including 1997-1998, 2000, and 2004, indicating that a stable academic community in this field had not yet been formed and that research attention remained limited. This stage was characterized by a narrow research perspective, traditional methods, and limited geographical coverage. Research was mainly driven by institutional exploration and policy adaptation. The issuance of the National Fitness Program Outline in 1995 marked the first time that adolescent sports were incorporated into the national sports development system. However, policy transmission was limited, and the prevailing social mindset of emphasizing intellectual development over physical exercise further constrained academic investment in this field. As a result, most studies were fragmented local empirical reports. For example, Yu Daozhong et al. (1995) conducted a localized adaptation study on the Physical Exercise Standards for Adolescents in the Tibet Autonomous Region, but the study lacked systematic theoretical construction. Research during this period mainly focused on two areas: initial exploration of institutional frameworks for adolescent physical exercise and preliminary attention to exercise among special populations. Its major limitation was the weak interaction between academic research and national policy development. Research outputs had limited practical value and failed to respond effectively to the emerging downward trend in adolescent physical fitness indicators.

(2) Steady Growth Stage (2006-2015)

The year 2006 marked a critical turning point in the evolution of research on adolescent physical exercise in China. In 2007, the number of publications reached five, indicating the beginning of a steady growth stage. During this ten-year period, 47 articles were published, with an average annual output of 4.7 articles, accounting for 25.4% of the total sample. Research shifted from fragmented exploration toward systematic responses, and an initial academic community gradually took shape. The main driving force behind this growth was strong national policy support. The Opinions of the CPC Central Committee and the State Council on Strengthening Youth Sports and Enhancing Youth Physical Fitness, issued in 2007, elevated youth physical health to a national strategic priority for the first time and explicitly required students to engage in at least one hour of physical exercise every day. This policy steered academic attention toward issues of policy implementation and effectiveness. In 2011, the National Student Physical Health Standard was released as a fundamental guideline for school physical education and a basic standard for educational quality. It also served as an important benchmark for evaluating students' comprehensive quality, school performance, and regional educational development. In the same year, publication output reached eight articles, a 100% increase compared with 2010, forming a positive interaction among policy introduction, problem emergence, and academic response. Compared with the previous stage, research in this period developed more rapidly. First, interdisciplinary research began to emerge. Second, the proportion of empirical studies increased markedly, with quantitative methods such as structural equation modeling being introduced. Third, research topics shifted from institutional-level discussions to practical mechanisms, including exercise habit formation, physical fitness monitoring and intervention, and optimization of school physical education curricula. However, bibliometric analysis also indicates several limitations. First, research coverage remained uneven, with insufficient attention to vulnerable groups such as rural adolescents and left-behind children. Second, research depth was limited, as most studies focused on descriptive questions of what exists and how to implement interventions, while

fewer studies examined underlying behavioral mechanisms. Third, policy responsiveness lagged behind policy development. For example, although the Several Opinions on Accelerating the Development of the Sports Industry and Promoting Sports Consumption, issued in 2014, emphasized youth sports participation, related academic attention did not become visible until 2015, which then helped accumulate thematic momentum for subsequent research expansion.

(3) Rapid Growth Stage (2016-2023)

In 2016, publication output surged to 13 articles, marking the entry into a rapid growth stage. During the eight-year period from 2016 to 2023, 114 articles were published, with an average annual output of 14.25 articles, accounting for 61.6% of the total sample. Publication output peaked in 2023 with 24 articles. This stage can be analyzed from three perspectives: policy, social demand, and methodology. From a policy perspective, the Healthy China 2030 Planning Outline, issued in 2016, elevated adolescent physical exercise to a foundational component of the national health strategy. In 2020, the Opinions on Deepening the Integration of Sports and Education to Promote the Healthy Development of Adolescents jointly issued by the General Administration of Sport of China and the Ministry of Education further emphasized an integrated design approach, aiming to promote the coordinated development of cultural learning and physical exercise, reflecting a substantial increase in policy density. The document explicitly calls for the integration of sports and education at the institutional level, promoting the healthy development of adolescents through collaborative mechanisms between educational and sports systems. In June 2022, the Standing Committee of the 13th National People's Congress adopted the revised Sports Law of the People's Republic of China. The Law explicitly stipulates that the state prioritizes the development of youth and school sports, promotes the integration of sports and education, coordinates academic learning with physical exercise, and emphasizes both physical fitness and moral development to foster the comprehensive development of adolescents. From a social perspective, rising rates of myopia and obesity among adolescents, along with increasingly prominent mental health problems, have become major public concerns. Issues such as "little glasses" and "little chubby children" have attracted widespread attention. From a methodological perspective, the application of CiteSpace and other bibliometric and data analysis tools has facilitated a shift from descriptive studies to more explanatory and analytical research, improving research rigor and scientific validity. Overall, this stage shows three major characteristics. First, research perspectives have become increasingly diversified, with interdisciplinary integration among physical education, psychology, sociology, and public health. Second, research themes have deepened, shifting from physical fitness improvement toward holistic education outcomes, including sports-education integration, digital media influence, and mental health interventions. This aligns with the practical need to optimize adolescents' extracurricular time under the Double Reduction policy. Third, research methods have become more sophisticated, with longitudinal studies, mixed methods, and mediation and moderation analyses becoming more common, thereby strengthening the connection between academic research, policy formulation, and practical implementation.

(4) Adjustment Stage (2024)

In 2024, publication output decreased to five articles. Based on bibliometric patterns and the logic of field development, this decline does not necessarily indicate reduced research interest. Rather, it reflects a rational adjustment from quantitative expansion toward quality-oriented development. On the one hand, articles in core journals typically involve a publication and indexing lag, meaning that some 2024 outputs may not yet have been fully indexed. On the other hand, after eight years of rapid expansion, scholars gradually shifted from trend-following studies to more in-depth investigations of specialized subfields. This transition led to longer research cycles and a short-term decline in publication volume, reflecting the maturation of the field.

(5) Mature Development Stage (2024-2025)

Based on publication trends and thematic evolution, it can be reasonably projected that publication output in 2025 will remain at a relatively high level. Although a decline occurred in 2024, it does not indicate a decline in research interest; instead, it reflects a structural transformation from quantitative expansion to quality-oriented development. Driven by policy advancement and technological progress, publication output reached its peak in 2023. Meanwhile, research topics became increasingly specialized, and disciplinary integration expanded significantly. Therefore, publication output in 2025 is expected to remain stable, while research quality is likely to improve further. Future research is likely to place greater emphasis on subfields such as personalized exercise interventions, the application of intelligent and digital technologies, and policy evaluation. This shift indicates that research on adolescent physical exercise in China has entered a mature stage characterized by stronger empirical orientation and practical application. Interdisciplinary and cross-sector collaboration is also expected to deepen, promoting further integration among research, policy, and practice.

3.1.2. Institutional Analysis

Table 3. Institutional Data Overview		
No.	Institution	Publications
1	Shanghai University of Sport	7
2	School of Physical Education and Training, Shanghai University of Sport	6
3	School of Physical Education and Health, East China Normal University	5

Based on Table 3, institutional data in the field of adolescent physical exercise were analyzed using CiteSpace. The institutional co-occurrence network shows three key characteristics: core-driven leadership, typological collaboration, and regional imbalance. The network contains 207 nodes and 148 links, with a network density of 0.0069. In terms of publication output, Shanghai University of Sport, the School of Physical Education and Training at Shanghai University of Sport, and the School of Physical Education and Health at East China Normal University rank among the top three institutions. These core institutions form a collaborative network mainly concentrated in the Yangtze River Delta region. However, overall institutional cooperation remains weak. Connections involving local universities and institutions in central and western China are sparse, indicating low participation and limited academic interaction. Future research should strengthen cross-regional collaboration, activate the research capacity of peripheral institutions, and enhance industry-university-research cooperation, thereby improving the efficiency of knowledge transfer and the practical application of research outcomes.

3.1.3. Author and Collaboration Network Analysis

Table 4. Author Productivity and Collaboration Overview		
No.	Author	Publications
1	Tang Yan	7
2	Zhang Jialin	6
3	Hu Yueying	5

4	Liu Mingyi	4
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Based on Table 4 , the author co-occurrence network constructed using CiteSpace reveals a structure characterized by core concentration and overall fragmentation. The network consists of 323 nodes and 450 links, with a network density of 0.0087, indicating relatively weak overall collaboration. In terms of publication output, Tang Yan, Zhang Jialin, Hu Yueying, and Liu Mingyi constitute the core author group. Tang Yan's research mainly focuses on sports policy and health promotion, Zhang Jialin emphasizes the integration of sports and education and curriculum optimization, Hu Yueying explores psychological mechanisms of physical exercise behavior, and Liu Mingyi concentrates on sports clubs and talent development. Together, these core authors form a relatively close local collaboration subnetwork. Overall, although the field involves a large number of researchers, collaboration is still characterized by localized density and widespread dispersion. Peripheral authors tend to engage in isolated or limited cooperation, and cross-team collaboration remains insufficient. Future research should strengthen links between core and peripheral authors, activate the academic community, and promote a transition from isolated research outputs to systematic and collaborative knowledge production.

3.2. Hotspot Clustering in Adolescent Physical Exercise Research

3.2.1. Keyword Co-occurrence Analysis

Table 5. Keyword Data Overview

No.	High-Frequency Keywords	Frequency	High-Centrality Keywords	Centrality
1	Adolescents	83	Adolescents	0.97
2	Physical exercise	36	Physical exercise	0.27
3	School sports	13	School sports	0.22
4	Integration of sports and education	9	Integration of sports and education	0.08
5	Health promotion	7	Mass sports	0.07
6	Physical exercise (variant)	7	Health promotion	0.04

Based on the keyword co-occurrence network generated by CiteSpace, the research trajectory of adolescent physical exercise can be clearly identified. Table 5 show that "adolescents" (frequency = 83, centrality = 0.97) is the core node of the entire network, with strong links to key terms such as "physical exercise" (36 occurrences, centrality = 0.27) and "school sports" (13 occurrences, centrality = 0.22). These keywords indicate that research mainly focuses on adolescent exercise behavior and developmental mechanisms. In addition, high-frequency terms such as "integration of sports and education" (9 occurrences, centrality = 0.08) and "health promotion" (7 occurrences, centrality = 0.04) indicate that, under the dual influence of policy orientation and health-driven goals, the field has gradually expanded toward three interconnected dimensions: school-based contexts, integration of sports and education, and health empowerment. The appearance of "mass sports" (centrality = 0.07) also suggests that researchers are extending their attention to broader social support systems for adolescent physical exercise. Overall, the keyword network shows a structure centered on adolescents and extending across multiple dimensions. The field maintains a strong focus on the core issues of youth physical exercise while also showing growing potential for interdisciplinary

collaboration. This provides important clues for future research on policy implementation, multi-stakeholder cooperation, and deeper structural mechanisms.

3.2.2. Keyword Cluster Analysis

Based on the keyword co-occurrence network, CiteSpace was used to generate a keyword clustering map (Figure 2). The effectiveness of clustering was evaluated using modularity Q and weighted mean silhouette S . In general, a Q value between 0 and 1 indicates the overall network structure; a value above 0.3 suggests significant clustering, while a value above 0.5 indicates a well-structured and reliable clustering pattern. An S value greater than 0.7 indicates high cluster homogeneity and strong reliability. In this study, the keyword clustering analysis yielded $Q = 0.6159$ and $S = 0.8966$, indicating that the clustering results are statistically significant and highly reliable.

The clustering map identified seven listed major clusters: #0 Physical Exercise, #1 Adolescents, #2 School Sports, #3 Shanghai, #4 Sports Education Integration, #5 Health Promotion, and #6 Physical Activity. The smaller the cluster number, the larger the cluster size and the richer the literature contained within it. Therefore, the clustering results provide important quantitative evidence for structural interpretation. Overall, the keyword clustering structure reveals a multi-layered pattern: foundational themes centered on physical exercise and adolescents; school-based practice represented by school sports; policy coordination reflected in integration of sports and education; health-oriented outcomes represented by health promotion; and regional and behavioral extensions indicated by Shanghai and physical exercise. This structure reflects the evolution of adolescent physical exercise research from population-focused studies toward school-based practice, multi-stakeholder coordination, and health-oriented value realization. It also provides an analytical basis for future research focusing on the implementation of sports-education integration and the improvement of school physical education quality.

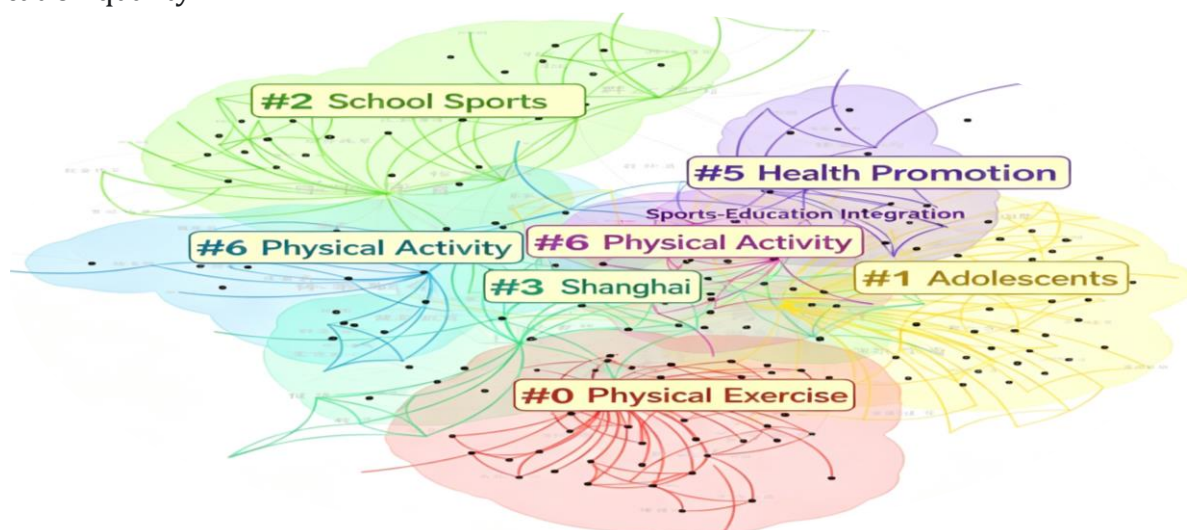


Figure 2. Keyword Clustering Map of Adolescent Physical Exercise Research

3.3. Research Trends in Adolescent Physical Exercise

3.3.1. Keyword Timeline Analysis

This study used CiteSpace to examine the evolutionary trajectory of research on adolescent physical exercise through keyword timeline visualization. In the timeline map, node size represents the frequency of keyword occurrence, node color indicates temporal progression, and links between nodes represent co-occurrence relationships among keywords. The timeline visualization makes it possible to identify changes in research hotspots and detect emerging research directions over time.

(1) Stage I: Fundamental Physical Fitness Enhancement Stage (1995-2005)

Research during this stage mainly focused on foundational issues in adolescent physical exercise, particularly physical fitness training and improvement of physical health. Key terms included physical exercise, adolescent physical fitness, obesity, and physical inactivity. The main objective was to improve adolescents' physical health through exercise interventions. Methodologically, studies were mainly quantitative, with limited exploration of psychological development and social adaptation among adolescents.

(2) Stage II: Policy-Driven and Comprehensive Development Stage (2006-2015)

Driven by a series of national policies and regulations during this period, research on adolescent physical exercise entered a new stage, shifting from a single-dimensional focus toward a more comprehensive approach and laying a foundation for cultivating well-rounded talent.

International comparative perspectives show that France places strong emphasis on national leadership and a governance model characterized by the separation of administrative and operational functions in its youth sports public service system. Under this model, government functions are restructured, responsibilities across departments are clearly defined, and multi-level coordination among social sectors contributes to the rapid development of youth sports talent cultivation.

In contrast, China's youth sports public service system has long been characterized by a government-led single-wheel driving model, with insufficient collaboration among social organizations, enterprises, and other stakeholders. To address potential inefficiencies caused by fragmented governance, this period also witnessed efforts to professionalize the governance system. In May 2010, the General Administration of Sport of China established the Youth Sports Department as a bureau-level internal institution responsible for guiding youth sports service system development and reserve talent cultivation. This initiative aimed to strengthen interdepartmental coordination within the government and form policy synergy to promote the sustained development of youth sports.

(3) Stage III: Technology-Enabled and Personalized Exercise Stage (2016-2025)

With the issuance of the Healthy China 2030 Planning Outline by the CPC Central Committee and the State Council and the implementation of the Double Reduction policy, greater national emphasis has been placed on public health and adolescent well-being, marking a new stage in research on youth physical fitness. The development and application of smart wearable devices have provided theoretical and practical support for innovation in smart sports. Examples include wearable technologies, big data analytics, and sports applications. Empirical evidence from China's market shows that the total number of smart wearable-related products registered with barcodes reached 181,000 by the third quarter of 2025, involving 6,000 enterprises. This represents a 91.4% increase compared to September 2020, with an average annual growth rate of 13.9%. China has implemented a purchase subsidy policy for smart wearables. According to the Implementation Plan for Purchase Subsidies for Mobile Phones, Tablets, and Smart Watches (Bands) jointly issued by the Ministry of Commerce and four other departments, eligible consumers can receive a 15% subsidy on the final sales price for each smart watch (band) purchased, with a maximum subsidy of 500 RMB per unit. Overall, these trends show that China has placed increasing emphasis on national physical fitness and health monitoring. On the one hand, digital technologies enable real-time tracking of physical health and promote sports consumption. On the other hand, research has become increasingly multidimensional, extending beyond physical indicators to examine the effects of exercise on psychological well-being, emotional regulation, and academic stress. This shift reflects a move toward more

scientific and professional training approaches and contributes to the development of more efficient and evidence-based exercise intervention systems.

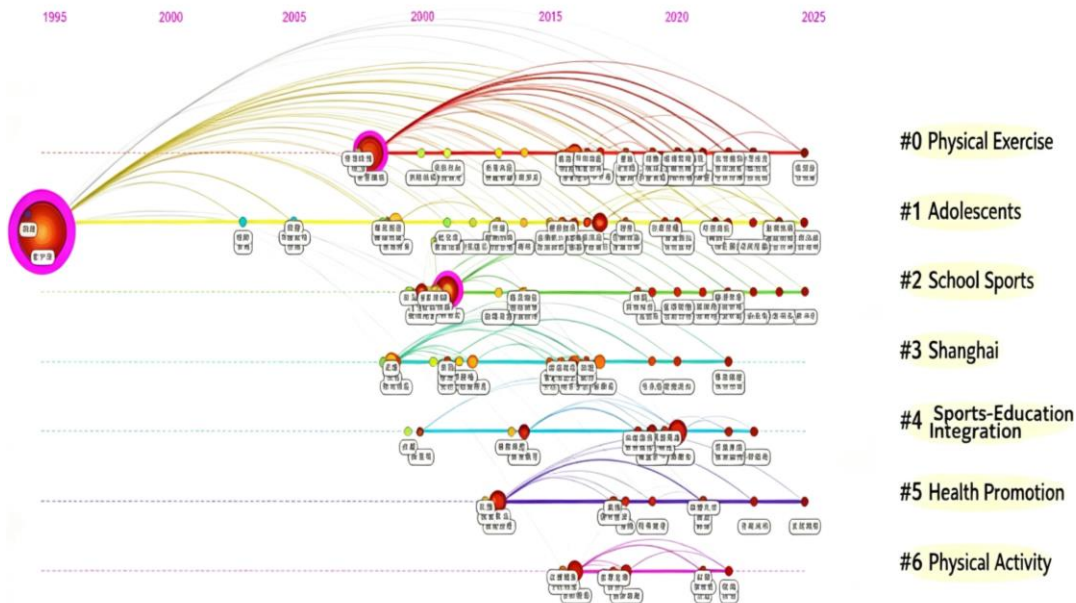


Figure 3. Keyword Timeline Visualization of Adolescent Physical Exercise Research

3.3.2. Keyword Burst Detection

Top 23 Keywords with the Strongest Citation Bursts

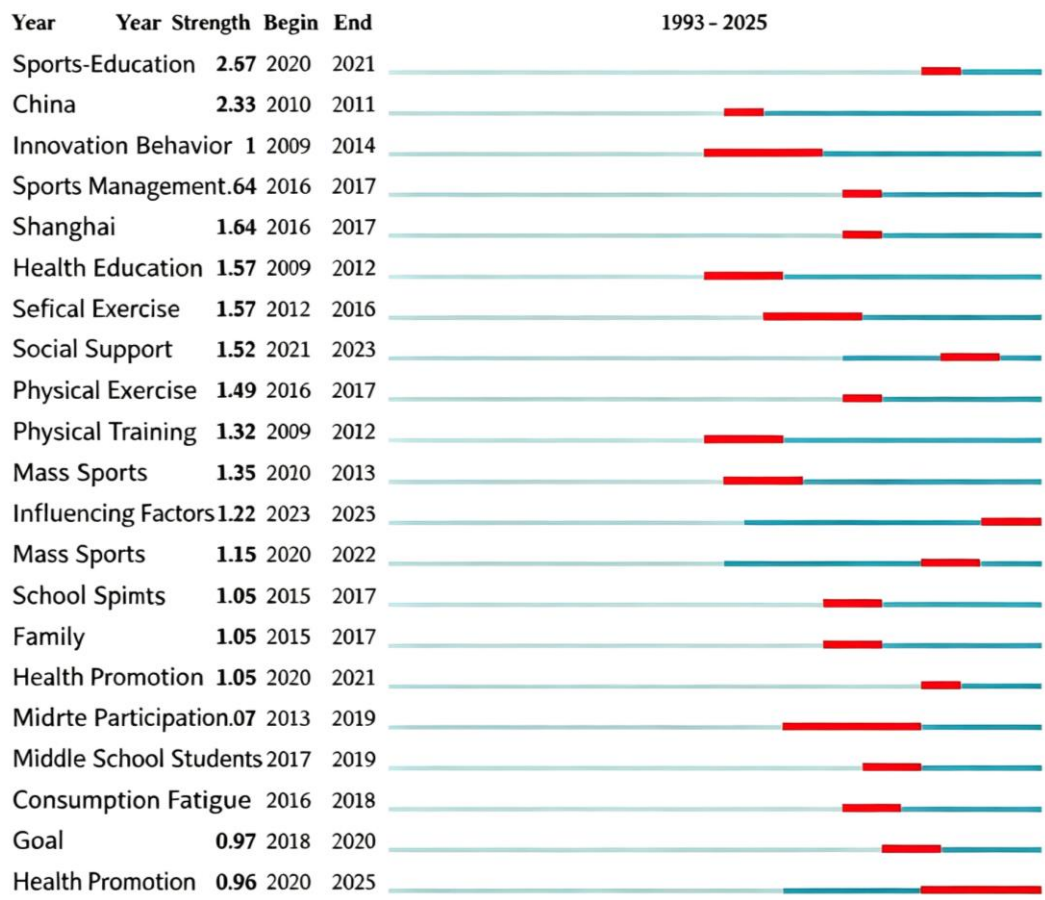


Figure 4. Keyword Burst Detection in Adolescent Physical Exercise Research

Keyword burst detection refers to a sudden increase in the frequency of a keyword within a specific period, reflecting shifts in research hotspots in a field. By analyzing burst keywords,

researchers can better capture the dynamic evolution and frontier issues of academic research. The temporal patterns of keyword change reveal the evolution of research interests and provide insights into potential future hotspots and trend. In Figure 4, the red horizontal lines indicate the time span of each burst keyword, marking the beginning and ending periods during which the keyword received heightened scholarly attention. The longer the duration of a keyword burst, the more sustained the research attention and the stronger its indication of an emerging or persistent frontier. Based on Figure 4 and Table 6, among the burst keywords in adolescent physical exercise research, "integration of sports and education" shows the strongest burst intensity, with a burst strength of 2.67 during 2020-2021. This indicates that the integration of sports and education has been an important research focus in China's adolescent sports development. In addition, keywords such as China, sports management, health education, and physical and mental exercise have also become important topics of scholarly attention in recent years. The timing and intensity of these bursts suggest that they represent emerging research frontiers in the field. Overall, research on adolescent physical exercise is shifting from a narrow focus on health promotion toward a more comprehensive model of physical and psychological development, reflecting growing social emphasis on holistic youth development. With ongoing technological advancement, intelligent systems and big data analytics have created new possibilities for personalized exercise interventions, improving the precision and effectiveness of exercise-based interventions. Furthermore, interdisciplinary approaches not only deepen theoretical understanding but also provide richer foundations for policy formulation, helping address complex issues such as mental health and social adaptation among adolescents. However, despite diversified research development, uneven social support systems and disparities in sports infrastructure still limit the application of research findings. Future research should therefore place greater emphasis on balanced development across regions and population groups, thereby promoting effective policy implementation and sustainable improvement in youth physical exercise systems.

Table 6. Keyword Burst Detection Results

No.	Keyword	Burst Strength	Start year	End year
1	Integration of Sports and Education	2.67	2020	2021
2	China	2.33	2010	2011
3	Exercise Behavior	2.01	2009	2014
4	Sports Management	1.64	2016	2017
5	Self-Efficacy	1.64	2016	2017

4. Conclusions and Recommendations

4.1. Conclusions

The collaboration network in the field of adolescent physical exercise shows a pattern of core concentration and overall fragmentation, indicating that the academic community has not yet fully matured. The density of the institutional collaboration network is only 0.0069, while the density of the author collaboration network is 0.0087; both are below 0.01. This suggests limited cross-disciplinary and cross-regional collaboration and almost no international cooperation. Core institutions and leading scholars have relatively weak spillover effects, and

the participation of local universities and institutions in central and western China remains limited, preventing the formation of a fully integrated collaborative system. Research hotspots are mainly centered on physical fitness enhancement, psychological intervention, and optimization of practical mechanisms. Although thematic specialization has increased, the overall depth of inquiry remains insufficient and systematic integration is still lacking. High-frequency keywords are mainly concentrated on conceptual themes such as integration of sports and education and health promotion. Although empirical studies have increased, they remain relatively weak in depth and rigor.

In addition, research on gender differences has not fully incorporated socio-cultural factors, and studies involving vulnerable groups such as rural adolescents and left-behind children remain unevenly distributed. The application of intelligent technologies in adolescent physical exercise research is still limited. Although big data and wearable devices have been introduced, a real-time dynamic health management and exercise intervention model has not yet been established. As a result, data-driven decision-making mechanisms remain underdeveloped, and technological applications have not been fully translated into effective research and practice outcomes.

4.2. Recommendations

Future research should further develop a multi-level collaborative network. Leading institutions such as Shanghai University of Sport and the School of Physical Education and Health at East China Normal University in the Yangtze River Delta region should play a central role in establishing a Regional Collaborative Alliance for Adolescent Physical Exercise Research. This alliance could promote joint research funding applications and data sharing, thereby encouraging greater participation from local universities and institutions in central and western China. Cross-disciplinary research funding schemes should also be established to promote collaboration among core scholars and experts in education, psychology, and related fields. International cooperation should be gradually expanded through academic forums and exchange platforms to address current gaps in cross-regional, cross-disciplinary, and international collaboration. At the methodological level, long-term longitudinal studies and big data technologies should be used to collect real-time physical exercise data. This would strengthen empirical support for key themes such as integration of sports and education and health promotion, and help construct an integrated analytical framework linking physical fitness, psychological factors, and practical intervention mechanisms. Special research programs should be designed to focus on vulnerable populations such as rural adolescents and left-behind children. Gender differences should be examined in combination with socio-cultural factors to address current imbalances in research coverage and depth. Furthermore, the application of intelligent technologies in adolescent physical exercise research should be expanded to include talent identification, injury prevention, and other practical scenarios. A comprehensive platform integrating physical fitness data and exercise feedback should be developed to support the construction of a real-time dynamic health management and exercise intervention model. Such a system would enable adaptive adjustments of research directions and practical strategies based on changes in adolescents' physical conditions and exercise feedback.

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