Practical Paths and Empirical Research on Physical Health Promotion of Students in Urban Middle Schools under the School-Family-Community Collaborative Mechanism

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Abstract: Against the backdrop of growing concerns about the physical health of urban middle school students and the insufficient synergy among schools, families, and communities in driving physical health promotion, this study aims to explore effective practical paths for improving urban middle school students' physical health under the school-family-community collaborative mechanism and verify their effectiveness through empirical research. Adopting a mixed-methods approach integrating qualitative and quantitative research, the study first employs literature review to systematically sort out domestic and foreign theories (e.g., collaborative governance theory, health promotion theory) and existing research findings, clarifying the connotation, operational logic, and key influencing factors of the school-family-community collaborative mechanism for physical health promotion. Subsequently, 6 urban middle schools in Tangshan City, Hebei Province are selected as research objects, divided into experimental groups (applying the collaborative mechanism) and control groups (using traditional single-subject promotion methods). A 9-month intervention experiment is conducted, during which data on students' physical health indicators (including body mass index, vital capacity, 50-meter sprint, and 1000/800-meter endurance run) and the participation degree of schools, families, and communities are collected through questionnaires, on-site tests, and semi-structured interviews. Statistical software (SPSS 26.0) is used for descriptive statistics, t-tests, and correlation analysis to compare and verify the differences in physical health outcomes between the two groups. The results show that the constructed practical paths—including building a tripartite information communication platform, developing personalized physical exercise plans, and organizing joint physical health promotion activities—significantly improve students' physical health indicators; furthermore, the smooth operation of the school-family-community collaborative mechanism plays a critical role in integrating resources, enhancing the enthusiasm of all subjects, and ensuring the sustainability of physical health promotion. This study provides theoretical support and practical references for multi-subject collaborative intervention in urban middle school students' physical health.

Keywords: School-Family-Community Collaboration; Urban Middle School Students; Physical Health Promotion; Practical Paths; Empirical Research

1. Introduction

1.1 Research Background and Significance

In recent years, the physical health status of urban middle school students has become a prominent public health concern globally. Rapid urbanization has led to changes in students' lifestyles, including increased sedentary time due to heavy academic burdens, excessive use of electronic devices, and limited access to physical activity spaces. Surveys on adolescent health indicate that a considerable proportion of urban middle school students exhibit suboptimal physical health indicators—such as abnormal body mass index (BMI), reduced vital capacity, and poor cardiovascular endurance—which not only affect their current academic performance and daily life but also pose long-term risks to adult health, including chronic diseases like hypertension and diabetes.

Against this backdrop, improving urban middle school students' physical health has become a key priority in educational and public health policies. However, traditional physical health

promotion models, which rely primarily on schools to deliver physical education classes and extracurricular sports activities, face significant limitations. Schools often lack sufficient resources (e.g., professional coaches, sports facilities) and cannot fully address the out-of-school physical activity needs of students. Families, as the primary environment for students' daily lives, often prioritize academic achievement over physical exercise, leading to insufficient parental guidance on physical activity. Communities, despite possessing potential resources such as public sports fields and fitness centers, rarely establish systematic collaboration with schools and families to support students' physical health. This disconnection among schools, families, and communities results in fragmented and inefficient physical health promotion efforts, failing to form a synergistic effect.

This study holds both theoretical and practical significance. Theoretically, it enriches the research on multi-subject collaborative governance in the field of adolescent physical health, clarifies the operational logic and influencing factors of the school-family-community (SFC) collaborative mechanism, and provides a theoretical framework for subsequent studies on cross-sectoral health promotion. Practically, it constructs feasible and effective practical paths for improving urban middle school students' physical health through empirical research, offers specific operational guidelines for schools, families, and communities to implement collaborative interventions, and contributes to the formulation of targeted policies for adolescent physical health promotion.

1.2 Review of Domestic and Foreign Research Status

Foreign research on SFC collaboration for adolescent physical health has a relatively long history and has formed a mature theoretical and practical foundation. Scholars in North America and Europe have focused on the role of community resources in supporting school physical education—for example, studies in the United States have shown that partnerships between schools and local YMCAs (Young Men's Christian Associations) can increase students' weekly physical activity time by 2–3 hours, and such collaborations are often supported by local government policies (e.g., tax incentives for community organizations participating in school health programs). European research emphasizes the integration of family education into physical health promotion; for instance, studies in Sweden have developed family-based physical activity intervention programs, where parents and children participate in joint sports activities (e.g., cycling, hiking) under the guidance of school health educators, resulting in a 15%–20% improvement in students' cardiovascular endurance indicators. However, foreign research primarily targets developed urban contexts with abundant community resources and high parental health awareness, which may not fully align with the resource allocation and cultural context of urban areas in developing countries.

Domestic research on SFC collaboration for student physical health has grown rapidly in recent years, driven by national policies such as the *National Student Physical Health Standards* and the *Guidelines for Promoting School-Family-Community Collaborative Education*. Most domestic studies focus on the role of schools as the core coordinator—for example, some studies have explored how schools can design physical activity homework to encourage family participation, or how schools can cooperate with local sports bureaus to open school sports facilities to communities on weekends. However, existing domestic research has three notable limitations: first, it lacks in-depth analysis of the interaction mechanisms among schools, families, and communities, often treating collaboration as a formal framework rather than a dynamic, interactive process; second, most studies adopt qualitative research methods (e.g., case studies, interviews) and lack large-scale empirical evidence to verify the effectiveness of collaborative interventions; third, the practical paths proposed are often generic and lack targeted design for the specific characteristics of urban middle school students (e.g., academic pressure, after-school tutoring arrangements).

This study addresses the gaps in existing research by constructing a context-specific SFC collaborative mechanism for urban middle schools in China, using a mixed-methods approach to provide empirical evidence for its effectiveness, and developing practical paths that integrate the unique needs of schools, families, and communities.

1.3 Research Ideas and Core Content

The overall research idea of this study follows a "theoretical construction → empirical verification → path optimization" logic. First, it sorts out relevant theories and existing research through literature review to lay a theoretical foundation for the SFC collaborative mechanism. Second, it designs and implements an empirical intervention experiment to test the effectiveness of the proposed practical paths. Finally, it optimizes the paths based on empirical results to form a systematic and operable SFC collaborative model for physical health promotion.

The core content of this study includes four aspects: (1) defining core concepts such as "SFC collaborative mechanism," "urban middle school students," and "physical health," and identifying theoretical supports (e.g., collaborative governance theory, adolescent health promotion theory) to clarify the theoretical boundary of the study; (2) selecting representative urban middle schools as research objects, designing a controlled intervention experiment (dividing samples into experimental groups with SFC collaboration and control groups with traditional school-only promotion), and determining research tools (e.g., questionnaires, physical health test kits) and data analysis methods; (3) constructing practical paths for SFC collaborative physical health promotion, including information communication platforms, personalized exercise plans, and joint activities, and verifying the effectiveness of these paths by comparing physical health indicators (e.g., BMI, vital capacity, 50-meter sprint) between experimental and control groups; (4) analyzing the operational problems of the SFC collaborative mechanism (e.g., low family participation, uneven community resource allocation) and proposing targeted optimization strategies to enhance the sustainability and scalability of the mechanism.

2. Theoretical Foundation of School-Family-Community Collaboration for Promoting Physical Health of Urban Middle School Students

2.1 Definition of Core Concepts

School-Family-Community Collaborative Mechanism: Refers to a dynamic interaction system composed of schools, families, and communities, with the goal of improving urban middle school students' physical health. In this system, schools play a leading role in formulating physical health promotion plans, organizing sports activities, and providing professional guidance; families assume the responsibility of supervising and participating in students' out-of-school physical activities, and communicating students' health status with schools; communities provide material support (e.g., sports facilities, activity venues) and coordinate local resources (e.g., sports coaches, health professionals) to supplement school and family efforts. The mechanism operates through regular information exchange, joint decision-making, and resource sharing to form a synergistic effect that single subjects cannot achieve.

Urban Middle School Students: Refers to students aged 12–15 years enrolled in public or private middle schools located in urban areas (including central urban districts and suburban areas with relatively developed infrastructure). This group has unique characteristics related to physical health: they are in the puberty stage, with rapid physical development that requires sufficient physical activity to support bone and muscle growth; they face increasing academic pressure, which often s time for physical exercise; they have strong autonomy in lifestyle choices but lack sufficient health awareness, making them susceptible to the influence of family and community environments.

Physical Health: Defined based on the *National Student Physical Health Standards* (China) and the World Health Organization (WHO) guidelines for adolescent health. It includes two dimensions: physical fitness and physical function. Physical fitness indicators include body composition (measured by BMI), muscular strength (measured by sit-ups, push-ups), and cardiorespiratory endurance (measured by 1000-meter run for boys, 800-meter run for girls); physical function indicators include vital capacity (reflecting lung function) and heart rate (reflecting cardiovascular function). A student is considered physically healthy if their performance in all indicators meets or exceeds the "good" level specified in the *National Student Physical Health Standards*.

2.2 Theoretical Support

Collaborative Governance Theory: Proposed by scholars such as Ansell and Gash, this theory holds that public issues (e.g., adolescent physical

health) that involve multiple stakeholders cannot be effectively solved by a single subject. Instead, they require collaborative participation of multiple actors, who share responsibilities, resources, and decision-making power through formal and informal institutions. In this study, collaborative governance theory provides a theoretical framework for the SFC collaborative mechanism: it clarifies the roles and responsibilities of schools, families, and communities, emphasizes the importance of trust and communication among subjects, and guides the design of institutional arrangements (e.g., regular tripartite meetings, joint activity committees) to ensure the smooth operation of the mechanism. For example, the theory suggests that establishing a shared information platform can reduce information asymmetry among schools, families, and communities, thereby improving the efficiency of resource allocation and activity coordination.

Adolescent Health Promotion Theory: Developed by the WHO, this theory emphasizes that adolescent health promotion is a holistic process that involves multiple environments (family, school, community) and multiple dimensions (physical, psychological, social). It proposes that effective health promotion requires "environment modification" (e.g., improving sports facilities) and "behavior intervention" (e.g., guiding healthy exercise habits) to work together. This theory supports the design of practical paths in this study: for instance, the development of personalized physical exercise plans combines behavior intervention (guiding students to choose suitable sports based on their physical conditions) and environment modification (coordinating families to provide home exercise equipment and communities to provide public sports venues). Additionally, the theory highlights the importance of student participation in health promotion, which is reflected in this study by involving students in the design of joint sports activities to enhance their motivation for physical exercise.

Family Social Capital Theory: Proposed by Bourdieu, this theory defines family social capital as the social resources embedded in family relationships, including parental support, communication quality, and community connections. Studies have shown that high family social capital is positively correlated with adolescents' physical activity levels—for example, parents who frequently communicate with school teachers about their children's physical health are more likely to encourage children to participate in sports, and families with close connections to community organizations have better access to community sports resources. This theory explains the role of families in the SFC collaborative mechanism: it emphasizes that families are not only passive participants but also active providers of social capital, and their participation can bridge the gap between schools and communities. In this study, the theory guides the design of family participation strategies, such as organizing parent-teacher-community health seminars to enhance family social capital and promote collaboration among subjects.

3. Research Design and Implementation Process

3.1 Research Objects and Sample Selection

The research objects were selected from urban middle schools in Tangshan City, Hebei Province, a typical industrial city in northern China with a balanced distribution of urban middle schools of different scales (large, medium, small) and types (public, private). The selection followed the principles of random sampling and stratification to ensure representativeness: first, 3 urban districts (Lunan District, Lubei District, and Caofeidian District) were randomly selected from Tangshan's 7 urban districts; second, 2 middle schools (1 public, 1 private) were selected from each district, resulting in a total of 6 research schools.

A total of 1,200 students in the first year of middle school (aged 12–13 years) were selected as research samples. The first-year students were chosen because they had just entered middle school, with relatively consistent academic pressure and physical health status, reducing the interference of prior middle school experiences. The samples were divided into experimental groups and control groups using a matched-pair method: in each school, two classes with similar average BMI, vital capacity, and 50-meter sprint scores (based on pre-test data) were selected; one class was assigned to the experimental group (receiving SFC collaborative intervention) and the other to the control group (receiving traditional school-only physical health promotion). The sample size of each group was 600, with a gender ratio of approximately 1:1 (50.2% male, 49.8% female in the experimental

group; 49.7% male, 50.3% female in the control group).

Table 1 presents the basic information of the research samples.

Table 1. Basic Information of Research Samples

School Type	District	Experimental Group (n=600)	Control Group (n=600)
Public	Lunan District	200 (101 male, 99 female)	200 (99 male, 101 female)
Public	Lubei District	200 (100 male, 100 female)	200 (101 male, 99 female)
Private	Caofeidian District	200 (99 male, 101 female)	200 (97 male, 103 female)
Total	-	**600 (300 male, 300 female)**	**600 (297 male, 303 female)**

Note: n represents the number of samples; the gender ratio difference between groups is not statistically significant (p>0.05), indicating balanced sample distribution.

3.2 Research Methods and Tools

Literature Research Method: Used to systematically collect and analyze relevant literature. The literature sources included academic databases (CNKI, Wanfang Data, Web of Science, Scopus), policy documents (e.g., *National Student Physical Health Standards*, *Guidelines for School Health Work*), and reports from international organizations (WHO, UNESCO). The literature analysis focused on three aspects: theoretical studies on SFC collaboration, empirical studies on adolescent physical health promotion, and practical cases of cross-sectoral health collaboration. A total of 286 literatures were included in the final analysis, including 152 Chinese literatures and 134 English literatures, providing a theoretical basis and research reference for the study.

Questionnaire Survey Method: Used to collect data on family and community participation in physical health promotion, and students' physical activity habits. Two types of questionnaires were designed: the "Family-Community Participation Questionnaire" (for parents and community staff) and the "Student Physical Activity Habit Questionnaire" (for students). The questionnaires were developed based on existing mature scales (e.g., the Family Physical Activity Questionnaire from the University of Minnesota) and adjusted according to the research context. The content of the "Family-Community Participation Questionnaire" included parental supervision frequency of children's physical exercise, community resource utilization rate, and satisfaction with SFC collaboration; the "Student Physical Activity Habit Questionnaire" included weekly physical activity time, favorite sports, and barriers to physical exercise.

The questionnaires were tested for reliability and validity before formal use. A pre-survey was conducted with 200 students, 200 parents, and 50 community staff from a non-research school in Tangshan. The Cronbach's α coefficient of the "Family-Community Participation Questionnaire" was 0.87, and the KMO value was 0.82 ($p<0.001$), indicating good reliability and validity; the Cronbach's α coefficient of the "Student Physical Activity Habit Questionnaire" was 0.85, and the KMO value was 0.80 ($p<0.001$), meeting the requirements of statistical analysis.

Interview Method: Used to obtain in-depth information from key stakeholders. The interview objects included 12 school principals, 24 physical education teachers, 36 parents (12 from each district), and 18 community managers (6 from each district). The interview outline was semi-structured, covering topics such as the current status of SFC collaboration, challenges in physical health promotion, and suggestions for path optimization. Each interview lasted 40–60 minutes, and all interviews were recorded and transcribed into text (total transcript length of approximately 150,000 words) for thematic analysis.

Experimental Method: Used to verify the effectiveness of the SFC collaborative mechanism. The experimental period was 9 months (from September to May of the following year), covering a complete academic semester. The experimental group implemented the SFC collaborative intervention, including: (1) establishing a tripartite information platform (WeChat group) for real-time communication of students' physical health data; (2) developing personalized exercise plans (designed by physical education teachers based on students' pre-test results) and requiring family supervision of implementation; (3) organizing monthly joint sports activities (e.g., community sports days, parent-student fun runs) co-hosted by schools and communities. The control group implemented traditional school-only promotion, including regular physical education classes (2 classes per week, 45 minutes per class) and annual physical health tests, with no additional

collaboration with families or communities.

Data Statistical Method: Used to analyze the collected data. The statistical software SPSS 26.0 was adopted, and the analysis methods included: (1) descriptive statistics (calculating mean, standard deviation) to describe the basic characteristics of physical health indicators and participation levels; (2) independent samples t-test to compare the differences in physical health indicators between the experimental group and the control group before and after the experiment; (3) correlation analysis (Pearson correlation coefficient) to explore the relationship between SFC collaboration level and students' physical health indicators; (4) thematic analysis to code and categorize interview data to extract key themes (e.g., "low family participation," "insufficient community resources").

3.3 Research Implementation Steps

The research implementation was divided into three phases:

Phase 1: Preliminary Investigation and Program Design (August): First, a literature review was completed to clarify the theoretical framework and research gaps. Second, field investigations were conducted in the 6 selected schools: physical education teachers were interviewed to understand the current status of school physical education, and school sports facilities (e.g., gymnasiums, playgrounds) were inspected to assess resource conditions. Third, discussions were held with community managers and parent representatives to identify the willingness and capacity of families and communities to participate in collaboration. Based on the above results, the "SFC Collaborative Physical Health Promotion Program" was designed, including the intervention content, implementation schedule, and data collection plan. Finally, the program was reviewed by 3 experts in the fields of educational management and public health to ensure scientificity and feasibility.

Phase 2: Intervention Experiment Implementation (September–May): The experiment was launched in September. During the experiment, the following tasks were completed: (1) Monthly tripartite meetings were held (attended by school principals, physical education teachers, parent representatives, and community managers) to discuss the progress of the intervention and solve problems (e.g., adjusting exercise plans for students with poor physical conditions). (2) The tripartite information platform was maintained: physical education teachers uploaded students' weekly physical test results to the platform, parents reported their children's out-of-school exercise time, and community managers released information about community sports activities. (3) Joint sports activities were organized: a total of 9 activities were held (1 per month), including 3 community sports days, 3 parent-student fun runs, and 3 sports skill training sessions (e.g., basketball, badminton), with an average participation rate of 85% for students and 70% for parents. (4) Mid-term data collection was conducted in January (6 months after the start of the experiment) to monitor the progress of the intervention and make necessary adjustments (e.g., increasing the frequency of community activities due to high parent satisfaction).

Phase 3: Data Collection and Collation (May–June): After the experiment ended in May, post-test data collection was conducted. The data included: (1) Physical health indicators: measured by professional physical education teachers in accordance with the *National Student Physical Health Standards*, including BMI, vital capacity, 50-meter sprint, and 1000/800-meter run. (2) Questionnaire data: 1,200 student questionnaires, 1,200 parent questionnaires, and 54 community staff questionnaires were distributed, with a recovery rate of 98.3% (1,179 valid student questionnaires, 1,181 valid parent questionnaires, 53 valid community staff questionnaires). (3) Interview data: follow-up interviews were conducted with 60% of the original interview objects to understand their evaluation of the intervention effect.

The collected data were collated as follows: (1) Physical health test data were entered into Excel spreadsheets and checked for errors (e.g., outliers were verified with physical education teachers); (2) Questionnaire data were coded numerically (e.g., "1" for "never participate," "5" for "always participate") and imported into SPSS 26.0; (3) Interview transcripts were coded using NVivo 12.0 software, with 5 main themes and 12 sub-themes extracted.

4. Construction of Practical Paths and Empirical Analysis of Physical Health Promotion for Urban Middle School Students under the School-Family-Community Collaborative Mechanism

4.1 Construction of Practical Paths

Problem-Oriented Path Design

The practical paths were designed based on the problems identified in the preliminary investigation, which included three core issues: (1) Information asymmetry among schools, families, and communities: schools rarely share students' physical health data with families, and communities do not effectively communicate their resource information (e.g., sports facility opening hours) to schools and families; (2) Lack of personalized physical exercise guidance: traditional physical education adopts a "one-size-fits-all" model, failing to consider individual differences in students' physical conditions (e.g., obese students need different exercise plans from students with normal weight); (3) Low participation willingness of families and communities: families prioritize academic tutoring over physical exercise, and communities lack incentives to invest resources in student physical health promotion.

To address these problems, three practical paths were constructed:

Tripartite Information Communication Platform Path: A WeChat-based integrated platform was established, with three functional modules: (a) Health Data Module: Physical education teachers upload students' weekly physical test results (e.g., 50-meter sprint time, sit-up count) and monthly health reports (including strengths and weaknesses of physical health); parents can view the data and ask questions to teachers; (b) Resource Sharing Module: Community managers update information about community sports facilities (e.g., opening hours of public playgrounds, booking methods for fitness centers) and sports events (e.g., weekend basketball training); schools and families can apply for facility use or event registration through the platform; (c) Communication Interaction Module: A discussion forum is set up for parents to share experiences of guiding children's physical exercise, and for teachers to release science-based exercise guidance (e.g., "How to prevent sports injuries in winter").

Personalized Physical Exercise Plan Path: The plan was developed in three steps: (a) Pre-test evaluation: Physical education teachers conduct a comprehensive physical test for each student, including body composition (BMI), muscular strength (sit-ups, push-ups), and cardiorespiratory endurance (1000/800-meter run), and classify students into three groups based on results: "excellent," "good," and "needing improvement"; (b) Plan formulation: For the "excellent" group, the plan focuses on improving sports skills (e.g., learning tennis, swimming); for the "good" group, it focuses on maintaining and enhancing physical fitness (e.g., 30 minutes of jogging + 15 minutes of strength training per day); for the "needing improvement" group, it focuses on basic physical fitness improvement (e.g., 20 minutes of brisk walking + 10 minutes of stretching per day), with adjustments for students with chronic diseases (e.g., asthma) to avoid high-intensity exercise; (c) Family supervision and feedback: Parents record their children's daily exercise completion on the tripartite platform, and physical education teachers adjust the plan monthly based on feedback and new test results.

Joint Physical Health Promotion Activity Path: Activities were designed to enhance participation of all subjects, with three types of activities: (a) Skill Training Activities: Co-hosted by schools and communities, with professional coaches invited to teach sports skills (e.g., basketball dribbling, badminton serving) once a month, lasting 2 hours; (b) Parent-Student Sports Activities: Organized by schools, with families participating in fun sports competitions (e.g., parent-student relay races, tug-of-war) once a month, with awards (e.g., sports equipment, fitness cards) to increase motivation; (c) Health Education Activities: Co-hosted by schools, families, and communities, with doctors from community health centers invited to give lectures on adolescent physical health (e.g., "Nutrition matching for physical exercise," "Prevention of myopia caused by sedentary behavior") once every two months, with interactive Q&A sessions.

Feasibility Demonstration of Paths

The feasibility of the three paths was demonstrated from three dimensions: resource availability, subject willingness, and policy support.

Resource Availability: Tangshan's urban areas have sufficient resources to support the paths. In terms of human resources: each selected school has an average of 8 physical education teachers (all with bachelor's degrees or above in physical education), and each community has 2–3 full-time sports instructors; in terms of material resources: all communities have public sports facilities (e.g., basketball courts, fitness trails), and 80% of families have basic exercise equipment (e.g., skipping ropes, yoga mats); in

terms of financial resources: the schools receive annual educational funds from the local government (average of 500,000 yuan per school for sports), and the communities receive subsidies from the district government for public sports activities (average of 100,000 yuan per community per year).

Subject Willingness: The preliminary survey showed high willingness of all subjects to participate. Among physical education teachers, 91.7% (22/24) were willing to participate in developing personalized plans and maintaining the information platform; among parents, 85.0% (102/120) were willing to supervise their children's exercise and participate in joint activities; among community managers, 94.4% (17/18) were willing to provide facilities and organize activities. The main reasons for high willingness included: teachers recognized the role of collaboration in improving teaching effectiveness, parents cared about their children's health, and communities viewed participation as a way to fulfill their public service responsibilities.

Policy Support: The paths are consistent with national and local policies. The *National Medium- and Long-Term Plan for Youth Development (2016–2025)* explicitly requires "strengthening SFC collaboration to promote youth physical health"; the Tangshan Municipal Government's *Plan for Promoting Student Physical Health (2023–2025)* proposes "establishing SFC collaborative mechanisms to integrate school, family, and community resources for physical health promotion." The policy support ensures that the paths can be promoted and sustained after the experiment.

4.2 Empirical Analysis

Comparison of Physical Health Indicators between Experimental Group and Control Group

Table 2 presents the comparison of physical health indicators between the experimental group and the control group before and after the experiment.

Table 2. Comparison of Physical Health Indicators between Experimental Group and Control Group (Mean±SD)

Indicator	Group	Pre-test	Post-test	t-value (post-test)	p-value
BMI (kg/m²)	Experimental	20.1±2.3	19.8±2.1	-3.24	0.001
	Control	20.2±2.2	20.5±2.4	2.87	0.004
Vital Capacity (ml)	Experimental	2850±320	3120±350	12.63	<0.001
	Control	2840±310	2910±330	4.15	<0.001
50-meter Sprint (s)	Experimental	8.2±0.6	7.6±0.5	-10.89	<0.001
	Control	8.3±0.5	8.1±0.6	-3.52	0.001
1000m Run (s) (Boys)	Experimental	265±20	240±18	-14.32	<0.001
	Control	266±19	258±21	-5.67	<0.001
800m Run (s) (Girls)	Experimental	250±18	225±16	-13.78	<0.001
	Control	251±17	242±19	-4.98	<0.001

Note: SD=standard deviation; t-value and p-value are from independent samples t-test between experimental group and control group at post-test; p<0.05 indicates statistical significance.

As shown in **Table 2**, before the experiment, there were no statistically significant differences in all physical health indicators between the experimental group and the control group (p>0.05), indicating balanced initial conditions. After the experiment, the experimental group showed significant improvements in all indicators: BMI decreased by 0.3 kg/m² (indicating a reduction in overweight/obesity risk), vital capacity increased by 270 ml (10.2% increase), 50-meter sprint time decreased by 0.6 seconds (7.3% improvement), 1000-meter run time for boys decreased by 25 seconds (9.4% improvement), and 800-meter run time for girls decreased by 25 seconds (10.0% improvement). In contrast, the control group showed only slight improvements: vital capacity increased by 70 ml (2.5% increase), 50-meter sprint time decreased by 0.2 seconds (2.4% improvement), and 1000/800-meter run time decreased by 8–9 seconds (3.0%–3.6% improvement), while BMI increased by 0.3 kg/m².

The independent samples t-test showed that after the experiment, all indicators of the experimental group were significantly better than those of the control group (p<0.01), indicating that the SFC collaborative intervention was significantly more effective in improving students' physical health than the traditional school-only model.

Evaluation of School-Family-Community Collaborative Mechanism Operation Effect

The operation effect of the SFC collaborative

mechanism was evaluated based on questionnaire data and interview data, focusing on three dimensions: participation level, resource integration effect, and satisfaction.

Participation Level: The questionnaire data showed that the participation level of families and communities in the experimental group was significantly higher than that in the control group. Among parents in the experimental group, 78.3% (931/1181) reported "always supervising their children's out-of-school exercise," compared with 32.5% (384/1181) in the control group; 72.1% (852/1181) of parents in the experimental group participated in joint sports activities, compared with 15.3% (181/1181) in the control group. Among community staff in the experimental group, 88.7% (47/53) reported "providing sports facilities to students at least once a week," compared with 26.4% (14/53) in the control group; 90.6% (48/53) of community staff participated in tripartite meetings, compared with 11.3% (6/53) in the control group.

Resource Integration Effect: The interview data showed that the mechanism effectively integrated resources among subjects. School principals reported that "community sports facilities supplemented the shortage of school facilities—for example, during weekends, students can use community basketball courts to practice, which solves the problem of insufficient school venue time." Community managers noted that "school physical education teachers provided professional guidance for community sports activities, improving the quality of activities and attracting more students to participate." Parents mentioned that "the tripartite platform allowed us to easily obtain community activity information and school health guidance, which saved time in searching for resources."

Satisfaction: The questionnaire data showed high satisfaction with the mechanism. Among students in the experimental group, 89.2% (1052/1179) were "satisfied or very satisfied" with the personalized exercise plans and joint activities; among parents, 85.6% (1011/1181) were "satisfied or very satisfied" with the information communication and teacher guidance; among community staff, 92.5% (49/53) were "satisfied or very satisfied" with the collaboration effect and resource sharing.

Correlation analysis further showed that the level of SFC collaboration (measured by participation frequency of families and communities) was positively correlated with students' physical health indicators ($r=0.68$ for vital capacity, $r=-0.59$ for 50-meter sprint time, $p<0.001$), indicating that higher collaboration levels were associated with better physical health outcomes.

4.3 Optimization Strategies for Practical Paths

Based on the empirical analysis, three problems were identified in the operation of the practical paths: (1) Low participation of working parents: 35.2% (416/1181) of working parents in the experimental group reported "no time to supervise children's exercise" due to long working hours; (2) Uneven distribution of community resources: Communities in suburban areas (e.g., Caofeidian District) had fewer sports facilities (average of 2 facilities per community) than those in central urban areas (average of 5 facilities per community), leading to lower participation in joint activities; (3) Lack of long-term incentive mechanisms: Some community staff reported "reduced enthusiasm for participation" after 6 months of the experiment, as there were no formal rewards for their efforts.

To address these problems, three optimization strategies were proposed:

Flexible Family Participation Strategy: For working parents, two measures were designed: (a) Developing "family exercise packages" suitable for fragmented time, such as 10-minute morning stretching exercises, 15-minute evening parent-student skipping rope games, and weekend "short-distance hiking" activities, to fit working parents' schedules; (b) Establishing a "peer supervision" system, where students in the same neighborhood form small groups (3–5 students per group) to exercise together after school, with one parent (who has flexible working hours) acting as the group supervisor, and the school providing a small stipend (e.g., 50 yuan per month) to the supervisor.

Balanced Community Resource Allocation Strategy: Coordination with local government and social organizations to balance resources: (a) The district government allocates special funds (e.g., 200,000 yuan per suburban community) to build additional sports facilities (e.g., fitness trails, table tennis tables) in suburban communities; (b) Establishing a "resource sharing alliance" between central urban communities and suburban communities, where central communities lend sports equipment (e.g.,

basketballs, badminton rackets) to suburban communities on a rotating basis, and suburban communities provide outdoor activity spaces (e.g., parks) for central community activities in return; (c) Cooperating with social sports organizations (e.g., local sports clubs) to provide free skill training in suburban communities once a month.

Long-Term Incentive Mechanism Construction Strategy: Establishing a multi-level incentive system for all subjects: (a) For families: Implementing a "health points" system, where parents earn points by supervising exercise and participating in activities; points can be exchanged for rewards such as free physical health checks for children or sports equipment; (b) For communities: Including SFC collaboration performance in the annual assessment of community managers, with bonuses (e.g., 10,000 yuan per community) for communities with high participation rates; (c) For schools: Providing additional educational funds (e.g., 100,000 yuan per school) to schools with effective collaboration, which can be used to purchase sports equipment or train physical education teachers.

These optimization strategies aim to address the practical problems in the paths, enhance the adaptability and sustainability of the SFC collaborative mechanism, and ensure that the paths can be promoted in more urban middle schools.

5. Conclusion

The SFC collaborative mechanism is an effective model for improving urban middle school students' physical health. Compared with the traditional school-only model, the mechanism integrates resources from schools, families, and communities, forms a synergistic effect in physical health promotion, and significantly improves students' physical health indicators (e.g., vital capacity, cardiorespiratory endurance).

Three practical paths—tripartite information communication platform, personalized physical exercise plan, and joint physical health promotion activity—are feasible and effective. The information platform solves information asymmetry, the personalized plan addresses individual differences in students' physical conditions, and the joint activities enhance participation of all subjects. Empirical data show that these paths can increase students' weekly physical activity time by 3–4 hours and improve key physical health indicators by 8%–10%.

The operation effect of the SFC collaborative mechanism is affected by multiple factors, including participation willingness of families and communities, resource availability, and policy support. Higher participation levels and more balanced resource allocation are associated with better physical health outcomes, while working parents' time constraints and lack of incentive mechanisms are the main barriers to mechanism operation.

The optimized strategies—flexible family participation, balanced community resource allocation, and long-term incentive mechanisms—effectively address the barriers to path operation, providing a basis for the promotion and application of the SFC collaborative mechanism in other urban areas.

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