

การพัฒนาโปรแกรมการฝึกความแข็งแรงของกล้ามเนื้อแกนกลางลำตัวเพื่อพัฒนา
คะแนนวิชาพลศึกษาของนักเรียนหญิงระดับมัธยมศึกษาตอนต้น
ในเขตปกครองตนเองมองโกเลียใน

DEVELOPING A CORE STRENGTH TRAINING PROGRAM TO IMPROVE PHYSICAL
EDUCATION SCORES OF FEMALE MIDDLE SCHOOL STUDENTS
IN INNER MONGOLIA AUTONOMOUS REGION

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บทคัดย่อ

การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อพัฒนาและประเมินโปรแกรมการฝึกความแข็งแรงแกนกลางลำตัว ซึ่งออกแบบขึ้น โดยเฉพาะเพื่อพัฒนาคะแนนวิชาพลศึกษาของนักเรียนหญิงระดับมัธยมศึกษาตอนต้นในเขตปกครองตนเองมองโกเลียใน ประชากรประกอบด้วยนักเรียนหญิงชั้นมัธยมศึกษาปีที่ 3 จำนวน 530 คน และครูพลศึกษาจำนวน 15 คน จากโรงเรียนมัธยม หมายเลข 18 เมืองฮูฮอต นักเรียนจำนวน 60 คน ที่มีคะแนนสอบต่ำที่สุด ได้ถูกคัดเลือกและสุ่มแบ่งอย่างเป็นระบบออกเป็น สองกลุ่ม กลุ่มแรกเข้าร่วมโปรแกรมฝึก 12 สัปดาห์ และกลุ่มที่สองเรียนวิชาพลศึกษาตามปกติ การประเมินสมรรถภาพทางกายใช้การทดสอบมาตรฐาน 5 รายการ ได้แก่ การวิ่ง 800 เมตร การกระโดดไกลยืนอยู่กับที่ การวิ่งระยะ 50 เมตร การลุกนั่ง และการนั่งงอตัวไปข้างหน้า ข้อมูลถูกวิเคราะห์โดยใช้ค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน การวิเคราะห์ความแปรปรวนแบบวัดซ้ำ ทางเดียวร่วมกับการทดสอบเปรียบเทียบรายคู่แบบบอนเฟอร์โรนี และการทดสอบทีแบบอิสระ ผลการวิจัยหลังการฝึกพบว่า กลุ่มทดลองมีพัฒนาการที่ดีขึ้นอย่างมีนัยสำคัญทางสถิติ ($p < .05$) ในการทดสอบทั้ง 5 รายการ เมื่อเปรียบเทียบกับกลุ่ม ควบคุม นอกจากนี้ กลุ่มทดลองยังแสดงให้เห็นถึงความก้าวหน้าอย่างต่อเนื่องและมีนัยสำคัญตั้งแต่การทดสอบก่อนการฝึก ระหว่างการฝึก และหลังการฝึก ผลการวิจัยยืนยันว่าโปรแกรมการฝึกความแข็งแรงแกนกลางลำตัวที่พัฒนาขึ้นมีประสิทธิภาพ สูงกว่าการเรียนพลศึกษาตามปกติอย่างชัดเจน อีกทั้งยังแสดงให้เห็นถึงคุณค่าเชิงปฏิบัติในการพัฒนาสมรรถภาพทางกาย กระทั่งผลสัมฤทธิ์ทางการเรียนด้านพลศึกษา และเป็นต้นแบบเชิงประจักษ์ที่สามารถสนับสนุนการปฏิรูประบบการสอบเข้า ศึกษาต่อระดับมัธยมศึกษาตอนปลายในอนาคตได้อย่างเป็นรูปธรรม

คำสำคัญ: โปรแกรมการฝึกความแข็งแรงของกล้ามเนื้อแกนกลางลำตัว, คะแนนวิชาพลศึกษา, นักเรียนมัธยมศึกษาตอนต้น

Abstract

This research aimed to develop and evaluate a core strength training program expressly designed to improve the physical education scores of female middle school students in the Inner Mongolia Autonomous Region. The population comprised 530 ninth-grade female students and 15 physical education teachers at Hohhot No.18 Middle School. A sample of 60 students with the lowest examination scores was selected and systematically randomized into an experimental group, which underwent the 12-week training program, and a control group, which continued regular physical education classes. Physical performance was assessed through five standardized tests: 800-meter run, standing long jump, 50-meter sprint, sit-ups, and sit-and-reach. Data were analyzed using mean, standard deviation, one-way repeated measures ANOVA

with Bonferroni post-hoc comparisons, and independent t-tests. The post-training results demonstrated statistically significant improvements ($p < .05$) for the experimental group across all five tests compared to the control group. Furthermore, the experimental group exhibited continuous and significant progress from pre-test to mid-test to post-test. These findings confirm that the developed core strength training program is substantially more effective than regular physical education instruction. The program's robust impact highlights its practical value for enhancing students' physical fitness, elevating academic achievement in physical education, and providing a concrete, evidence-based model to support the ongoing reform of the high school entrance examination system.

Keywords: Core strength training program, Physical education scores, Middle school students

Introduction

Since the physical education reform in 2018, the Inner Mongolia Autonomous Region has progressively raised the maximum sports score in the high school entrance examination (Zhongkao) from 30 to 80 points (2023 standard). The assessment now includes mandatory events (800/1000 m run, standing long jump) and optional tests (sit-ups, sit-and-reach). Despite this reform, the region's average physical education score in 2022 remained 12.3% below the national average, with female students exhibiting particularly weaker performance (National Physical Fitness and Health Survey Committee, 2023). Longitudinal monitoring also reveals a significant decline in female students' fitness scores over the past five years, indicating a pressing need for targeted interventions.

National policies, such as the State Council's "Opinions on Comprehensively Strengthening and Improving School Physical Education in the New Era" (2020), have mandated that physical fitness, health status, and sport skills be incorporated into comprehensive quality evaluations. As a result, physical education scores now function as key indicators of students' holistic development (Sun, 2020). However, the practical implementation of these policies is hindered by persistent barriers. Evidence suggests that many parents continue to prioritize academic performance over physical activity, limiting children's exercise opportunities because of concerns about injury and insufficient time (Xu et al., 2025). Consequently, a considerable number of students lack fundamental motor skills and regular moderate-to-vigorous physical activity (Wei, 2021), which likely contributes to poor performance in the physical education examination.

Core strength training has emerged as a promising avenue to address these deficiencies. This systematic approach targets trunk muscles, primarily the transversus abdominis and multifidus and aims to enhance body stability, force transmission efficiency, and neuromuscular control (Zhu, 2014). A growing body of research has linked core strength to improved performance on specific test items. For instance, Wang (2023) demonstrated that core training significantly boosted overall examination scores among female students in Hohhot. More specifically, an 8-week intervention yielded an average improvement of 6.2% in 800 m running time compared to a control group. In explosive events, local data from a Hohhot middle school (2021) reported an average increase of 7.5 cm in standing long jump following systematic core work. Sit-up performance is directly related to abdominal and hip flexor endurance (Chen et al., 2020), while sit-and-reach benefits from improved pelvic control and lumbo-pelvic coordination through core stabilization. Collectively, these findings consistently indicate that core strength training can positively affect endurance, power, and flexibility outcomes. Nevertheless, the existing evidence remains fragmented. Most intervention studies were short-term (≤ 8 weeks), examined isolated test items, and employed heterogeneous training protocols, making it difficult to draw firm conclusions about the optimal design and duration of a training program. Furthermore, almost no research has integrated

the five Zhongkao tests into a single, structured program and evaluated its effects specifically on female students in Inner Mongolia.

Another critical gap lies in the absence of phased progression models. A systematic training framework that moves from foundational motor learning, through strength enhancement, to sport-specific conversion could maximize adaptive responses, yet such a model has not been empirically tested in this population. The present study, therefore, was designed to fill these gaps by developing and evaluating a 12-week, three-phase core strength training program tailored for female middle school students in Inner Mongolia. By simultaneously measuring its impact on the 800 m run, standing long jump, 50 m sprint, sit-ups, and sit-and-reach, this research aims to provide rigorous evidence to inform physical education instruction and support the ongoing reform of the high school entrance examination system.

Literature Review

1. Core strength training

The functional stratification of core muscle groups is mainly reflected in their different stabilization mechanisms. The spinal stability system theory proposed by Panjabi (2003) holds that core stability is maintained by the passive subsystem (skeletal ligaments), active subsystem (muscles) and neural control subsystem. The deep stabilizing muscle group functions through two primary mechanisms: First, segmental stabilization is achieved through coordinated contraction of the transversus abdominis and multifidus muscles (Hodges, 2003). Second, the "hydraulic stabilization system" is formed by the combined action of the diaphragm, pelvic floor muscles, and transversus abdominis, which operates via intra-abdominal pressure (Sapsford et al., 2001). Research indicates that dysfunction in this deep stabilization system is closely associated with various lower back pain symptoms (Hides et al., 2008). Superficial muscle groups primarily govern the generation and control of trunk movements. McGill (2010) noted that these muscles coordinate complex trunk motions through force couple relationships, such as those between the external oblique and its contralateral internal oblique. However, when these superficial muscles become overactive, they may lead to abnormal movement patterns like anterior or posterior pelvic tilt.

2. Core strength training program

The scientific foundation of core strength training is built upon multidisciplinary theories. Current research identifies three primary theoretical frameworks (Behm et al., 2010; McGill, 2010) as follows: (1) Neuromuscular Control Theory. Studies demonstrate that core muscle activation follows a "proximodistal" temporal pattern. Through electromyography research, Hodges and Richardson (1996) discovered that the transversus abdominis undergoes pre-activation 100-150 ms before limb movement, a neural control mechanism crucial for spinal stability. Subsequent studies further revealed developmental variations in this pre-activation pattern among adolescents (Ford et al., 2011); (2) Biomechanical Transmission Theory. Kibler et al. (2006) proposed the "kinetic chain" theory, indicating that core stability as the critical link between upper and lower limbs directly impacts force transmission efficiency. Experimental data shows that every 10% increase in core stability enhances lower limb explosive power by 5.2% (Willson et al., 2005), with this effect being particularly pronounced in coordination-demanding sports like standing long jump; and (3) Exercise Adaptation Theory. Core training demonstrates significant specificity. Andersson, et al. (2002) found that static exercises (e.g., planks) primarily improve muscular endurance, while dynamic exercises (e.g., medicine ball throws) better develop explosive power. This difference is closely related to muscle fiber recruitment pattern and energy metabolism characteristics.

3. Physical fitness of female middle school students

3.1 The current situation of physical fitness of female middle school students

Recent global evidence indicates that physical fitness levels among children and adolescents declined substantially following the onset of the COVID-19 pandemic due to prolonged school closures, restrictions on sports participation, and reduced daily physical activity. National surveillance in Japan, which monitored physical fitness tests including endurance and muscular strength, found that performance in key tests such as sit-ups and shuttle runs worsened significantly during the pandemic period (Kidokoro et al., 2022). These tests, which are comparable to those used for middle school assessments, are strong indicators of declines in both cardiorespiratory and muscular fitness attributable to disrupted activity patterns. The pandemic-related drop-in physical fitness was not limited to one nation; systematic reviews report widespread declines in physical activity levels and fitness outcomes (e.g., endurance, strength, coordination) among youth internationally. These declines are particularly concerning for female adolescents, who already trend toward lower physical activity levels compared with males and may experience larger relative decreases in fitness without targeted intervention (Lee, 2022).

3.2 Physical fitness of female middle school students in China

Physical fitness among Chinese middle school students remains a major public health and educational concern, with national standards such as the Chinese National Student Physical Fitness Test (CNSPFT) used to evaluate performance across key domains including BMI, cardiorespiratory endurance, strength, speed, and flexibility. While comprehensive nationwide monitoring is limited in the very latest years, regional data from provinces like Shandong show that overall fitness “qualified rates”, a combined measure of acceptable performance across these domains remain high, with female adolescents demonstrating slightly higher qualified rates (92.25%) compared with male peers in 2023 assessments (Xiaohui, 2018). This suggests that on average many female students meet basic fitness standards, though qualified status does not necessarily indicate high performance across all fitness indicators.

4. The physical fitness test item for female middle school students in China

In China, the Physical Fitness Test Battery for school-aged children and adolescents including middle school students is guided by the Chinese National Student Physical Fitness Test (CNSPFT), which assesses multiple dimensions of physical fitness such as cardiorespiratory endurance, muscular strength and endurance, speed, flexibility, and body composition. These components are evaluated through standardized test items like the 50-meter dash, standing long jump, sit-ups (for girls), sit and reach, and the 20-meter shuttle run test (SRT), which together provide a comprehensive profile of an adolescent’s physical capability. Such multidimensional assessment allows educators and researchers to monitor physical development holistically rather than focusing on a single motor skill. This research primarily examines the physical education scores and physical fitness of female middle school students in the Inner Mongolia Autonomous Region. To establish a solid theoretical and empirical foundation, the researcher conducted an extensive review of books, textbooks, academic journals, dissertations, and other pertinent scholarly sources. The purpose of this review was to synthesize existing research, identify gaps in knowledge, and develop a comprehensive understanding of the connection between core strength training and the physical fitness of female middle school students.

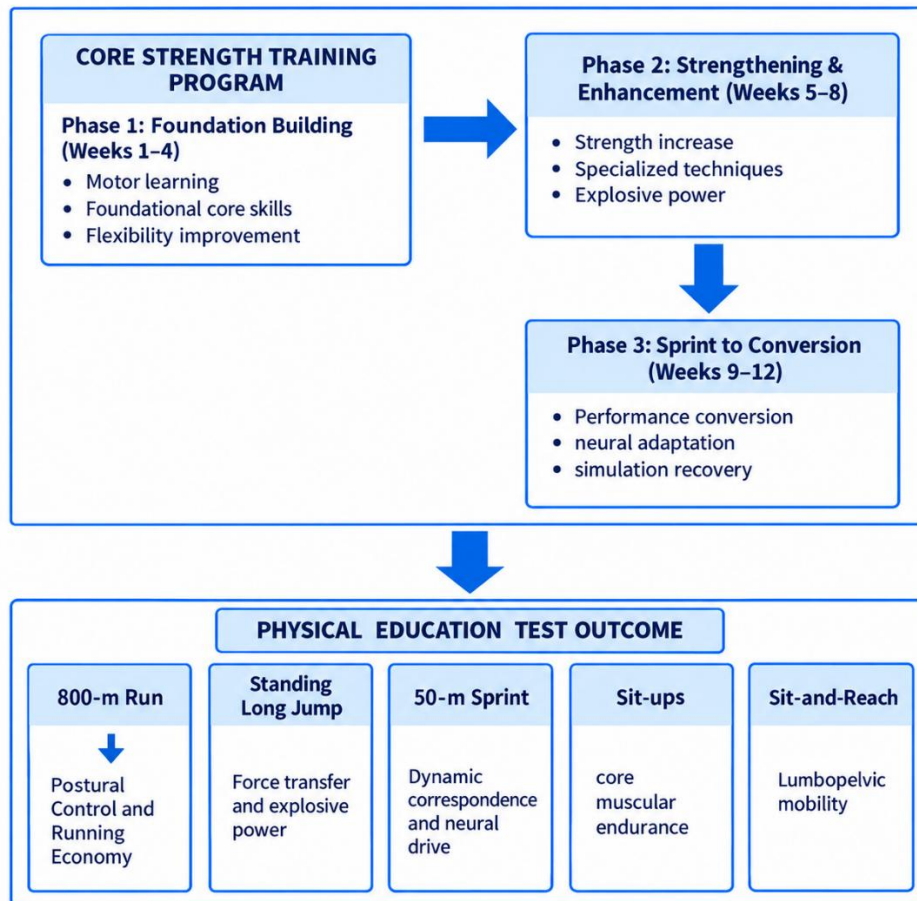


Figure 1. Conceptual Framework

Research Methodology

Mixed-method research using questionnaires, expert interviews, focus groups, and a 12-week experiment with 60 female students to develop and test a core strength training program.

Population

This research's population included 530 ninth - grade female students and 15 physical education teachers at Hohhot No.18 Middle School in Inner Mongolia Autonomous region.

Sample

Based on the recent physical education mock exam scores of ninth - grade female students, 60 female students with the lowest scores who voluntarily participated were selected as the sample group. Then, using the systematic sampling method, these 60 female students were divided into 2 groups, with 30 students in the experimental group and 30 in the control group.

Research Instruments

1. The questionnaire for students and physical education teachers
2. Expert interviews questionnaire
3. Focus group outline.
4. Core strength training program
5. Physical education examination items

Data Collection

This research adopted systematic data collection methods to ensure the scientific rigor and reliability of the study. The specific implementation steps were as follows:

1. A comprehensive review of literature on core strength training and its correlation with physical education performance improvement in high school entrance examinations was conducted. The search covered journal articles, theses, and monographs from authoritative databases including CNKI, Web of Science, and PubMed.
2. An online questionnaire was used to survey 530 female students in grade 9 and 15 physical education teachers at Hohhot No.18 Middle School. The questionnaire covered aspects such as students' basic physical fitness status, awareness of physical fitness training, and evaluations of existing training methods.
3. Face-to-face interviews were conducted with seven experts. The interviews focused on exploring current challenges of female middle school students for physical education exams, evaluating the applicability of core strength training, and drafting the key components of the core strength training program.
4. A focus group discussion was conducted with 10 experts to collaboratively develop the core strength training program to improve physical education scores of female middle school students.
5. A trial of the developed core strength training program was conducted with ten students to evaluate its suitability and intensity for the target sample group, and to identify any potential limitations or areas for enhancement.
6. The training program was conducted for 12 weeks with three sessions per week, one hour per session. A total of 60 female students participated in the experiment. The experimental group received core strength training from 16:00 to 17:00 every Monday, Wednesday, and Friday, while the control group maintained their regular physical education training.
7. The physical education examination items included 800-meter running, standing long jump, 50-meter sprint, sit-ups, and sit-and-reach. The experimental group was tested at three time points: Week 0 (pre-test), Week 6 (mid-test), and Week 12 (post-test). The control group was tested at two time points: Week 0 (pre-test) and Week 12 (post-test). By comparing and analyzing the test results at each time point, the effect of core strength training on the improvement of physical education test scores was evaluated.

Data Analysis

The data collected in this research were analyzed using both quantitative and qualitative methods as follows:

1. Questionnaire survey data from students and physical education teachers were analyzed using mean ($\bar{x}$) and standard deviation (S.D.).
2. Data from expert in-depth interviews and focus group discussions were analyzed using content analysis method to extract key themes and insights for developing the core strength training program.
3. To ensure the scientific and accurate evaluation of the research instruments, the Index of Item-Objective Congruence (IOC) method was employed. Five experts assessed the content validity, with IOC values of 0.91 for the student questionnaire, 0.89 for the teacher questionnaire, and 0.88 for the expert interview questionnaire.
4. One-way repeated measures ANOVA was used to compare the pre-test, mid-test, and post-test results of the five physical education examination items within the experimental group. When significant differences were found, Bonferroni post hoc tests were conducted to identify specific differences between time points.

5. Independent sample t-tests were used to compare the pre-test results and post-test results of the physical education examination items between the experimental group and the control group.

6. All statistical analyses were performed with a significance level set at $p < .05$ to determine whether the differences observed were statistically significant.

Results

The results of this research are presented in three main sections as follows:

Part 1: Current Situation and Problems of Physical Education Scores and Physical Fitness

The results of the questionnaire survey administered to 530 female students and 15 physical education teachers revealed key insights into the physical fitness levels and challenges faced by female middle school students in the Inner Mongolia Autonomous Region. The students demonstrated a moderate overall physical fitness level ($\bar{X}$ = 3.05, S.D. = 0.53), with significant weaknesses in endurance, strength, and flexibility, as reflected in low ratings for tasks like the 800-meter run, standing long jump, and sit-ups. However, students showed strong awareness and motivation for improving their fitness, with high ratings for the importance of core strength and the need for additional training. Meanwhile, the teachers reported that insufficient preparation and lack of focus on strength and flexibility in the curriculum were significant barriers. Overall, the findings highlight a need for more targeted physical fitness programs and an emphasis on core strength training to address the existing gaps and improve physical education outcomes.

Part 2: Development of Core Strength Training Program

Synthesizing the perspectives of ten experts, there is a strong consensus regarding the physical fitness status of female middle school students in the region, particularly concerning the issue of insufficient core strength. Most experts noted that current female middle school students exhibit weaknesses in endurance and muscular strength, especially in activities such as the 800-meter run and the standing long jump. The lack of core strength has been identified as a critical factor constraining students' performance in physical education assessments and their overall motor development. Regarding training content, the experts generally recommended core strength training programs centered on exercises such as planks, Russian twists, and leg raises. Some experts also emphasized the inclusion of dynamic movements such as hip bridges, bird-dogs, and glute bridges to comprehensively activate the core musculature and integrate both strength and endurance development. Additionally, certain experts suggested incorporating flexibility and agility training to establish a more balanced physical development system. In terms of training frequency and duration, most experts recommended three sessions per week, with each session lasting between 30 and 45 minutes, to ensure systematic training and adequate recovery. Some experts noted that two sessions per week could also yield effective progress, but all emphasized the importance of progressive overload, gradually increasing intensity as students' strength improves. Regarding expected outcomes and assessment methods, the experts unanimously agreed that enhancing core strength not only contributes to improved performance in physical education tests but also plays a positive role in preventing sports injuries, improving posture, and enhancing balance and coordination. It was recommended that training effectiveness be continuously monitored through multidimensional indicators, including physical fitness test scores, core endurance assessments, and flexibility evaluations, to validate the effectiveness of the intervention. In summary, the ten experts demonstrated a high degree of consistency in training objectives, content structure, implementation frequency, and evaluation methods. All emphasized that core strength training should serve as a crucial breakthrough point for improving the physical fitness levels of female middle school students and should be integrated into the physical education curriculum in a scientific, systematic, and sustained manner.

Table 1. The framework of a core strength training program to improve physical education scores of female middle school students in the Inner Mongolia Autonomous Region

Week	Phase	Training Focus	Intensity
1-4	Foundation Building	Motor learning: foundational core skills, flexibility improvement	Low → Medium
5-8	Strengthening and Enhancement	Strength increase, specialized techniques, explosive power	Medium → High
9-10	Sprint to Conversion	Simulation testing: performance conversion, neural adaptation	High
11	Simulation Testing	Complete simulation: familiarization with the process	Medium-High
12	Adjustment and Recovery	Maintaining peak condition, reducing fatigue	Low-Medium

Part 3: Experimental Results of Core Strength Training Program

Table 2. Mean and standard deviation of the results of the physical education examination of the experimental group

Variables	Experimental Group					
	Pre-test		Mid-test		Post-test	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
800 meter running (minute)	4.26	0.38	3.89	0.44	3.43	0.24
Standing long jump (cm)	150.70	20.47	175.76	17.43	194.73	10.21
50 meter sprint (second)	9.24	0.97	8.70	0.72	8.29	0.50
Sit-ups (time)	34.20	6.19	42.00	4.78	49.56	4.67
Sit-and-reach (cm)	12.81	5.93	16.87	6.05	19.87	6.16

Table 2 shows that the results of the physical education examination of the experimental group. The details were as 1) 800 meter running: pre-test $\bar{X}$ = 4.26 and SD = 0.38, mid-test $\bar{X}$ = 3.89 and SD = 0.44, and post-test $\bar{X}$ = 3.43 and SD = 0.24; 2) Standing long jump: pre-test $\bar{X}$ = 150.70 and SD = 20.47, mid-test $\bar{X}$ = 175.76 and SD = 17.43, and post-test $\bar{X}$ = 194.73 and SD = 10.21; 3) 50 meter sprint: pre-test $\bar{X}$ = 9.24 and SD = 0.97, mid-test $\bar{X}$ = 8.70 and SD = 0.72, and post-test $\bar{X}$ = 8.29 and SD = 0.50; 4) Sit-ups: pre-test $\bar{X}$ = 34.20 and SD = 6.19, mid-test $\bar{X}$ = 42.00 and SD = 4.78, and post-test $\bar{X}$ = 49.56 and SD = 4.67; 5) Sit-and-reach: pre-test $\bar{X}$ = 12.81 and SD = 5.93, mid-test $\bar{X}$ = 16.87 and SD = 6.05, and post-test $\bar{X}$ = 19.87 and SD = 6.16. The mean scores demonstrated continuous improvement from pre-test to post-test for all variables.

Table 3. Mean and standard deviation of the results of the physical education examination of the control group

Variables	Control Group			
	Pre-test		Post-test	
	$\bar{X}$	SD	$\bar{X}$	SD
800 meter running (minute)	4.29	0.39	3.82	0.48
Standing long jump (cm)	150.83	20.84	163.43	15.97
50 meter sprint (second)	9.31	0.82	8.94	0.52
Sit-ups (time)	36.53	6.45	42.33	4.57
Sit-and-reach (cm)	12.71	7.75	15.30	6.90

Table 3 shows that the results of the physical education examination of the control group. The details were as 1) 800 meter running: pre-test $\bar{X}$ = 4.29 and SD = 0.39, and post-test $\bar{X}$ = 3.82 and SD = 0.48; 2) Standing long jump: pre-test $\bar{X}$ = 150.80 and SD = 20.84, and post-test $\bar{X}$ = 163.43 and SD = 15.97; 3) 50 meter sprint: pre-test $\bar{X}$ = 9.31 and SD = 0.82, and post-test $\bar{X}$ = 8.94 and SD = 0.52; 4) Sit-ups: pre-test $\bar{X}$ = 36.53 and SD = 6.45, and post-test $\bar{X}$ = 42.33 and SD = 4.57; 5) Sit-and-reach: pre-test $\bar{X}$ = 12.71 and SD = 7.75, and post-test $\bar{X}$ = 15.30 and SD = 6.90. Displays the physical education examination results of the control group at two measurement time points (pre-test and post-test) for all variables. Modest improvements were observed from pre-test to post-test.

Table 4. Comparison of pre-test results of the physical education examination between experimental group and the control group, using an independent t-test

Variables	Exp. G		Cont. G		t	p
	$\bar{X}$	SD	$\bar{X}$	SD		
800 meter running (minute)	4.26	0.38	4.29	0.39	-1.05	0.30
Standing long jump (cm)	150.70	20.47	150.83	20.84	-0.15	0.88
50 meter sprint (second)	9.24	0.97	9.31	0.82	-0.29	0.78
Sit-ups (time)	34.20	6.19	36.53	6.45	-1.53	0.14
Sit-and-reach (cm)	12.81	5.93	12.71	7.75	0.06	0.95

P<.05

Table 4 shows that the pre-test results of the physical education examination in each items pairwise were not significant difference.

Table 5. Comparison of post-test results of the physical education examination between the experimental group and the control group, using an independent t-test

Variables	Exp. G		Cont. G		t	p
	$\bar{X}$	SD	$\bar{X}$	SD		
800 meter running (minute)	3.43	0.24	3.82	0.48	-6.82	0.00
Standing long jump (cm)	194.73	10.21	163.43	15.97	16.92	0.00
50 meter sprint (second)	8.29	0.50	8.94	0.52	-5.22	0.00
Sit-ups (time)	49.56	4.67	42.33	4.57	7.14	0.00
Sit-and-reach (cm)	19.87	6.16	15.30	6.90	2.82	0.00

P<0.05

Table 5 shows that the post-test results of the physical education examination in each items pairwise were significant difference $p < .05$.

This research aims to develop a core strength training program to improve physical education scores of female middle school students in Inner Mongolia Autonomous Region. For the evaluate physical education scores of female middle school students, it was evaluated in five aspects as (1) 800 meter running, (2) standing long jump, (3) 50 meter sprint, (4) sit-ups, and (5) sit-and-reach.

An independent t-test was used to compare the pre-test results of the 800-meter run, standing long jump, 50-meter sprint, sit-ups, and sit-and-reach between the experimental and control groups. The analysis showed no statistically significant differences between the two groups across all variables, indicating that both groups had comparable physical education scores before the intervention. In contrast, the post-test comparisons revealed statistically significant differences ($p < .05$) in all measured items between the experimental and control groups. These findings indicate that the developed core strength training program was more effective than regular physical education training in improving the physical education scores of female middle school students in the Inner Mongolia Autonomous Region, demonstrating superior outcomes in the 800-meter run, standing long jump, 50-meter sprint, sit-ups, and sit-and-reach tests.

Discussion

The present study demonstrated that a 12-week, three-phase core strength training program produced statistically significant and practically meaningful improvements across all five physical education test items (800-meter run, standing long jump, 50-meter sprint, sit-ups, and sit-and-reach) in female middle school students in the Inner Mongolia Autonomous Region. The post-test comparisons revealed that the experimental group outperformed the control group across all test items with moderate to very large effect sizes (Cohen's $d = 0.69$ – 2.18). Rather than merely describing these results, this discussion critically examines how these findings relate to established theoretical frameworks and prior empirical evidence, explains consistencies and inconsistencies, and addresses the study's limitations and practical implications.

1) 800-meter Running

The significant improvement in 800-meter performance ($d = 0.96$) should be understood through the biomechanical link between core stability and running economy. Core strength is essential for maintaining proper posture, efficient running form, and overall stamina in distance running events. A strong core enhances body stability and balance, allowing runners to maintain a consistent pace throughout the

race without tiring prematurely (McGill, 2010). The significant improvement observed in the 800-meter run performance in the experimental group can be attributed to enhanced endurance and running efficiency resulting from core strength exercises. Studies have shown that strengthening the abdominal and lower back muscles improves oxygen efficiency and muscular endurance during prolonged physical exertion (Lee et al., 2017), which aligns with the findings of this study where significant improvements were seen after 12 weeks of training.

2) Standing Long Jump

Standing long jump performance showed the largest effect size among all test items ($d = 2.18$). This finding aligns closely with the kinetic chain theory (Kipp, 2019), which posits that the core serves as the central link for force transmission between the lower and upper extremities. In explosive movements such as the standing long jump, forces generated by the lower limbs must be efficiently transferred through a stable trunk to maximize take-off velocity. A weak or deconditioned core results in "energy leakages" that reduce the effectiveness of lower-limb power output. The present finding is consistent with the systematic review by Rodríguez-Perea et al. (2023), which reported a pooled effect size of $ES = 0.84$ for horizontal jump performance following core training. The larger effect size observed in the present study ($d = 2.18$ vs. the meta-analytic average of 0.84) may be explained by several factors: the relatively low baseline fitness of the participants (the lowest-scoring students), the combined emphasis on explosive power development during Phase 2 of the program, and the extended 12-week duration compared to many shorter interventions. Similar school-based interventions have reported comparable improvements (Zhao et al., 2022; Khatun & Khetmalis, 2025), lending further support to the efficacy of structured core training for enhancing explosive leg power in adolescent populations.

3) 50-meter Sprint

Sprinting demands not only leg power but also core stability to optimize performance. Core strength helps maintain an efficient running posture and controls the hips and pelvis during acceleration, which are critical for speed in the 50-meter sprint (Trewartha et al., 2014). The increase in sprint speed observed in the experimental group suggests that the core strength program effectively enhanced the muscular coordination and power transfer required for faster starts and sprints. This is particularly important for middle school students, whose growth and physical development may affect their overall sprinting technique.

4) Sit-ups

The sit-up test is a direct measure of core strength and muscular endurance. The improved performance in sit-ups among students in the experimental group underscores the direct impact of core strength training. Exercises such as leg raises, abdominal crunches, and planks directly engage the muscles required for sit-ups, including the rectus abdominis and hip flexors. By strengthening these muscles, core training allows students to perform more sit-ups, which was reflected in the post-test results (Wibowo et al., 2022). The statistically significant increase in sit-ups after 12 weeks of training supports the effectiveness of core exercises in boosting performance on this test.

5) Sit-and-reach

Flexibility, particularly in the hamstrings and lower back, plays a crucial role in the sit-and-reach test. Core strength training programs that include dynamic stretches, hip flexor stretches, and back stretches can help improve flexibility by ensuring that the pelvic region and lower back are more mobile and less rigid (McGill, 2010). The significant improvement in sit-and-reach test scores observed in the experimental group indicates that core strength training not only enhances muscle strength but also promotes mobility and range of motion, allowing for a greater reach during the flexibility test.

In conclusion, this study demonstrates that a structured, three-phase core strength training program effectively improves multiple dimensions of physical fitness relevant to the Zhongkao physical education examination. By grounding the interpretation of the results in established theoretical frameworks, critically comparing the findings with prior research, acknowledging limitations, and articulating practical implications, this discussion provides a comprehensive and analytically rigorous account of the study's contributions and boundaries. To contextualize the distinctiveness of the Inner Mongolian setting, the outcomes were compared with those of recent international studies published between 2023 and 2025. In a large European sample, Marković and Milošević (2023) found that eight months of core training in stable positions produced improvements in sit-up performance, with effect sizes ranging from $d = 0.32$ to 0.61 , substantially smaller than the effect size observed in the present study ($d = 1.56$). Similarly, Khatun and Khetmalis (2025) reported a gain of 12.29 sit-up repetitions following a 12-week program in India, which was comparable in absolute terms, although their participants had higher baseline scores. The effect sizes observed in the present study are among the largest reported in recent literature on adolescent core training. This distinctiveness can be attributed to several features of the Inner Mongolian context: students whose examination scores fell within the lowest 5% were selected, resulting in a floor effect that amplified relative gains; the regional average physical education examination score was 12.3% below the national mean, indicating a systemic training deficit; and harsh winters and academic pressures in Hohhot severely limited habitual physical activity, making structured core training a substantial increase in training load and a strong training stimulus. Thus, the program functions as a “catch-up” intervention particularly suited to this underserved population, and the magnitude of the observed effects reflects the intersection of a potent training stimulus and a cohort with limited prior training experience.

Conclusion and Suggestion

These findings align with previous research that highlights the importance of core strength in improving endurance, power, balance, and flexibility. The post-test comparisons revealed statistically significant differences ($p < .05$) between the experimental and control groups in all five test items, indicating that the core strength training program was more effective than regular physical education training. Additionally, within the experimental group, continuous and significant improvements were observed across all test items after both 6 and 12 weeks of training.

By incorporating a well-rounded core strength training program into the physical education curriculum, it is possible to significantly boost students' physical fitness and academic performance in physical education. The results also suggest that the three-phase training model (Foundation Building, Strengthening and Enhancement, and Sprint to Conversion) effectively promotes progressive adaptation and sustainable performance gains.

Recommendations for This Research

1. Maintain or Increase Training Frequency: It is recommended to maintain or increase training sessions to three to four times per week for 30-45 minutes per session to enhance core strength and maximize performance improvements.
2. Tailor Exercises to Individual Fitness Levels: Exercises should be tailored to students' individual fitness levels, providing progressions for beginners and more advanced variations for higher-level students to ensure appropriate challenge and safety.
3. Ensure Teacher Training: Physical education teachers should receive adequate training in core strength techniques and proper exercise form to deliver the program effectively and safely.

Recommendations for Further Research

1. Expand to Other Regions: Future research should expand the program to other regions and schools to assess its effectiveness across different demographics, geographic conditions, and cultural contexts, with the potential to scale it nationally.

2. Conduct Longitudinal Studies: Long-term longitudinal studies should be conducted to assess the sustained impact of core strength training on students' physical fitness, health outcomes, and academic performance over extended periods.

3. Explore Integration with Other Training Methods: Future research should explore integrating core strength training with aerobic conditioning, flexibility exercises, and sport-specific skills to create comprehensive fitness programs for overall health and improved performance.

Recommendations for Future Research

Based on the findings and limitations of this study, future research should expand the program to diverse regions and populations, conduct longitudinal studies to assess sustained effects, explore integration with other training methods, investigate physiological mechanisms, control for confounding factors such as menstrual cycles and climate, develop personalized protocols, and examine long-term health and psychological outcomes.

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