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Research on the promotion of college students' physical health through smart-digital resources in public physical education

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Abstract. To explore the mechanisms through which smart-digital teaching resources promote physical health among college students in public physical education, a survey was conducted with 1,200 students across eight universities in Hubei Province. From these, 240 students were selected for a 16-week teaching experiment, with the experimental group receiving a smart-digital intervention ("smart wearables + digital textbooks + exercise apps") and the control group receiving traditional instruction. Results indicate that students' use of smart-digital resources is characterized by "high tool dependence but weak immersive experience" (app usage rate 87.3%, Virtual Reality (VR) / Augmented Reality (AR) usage only 23.5%). The experimental group demonstrated significantly better physical health outcomes than the control group ($p < 0.01$, $d = 1.15$). Moreover, smart-digital resources influenced physical health indirectly through "exercise self-efficacy" ($\beta = 0.43$, mediating effect accounting for 78.2%), with notable gender differences (male $\beta = 0.51$ higher than female $\beta = 0.34$). In conclusion, smart-digital resources can effectively enhance physical health, but their application needs to move beyond superficial use, strengthen scenario-based integration, and provide differentiated interventions tailored for female students.

Keywords: smart-digital resources, college public physical education, physical health, self-efficacy, exercise apps, teaching experiment

1. Introduction

1.1. Research background and policy drivers

The deepening implementation of the "Digital China" strategy and the comprehensive deployment of new educational infrastructure are profoundly reshaping the development paradigm of college physical education. The 2022 *Education Informatization 2.0 Action Plan* issued by the Ministry of Education explicitly emphasizes promoting the deep integration of information technology with education and teaching. In 2025, five governmental departments jointly issued the *Student Physical Fitness Strengthening Plan*, further identifying "digitally empowering sports" as a key initiative [1]. Against this backdrop, college physical education is undergoing a fundamental transformation from "informatization" to "smart-digitalization." Smart-digitalization emphasizes the core driving role of data intelligence, integrating big data collection, artificial intelligence algorithms, and Internet of Things (IoT) sensing systems to achieve precise perception of the teaching process, intelligent decision-making, and personalized adaptation [2].

Smart-digital resources, as the core carrier of this transformation, encompass diverse technological forms, including smart wearables, Virtual Reality (VR) / Augmented Reality (AR) training systems, digital textbooks, and exercise big data platforms. These resources provide technological possibilities for addressing structural challenges in traditional public physical education courses, such as repetitive teaching content, neglect of individualized student needs, and limited effectiveness in promoting physical health [3]. However, the abundance of technological supply does not automatically translate into improved educational outcomes. The actual application effects, underlying mechanisms, and optimization pathways of smart-digital resources in college physical education remain in need of systematic empirical validation.

1.2. Research gaps and problem statement

Existing research exhibits a clear structural imbalance: a substantial portion of the literature focuses on describing teaching scenarios with smart-digital technologies or surveying teacher acceptance, while longitudinal tracking of student physical health outcomes is scarce. In particular, there is a lack of studies employing rigorous experimental designs to infer causal relationships [4]. Hubei Province, as a national hub for higher education institutions, provides a representative context for studying public physical education: course resources are abundant but unevenly distributed, and student physical health exhibits the pattern of "meeting baseline standards but low rates of excellence" [5]. This situation not only provides space for the application and promotion of smart-digital resources but also creates an urgent need for precise, targeted interventions.

This study integrates self-efficacy theory and the theory of planned behavior, combining large-scale survey data with randomized controlled experiments to systematically address three core questions: (1) What are the current characteristics and group differences in college students' use of smart-digital resources in public physical education? (2) Does the smart-digital teaching model demonstrate significant advantages over traditional instruction in promoting physical health? (3) What are the pathways and boundary conditions through which smart-digital resource usage affects physical health?

2. Literature review and research hypotheses

2.1. Theoretical links between smart-digital resources and physical health promotion

2.1.1. Three-level promotion logic

The mechanism through which smart-digital resources promote physical health can be conceptualized as a three-level, nested logic. At the monitoring level, wearable devices such as smart wristbands and sports watches collect real-time physiological data—heart rate, step count, and calorie expenditure—to construct dynamic health profiles [6]. The feedback level leverages exercise apps and AI algorithms to generate personalized training plans and real-time exercise guidance, facilitating a shift from "experience-driven" to "data-driven" decision-making [7]. At the experience level, VR/AR technologies create immersive exercise environments, reducing psychological load and enhancing engagement and enjoyment [8]. These three levels form a complementary technological ecosystem that collectively serves the goal of promoting physical health.

2.1.2. Technology acceptance paradox and the "shallow digitalization" dilemma

The technology acceptance paradox is particularly pronounced in physical education: while students generally recognize the usefulness of exercise data monitoring, adoption rates for high-interactivity technologies remain significantly low [9]. This phenomenon of "shallow digitalization"—characterized by widespread use of basic tools but limited engagement with advanced technologies—may severely constrain the deep health-promoting effects of smart-digital resources, representing a central practical issue addressed in this study.

2.2. The mediating role of self-efficacy

Self-efficacy, defined as an individual's belief in their capacity to perform specific tasks, is a key psychological variable influencing exercise behavior change [10]. Smart-digital resources enhance students' exercise self-efficacy by providing mastery experiences through real-time data feedback, such as running pace visualization and heart rate zone tracking, which in turn promotes exercise adherence [11]. This "cognition–behavior" transmission mechanism provides the theoretical foundation for hypothesizing a mediating effect in this study.

2.3. Research hypotheses

Based on the literature review, this study proposes the following hypotheses: H1: Smart-digital resource usage has a significant positive effect on students' physical health levels. H2: Exercise self-efficacy mediates the relationship between smart-digital resource usage and physical health. H3: Gender moderates the effect of smart-digital resource usage on physical health, with a stronger effect for males than females. H4: Smart-digital teaching models are more effective than traditional instruction in improving students' physical health.

3. Research subjects and methods

3.1. Research subjects and sampling design

3.1.1. Cross-sectional survey

A stratified random sampling method was employed to select public physical education students from eight universities in Hubei Province, including two universities each from central, provincial, and local undergraduate institutions. A total of 1,200 questionnaires were distributed, and 1,089 valid responses were returned, yielding an effective response rate of 90.8%. Among the respondents, 582 were male (53.4%) and 507 were female (46.6%).

3.1.2. Teaching experiment

From a compulsory public physical education course at a provincial key university, 240 overweight or obese students (Body Mass Index (BMI) ≥ 24 kg/m²) were randomly assigned to the experimental group (n = 120, smart-digital teaching) or the control group (n = 120, traditional teaching). Based on G*Power 3.1 software calculations, assuming an effect size of d = 0.5 (medium effect), a significance level of α = 0.05, and a power of $1-\beta$ = 0.80, each group required approximately 64 participants. Considering a potential 20% attrition rate, 120 students per group were ultimately selected. The experimental period lasted 16 weeks (September 2024–January 2025), covering a full academic semester.

3.2. Research instruments

The study employed the following instruments with established reliability and validity: Smart-Digital Resource Usage Questionnaire (self-developed), covering four dimensions: basic usage, wearable device adherence, immersive technology experience, and self-monitoring awareness of physical health. Content

Validity Index (CVI) = 0.92, Cronbach's α = 0.87. Physical Health Assessment, based on the *National Student Physical Health Standards* (2014 revision), including body composition (BMI, body fat percentage), physiological function (vital capacity, weight index), and physical fitness (50 m sprint, standing long jump, 800 m/1,000 m endurance run). Standardized equipment was used, and testers received certified training. Exercise Self-Efficacy Scale, consisting of eight items scored on a 5-point Likert scale, with demonstrated reliability and validity in Chinese university populations.

3.3. Teaching experiment design

Students were divided into two groups. The experimental group received smart-digital instruction: prior to class, digital textbooks (e.g., Wudang martial arts micro-lectures, 3D soccer animations) were distributed via Chaoxing Learning Platform for pre-class study and quizzes; during class, smart heart rate wristbands monitored exercise intensity (target heart rate 60%–80% of maximum) and AR technology assisted in movement correction; after class, students logged exercise using the KEEP app, which generated AI-based personalized training plans under teacher supervision. The control group received traditional instruction: no pre-class preparation, in-class activities followed the "teacher demonstration - student practice - collective correction" sequence, and after-class exercise was self-directed without data tracking. Both groups had the same instructional time (2 hours per week, 32 hours total), identical teaching content, and instructors with equivalent qualifications. The only difference was the use of smart-digital resources.

3.4. Data analysis

Descriptive statistics and between-group comparisons were conducted using SPSS 26.0, while Structural Equation Modeling (SEM) was performed using Mplus 8.3. The Bootstrap method was used to test mediating effects, and multi-group SEM examined gender moderation effects. Effect sizes were calculated using Cohen's d, with $d > 0.8$ considered large and 0.5–0.8 medium [12].

Gender differences: Male students showed significantly higher exercise app usage depth (t = 4.32, $p < 0.001$) and greater acceptance of smart wearables (χ^2 = 28.4, $p < 0.001$) than female students, whereas female students preferred theoretical study using digital textbooks (t = –3.15, $p < 0.01$). Grade differences: A "digital fatigue" phenomenon was observed, with app usage decreasing from 68.5% in first-year students to 42.1% in fourth-year students (χ^2 = 45.3, $p < 0.001$).

4. Effects of smart-digital teaching on physical health

4.1. Comparison of changes in physical health indicators

After the intervention, significant differences were observed between the experimental and control groups in the magnitude of change across all physical health indicators. In terms of body composition, the experimental group showed significantly greater reductions in BMI ($t = -3.45$, $p < 0.01$, $d = 0.58$) and body fat percentage ($t = -4.12$, $p < 0.001$, $d = 0.72$) compared with the control group, with effect sizes reaching medium and medium-to-large levels, respectively. Regarding physiological function, the improvement in the vital capacity–weight index in the experimental group was significantly greater than that in the control group ($t = 5.23$, $p < 0.001$, $d = 0.91$), representing a large effect. For physical fitness, the experimental group demonstrated significantly greater improvements in 1,000 m/800 m endurance running performance ($t = -5.67$, $p < 0.001$, $d = 1.15$, large effect) and standing long jump performance ($t = 4.56$, $p < 0.001$, $d = 0.78$, medium-to-large effect) than the control group. In terms of the overall physical health score, the experimental group showed a significantly greater increase than the control group (t = 6.34, p < 0.001, d = 1.02), indicating a large effect size. Overall, smart-digital teaching produced significantly greater improvements in college students' physical health than traditional instruction, with effect sizes generally ranging from medium to large.

Key finding: The experimental group achieved large effect sizes in endurance performance (d = 1.15) and overall physical health score (d = 1.02), significantly outperforming the control group. This advantage is closely associated with the real-time feedback mechanism of smart heart rate wristbands, which enables students to directly perceive physiological states such as entering the "fat-burning zone," thereby forming a positive reinforcement loop of "effort–feedback–persistence."

4.2. Verification of the mediating role of exercise self-efficacy

The mediation analysis indicates that exercise self-efficacy plays a significant mediating role between smart-digital resource usage and physical health. The standardized path coefficient from smart-digital resource usage to exercise self-efficacy is β = 0.58 (p < 0.001), while the path from exercise self-efficacy to physical health is β = 0.74 (p < 0.001). The direct effect of smart-digital resource usage on physical health is not significant (β = 0.12, p = 0.18); however, the indirect effect via exercise self-efficacy is significant (β = 0.43), accounting for 78.2% of the total effect.

Model fit indices indicate a good fit: χ^2/df = 2.14, CFI = 0.94, TLI = 0.93, RMSEA = 0.056, SRMR = 0.048.

Core mechanism: Smart-digital resources do not directly improve physical health; rather, they operate through a transmission pathway of "psychological empowerment → behavioral activation → health improvement."

4.3. Moderating effect of gender

Multi-group Structural Equation Modeling (SEM) reveals significant gender differences in the mediating pathway ($\Delta\chi^2(1)$ = 8.42, p < 0.01). The mediating effect is stronger in the male group (β = 0.51) and weaker, though still significant, in the female group (β = 0.34, p < 0.05). Specifically, the effect of smart-digital resource usage on exercise self-efficacy is significantly greater among males (β = 0.64) than females (β = 0.46), whereas the effect of exercise self-efficacy on physical health does not differ significantly between the two groups (p > 0.05).

Multi-group Structural Equation Modeling (SEM) indicates significant gender differences in the mediating pathway coefficients ($\Delta\chi^2(1)$ = 8.42, p < 0.01). The mediating effect is stronger in the male group (β = 0.51), whereas it is weaker, though still statistically significant, in the female group (β = 0.34, p < 0.05). Findings from in-depth interviews further reveal that female students exhibit higher levels of "technology anxiety" toward smart devices, and their exercise behaviors rely more on peer companionship rather than data-driven motivation. This reduces the efficiency with which technological empowerment is translated into psychological gains.

5. Discussion

5.1. The "double-edged sword" effect of smart-digital resources on physical health promotion

This study confirms the positive role of smart-digital resources in promoting college students' physical health, particularly in improving endurance performance, where a large effect size was observed (d = 1.15). This outcome is closely associated with the real-time heart rate feedback provided by wearable devices. However, the findings also reveal structural constraints related to insufficient depth of application: the usage rate of VR/AR technologies is only 23.5%, and the regular usage rate of wearable devices is below 40%, indicating a pronounced phenomenon of "shallow digitalization." These findings are consistent with prior research on the challenges of applying VR technology in education, suggesting that the development of smart-digital resources must move beyond mere "usability" toward "optimal usability." This requires iterative improvement focused on user experience and the strengthening of context-based integration within teaching scenarios.

5.2. The critical mediating role of exercise self-efficacy

The mediation model reveals a complete transmission chain of "technology → psychology → behavior → health," which carries important theoretical implications. Compared with previous studies that examine the mediating role of exercise self-efficacy primarily in relation to exercise behavior, this study extends the outcome variable to the objective physiological domain of physical health and quantifies the mediating effect at 78.2%. This provides more refined empirical evidence for understanding the mechanisms of smart-digital resource effectiveness. The relatively weaker effects observed in the control group can be attributed to the absence of real-time data feedback in traditional teaching, which makes it difficult for students to establish a clear link between "effort" and "progress." As a result, improvements in self-efficacy are constrained (post-test increase: experimental group +6.8 vs. control group +2.3, $t = 4.89$, $p < 0.001$).

5.3. Educational implications of gender differences

The "technology acceptance gap" observed among female students indicates the necessity of incorporating a gender-sensitive perspective into the design of smart-digital resources. Specific strategies include: developing socially oriented exercise apps with low learning thresholds (e.g., partner-matching for running, AI-assisted yoga posture correction), and reducing the emphasis on purely data-driven competitive rankings; preserving the social attributes of traditional physical education to avoid exacerbating "technological isolation"; and offering "exercise data analysis workshops" tailored for female students to enhance data literacy and technological confidence.

5.4. Research limitations and future directions

This study has three main limitations. First, the 16-week intervention period remains relatively short, and the long-term sustainability of the effects of smart-digital resources requires further longitudinal tracking. Second, the sample is limited to Hubei Province, and caution is needed when generalizing the findings to other regions. Third, potential confounding variables, such as socioeconomic status, were not controlled. Future research should conduct longitudinal studies of at least one year and explore hybrid intervention models combining "smart-digital resources + sports clubs" to sustain behavioral change over time.

6. Conclusions and recommendations

6.1. Main conclusions

1. The use of smart-digital resources among students in college public physical education exhibits a structural imbalance characterized by the widespread adoption of basic tools but the underutilization of advanced technologies. The adherence rate to wearable devices is below 40%, while the application rate of VR/AR technologies is only 23.5%.

2. Compared with traditional teaching, the smart-digital teaching model is more effective in promoting students' physical health, particularly demonstrating large effect size advantages in endurance performance (d= 1.15) and overall physical health scores (d = 1.02).

3. Smart-digital resources indirectly influence physical health through the mediating role of exercise self-efficacy, with the mediating effect accounting for 78.2% of the total effect. Significant gender differences are observed, with stronger effects among male students than female students.

6.2. Practical recommendations

Based on the findings, this study proposes the following practical recommendations for optimizing the application of smart-digital resources: First, at the system construction level, an integrated framework based on the "Chaoxing Learning Platform + smart wearables" should be established to develop digital physical health profiles. AI algorithms can be used to identify individual weaknesses and deliver personalized intervention plans, facilitating a shift from "uniform instruction" to "precision-based intervention." Second, at the device optimization level, an AI-driven health recommendation system should be developed to translate abstract heart rate data into intuitive and actionable feedback, thereby reducing cognitive load and improving technology acceptance, particularly among female students. Third, at the literacy development level, "exercise data analysis workshops" should be offered, especially for female and lower-grade students. Data literacy should be incorporated into the "scientific spirit" dimension of physical education curricula, helping to alleviate technology-related anxiety and foster lifelong exercise self-efficacy.

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