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An Empirical Study on Personalized Physical Fitness Teaching for Junior High School Students Supported by Intelligent Heart Rate Monitoring

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Abstract. To solve the problem of less personalization and no scientific monitoring in junior high fitness teaching, this study tests how smart heart rate monitoring helps personalized PE. It uses heart rate monitoring and personalized teaching theories to build a 4-step strategy: data focus, difference match, real-time adjust, and safety backup. 180 eighth-grade students joined an 8-week quasi-experiment. The test group used real-time heart data for personalized teaching, while the control group used traditional uniform teaching. Results show the test group's endurance, strength, and speed are much better than the control group ($P<0.01$), especially in 1000m/800m runs and pull-ups/sit-ups. This tech improves teaching accuracy and student participation a lot. It gives a scientific and easy way to make personalized PE teaching real in junior high schools.

Keywords: Heart Rate Monitoring, Junior High School Students, Physical Fitness Teaching, Personalized Teaching, Empirical Research

1. Introduction

Teenagers' physical health get wide attention these years, junior high school students' fitness are not good enough, weak strength and poor endurance are serious problems. Traditional PE teaching rely on teachers' experience, use one-size-fits-all training and lack individual monitoring. Heart rate is a key body index, it have real-time monitoring advantages, smart heart rate devices are feasible in PE class. Few studies focus on junior high students, so this study explore its use in personalized fitness teaching [1]. It has theoretical and practical meaning, solve traditional teaching problems, and put forward three research questions and goals to test the technology's effect.

2. Research methods

2.1. Theoretical basis

Intelligent heart rate monitoring rely on PPG technology to collect real-time heart rate data, it divide heart rate zones to show students' exercise load and physical state. The suitable exercise heart rate for junior high school students are 60%-90% of maximum heart rate, the key formula is

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HRmax=220-age, different heart rate zones correspond to different training effects (see Table 1). Personalized teaching follow the core idea of "teaching students in accordance with their aptitude", it design different teaching content and strategies based on students' physical condition, sports ability and learning needs, ensure every student can develop best in a suitable training environment. Period training theory divide training process into stable, fatigue, recovery and supercompensation stages, adjust exercise load according to students' physiological cycle; supercompensation theory point out that proper training load with enough rest can make body energy substances recover beyond the original level, this is the core mechanism of physical fitness improvement.

Table 1. Heart rate zones and corresponding differentiated training effects

Serial Number	Heart Rate Range (beats/min)	Exercise Status	Suitable Duration (min)
1	120~140	Aerobic exercise zone with maximum oxygen uptake	40~80
2	120~140	Within effective running value range	40~80
3	120~180	Running with large stroke volume of the heart	10~40
4	140~160	Moderate-intensity running	20~60
5	150~180	Anaerobic metabolism improvement	2~10
6	170~180	Indicator heart rate for interval running of different distances	1~5
7	>180	Maximizing work capacity under insufficient oxygen supply	<5

2.2. Personalized teaching plan design

This study build a four-dimensional integrated teaching strategy: first, data anchoring, establish students' fitness files with resting heart rate, maximum heart rate and fitness test data; second, differential adaptation, divide students into advanced group A, progressive group B and basic group C by heart rate and fitness level; third, dynamic regulation, adjust training intensity and content in real time with classroom heart rate feedback; fourth, safety guarantee, set three-level early warning to avoid overtraining [2]. The teaching process include pre-class data collection and plan making, in-class real-time monitoring and task adjustment, after-class report generation and plan optimization, keeping students' average heart rate at 130-165 beats per minute.

2.3. Experimental design

This research select 180 eighth-grade students from 4 classes of Shenzhen Middle School Pingshan Innovation School, divide them into experimental group (HEG, 90 students) and control group (RTG, 90 students). Pre-test show no significant differences between two groups in gender ratio and basic fitness ($P>0.05$), so they are comparable [3]. Independent variable are personalized teaching supported by heart rate monitoring and traditional unified teaching; dependent variable are changes of students' fitness indexes, including endurance, strength and cardiopulmonary function. Experimental equipments include X01 heart rate belts, fitness test tools and "Sports-Medicine-Education" intelligent system, there is a formula to calculate each student's target heart rate. All tests are based on national students' physical fitness standards, including boys' 1000m run, pull-ups and girls' 800m run, 1-minute sit-ups, etc., which are conducted before and after 8-week intervention [4].

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3. Experiment research

3.1. Experimental setup

The experiment last 8 weeks from April 10 to June 9, 2023, there are 4 PE classes per week and each class last 40 minutes. The experiment are held on the playground of Shenzhen Middle School Pingshan Innovation School. The experimental group are re-divided into Group A, Group B and Group C according to pre-test data, it carry out personalized training relying on real-time heart rate. The control group use traditional unified teaching, with the same training time and basic content as the experimental group, and no heart rate monitoring intervention.

3.2. Experimental implementation

3.2.1. Pre-experiment stage (2 weeks)

Conduct fitness pre-test and one-week heart rate baseline monitoring for both groups, build basic data files. There are no significant differences in all indicators between the two groups ($P>0.05$), it prove that the experimental grouping is scientific and the basic conditions are consistent.

3.2.2. Intervention implementation stage (8 weeks)

The experimental group implement the four-dimensional personalized teaching strategy. Teachers control students' training state in real time through the heart rate monitoring platform, add high-intensity interval links when the average heart rate are lower than the target value, and switch to relaxation training immediately if exceeding the threshold. The control group carry out traditional teaching such as collective running and unified intensity training, teachers adjust the rhythm by experience.

3.2.3. Experiment final stage (1 week)

Conduct fitness post-test for both groups and sort out experimental data. Select 30 PE teachers and 180 students to carry out interviews, collect subjective evaluations of teaching and learning.

3.3. Experimental control

Strictly control the consistency of teaching duration, training content and teachers' qualifications. Ensure no differences in daily routines and diets between the two groups to avoid external interference. Conduct unified training for teachers to make the experiment standardized and normalized.

4. Experimental results and analysis

4.1. Pre-test fitness comparison analysis

Pre-test data show in Table 2, there are no significant differences in all fitness indexes between experimental group and control group ($P>0.05$). This result prove that the experimental grouping is reasonable, the research foundation of the two groups are consistent, and the follow-up intervention experiment can be carried out smoothly without obvious deviation.

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Table 2. Pre-test comparison of physical fitness indicators between experimental group and control group

Test Indicators	Control Group (n=90)	Experimental Group (n=90)	t-value	p-value
Height (Male, cm)	164.00±8.40	165.00±8.35	-0.493	0.624
Weight (Male, kg)	53.04±11.35	56.07±12.46	-1.389	0.172
BMI (Male)	19.44±3.39	20.27±3.08	-1.423	0.161
1000m Run (Male, s)	244.09±36.00	240.94±22.00	0.508	0.614
Pull-ups (Male, reps)	6.04±5.84	7.51±4.90	-1.471	0.148
Standing Long Jump (Male, cm)	192.26±27.65	198.81±22.76	-1.311	0.196
Height (Female, cm)	157.21±5.13	158.49±5.02	-0.981	0.332
Weight (Female, kg)	49.98±11.71	49.22±9.89	0.323	0.748
BMI (Female)	20.21±3.74	19.78±3.04	0.553	0.812
800m Run (Female, s)	226.76±30.27	225.36±19.87	0.24	0.197
1-minute Sit-ups (Female, reps)	49.59±7.04	47.78±6.10	1.28	0.208
Standing Long Jump (Female, cm)	163.86±17.86	165.29±15.11	-0.381	0.705

4.2. Post-test fitness comparison analysis

After 8 weeks of teaching intervention, the experimental group students show obvious advantages in most fitness indexes. In terms of endurance, the average time of boys' 1000m run in the experimental group is 223.30 seconds, which are 17.02 seconds shorter than the control group's 240.32 seconds; the average time of girls' 800m run is 208.45 seconds, 15.05 seconds less than the control group's 223.50 seconds, and the differences are extremely significant ($P<0.01$). In terms of strength, the average score of boys' pull-ups in the experimental group is 12.61 times, 5.1 times more than the control group's 7.51 times; the average number of girls' 1-minute sit-ups is 54.90 times, 3.57 times higher than the control group's 51.33 times, with significant differences ($P<0.05$). There are no significant differences in standing long jump between the two groups ($P>0.05$), because this item are more affected by explosive power and technical movements (see Table 3).

Table 3. Post-test comparison of physical fitness indicators between experimental group and control group

Test Indicators	Control Group (n=90)	Experimental Group (n=90)	t-value	p-value
1000m Run (Male, s)	240.32±36.65	223.30±19.28	2.924	0.005
Pull-ups (Male, reps)	7.51±6.24	12.61±6.37	-4.348	0
Standing Long Jump (Male, cm)	194.57±25.36	201.49±23.35	-1.423	0.162
800m Run (Female, s)	223.50±27.80	208.45±18.39	2.731	0.009
1-minute Sit-ups (Female, reps)	51.33±7.14	54.90±4.94	-2.68	0.011
Standing Long Jump (Female, cm)	164.83±17.51	167.55±14.87	-0.741	0.463

4.3. Comparison of fitness index growth rates

The growth rates of all fitness indexes in the experimental group are much higher than those in the control group. The growth rate of 1000m/800m running results is about 7.3%, and the growth rates of pull-ups and sit-ups are 67.90% and 14.90% respectively. The corresponding growth rates of the

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control group are only 1.54% and 3.55%, which directly reflect the empowering effect of personalized teaching supported by intelligent heart rate monitoring.

4.4. Subjective evaluation result analysis

Interview data show that 85% of teachers think heart rate monitoring technology effectively improve teaching accuracy and get rid of the limitations of empirical teaching. 78% of students say personalized training are more suitable for their own physical conditions, and their interest in PE class increase significantly. Only 7.9% of students in the experimental group report slight fatigue, which are far lower than 15.6% of the control group. This data fully confirm the safety and adaptability of the personalized teaching mode, and also prove that the technology can balance training effect and physical comfort for junior high school students.

5. Conclusion

Firstly, current junior high school physical fitness teaching have many core bottlenecks, such as insufficient personalization, lack of scientific monitoring and low students' interest, smart heart rate monitoring technology can solve these problems targeted. Secondly, the four-dimensional personalized teaching strategy built in this study realize a new "visible-controllable-adjustable" teaching mode, it can significantly improve students' physical fitness level, especially have outstanding effects on endurance and strength events. Thirdly, heart rate monitoring not only help teachers accurately control exercise load and ensure training safety, but also stimulate students' learning interest through real-time data feedback, it achieve the double improvement of teaching effectiveness and classroom participation.promote the popularization of smart heart rate monitoring technology in junior high PE classes, include it into the construction of school sports facilities[5]. Secondly, strengthen professional training for PE teachers, improve teachers' ability of heart rate data analysis and personalized teaching plan design. Thirdly, optimize teaching plans according to the actual situation of different regions and schools, promote the large-scale implementation of personalized PE teaching. Future research can further expand the research boundary, explore the application effect of heart rate monitoring technology in different sports such as ball games and gymnastics, and students of different ages like primary and high school. Combine artificial intelligence algorithms to optimize personalized training plans, provide more systematic and refined technical and teaching support for the improvement of adolescents' physical health.

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