

Effects of an exercise intervention based on mobile health technology on the physical health of overweight and obese male university students – A randomized controlled trial

Qinlong Zhang, Zhen Li, Lei Jiang, Yanan Gao, Tingjun Gong, Jian Li, Zhixiong Zhou

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Effects of an exercise intervention based on mobile health technology on the physical health of overweight and obese male university students? A randomized controlled trial

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Abstract

Background: Obesity has become one of today's global health challenges. According to the World Health Organisation, in 2022, 2.5 billion adults aged 18 years and older will be overweight, including more than 890 million adults with obesity. This equates to 43% of adults aged 18 years and older (43% of males and 44% of females) being overweight. Exercise is the most effective non-pharmacological way to improve obesity, and some studies have shown that exercise can significantly improve the body shape of obese male college students and promote physical health. Obesity brings people not only great physical health risks, but also unappreciated psychological harm. Obesity may seriously affect college students' learning and mental health, and these potential risks have been confirmed in studies that obesity is correlated with both self-esteem and academic performance, so some studies have referred to the verbal and physical abuse suffered by overweight people as weight stigma, and confirmed that weight stigma is negatively correlated with self-esteem in overweight people. Effective exercise interventions can help overweight people restore their self-confidence, but how to help overweight people face the enormous psychological pressure and external views of effective exercise interventions is an urgent problem, offline exercise in an open environment, always surrounded by the outside world's astonished eyes, part of the population will be under this invisible pressure to gradually give up training. With the development of science and technology, the development of mHealth technology provides new possibilities to deal with this challenge, therefore, it has become imperative to carry out research on exercise intervention based on mHealth technology.

Currently, on the one hand, whether mHealth can achieve the same effect as offline fitness is still worthy of further debate; on the other hand, weight loss is not only related to exercise, related studies believe that weight loss is also related to the daily PA, low PA patients suffer from cardiovascular disease and death risk is significantly higher, so it is very important to conduct research on the specific role that PA can play in exercise intervention. In summary, this study explores the relationship between physical health improvement, physical activity and body fat percentage in overweight and obese college students around mobile health technology.

Objective: Exercise interventions based on mobile health technology are widely available, but the effectiveness and feasibility of interventions using mobile health apps and exercise watches to improve the physical health of overweight and obese male college students are unknown, and this study compares the effects of online interventions carried out by mobile health technology and offline interventions guided by physical trainers on the physical health of overweight and obese male college students.

Methods: This study used a randomised controlled trial with a pre-test post-test design, and participants were randomly divided into an online group, an offline group and a control group. The online group exercised online through the fitness APP, and the offline group was instructed by a professional trainer to exercise offline, and both groups wore sports watches to monitor their

activities, and the training content was the same. The control group did not carry out any intervention.

Results: At the end of the intervention, the BMI and body fat rate of the online and offline groups decreased significantly ($P<0.01$), and several physical fitness indexes, such as muscle mass and lung capacity, increased significantly ($P<0.05$). The changes in the indicators between the online and offline groups were basically the same, and the differences were not significant ($P>0.05$). It was found that there was a dose-effect relationship between the amount of physical activity and the rate of change in body fat, with the rate of change in body fat increasing by 0.0690 and 0.0544 units for each unit increase in the duration of moderate-intensity and high-intensity exercise, respectively.

Conclusions: Exercise intervention based on mobile health technology effectively improves the physical fitness of overweight and obese male college students, and the effect is consistent with offline intervention. There was a significant dose-effect relationship between the amount of physical activity and the rate of change in body fat, which provided a scientific basis for the development of personalised training programmes. Clinical Trial: Registration number?ChiCTR2400092057
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Original Manuscript

Effects of an exercise intervention based on mobile health technology on the physical health of overweight and obese male university students—A randomized controlled trial

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Abstract

Objectives

Exercise interventions based on mobile health technology are widely available, but the effectiveness and feasibility of interventions using mobile health apps and exercise watches to improve the physical health of overweight and obese male college students are unknown, and this study compares the effects of online interventions carried out by mobile health technology and offline interventions guided by physical trainers on the physical health of overweight and obese male college students.

Methods

This study used a randomised controlled trial with a pre-test post-test design, and participants were randomly divided into an online group, an offline group and a control group. The online group

exercised online through the fitness APP, and the offline group was instructed by a professional trainer to exercise offline, and both groups wore sports watches to monitor their activities, and the training content was the same. The control group did not carry out any intervention.

Results

At the end of the intervention, the BMI of the online and offline groups decreased by 1.5 kg/m² and 1.6 kg/m², respectively ($P < 0.01$), and the body fat rate decreased by 1.69% in the online group and 1.72% in the offline group ($P < 0.01$). Several physical fitness indicators, such as muscle mass, increased significantly by an average of 1,115.23g in the online group and 1,120.56g in the offline group ($P < 0.05$), and lung capacity improved by 5.2% and 5.5% in the online and offline groups, respectively ($P < 0.05$). The changes in these indicators between the online and offline groups were not significantly different ($P > 0.05$). Additionally, a dose-effect relationship was found between the amount of physical activity and the rate of change in body fat, with the rate of body fat reduction increasing by 0.0690 units per unit increase in the duration of moderate-intensity exercise and by 0.0544 units per unit increase in the duration of high-intensity exercise.

Conclusion

Exercise intervention based on mobile health technology effectively improves the physical fitness of overweight and obese male college students, and the effect is consistent with offline intervention. There was a significant dose-effect relationship between the amount of physical activity and the rate of change in body fat, which provided a scientific basis for the development of personalised training programmes.

Keywords: health promotion; physical activity; monitoring; dose-effect relationship

Introduction

Obesity has become one of today's global health challenges. According to the World Health Organisation, in 2022, 2.5 billion adults aged 18 years and older will be overweight, including more than 890 million adults with obesity. This equates to 43% of adults aged 18 years and older (43% of males and 44% of females) being overweight^[1]. Exercise is the most effective non-pharmacological way to improve obesity, and some studies have shown that exercise can significantly improve the body shape of obese male college students^[2] and promote physical health^[3]. Obesity brings people not only great physical health risks, but also unappreciated psychological harm. Obesity may seriously affect college students' learning and mental health^[1], and these potential risks have been confirmed in studies that obesity is correlated with both self-esteem and academic performance^[4], so some studies have referred to the verbal and physical abuse suffered by overweight people as weight stigma, and confirmed that weight stigma is negatively correlated with self-esteem in overweight people^[5]. Effective exercise interventions can help overweight people restore their self-confidence^[6],

but how to help overweight people face the enormous psychological pressure and external views of effective exercise interventions is an urgent problem, offline exercise in an open environment, always surrounded by the outside world's astonished eyes, part of the population will be under this invisible pressure to gradually give up training. With the development of science and technology, the development of mHealth technology provides new possibilities to deal with this challenge ^[7], therefore, it has become imperative to carry out research on exercise intervention based on mHealth technology.

Mobile health technology refers to the use of mobile devices and related mobile applications to monitor, assess and improve an individual's health and health behaviours ^[8]. Studies have shown that mHealth technology can effectively improve physical activity levels ^[9] and lifestyles ^[10], greatly facilitating people's lives. Current research mainly focuses on online care for special populations and knowledge popularisation ^[11], and the study population focuses on women with shorter intervention cycles ^[12], and there is a lack of randomised controlled trials in which mHealth technology combined with exercise intervention is used as an effective intervention, which does not prove its effectiveness and restricts its widespread application.

Wearable devices are currently widely used in remote medical monitoring ^[13], to help doctors understand individual disease trajectories; in the field of exercise intervention mainly to provide real-time physical activity feedback, with the help of wearable devices can be obtained in a timely manner health intervention, timely adjustment of the intervention program, to cultivate self-monitoring of physical activity habits of the research subjects, to provide a basis for the objective quantitative evaluation of the behavioural patterns of the research subjects, and to improve the effectiveness of health intervention for the subjects based on traditional health interventions to improve support for individual personalisation of subjects, better match research subjects' personal preferences and characteristics, and provide the possibility for personalised interventions ^[14]. Such adjustments often take time to provide feedback, and if the dose-effect relationship between physical activity and physical health indicators can be established, the time can be greatly reduced, and the training programme can be scientifically and effectively formulated and the training load can be determined before the training starts, so as to achieve goal-oriented exercise interventions and stimulate a stronger awareness of exercise.

Currently, on the one hand, whether mHealth can achieve the same effect as offline fitness is still worthy of further debate; on the other hand, weight loss is not only related to exercise, related studies believe that weight loss is also related to the daily PA, low PA patients suffer from cardiovascular disease and death risk is significantly higher ^[15], so it is very important to conduct research on the specific role that PA can play in exercise intervention. In summary, this study explores the relationship between physical health improvement, physical activity and body fat percentage in overweight and obese college students around mobile health technology.

Methods

Study design and participants

This was a pre- and post-test study employing a randomized controlled experimental design with an additional control group. The 12-week intervention was conducted from April to June 2024 at a comprehensive university.

Participants were eligible if they were aged 20–30 years and had a BMI ≥ 24. Exclusion criteria included: (1) contraindications to exercise, (2) chronic conditions such as cardiovascular disease or diabetes, (3) infectious diseases such as Hepatitis B or Tuberculosis, and (4) chronic smoking. All participants provided written informed consent before enrollment. The study was approved by the Ethics Committee of the Capital Institute of Sports (Code: 2024A063, Approval Date: 2017/12/26) and registered in the Chinese Clinical Trial Registry (Registration No.: ChiCTR2200063892).

Participants were randomly assigned to one of three groups (online intervention, offline intervention, or control) using a computer-generated simple randomization method. Group assignment and data analysis were conducted by independent researchers blinded to the intervention.

Description of intervention

Subjects in the online and offline groups underwent 12 weeks of aerobic combined strength training, with the same frequency of weekly interventions in both groups, three times per week^[16] for 80 minutes (10 minutes warm-up, 60 minutes training, 10 minutes relaxation)^[17].

Table 1 Offline group training content

Offline group					
First training					
Warm-up section (10 minutes)					
Neck circle, Shoulder circle, Wrist rotation, Low side lunge, Marching knee hold					
Basic section (60 minutes)					
Training movement	Training area	Weight	Number of times/time	No. of groups	Intermittence
Dumbbell overhead row	Helper	15RM(65%1RM)	15times	3	30-60s
Dumbbell squat	Leg	15RM(65%1RM)	15times	3	30-60s
Dumbbell flat bench press	Chest	15RM(65%1RM)	15times	3	30-60s
Roll-up	Stomach	Own weight	15times	3	30-60s
Run	Whole body	VO2max70%	30min	1	0
Relaxation section (10 minutes)					
Arm Stretch, Back Stretch, Waist Stretch, Chest Stretch, Leg Stretch					
Second training					
Warm-up section (10 minutes)					
Neck circle, Shoulder circle, Wrist rotation, Low side lunge, Marching knee hold					

Basic section (60 minutes)

Training movement	Training area	Weight	Number of times/time	No. of groups	Intermittence
Dumbbell curl	Helper	15RM(65%1RM)	15times	3	30-60s
Dumbbell squat jump	Leg	15RM(65%1RM)	15times	3	30-60s
Dumbbell Incline Chest Clamp	Chest	15RM(65%1RM)	15times	3	30-60s
Roll-up	Stomach	Own weight	15times	3	30-60s
Run	Whole body	VO2max70%	30min	1	0

Relaxation section (10 minutes)

Arm Stretch, Back Stretch, Waist Stretch, Chest Stretch, Leg Stretch

Third training

Warm-up section (10 minutes)

Neck circle, Shoulder circle, Wrist rotation, Low side lunge, Marching knee hold

Basic section (60 minutes)

Training movement	Training area	Weight	Number of times/time	No. of groups	Intermittence
Dumbbell pull	Helper	15RM(65%1RM)	15times	3	30-60s
Dumbbell lunge curl	Leg	15RM(65%1RM)	15times	3	30-60s
Dumbbell Squatting Bird	Chest	15RM(65%1RM)	15times	3	30-60s
Roll-up	Stomach	Own weight	15times	3	30-60s
Run	Whole body	VO2max70%	30min	1	0

Relaxation section (10 minutes)

Arm Stretch, Back Stretch, Waist Stretch, Chest Stretch, Leg Stretch

Table 2 Online group training content

Online group

First training

Warm-up section (10 minutes)

Neck circle, Shoulder circle, Wrist rotation, Low side lunge, Marching knee hold

Basic section (60 minutes)

	Training area	Training movement	Weight	Number of times/time	No. of groups	Intermittence
A	Leg	Dumbbell squat	15RM(65%1RM)	15times	3	30-60s
		Dumbbell squat jump	15RM(65%1RM)	15times	3	30-60s
		Dumbbell lunge curl	15RM(65%1RM)	15times	3	30-60s
		Roll-up	Own weight	15times	3	30-60s

	Whole body	Run	VO2max70%	30min	1	0
	Relaxation section (10 minutes)					
	Arm Stretch, Back Stretch, Waist Stretch, Chest Stretch, Leg Stretch					
	Second training					
	Warm-up section (10 minutes)					
	Neck circle, Shoulder circle, Wrist rotation, Low side lunge, Marching knee hold					
	Basic section (60 minutes)					
	Training area	Training movement	Weight	Number of times/time	No. of groups	Intermittence
B	Helper	Dumbbell curl	15RM(65%1RM)	15times	3	30-60s
		Dumbbell pull	15RM(65%1RM)	15times	3	30-60s
		Dumbbell overhead row	15RM(65%1RM)	15times	3	30-60s
	Stomach	Roll-up	Own weight	15times	3	30-60s
	Whole body	Run	VO2max70%	30min	1	0
	Relaxation section (10 minutes)					
	Arm Stretch, Back Stretch, Waist Stretch, Chest Stretch, Leg Stretch					
	Third training					
	Warm-up section (10 minutes)					
	Neck circle, Shoulder circle, Wrist rotation, Low side lunge, Marching knee hold					
	Basic section (60 minutes)					
	Training area	Training movement	Weight	Number of times/time	No. of groups	Intermittence
C	Chest	Dumbbell incline chest clamp	15RM(65%1RM)	15times	3	30-60s
		Dumbbell flat bench press	15RM(65%1RM)	15times	3	30-60s
		Dumbbell squatting bird	15RM(65%1RM)	15times	3	30-60s
	Stomach	Roll-up	Own weight	15times	3	30-60s
	Whole body	Run	VO2max70%	30min	1	0
	Relaxation section (10 minutes)					
	Arm Stretch, Back Stretch, Waist Stretch, Chest Stretch, Leg Stretch					

The online group was taught how to use the sports watch by the researcher during the baseline test, as well as safety education. After completing the baseline test, online training was organised and supervised through Tencent Conference. Each person conducted three exercise interventions per week, independently selected personalised training programmes for the training situation, wore the exercise watch during training and trained independently against the demonstration videos via the First Body Fitness APP. At the end of each training session, a training punch card was posted in the WeChat group in the form of a picture or video. Online group of subjects according to their own training, the day before participating in the training to choose the training group need to practice, according to the training content is divided into three groups A, B, C (strength training + aerobic

training) training content composition, A, B, C three groups corresponding to the three time periods of all subjects to practice the content of the same to facilitate the supervision of the researchers. The order of the three weekly training sessions could be chosen freely.

In the offline group, each participant was instructed by a professional physical trainer to perform three exercise interventions per week. In the offline group, strength training was performed with dumbbells, plus abdominal curls; aerobic training was performed in the form of running for 30 min each time, totalling 1 set. Warm-up and relaxation were performed for 10 min before and after the exercises. Three times a week, the training is carried out in accordance with the prescribed programme, and cannot be switched or adjusted.

Online and offline groups are required to wear sports watches to measure physical activity data all day long, and upload them to the backstage punch card through the Shouti Fitness APP on time every day. The control group is not required.

Study measurements

Body composition test: The body composition test was performed using a dual-energy X-ray bone densitometer. Subjects are required to stay properly hydrated the day before and on the day of the test, and avoid drinking and eating for 2 hours before the test, and change into light clothes in advance. During the test, shoes and socks are removed, no metal jewellery can be worn, and the subject is required to lie flat on the centre line of the test bed area, symmetrically on the left and right sides, with palms up against the sides of the body placing the feet straight, and no talking during the test. The duration of each test was 10-15 minutes ^[18].

Maximum oxygen uptake test: subjects were asked to start from a stationary state, wearing K5 equipment, using the Bruce test method to: 2.7KM/H speed, 10% gradient; 4KM/H speed, 12% gradient; 5.5KM/H speed, 14% gradient; 6.8KM/H speed, 16% gradient; 8KM/H speed, 18% gradient, adjusting the speed and gradient every three minutes, until they could not continue to run. , until they could not continue to keep running, usually ending around 12 minutes ^[19].

Maximum strength test: subjects were asked to learn the barbell bench press and hard pull squat movement pattern, starting with an empty bar and gradually increasing the barbell piece. Subjects can not perform strenuous physical activity in the 24 hours before the test, the day of the test in the physical fitness gym, by completing a number of times the maximum strength of the test movements to complete the preparatory activities, select the subject predicted weight to start the test, gradually incremental, until the inability to complete the prescribed movement, record the last successful 1RM, usually obtained within four times, rest 3-5 minutes between two tests ^[20].

Physical fitness tests: lung capacity, standing long jump, 1000 m, 50 m, seated forward bending, and pull-up tests were conducted in accordance with the provisions of the National Physical Fitness Standards for Students (Revised 2014) ^[21].

Statistical analysis

In this study, we used previous studies ^[22] to estimate the required sample size. Assuming an effect size of approximately 0.85 (based on changes in body fat percentage), a one-tailed α level of 0.05, a statistical power of 0.50, and a pre-post correlation coefficient of 0.80, we determined that a minimum of 22 subjects per group would be needed. Accounting for a 15% dropout rate, we recruited 24 participants per group to ensure sufficient power.

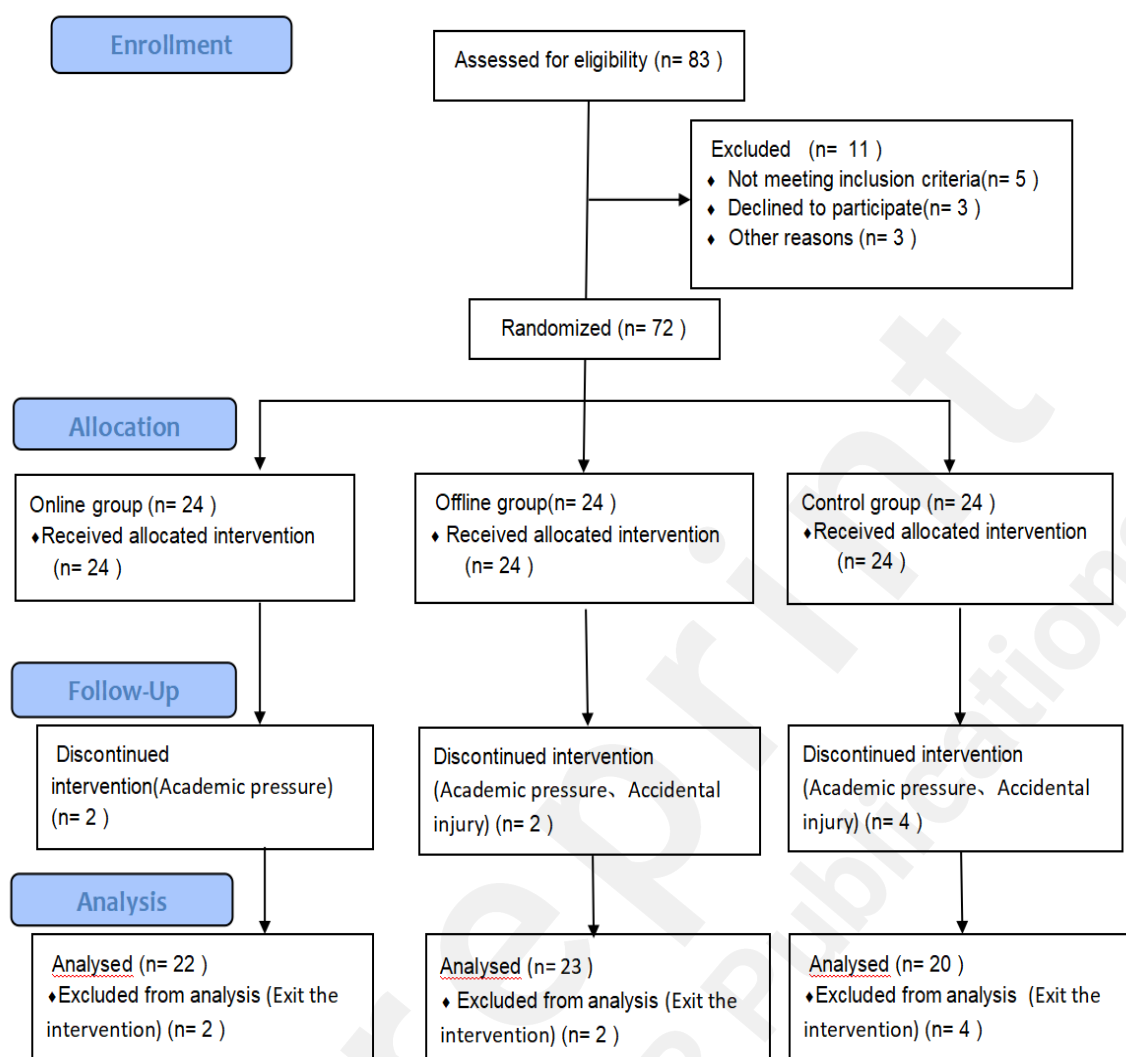
In this study, the experimental indicators were analysed using paired tests, ANOVA, and a non-parametric test 'Wilcoxon signed rank sum test' was used for some of the data that did not conform to normal distribution.

Results

Study sample characteristics

As shown in the figure, 83 subjects were recruited for this study and a total of 72 were enrolled. The other 11 subjects were excluded because they did not sign the informed consent form ($n=8$) and were unwilling to participate ($n=3$). During the 12-week intervention period, a total of two people dropped out of the online group, two people dropped out of the offline group, and four people dropped out of the control group, with no significant differences in baseline characteristics among the three groups.

Figure 1



Flowchart of subject screening

Table 3 Baseline characteristics

Norm	Online group (n=22)	Offline group (n=23)	Control group [n=20]	F	P
Age	23.23±2.64	23.57±2.47	23.35±2.66	0.099	0.906
Height (m)	1.77±0.05	1.78±0.06	1.77±0.05	0.461	0.633
Weight (kg)	89.62±10.47	92.14±8.83	91.48±12.01	0.348	0.707
BMI[kg/□□]	28.57±2.68	29.05±2.89	29.23±3.11	0.298	0.743
Body fat percentage (%)	32.07±5.36	33.23±4.32	33.85±5.66	0.660	0.520
Muscle mass (g)	57180.32±4685.74	59116.57±5651.81	56578.0±7108.65	1.127	0.330
Standing long jump (m)	2.22±0.16	2.18±0.16	2.13±0.13	1.852	0.170
1000 metres (min)	4.73±0.86	4.91±0.69	5.00±0.79	0.675	0.513
50 metres (s)	8.07±0.69	8.24±0.53	8.34±0.51	1.195	0.310
Seated forward bending (cm)	5.04±8.31	2.21±5.92	1.27±6.26	1.720	0.188
Pull-ups (pcs)	1.05±2.03	0.39±0.78	0.40±0.88	1.655	0.199
Bench Press 1RM (kg)	57.16±13.79	64.67±14.07	61.25±15.68	1.515	0.228
Deep Squat 1RM (kg)	96.25±14.88	98.80±24.53	86.88±20.03	2.009	0.143
Hard Pull 1RM (kg)	96.82±22.04	102.39±19.68	91.25±13.27	1.869	0.163
Lung capacity (ml)	5244.36±632.86	5304.26±925.62	5367.0±552.93	0.148	0.863
Maximum oxygen uptake ml/(kg-min)	47.98±8.73	47.81±5.84	46.19±6.68	0.392	0.677

Intervention effects

Table 4 Comparison between groups

Norm	Online group (n=22)	Offline group (n=23)	Control group [n=20]	P		
				P Online-Offline	P Online- Control	P Offline-Control
BMI[kg/m²]	-0.89±1.17	-0.68±0.94	0.24±0.78	0.757	0.001	0.009
Muscle mass (g)	1115.23±1765.42	1377.74±2203.05	-49.55±1310.40	0.879	0.104	0.033
Body fat percentage (%)	-1.69±2.24	-2.25±3.20	0.48±1.37	0.721	0.001	0.007
Lung capacity (ml)	536.82±745.55	450.35±664.47	3.50±79.62	0.271	0.003	0.014
Maximum oxygen uptake ml/(kg·min)	3.72±5.83	4.27±5.67	-0.46±1.15	0.922	0.010	0.001
Standing long jump (m)	0.10±0.17	0.07±0.13	-0.01±0.04	0.427	0.041	0.020
1000 metres (min)	0.12±0.26	0.11±0.26	-0.07±0.14	0.946	0.028	0.016
50 metres (s)	0.32±0.56	0.41±0.61	-0.06±0.16	0.358	0.043	0.021
Seated forward bending (cm)	3.11±4.73	3.86±5.21	-0.19±0.80	0.820	0.048	0.002
Pull-ups (pcs)	1.36±1.97	1.57±2.23	0.05±0.39	0.820	0.038	0.026
Bench Press 1RM (kg)	7.07±10.12	7.39±13.04	-0.13±2.98	0.594	0.003	0.100
Deep Squat 1RM (kg)	9.91±13.59	12.28±19.13	-0.63±3.33	0.837	0.003	0.011
Hard Pull 1RM (kg)	11.14±14.24	9.67±18.53	-0.50±2.88	0.934	0.001	0.041

Note: Age, baseline physical characteristics, and any other factors were controlled as covariates.

As can be seen from Table 4, the p-value of the difference between the pre- and post-test data of each variable in the online group and the offline group is greater than 0.05, and there is no significant difference.

In the online group and the control group, except for 'muscle mass', the p-value of the difference between the pre- and post-test data of each variable is less than 0.05, which can be regarded as a significant difference.

In the offline group and the control group, except for 'bench press 1RM', the p-value of the difference between the pre- and post-test data of each variable is less than 0.05, which can be regarded as a significant difference.

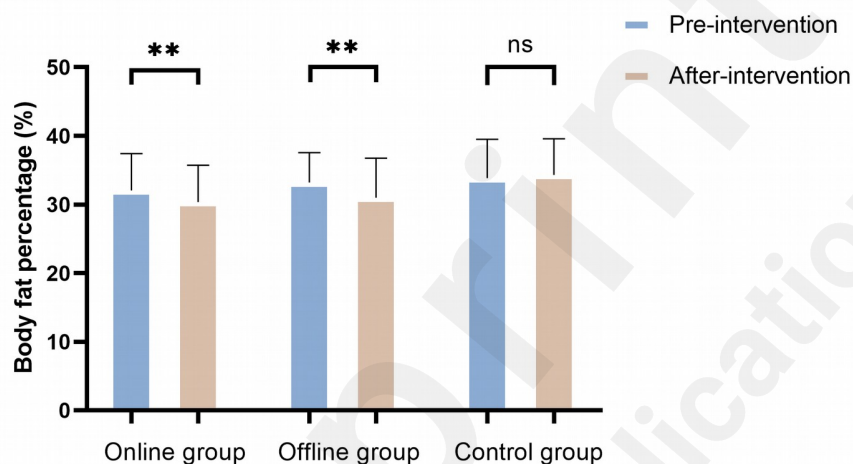


Figure 2 Differences between groups in body fat percentage

The difference in the change in body fat percentage before and after the experiment among the three groups of subjects showed a significant difference in the within-group paired-sample t-test analysis, with the on-line group ($F=3.560$ $P=0.002$) the off-line group ($F=3.479$ $P=0.002$); and the control group ($F=1.567$ $P=0.134$). In the one-way ANOVA test of variance between groups, there was a significant difference ($F=7.364$ $P=0.001$), in which there was a significant difference between the online group and the control group ($P<0.01$), the offline group and the control group ($P<0.01$) and there was no significant difference between the online group and the offline group.

Changes in weekly average moderate to high intensity physical activity

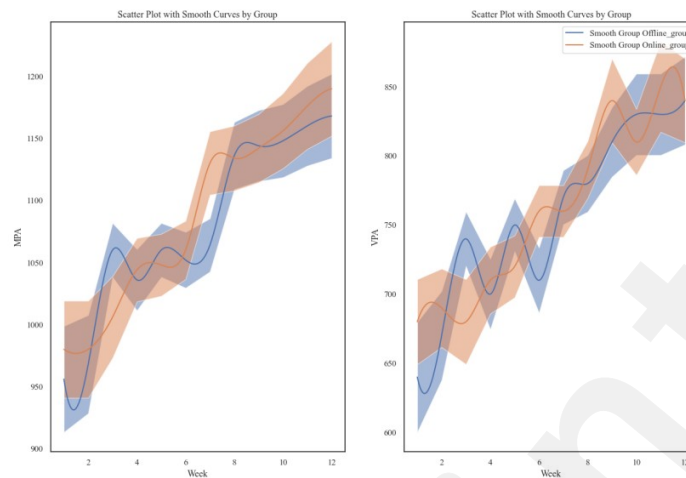


Figure 3 Changes in the amount of moderate to high intensity physical activity

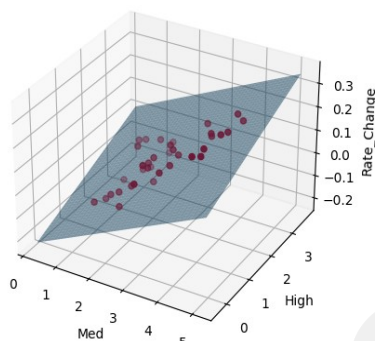
The mean value of weekly moderate-intensity physical activity in the online group was 1087 MET*MIN; in the offline group it was 1079 MET*MIN. t-test for independent samples revealed that there was no significant difference in the amount of moderate-intensity physical activity between the two groups.

The mean weekly high intensity physical activity in the online group was 761 MET*MIN; in the offline group it was 756 MET*MIN. there was no significant difference in the amount of high intensity physical activity between the two groups as found by independent samples t-test.

The mean value of total weekly MET*MIN in the online group was 1848 MET*MIN, and the mean value of total weekly MET*MIN in the offline group was 1835 MET*MIN, which far exceeded the WHO recommendation of 900 MET*MIN per week.

Relationship between the amount of physical activity and the rate of change in body fat

Linear regression models

**Figure 4 Linear regression model****Table 5 Linear regression data**

PA	Coef	Std err	t	P	95%CI[0.025-0.975]
MPA	0.0690	0.009	7.644	0.099	0.051-0.087
VPA	0.0544	0.014	3.968	0.461	0.026-0.082

$$\text{Rate_change} = -0.2108 + 0.0690 * \text{med} + 0.0544 * \text{high}$$

The model is interpreted as follows: all else being equal, each unit increase in moderate-intensity exercise time will increase the rate of change in body fat by 0.0690 units; each unit increase in high-intensity exercise time will increase the rate of change in body fat by 0.0544 units. The calculated VIF value for med and high was 1.5915 and there was no significant multicollinearity. In addition, since the duration of exercise was calculated separately for each intensity, it can be assumed that there is no interaction.

$$Y = -0.2108 + 0.0690 * \text{med} + 0.0544 * \text{high}$$

Testing

Table 6 Validation of parameters related to LinearRegression

Validation of LinearRegression Related Parameters	Relationship and value
regression intercept	W0=-0.21080691390909367
regression coefficient	W1=[0.06900332 0.05437355]
R-square coefficient of determination	0.8428
mean square error	0.0021
Mean absolute value error	0.0378
Median absolute value error	0.0439

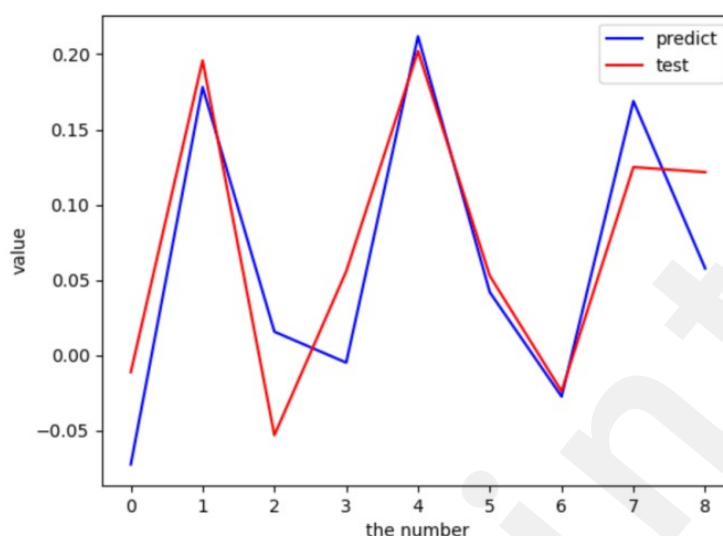


Figure 5 Graph of true values of test set and training predictions

Validation of the test set data yields a mean square error of 0.0021.

The graph of the true values of the test set and the training predictions as shown in Fig. 5 can be found that the overall values are relatively close to each other, and due to the small sample size itself, there will be a certain degree of error.

Discussion

In this study, the physical health of the online group and the overweight and obese male college students guided by professional physical fitness trainers based on mobile health technology interventions were significantly improved, and the amount of physical activity of the online group gradually increased with the interventions, which confirms the hypothesis that the interventions using the mobile health APP and sports watch can effectively improve the physical health of the overweight and obese male college students; and secondly, the study found that there is a significant dose-effect relationship between the rate of change of body fat and the amount of physical activity. Secondly, it was found that there was an obvious dose-effect relationship between the rate of change in body fat and the amount of physical activity, specifically $Y = -0.2108 + 0.0690 * \text{med} + 0.0544 * \text{high}$, which provides a reliable theoretical basis for the development of scientific training programmes.

Effectiveness of mHealth technology-based exercise interventions to improve body fat percentage

The effectiveness of mHealth technology-based exercise interventions in

improving body fat percentage has gained widespread attention. With the proliferation of smartphones and wearable devices, these technologies offer flexible and personalised exercise programmes for obese and overweight people. Several high-level studies have demonstrated that mHealth interventions are effective in promoting reductions in body fat percentage.

A growing body of research validates the effectiveness of mHealth technology in body fat percentage management. For example, it was found that participants who used a mobile health app reduced their body fat percentage by an average of 1.22 per cent over a 12-week period. This study highlighted the importance of personalised feedback and goal setting, where participants were provided with real-time data through the app, leading to enhanced self-monitoring skills and motivation to exercise [23].

In addition, Wang W et al. found that participants' activity level and exercise intensity significantly increased when wearing a smartwatch for exercise monitoring, which ultimately led to an effective decrease in body fat percentage. The real-time data feedback from wearable devices helped participants to adjust their exercise intensity, which improved the efficiency and effectiveness of exercise [24].

In this study, after 12 weeks of mHealth technology intervention, it was found that the body fat rate of the online group decreased significantly, which was basically the same as the situation of the online group, so the body fat rate of obese people can be effectively improved by mHealth technology.

However, despite numerous studies confirming the effectiveness of mHealth technology, some potential limitations need to be noted. Most of the current studies have small sample sizes and focus on specific populations, and the generalisability of the results needs to be verified. In addition, individual factors such as motivation, social support and lifestyle may have a significant impact on the effectiveness of the intervention, and these factors need to be explored in greater depth in future studies.

Quantitative Effectiveness of Physical Activity and Fat Loss of the Intervention

Body fat is one of the most important indicators of an individual's health status, and the role of physical activity level in body fat changes has received increasing attention. The amount of physical activity is not only an important factor influencing the change of body fat [25], but also can be used as an effective reference indicator to predict and intervene in the change of body fat [26].

Studies have shown that there are differences in the effects of different intensities of physical activity on body fat [27]. Both high-intensity interval training and moderate-intensity continuous aerobic exercise have been shown to have significant effects on body fat reduction. These types of exercise not only expend large amounts of energy

during exercise, but also further promote fat burning by increasing post-exercise oxygen consumption. Therefore, the exercise intensity and type of physical activity are closely related to the rate of change in body fat, further emphasising its significance as a reference for body fat change. The dose-effect relationship between physical activity and the rate of change in body fat is unclear^[28]. This study conducted linear regression analysis around moderate-intensity and high-intensity physical activity and body fat change rate, and found that there is a dose-effect relationship between physical activity and body fat change rate, and the current study around children^[29], the elderly^[30], so it can provide a more scientific weight loss reference for overweight and obese male college students, but due to the small sample size, the follow-up can be further improved to improve the dose-effect relationship of the Accuracy. The use of physical activity as a reference for the rate of change of body fat can provide personalised health management for different populations. By monitoring the physical activity of individuals, the level of energy consumption can be assessed, thus providing data support for body fat management; secondly, high body fat is closely related to a variety of chronic diseases^[31]. By monitoring and adjusting the amount of physical activity, the level of body fat can be effectively controlled and the risk of chronic diseases can be reduced. Future research and practice should continue to explore how to more accurately use physical activity as an indicator to optimise health intervention programmes and improve the overall effectiveness of body fat management.

Effectiveness of mobile health technology exercise interventions to improve physical health

With the popularity of smart devices, mHealth technologies are developing rapidly and are widely used around the world. These technologies help users monitor health indicators, record daily activities, get health advice, and develop personalised exercise plans in a convenient way. Common mHealth technologies include smart wearables, health tracking apps, telemedicine, and health education and motivation platforms. Wearable devices are more common mHealth devices, mainly used for daily monitoring of physical indicators^[32], to provide convenience for different groups^[33], at present the use of wearable devices to help college students to improve health behaviours of intervention experiments are still in the exploratory stage, through the study found that the use of wearable devices to monitor the daily PA is not effective in promoting changes in physical activity^{[34][35]}, this result may be related to the lack of personalised feedback after accessing wearable devices^[36, 37], whereas technologies such as mHealth apps and telemedicine are now able to provide effective assistance to patients in post-treatment rehabilitation^[13, 38], therefore, the question of whether combining wearable devices with mHealth apps can provide greater

assistance to counterparts has become an emerging one.

In traditional exercise interventions, a uniform training programme is usually adopted, and the offline intensive training has psychological and other disturbing factors for overweight and obese people^[39], which can seriously affect the health promotion effect of obese people. Compared with the traditional exercise intervention, this study measured the physical activity and various physical indicators through wearable devices^[40], combined with the first body fitness APP for overweight and obese male college students to push personalized training program feedback, and through social software for goal setting, self-monitoring and other behavioral interventions^[41], so that the training process of scientific, individualized, and achieved a good intervention effect, proving the effectiveness of mobile health technology for exercise intervention is effective^[42]. In terms of body shape, the online intervention group's body fat rate decreased by an average of 1.69% ($p < 0.01$); muscle mass increased by an average of 1,115.23g ($p < 0.01$), and there was also a significant improvement in physical fitness and physical function. Currently, although many health and fitness apps aim to promote increased physical activity or exercise participation^[43], with the primary outcome being changes in body weight^[44], few apps aim to improve the quality of functional movement and physical fitness, while meeting individual needs and providing personalised exercise guidance, so this study informs the aspect of mHealth in enhancing physical fitness.

Study strengths and limitations

This study demonstrates notable strengths, including the innovative use of mobile health technology, which enhances participant engagement and allows for real-time monitoring of physical activity, thereby fostering adherence to exercise interventions. The objective data collected from wearable devices, such as fitness trackers, ensures that physical activity measurements are accurate and reliable, minimizing the biases often associated with self-reported data. Additionally, the randomized controlled trial (RCT) design strengthens the causal relationship between the interventions and improvements in physical health metrics among overweight and obese male college students. This robust methodological approach is one of the key strengths of the study, allowing for more confident conclusions regarding the effectiveness of mobile health interventions.

However, several limitations should be acknowledged. First, the relatively small sample size may restrict the generalizability of the findings. Although the sample size was appropriate for the scope of the study, it may not fully represent the wider population of overweight and obese college students. Despite this, we believe the study's randomized design mitigates the impact of this limitation, as it reduces selection bias and increases the internal validity of the results. Additionally, the short duration of the intervention limits the ability to assess the long-term sustainability of

health benefits. The 12-week intervention period provided valuable insights into short-term changes in physical health, but further research with longer follow-up durations is necessary to evaluate the lasting effects of such interventions.

Regarding confounding factors, while we controlled for baseline physical fitness and demographic variables (such as age and BMI), there were still unmeasured factors, such as diet, sleep patterns, and genetic predispositions, that could influence the outcomes. We acknowledge that these factors were not fully controlled for in this study. However, we believe that the use of objective activity data, in combination with the randomized controlled design, reduces the impact of potential confounders on the observed effects, providing a more accurate reflection of the intervention's impact on physical health.

Moreover, the online intervention group was allowed to freely choose the order in which they completed training modules, which may have introduced variability in the intervention delivery and potentially biased the outcomes. We acknowledge this as a limitation and recommend that future studies implement a more standardized training sequence to enhance consistency across participants.

Statistically, potential multicollinearity between different exercise intensities was considered. Despite our best efforts to control for the variables involved, further studies should consider larger sample sizes and longer intervention times to better explore the role of interactions and to ensure that findings can be generalised more widely.

Conclusion

Mobile health-based technology was as effective as offline exercise interventions in improving body fat percentage and athletic quality in obese college students. There was a quantitative-effect relationship between the amount of physical activity and the amount of body fat reduction of the exercise intervention, with the rate of change in body fat increasing by 0.0690 and 0.0544 for every 1-megaton increase in moderate-intensity and high-intensity exercise time, respectively.

Online and offline training were basically similar for overweight and obese male college students in terms of improvement in body shape, physical fitness, and physical function. Therefore, online training based on mobile health technology is feasible and effective.

The dose-effect relationship between the amount of physical activity and the rate of change in body fat can provide a more scientific basis for training, develop personalised training programmes, obtain quantitative feedback on energy expenditure, and improve training efficiency. The online training in this study also introduced interventions such as wearable testing devices on top of mobile health

apps, and the effectiveness of mobile health apps as a stand-alone intervention for implementing health behaviour interventions can be explored separately in the future to continuously improve the potential functions of mobile health apps.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Materials, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the Capital Institute of Sports and registered in the Chinese Clinical Trial Registry (registration number: ChiCTR2200063892). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

QZ and ZL contributed equally to the study design, data collection, statistical analysis, and drafting of the manuscript. LJ assisted with data analysis. YG, TG, and JL assisted with data collection and implementation of the intervention. YZ and ZZ supervised the project, provided critical revisions to the manuscript, and approved the final version for submission. All authors have read and approved the final manuscript.

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Supplementary Files

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