Experimental study on physical intervention of Virtual Reality cycling on simple obese college students

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Abstract

Purpose

The aim of this study was to investigate the effectiveness of Virtual Reality (VR) cycling as an intervention for physique improvement in simple obese college students.

Methods

A literature review, questionnaire survey, and 12-week experimental comparison were conducted using mathematical statistical methods on 41 simple obese college students in Nanjing, China.

Results

The results showed that 12 weeks of VR cycling had a significant effect on fat loss and shaping in simple obese college students. The weight, BMI, waist circumference, hip circumference, and waist-to-body ratio decreased by 5.25%, 5.22%, 4.44%, 2.44%, and 2.1%, respectively, while lung capacity increased by 9.15%. Significant differences were observed within 10%, 5%, and 1%. Moreover, there were gender-based differences in the morphological changes. Men's abdominal fat consumption was slightly greater than that of women, resulting in a significant reduction in the waist and buttocks of men compared to women.

Conclusion

The study concludes that VR cycling is a more engaging and interesting intervention for fat loss and shaping than traditional aerobic exercise. By adjusting the exercise time and course difficulty, participants are more likely to adhere to the exercise regimen, leading to significant weight loss and other positive outcomes. The results of this study could be useful for designing effective interventions to improve the physique of obese individuals.

Introduction

Obesity is a pressing global health concern, with rates rising rapidly in both men and women over the past 40 years, posing a significant burden on society [1]. In addition to being overweight, obesity is also considered a “silent killer”, contributing to the development of numerous diseases such as cardiovascular diseases, type 2 diabetes, joint diseases, and certain cancers [2, 3]. Simple obesity, which accounts for about 95% of all cases of obesity, is caused by excessive accumulation of fat in the body due to excessive intake or energy consumption without other obvious causes [4]. The underlying mechanisms of simple obesity are complex and multifactorial, with factors such as daily eating habits, physical activity, psychosocial and genetic factors potentially playing a role [5]. Various weight management methods exist for simple obesity, including lifestyle changes through physical activity and dietary adjustments [6].

Virtual Reality (VR) is a technology that combines virtual and reality to create a computer simulation system that immerses the user in a virtual world [7]. VR cycling involves the user experiencing a cycling workout in a virtual reality environment. By wearing VR glasses or using camera image capture, users can ride through various scenes generated by virtual reality technology to achieve fitness and weight loss goals [8]. The technology embeds life cycling scenes into VR devices and uses holographic 3D images to create completely virtual roads that can easily integrate people, cars, and scenes, enabling users to ride freely in the virtual environment [9]. Figure 1 depicts the different VR cycling virtual scenes.

Methods

Participants

The study recruited 41 college students (25 males and 16 females) from an university in the east region of China. Inclusion criteria required participants to be between 18 and 24 years old, have no self-reported diagnosed physical or mental disability, and fluctuate within 5% of their weight in the past six months [10]. All participants provided informed consent before taking part in the experiment and were required to attend practice sessions at a designated time and place, with the option to ride at a gym or other location in case of special circumstances. None of the participants reported motion sickness or visual fatigue during the 12-week VR cycling program, which was approved by the Nanjing Sport Institute Human Experimentation Ethics Committee (serial number: RT-2022-11). The first 41 college students diagnosed with simple obesity were selected [11, 12], with an age range of 18–24 years old.

Diagnostic basis

The diagnosis of simple obesity requires meeting the following criteria:

(1) Secondary obesity must be excluded through medical history, physical examination, and laboratory testing; (2) The measured body weight must exceed 20% of the standard body weight, with fat percentages greater than 20% for men and 30% for women, and a body mass index greater than $28kg/m^2$ [13].

Requirements in VR cycling

Before starting VR riding, ensure that the resistance of the dynamic bicycle is set to zero. Adjust the seat height to be roughly the same as the hip joint to reduce pressure on the knee joint. Male cyclists should slightly tilt the seat forward and align the handlebar with the seat or keep it slightly higher. Secure the sheath on the pedal and wear cycling gloves and water glasses if necessary. During VR riding, simulate different road scenarios by adjusting the resistance. Keep the foot surface and knee joint parallel and maintain a straight line from waist to back. Bend the elbow joints slightly during cycling and avoid shaking the head. Follow the music rhythm, take small water breaks, and replenish as necessary [14, 15].

VR Cycling Applications

VR glasses can be matched with various applications to provide different cycling scenarios. Trainees can choose their preferred road scenes during weekly practices [16]. However, each cycling scene should include specific exercises, such as warm-up, standing cycling on flat roads, high-resistance climbing, sitting posture sprint, intermittent cycling, stretching, and cool-down, with each session lasting 45–50 minutes. In this study, the VR glasses (Fig. 2) and related apps (Fig. 3) used in the experiment are listed below.

Research methods

Participants completed 12 weeks of VR cycling, 3 times a week for 45–50 minutes at a fixed location. Measurements of height, weight, waist and hip circumference, BMI value, waist-hip ratio, and vital capacity were taken at the beginning, 6 weeks, and 12 weeks, and analyzed for comparison [9]. During the 12 weeks, participants refrained from other aerobic or anaerobic training. Test data was analyzed using EXCEL and Stata16.0 software.

The VR cycling program included immersive scenes such as road tracks, forest sections, mountain sections, night sections, and water sections, and included warm-up, flat road standing riding, large resistance climbing, sitting posture sprint, intermittent, and stretching [17]. Participants received dietary monitoring intervention and feedback on WeChat groups and were given simple nutrition matching and balanced diet suggestions. Participants were also advised to avoid or reduce smoking and drinking for optimal training results.

Figure 4 displays the SHUA SH-956 (China) dynamic bicycles used in the experiment, which was conducted at a fixed fitness location in a university. Participants were required to complete the practice courses in the same location, except for unforeseen circumstances. The duration and content of each VR cycling scene were different, and participants could adjust the time according to their preference, but the experiment was designed to control the duration to 45–50 minutes. The traditional dynamic cycling course was comprised of warm-up, flat road standing posture cycling, large resistance climbing, sitting posture sprint, intermittent, and stretching [18]. The VR cycling program added more realistic virtual reality scenes through VR glasses and headphones [19], as depicted in Table 1 and Fig. 5, respectively.

Table 1. Basic course contents of VR cycling mountain road.

Arrangement	Content	Duration
Warm-up	Slow rhythm music, Riding on a bike, holding one hand, the body of each joint muscles to warm up	6-7min
Riding in a standing Position on a flat road	1, 2, 3 alternate standing position riding, enter the VR scene flat road, adapt to riding, resistance increased to 3	7-8min
High resistance climb	With 3 handlebars in hand, the VR scene enters the mountain road. The resistance of the virtual mountain road increases. When riding on the top of the mountain, the resistance slowly increases by 3-8.	8-9min
Sitting sprint	Hold 1 position, VR scene enters the downhill section, virtual sprint, resistance drops to 0, feet parallel to the ground, legs swing at the fastest frequency.	7-8min
Practice periodically	1, 2, and 3 positions alternate. The VR scene enters the road with potholes, resistance 3-6, intermittent riding, alternating sitting and standing positions.	9-10min
Stretch	Enter the homing section with a one-position VR scene in hand, alternate sitting and standing positions, combine soothing music, and perform muscle stretching with 0-2 resistance.	7-8min

PS: Resistance points 0-10,10 for the maximum resistance.

Figures 5, 6, and 7 depict various virtual sections that participants enter through VR glasses during the cycling practice. By switching between different scenes, participants can have a new experience in each exercise and increase their interest and motivation in the practice.

Results

The 12-week VR cycling experiment showed a significant fat-reducing and shaping effect on simple obese college students. Participants' weight, BMI, waist circumference, hip circumference, waist-to-hip ratio all decreased significantly ($p < 0.01$), with decreases ranging from 2.1–5.25%. Lung capacity also significantly increased ($p < 0.05$) by about 9.15%. All indicators had significant differences and were statistically significant. Significant differences were found in lung capacity, weight, waist circumference, hip circumference, BMI value, waist-to-hip ratio within 10%, 5%, and 1%.

Table 2
Descriptive statistics.

Var Name	Total		Female		Male	
	Mean	SD	Mean	SD	Mean	SD
age	20.122	1.833	20.000	1.506	20.200	2.041
height	1.699	0.079	1.626	0.057	1.746	0.051
pre_weight	82.699	6.830	77.053	4.861	86.312	5.305
pre_bmi	28.652	1.580	29.165	1.813	28.324	1.348
pre_waistline	96.015	3.694	93.912	2.955	97.361	3.528
pre_hipline	95.802	2.668	94.350	1.763	96.732	2.759
pre_whr	1.002	0.014	0.995	0.017	1.006	0.010
pre_fvc	3292.098	582.268	2758.500	435.236	3633.600	367.919
N	41		16		25	

PS: N represents the number of observed values, Mean represents the mean value, SD represents the standard deviation.

Table 3
Differences in indicators before and after the experiment.

Var name	mean(pre_experiment)	mean(post_experiment)	mean-diff	t
weight	82.699	78.361	4.338***	3.040
BMI	28.652	27.157	1.495***	4.491
waistline	96.015	91.751	4.264***	5.118
hipline	95.802	93.466	2.337***	3.571
whr	1.002	0.981	0.020***	6.376
fvc	3292.098	3593.171	-301.073**	-2.297

PS: *, ** and *** represent the significance level of 10%, 5% and 1% respectively.

Table 4
Differences in indicators before and after female experiments.

Var name	mean(pre_experiment)	mean(post_experiment)	mean-diff	t
weight	77.053	73.303	3.750**	2.260
BMI	29.165	27.734	1.431**	2.473
waistline	93.912	88.969	4.944***	4.769
hipline	94.350	90.769	3.581***	5.263
whr	0.995	0.980	0.015**	2.658
fvc	2758.500	3029.500	-271.000*	-1.724

Discussion

Table 2 shows that the men in this batch of participants have a slightly higher average weight than women, while the women have a slightly higher average BMI, which is consistent with the general trend. Women also have a slightly smaller average waist circumference, hip circumference, and waist-to-hip ratio, which is related to the physiological differences between men and women, with men having an average waist-to-hip ratio exceeding 1. This ratio is an important indicator for identifying central obesity [20], which is associated with increased risk of cardiovascular diseases and diabetes in severely obese people [21]. Therefore, participants should aim to control their weight through a balanced diet and regular exercise to improve their overall health.

The study showed significant reductions in weight (5.25%), BMI (5.22%), waist circumference (4.44%), hip circumference (2.44%), and waist-to-hip ratio (2.1%) of the participants after the experiment ($p < 0.01$). Additionally, the participants' lung capacity increased significantly by 9.15% ($p < 0.05$). All indicators demonstrated significant differences and are statistically significant, with the t value of lung capacity being − 2.297 and significant within 5%.

To present the experimental data in a more intuitive way, Fig. 8 displays the data in the form of charts.

Figure 8 clearly illustrates the changes in the indices over the course of the experiment, with 1, 2, and 3 representing 6 months prior to the experiment, 6 months during the experiment, and 12 months after the experiment, respectively. The indices show a slightly linear connection, indicating the upward or downward trend of different indicators in a more intuitive way. Among them, the weight, BMI, waist circumference, hip circumference, and waist-to-hip ratio show a clear downward trend during the experimental process, which can be attributed to the relatively more time standing and riding in VR cycling. This exercise engages all parts of the body, particularly the core areas such as the waist and buttocks. The 45–50 minutes dynamic cycling class, combined with a relatively closed environment, focuses on calorie consumption, equivalent to jogging. The VR cycling course is vivid and interesting, simulating a virtual reality environment, and the rhythmic pedal frequency of the dynamic bicycles enables participants to achieve obvious weight loss effects. After 12 weeks of exercise, lung capacity demonstrated a clear upward trend. The VR cycling practice exercises the entire body, and the rhythmic music, experience of VR cycling, and the dynamic frequency of the bicycles greatly improve the participants' cardiopulmonary function, resulting in a significant improvement in the participants' indices after 12 weeks of VR cycling practice [22].

Table 4 shows that female participants experienced a significant decrease in weight before and after the experiment ($p < 0.05$), with a decrease of about 4.87%. Moreover, BMI decreased significantly ($p < 0.05$), with a decrease of about 4.91%. Waist circumference also decreased significantly ($p < 0.01$), with a decrease of about 5.26%, while hip circumference decreased significantly ($p < 0.01$), with a decrease of about 3.80%. In addition, the waist-to-hip ratio decreased significantly ($p < 0.05$), with a decrease of about 1.51%. Lung capacity increased significantly ($p < 0.1$), with an increase of about 9.82%. All indicators showed significant differences and are statistically significant. The t-values of weight, BMI, and waist-to-hip ratio are 2.260, 2.473, and 2.658, respectively, with significant differences at the 5% significant level. The t-values of waist circumference and hip circumference are 4.669 and 5.263, respectively, with significant differences at the 1% significant level. Furthermore, the t-value of lung capacity is -1.724, with a significant difference at the 10% significant level. These findings indicate that the changes in the indicators were statistically significant for female participants.

Table 5 shows that male participants experienced significant weight loss before and after the experiment ($p < 0.01$), with a decrease of about 5.46% in weight and 5.42% in BMI. In addition, their waist circumference decreased significantly ($p < 0.01$) by about 3.93%, and their hip circumference decreased significantly ($p < 0.05$) by about 1.59%. The waist-to-hip ratio also decreased significantly ($p < 0.01$) by about 2.39%, while lung capacity increased significantly ($p < 0.01$) by about 8.82%. All indicators showed significant differences and are statistically significant.

There were notable differences between men and women in the changes of indicators. From the comparison of Tables 3 and 4, it can be observed that men's weight and BMI were 0.59% and 0.51% lower, respectively, than those of women as a whole. The waist-to-hip ratio of men decreased by 0.88% more than that of women, while women's waist circumference and hip circumference decreased by 1.33% and 2.21% more than men, respectively. Additionally, the lung capacity of women increased by 1% more than that of men. The overall weight and body fat consumption of men was greater than that of women throughout the experiment, as evidenced by the different analyses of the increase and decrease of various indicators. The change in the waist-to-hip ratio of men was more significant than that of women, but the decrease in waist circumference and hip circumference of women was more obvious than that of men. This may be attributed to the inherent physiological differences between men and women. Obese men tend to have an "apple-shaped" figure, characterized by a large abdomen and buttocks with most body fat concentrated in the abdomen, resulting in a waist-to-hip ratio greater than 1. Although some women participants were obese, they had special physiological curves, leading to a smaller waist-to-hip ratio than men before the experiment, and some women had a "pear-shaped" figure [23]. It is important to note that women have a higher congenital fat content than men before the test. Throughout the experiment, VR cycling was found to be more effective in targeting the core areas of the waist, hips, and legs. Although women experienced a greater percentage decrease in their waist and hip circumference, men were found to consume more abdominal fat through VR cycling, resulting in a greater improvement in their waist-to-hip ratio compared to women. Moreover, women generally had lower lung capacity before the experiment, and the increase in lung capacity was more significant in women after 12 weeks of cycling exercise. On the other hand, men had higher lung capacity before the experiment, and some obese men had lung capacity higher than the standard value before the experiment. As a result, the increase in lung capacity for men was not as obvious as that of women. The experimental data is presented visually in the form of charts in Fig. 9.

From Fig. 9, it is evident that the trends of the red line representing men and the blue line representing women differ before the experiment (1), during the experiment (2), and after the experiment (3). While lung capacity increased, other indicators showed a decline. It is noteworthy that the decline in waist and hips was significantly greater in men compared to women, as VR riding exercises the buttocks and waist together. Since the waist-to-hip ratio is an essential indicator of central obesity, changes in waist and hips during the experiment were different between men and women, especially with respect to the waist-to-hip ratio, which exhibited significant changes. These changes can be attributed to the differences in the physiological characteristics of men and women.

Table 5
Differences in indicators before and after male experiments.

Var name	mean(pre_experiment)	mean(post_experiment)	mean-diff	t
weight	86.312	81.598	4.715***	3.373
BMI	28.324	26.788	1.537***	4.062
waistline	97.361	93.532	3.829***	3.959
hipline	96.732	95.192	1.540**	2.031
whr	1.006	0.982	0.024***	6.605
fvc	3633.600	3953.920	-320.320***	-3.095

PS: *, ** and *** represent the significance level of 10%, 5% and 1% respectively.

Table 6. Summary of experience feedback for 41 participants.

	Imagery	Consistency	Immersion	Acceptance and Satisfaction of VR Cycling
Relatively good	24	40	26	29
Generally good	13	8	13	9
Relatively poor	4	3	2	4

Table 6 summarizes the results of a post-experiment survey of 41 participants, revealing their experiences with VR cycling. Among them, 29 participants reported high levels of acceptance and satisfaction with the VR cycling experience. The interactive features of the VR system, such as cycling routes, speed, direction, and slope, fully immersed the participants in a three-dimensional virtual environment, indicating that VR cycling has great potential as an attractive form of exercise [24]. Four participants had an average experience, mainly due to the visual quality and immersion of wearing VR glasses while cycling. If funding and technology are improved in the future, the visual quality, continuity, and immersion of VR cycling will be more realistic and vivid, resulting in an even better experience for participants.

Conclusions

There are noticeable differences in the changes in body shape between male and female participants. Due to their physiological differences, the waist circumference of female participants is slightly smaller than that of men. Additionally, after 12 weeks of exercise, men tend to consume more abdominal fat than women, resulting in a significantly lower waist-to-buttock ratio for men than for women.

Compared to traditional aerobic exercise, VR riding offers a more engaging and immersive experience. The virtual riding environment simulates different terrains, and with the addition of dynamic music, it provides a motivating atmosphere that helps prevent boredom. The difficulty setting of each practice course, combined with the time limit, makes the weight loss effect more evident. These factors make it easier for participants to adhere to the complete fat loss shaping experiment.

VR cycling is an innovative approach that utilizes virtual reality technology to create a fully immersive experience for participants. By wearing VR goggles, participants are transported into a three-dimensional virtual environment, enhancing the overall experience. This technology has the potential to continually improve and evolve, providing an opportunity for further refinement and innovation in the world of fitness. Moreover, by combining technology with traditional sports, VR cycling can offer a more enjoyable and engaging exercise experience.

Shortcomings

The current limitations of the VR cycling technology used in this study are mainly due to financial and technical constraints. The virtual scenes available for cycling are limited, and the VR glasses used are of medium quality compared to other VR glasses available in the market, which affects the level of immersion, authenticity and interaction experienced by the participants. Additionally, some participants may experience dizziness or discontinuity during the exercise. In the future, with more funding available, it would be possible to develop proprietary applications that can be used with VR or AR glasses of higher quality to create a more comfortable and realistic experience for the participants.

Declarations

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Author contributions

Meng Zhao and Ying Lei conceptualized the work. Ying Lei performed literature review, drafted and revised the manuscript. Ziran Wei edited the manuscript. Ming You, and Lei Chen critically evaluated the manuscript. All authors read and approved the final manuscript.

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Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The authors hereby declare that all methods were carried out in accordance with relevant guidelines and regulations. Ethical approval was obtained from the Nanjing Sport Institute Human Experimentation Ethics Committee (Serial number: RT-2022-11). Informed consent was provided by the participants.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

VR cycling virtual scene mode.

Figure 2

Experimental VR glasses.

Figure 3

VR cycling related APP

Figure 4

Experimental cycling.

Figure 5

Waterway scene.

Figure 6

Mountain road scene.

Figure 7

Highway scene (departure section, forest section, night section).

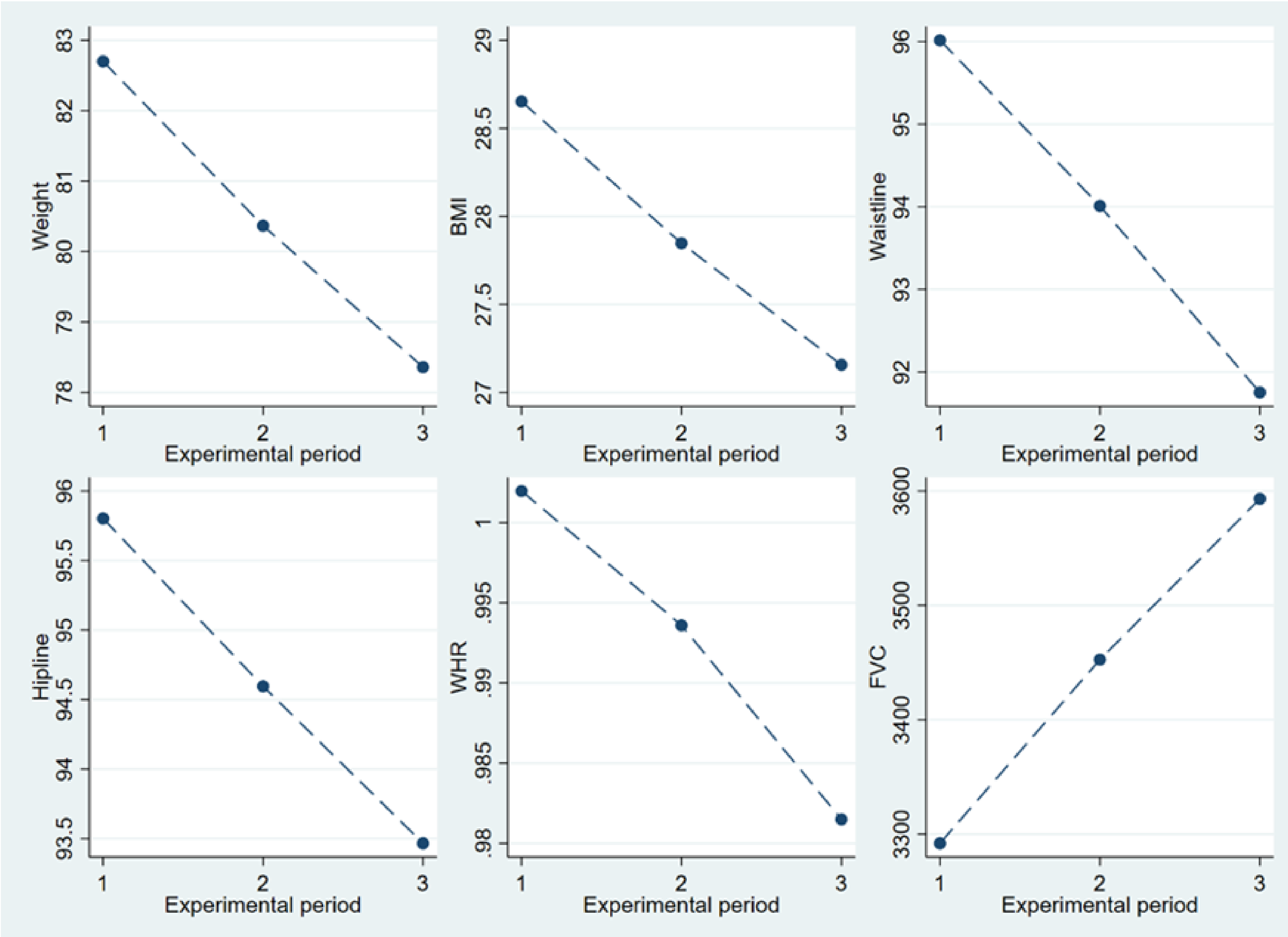

Figure 8

Differences in indicators before and after the experiment.

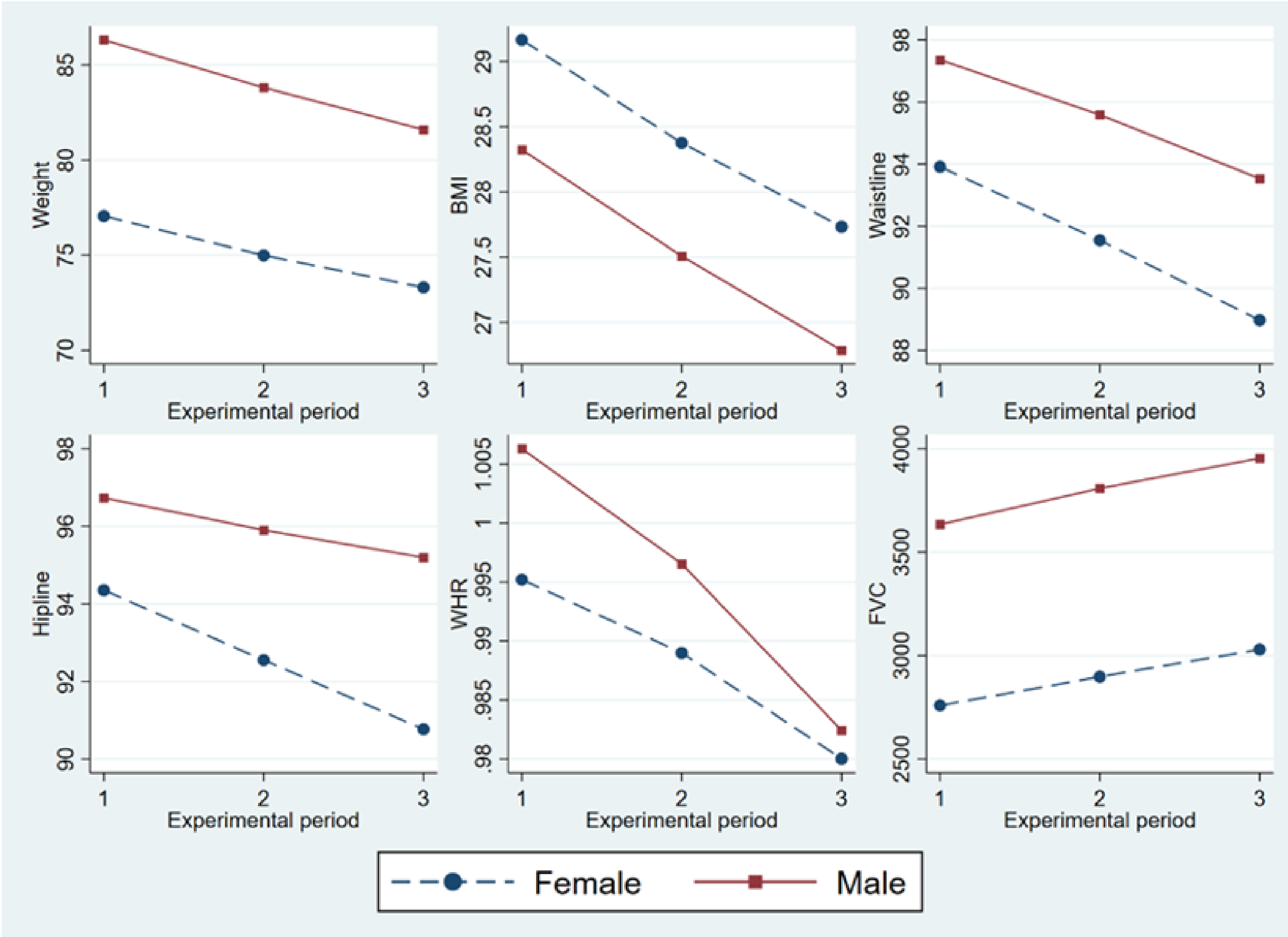

Figure 9

Differences in indicators before and after the experiment (by sex).