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Article

Virtual Reality Exercise Program Effects on Body Mass Index, Depression, Exercise Fun and Exercise Immersion in Overweight Middle-aged Women: A Randomized Controlled Trial

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Abstract: Background: This study explored the effects of a virtual reality exercise program on overweight middle-aged women. Methods: This randomized controlled trial included women 4065 years of age with a body mass index (BMI) of 23 kg/m2 or more living in D city. The virtual reality environment was set up by attaching an IoT sensor to an indoor bicycle and linking it with a smartphone, enabling exercise in an immersive virtual reality through a head-mounted display. Results: In the virtual reality exercise group, the BMI was significantly decreased after the 8-week intervention compared with the baseline value (F=100.806, p<.001). The depression scores were significantly different among the three groups, with the intervention effect being more significant in the virtual reality exercise group than in the indoor bicycle exercise and control groups (F=3.462, p<.001). Furthermore, the levels of exercise fun (F=12.373, p<.001) and exercise immersion (F=14.629, p<.001) were significantly higher in the virtual reality exercise group than in the indoor bicycle exercise and control groups. Conclusions: The virtual reality exercise program positively affected the BMI and the levels of depression, exercise fun, and exercise immersion in overweight middle-aged women. It is an effective home exercise program for obesity management in this population.

Keywords: virtual reality; exercise; overweight; body mass index; depression; immersion

1. Introduction

While rapid economic growth and urbanization have brought the conveniences of modern life, the resulting decrease in physical activity and lack of exercise has led to an increased obesity rate worldwide. More than 1 billion adults are overweight globally, with at least 300 million being clinically diagnosed with obesity [1]. Obesity increases the risk of various diseases, including hypertension, diabetes, arteriosclerosis, hyperlipidemia, cardiovascular disease, and certain cancers. With an increased risk of premature death by obesity, it is no longer a cosmetic problem but a disease threatening the welfare of people worldwide [2]. In South Korea, the Korea National Health and Nutrition Examination Survey data reported an obesity prevalence of 34.6% among adults in 2018, demonstrating a steady increase. These data also showed that the prevalence of obesity decreased with increasing age in men after age 40. In contrast, it increased with increasing age in women after age 40, suggesting the need for obesity management in midlife [3].

The reason for middle-aged women having a higher obesity rate than men of the same age is that women accumulate excessive body fat during menopause due to decreased metabolism and decreased secretion of growth hormone and estrogen, which are

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lipolytic hormones [4]. Compared with those with normal weight, middle-aged women who are overweight or have obesity have a higher risk for cancer, such as breast and ovarian cancer, and are more vulnerable to chronic diseases, such as diabetes and hypertension [5]. Obesity in women has also been found to affect the health-related quality of life due to depression and activity restriction [6]. Obesity can be said to be a negative consequence of endocrine diseases, neurological abnormalities, genetic influences, and environmental causes, including eating habits and lack of exercise, that cause imbalance in intake and consumption [7]. To overcome obesity, consistent efforts are required, including diet, exercise, and behavioral therapy for stress reduction [8]. Among them, exercise positively affects the immune function and obesity factors in middle-aged women, helps to lose weight, prevents metabolic diseases, and is important in terms of delaying aging and preventing diseases [9].

However, various factors are decreasing the exercise rate, one being the coronavirus disease 2019 (COVID-19) pandemic. In South Korea, after the first case of COVID-19 was confirmed in January 2020, the country began implementing social distancing by announcing guidelines on infection control, prevention, and behavior [10]. Social distancing is an effective strategy for reducing the spread of infectious diseases by minimizing contact between individuals and groups; however, continuous social isolation also causes various side effects such as depression, anxiety, panic disorder, and decreased physical activity [11]. Another cause of reduced exercise rate is fine dust, an environmental factor. Fine dust contains various components, such as metal, ionic, and carbon [12]. As the concentration of fine dust gradually increases over the years, the social interest in its effects on the human body is also on rise. The effects of fine dust on human health vary depending on the particulate matter size, number, and exposure time [13]. Prolonged exposure to particulate matter lowers immunity, causing acute inflammation, likely leading to respiratory diseases such as asthma and pneumonia, cardiovascular diseases, and various cancers. It also increases respiratory disease hospitalization and mortality rates [14]. The decrease in outdoor activities for these reasons is leading to a decrease in the exercise practice rate. Experts predict another infectious disease may appear after the COVID-19 epidemic and that our daily lives must prepare for such environmental changes [15]. One aspect of such changes is a shift from traditional physical activity performed outdoors or in groups to indoor exercise, particularly at home [16]. Among the various types of home exercise, including treadmill exercise, indoor cycling, yoga, and others, indoor cycling is a simple aerobic activity that can be performed at home with no spatial or temporal restrictions for busy modern people. It is also suitable for overweight people, allowing them to exercise without straining their joints [17]. However, it is important to stay interested until obtaining the desired amount of exercise, and many people are bored of repetitive routines and give up on exercise.

Recently, virtual reality indoor exercise programs have been developed to enhance the fun and interest in indoor exercise to compensate for these shortcomings [18]. Virtual reality is a core novel technology that will lead the fourth industrial revolution, this cutting-edge technology allows users to have real-world experiences by interacting in a virtual world provided by computers, similar to reality [19]. The advantage of virtual reality is that it allows one to experience the computer-generated world as if it were real, creating a sense of "being there" in users' minds and allowing them to experience immersion [20]. In addition, the level of participation is improved by improving cognition and concentration and by the pleasure of virtual reality [21]. Virtual reality-applied exercise does not have any time and space restrictions, unlike exercise in the real world, improves enjoyment and energy, and reduces fatigue [22, 23]. The fun factor of virtual reality can effectively promote immersion and enhance motivation and learning [24]. Recently, virtual reality exercise programs have been applied in various fields of the medical sector, with positive results, such as improvement in physical function and exercise performance among older adults, enhanced cognitive function in patients with dementia and stroke, and fall prevention in patients with Parkinson's disease [25-28].

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Virtual reality is applicable in various fields in the post-COVID-19 era. A new paradigm shift is required in exercise intervention methods and the change into non-face-to-face life patterns [29]. To date, no studies have investigated the application of virtual reality programs among the general public in South Korea. Therefore, in this study, we developed a new exercise intervention method that provides a virtual reality indoor cycling experience using a head-mounted display (HMD). We compared its effects with regular indoor bicycle exercise and no exercise.

2. Materials and Methods

2.1. Study design and population

The data collection of this study was conducted from February to May 2021 for overweight middle-aged women living in D City through a recruitment notice at E University Hospital. This randomized controlled trial examined the effects of an 8-week virtual reality exercise program on the body mass index (BMI) and levels of depression, exercise fun, and exercise immersion among overweight middle-aged women living in the city and compared to those with indoor bicycle exercise and no exercise (Figure 1). The study population included women 40-65 years of age with a BMI of 23 kg/m^2 or higher, who had not participated in an indoor bicycle exercise program for the past 6 months, had no visual or auditory impairment, could use a smartphone, and agreed to participate in the study. Participants with a history of psychiatric or orthopedic diseases or recent surgery, and those who complained of cybersickness and headaches, were excluded.

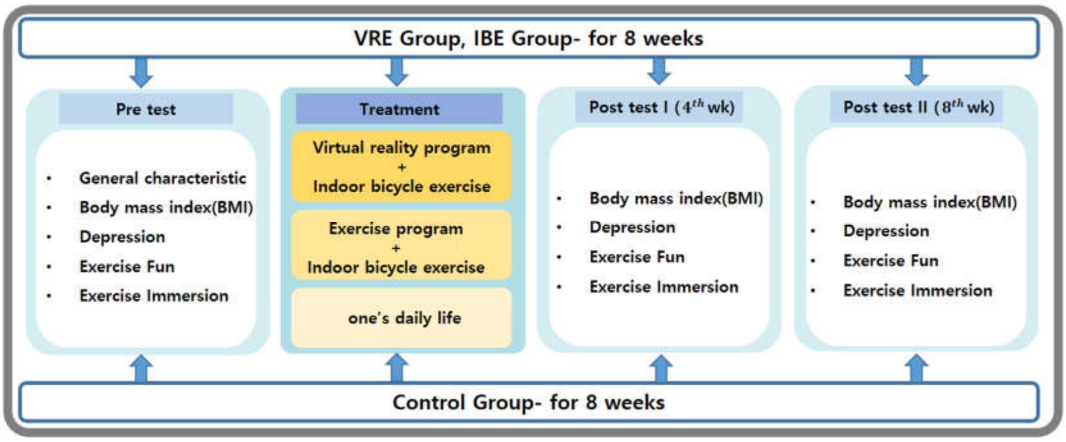

Figure 1. Study design.

2.2. Randomization

The recruitment order was coded to prevent participant allocation bias, and the participants were randomly assigned to the virtual reality exercise, indoor bicycle exercise, or control groups using the random Excel (version 19.0) function.

2.3. Interventions

The exercise program was constructed in consideration of the exercise type and intensity according to the recommendations of the American College of Sport Medicine, in consultation with an internal medicine specialist, a professor of nursing, and an exercise prescriber. Exercises suitable for overweight or people with obesity include low-impact aerobic exercises, such as walking, stationary bicycle riding, running, and swimming, which do not strain joints [31]. This study utilized indoor cycling because it does not put much strain on the joints, is easy to access, and can be performed at home. In terms of exercise intensity, low exercise intensity was applied, suitable for overweight or people with obesity [32]. The intensity of the indoor bicycle exercise was set at gear 2 (out of 10 gears), and the perceived exercise intensity was considered [33] by setting the intensity of exercise such that participants became "slightly out of breath."

The exercise program consisted of warm-up, main, and finishing exercises. Warm-up exercises consisted of warm-up stretching before exercise, which relieved the stimulation of the heart and muscles and improved exercise capacity by improving blood flow. Indoor bicycle exercise was applied as the main exercise. As a finishing exercise, cool-down stretching was performed to accelerate the decomposition of lactic acid accumulated in the blood and help with fatigue recovery after the main exercise. Since an adequate exercise time for people with obesity is 40-60 min [34], the exercise intervention in this study consisted of 10 min of warm-up, 30 min of the main exercise, and 10 min of finishing exercise, for a total duration of 50 min. As for the frequency of exercise, exercising once a week caused muscle pain and fatigue, exercising twice a week had a slight effect, and exercising more than three times a week had the maximal effect [35]. Therefore, this study performed exercises three to five times a week.

The virtual reality exercise group performed the virtual reality indoor cycling program, and the indoor bicycle exercise group performed the regular indoor cycling program. In contrast, the control group was allowed to perform daily activities for 8 weeks without an exercise intervention. The exercise program in the two exercise groups was the same as described above. The only difference is that a virtual reality environment was provided during the indoor bicycle exercise in the virtual reality exercise group. This was achieved by attaching an IoT sensor to the indoor bicycle, connected to the VRFit application downloaded on a smartphone. After setting the virtual reality background and music on the VRFit application screen, the set virtual background and music would appear. Exercise would begin when turning the bicycle pedal after attaching the smartphone to the HMD. The two groups were encouraged to exercise three to five times weekly for 8 weeks. The exercise programs were provided at home. The warm-up and cool-down stretching exercises were conducted by following the instructions on the handout provided by the author.

2.4. Outcome measurement

Before the start of the intervention, all participants underwent height and weight measurements to calculate their BMI. They also completed questionnaires on general data (marital status, education, employment, income, chronic diseases, alcohol consumption, and medication use), depression symptoms over the past 2 weeks, and the amount of fun and immersion related to daily exercise. The BMI and levels of depression, exercise fun, and exercise immersion were measured in the same way at weeks 4 and 8 from the start of the intervention in all three groups.

2.4.1. BMI

A manual extensometer and a digital scale for weight measurement were used for height measurement (H5, CAS, Seoul, China). The BMI was calculated as follows: BMI = weight (kg)/[height (m)]^2.

2.4.2. Depression

The Korean version of the Patient Health Questionnaire-9 (PHQ-9) was used to measure the level of depression. The PHQ-9 is a depression scale based on the Diagnostic and Statistical Manual of Mental Disorder, 4th Edition. The scale consists of a total of nine items scored on a four-point Likert scale (0-3), with 3 indicating "almost every day" and 0 indicating "never." The total score is 27 points, with a higher score indicating more severe depressive symptoms. The scale's reliability was assessed as high, with Cronbach's alpha of .80, with the same findings in this study (Cronbach's α =.80).

2.4.3. Exercise fun

A numeric rating scale was used to measure the subjective level of exercise fun. The following four items were rated on a scale from 0 to 10: 1) Exercise is fun; 2) Exercise made me feel good; 3) Exercise relieved stress; and 4) Exercise made me feel happy. The total score ranged from 0 to 40 points, with higher scores indicating a higher level of exercise fun.

2.4.4. Exercise immersion

To measure exercise immersion, we used the Sports Immersion Scale, developed by Jung Yong-gak (1997), through modification of the Expansion of Sport Commitment Model scale developed by Scanlan, Carpenter, Schmidt, and Keeler (1993). The scale consists of 12 items in two cognitive and behavioral immersion areas. Each item was scored on a five-point Likert scale (1-5), with "1" indicating "strongly disagree," and 5 indicating "strongly agree." The total score ranged from 12 to 60 points, with a higher score indicating a higher level of exercise immersion. The scale's reliability was assessed as high, with Cronbach's alpha of .86-.94, with similar findings in this study (Cronbach's α =.94).

2.5. Sample size calculation

The sample size for this study was calculated using the G-Power 3.1.9 program. By selecting repeated measures analysis of variance (ANOVA) and setting the effect size [30] at 0.2, significance level at 0.05, power at 0.9, number of groups at 3, and number of measurements at 3, the obtained number of samples was 69. To account for a 10% dropout rate during the intervention, the final sample size was defined as 75.

2.6. Statistical analysis

All data were analyzed using IBM SPSS Statistics for Windows version 26.0. The participants' general characteristics were analyzed by frequency, percentage, and average, and the homogeneity of the general characteristics was analyzed using ANOVA and the χ2-test. Prior homogeneity of the dependent variables of the three groups was analyzed using ANOVA. The three groups were compared using ANOVA to verify the post-intervention effects, and post-hoc analysis was conducted using Scheffé's method. Repeated measures ANOVA was employed to test the effect difference according to the time change. When the sphericity was not satisfied due to the sphericity test, Wilks' Lambda multivariate verification was performed for analysis. The effect sizes of group and time were analyzed with partial eta square (partial η^2). to explain the degree of influence of the independent variable on the dependent variable,

3. Results

3.1. Homogeneity of the participants' general characteristics and prior dependent variables

A total of 75 participants were recruited, 25 in each group. During the study, two participants in the virtual reality exercise, one in the indoor bicycle exercise, and two in the control group dropped out. Thus, 70 participants completed the study; 23 in the virtual reality exercise, 24 in the indoor bicycle exercise, and 23 in the control group (Figure 2).

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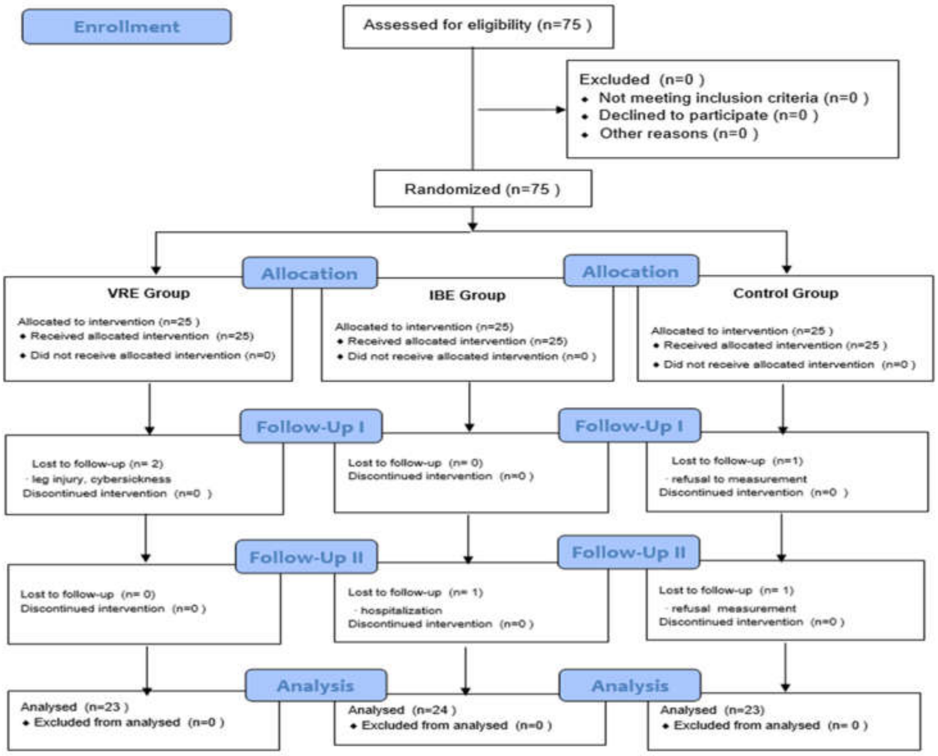

Figure 2. Flow diagram.

There was no significant difference in the general characteristics among the three groups at baseline, indicating homogeneity. Further, the one-way ANOVA for homogeneity of the dependent variables showed no significant differences in the BMI or the level of depression, exercise fun, and exercise immersion, indicating homogeneity of the three groups (Table 1).

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Table 1. Homogeneity of the participants' characteristics and dependent variables among groups (N=70).

Variables	Category	VRE(n=23) M (SD) or n (%)	IBE(n=24) M (SD) or n (%)	Control(n=23) M (SD) or n (%)	X^2 or F	*p*-value
Age (y)		47.74±5.50	49.00±6.77	48.26±7.56	0.213	.809
Marital status	Married	20 (87.0)	18 (75.0)	17 (73.9)		
	Single	2 (8.7)	5 (20.8)	4 (17.4)		
	Divorced	0	0	1 (4.3)		
	Widow	1 (4.3)	1 (4.2)	1 (4.3)	3.55	.742
Education	Less than high school	7 (30.4)	9 (37.5)	4 (17.4)		
	More than college	16 (69.6)	15 (62.5)	19 (82.6)	2.385	.303
Employment	Yes	17 (73.9)	19 (79.2)	15 (65.2)		
	No	6 (26.1)	5 (20.8)	8 (34.8)	1.175	.556
Income (won/month)	< 3,000	4 (17.4)	8 (33.3)	6 (26.1)		
	3,000–6,000	11 (47.8)	10 (41.7)	9 (39.1)		
	> 6,000	8 (34.8)	6 (25.0)	8 (34.8)	1.858	.762
Alcohol consumption	Yes	12 (52.2)	14 (58.3)	14 (60.9)		
	No	11 (47.8)	10 (41.7)	9 (39.1)	0.376	.829
Disease	Yes	4 (17.4)	7 (29.2)	7 (30.4)		
	No	19 (82.6)	17 (70.8)	16 (69.6)	1.252	.535
Drug use	Yes	5 (21.7)	8 (33.3)	5 (21.7)		
	No	18 (78.3)	16 (66.7)	18 (78.3)	1.110	.574
BMI		26.04±2.25	25.07±2.00	25.39±1.67	0.56	.242
Depression		5.48±4.50	5.92±3.22	6.00±2.84	0.14	.869
Exercise fun (NRS)		17.57±8.78	21.42±8.21	16.04±9.55	2.31	.107
Exercise immersion		30.00±7.20	32.54±8.61	28.57±8.41	1.45	.241

3.2. Outcome variables

The study outcomes in all three groups are presented in Table 2.

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Table 2. Comparison of BMI, depression, exercise fun, and immersion among groups (N=70).

Variables		VRE(n=23)	IBE(n=24)	Control(n=23)	F	*p*	F**(*p*)
BMI (kg/m2)	Baseline	26.04±2.25	25.07±2.00	25.39±1.67	1.45	.242	Time 109.302 (*p*<.001)
	After 4 weeks	25.35±2.09	24.86±1.97	25.40±1.07	0.57	.568	G*T 59.491 (*p*<.001)
	After 8 weeks	24.65±1.96	24.70±1.81	25.43±1.78	1.302	.279	Group 0.548 (*p*=.581)
	Difference (baseline vs. week 8)	1.39±0.40[a]	0.38±0.38[b]	0.04±0.26[c]	100.806	<.001	(Scheffé a>b>c)
Depression	Baseline	5.48±4.50	5.92±3.22	6.00±2.84	0.14	.869	Time 16.731 (*p*<.001)
	After 4 weeks	3.05±1.89	5.54±3.51	5.91±3.84	5.47	.006	G*T 3.462 (*p*=.010)
	After 8 weeks	2.48±1.47[a]	4.17±2.71[ab]	5.30±3.13[b]	7.22	.001	Group 3.555 (*p*<.001)
Exercise fun	Baseline	17.57±8.78	21.42±8.21	16.04±9.55	2.31	.017	Time 8.571 (*p*<.001)
	After 4 weeks	29.61±5.47	18.88±6.65	15.35±10.28	21.31	<.001	G*T 12.373 (*p*<.001)
	After 8 weeks	32.83±4.61[a]	18.92±7.10[b]	16.00±10.50[b]	30.85	<.001	Group 14.052 (*p*<.001)
Immersion	Baseline	30.00±7.20	32.54±8.61	28.57±8.42	1.45	.242	Time 7.163 (*p*=.002)
	After 4 weeks	42.91±5.49	29.38±7.57	26.86±9.64	28.62	<.001	G*T 14.629 (*p*<.001)
	After 8 weeks	45.91±5.95[a]	29.13±6.84[b]	27.65±8.90[b]	44.30	<.001	Group 21.219 (*p*<.001)

** Repeated measures analysis of variance

a, b, c [please define the meaning of these footnotes]

3.2.1. BMI

At baseline, the average BMI among all participants was 25.49 kg/m², and the average body weight was 65.08 kg.

In the virtual reality exercise group, the mean BMI decreased from 26.04 kg/m² at baseline to 25.35 kg/m² at week 4 and 24.65 kg/m² at week 8, with a statistically significant difference between the baseline and 8-week values (F=100.806, p<.001). In the indoor bicycle exercise group, the BMI also decreased from baseline to week 8, but the difference was not statistically significant. In the control group, no changes in BMI were observed over the 8 weeks.

In the comparison among groups, there were no significant differences in the BMI among the three groups at any of the three measurement points (baseline, week 4, and week 8). However, repeated measures ANOVA showed a significant difference in the group-time interaction (F=59.491, p<.001). The partial eta-squared, the effect size of the virtual reality exercise program according to group and time point, was .640.

3.2.2. Depression

The depression scores decreased from baseline to week 8 in all three groups, with the most significant difference in the virtual reality exercise group (5.48±4.50 at baseline vs. 2.48±1.47 at week 8). At baseline, there was no significant difference among the groups; however, the depression scores at week 4 (F=5.47, p=.006) and week 8 (F=7.22, p=.001) showed a statistically significant difference among the three groups. Repeated measures ANOVA showed a significant difference in the group-time interaction (F=3.462, p=.010). The effect size of the virtual reality exercise program according to group and time point was .094.

3.2.3. Exercise fun

From baseline to week 8, the total exercise fun score increased in the virtual reality exercise group (17.57±8.78 vs. 32.83±4.61) and decreased in the indoor bicycle exercise group (21.42±8.21 vs. 18.92±7.10); no differences were observed in the control group. Furthermore, at baseline, there was no significant difference among the groups; however, the total exercise fun scores at week 4 (F=21.31, p<.001) and week 8 (F=30.85, p<.001) showed a statistically significant difference among the three groups. Repeated measures ANOVA showed a significant difference in the group-time interaction (F=12.373, p<.001). The effect size of the virtual reality exercise program according to group and time point was .273.

3.2.4. Exercise immersion

Similar to the exercise fun score, from baseline to week 8, the exercise immersion score increased in the virtual reality exercise group (30.00±7.20 vs. 45.91±5.95) and decreased in the indoor bicycle exercise group (32.54±8.61 vs. 29.13±6.84). No notable differences were observed in the control group. In addition, at baseline, there was no significant difference among the groups; however, the exercise immersion scores at week 4 (F=28.62, p<.001) and week 8 (F=44.30, p<.001) showed a statistically significant difference among the three groups. Repeated measures ANOVA showed a significant difference in the group-time interaction (F=14.629, p<.001). The effect size of the virtual reality exercise program according to group and time point was .307.

4. Discussion

The results of this randomized controlled trial showed that the 8-week virtual reality exercise program positively affected the BMI and the levels of depression, exercise fun, and exercise immersion in overweight middle-aged women.

A significant interaction was observed between time and the groups, including a difference in all three groups' BMI, following the 8-week intervention. After 8 weeks of exercise, the mean BMI and body weight decreased by 1.39 kg/m^2 and 3.5 kg in the virtual reality exercise group and by 0.38 kg/m^2 and 0.95 kg in the indoor bicycle exercise group, respectively. In previous studies that applied an exercise intervention for 8 weeks, the weight decreased by 1 kg with a fast walking exercise [36]. The BMI decreased by 0.5 kg/m^2 and 1.36 kg/m^2 with rhythmic gymnastics exercise [37] and combined exercise [38], respectively, indicating a significant effect of an 8-week exercise on the BMI and body weight. In particular, the post-hoc analysis in this study revealed a significant difference between the virtual reality exercise and indoor bicycle exercise groups. Even with the same indoor bicycle exercise, the exercise intervention using virtual reality was more effective. Virtual reality exercise program implemented in various age groups, such as college students [39], middle-aged adults [40], and older adults [25,41], had a positive effect

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on calorie consumption, improvement of physical function, and improvement of muscle strength and exercise function. Our findings indicate that the virtual reality exercise program used in this study can have a more significant positive effect on body weight and BMI than the indoor cycling exercise alone by increasing the exercise effect. In conclusion, the virtual reality exercise program was effective as an at-home workout program as the BMI decreased significantly compared to that in the indoor bicycle exercise and control groups after 8 weeks of exercise.

In this study, depression symptoms were measured and analyzed using the Korean version of the PHQ-9. The average depression score at baseline was 5.8, suggesting that the exercise program participants had mild depression. After the 8-week intervention, the number of participants with a PHQ-9 score of 5 or higher decreased from 11 to one in the virtual reality exercise group and from 16 to 8 in the indoor bicycle exercise group. Additionally, there was a significant difference in the depression scores among the three groups; compared with the indoor bicycle exercise and control groups, the virtual reality exercise group showed a statistically significant decrease in depression scores after the intervention. Therefore, the exercise intervention using virtual reality was found to be more effective in reducing depression. It is difficult to identify the underlying mechanism by which the virtual reality exercise program improved depressive symptoms as it involves psychological and neurobiological interactions. However, this is a common result, with several studies reporting a more significant effect on depression when virtual reality training was applied to patients with stroke [42], adults 19-50 years of age [43], and older adults [44,45]. A virtual reality exercise program seems to be an effective intervention method for reducing depression. Virtual reality enables users to indirectly experience situations that are not easy to experience. The audiovisual stimuli received through the screen may have aroused interest, with the interaction pleasure having a psychologically positive effect on depression.

Regarding the levels of exercise fun and exercise immersion in this study, the interaction between time and group was significant, indicating a difference in exercise fun and exercise immersion scores among the three groups according to time. The application of an exercise intervention using a virtual reality therapy method was effective as the post-hoc analysis revealed a significant difference between the virtual reality exercise and indoor bicycle exercise groups. As one of the technological fields that will lead the next generation, virtual reality attracts attention as a technology that can provide new fun and value [46]. In three-dimensional virtual space, participants indirectly experience situations that cannot be experienced in the real world, and the experience of realism and immersion amuses them [47]. In this study, a virtual reality program provided indirect experiences of various environments for the exercise. The fun factor of the exercise was increased by the sense of interaction with the surrounding environment. In a previous study on exercise immersion, applying virtual reality to a cycling exercise game increased immersion, which motivated participants in the virtual reality group to move a longer distance [48]. In addition, a virtual reality program using a sensor designed to capture physical movements allowed participants to immerse themselves in the virtual reality world easily, and participants could become more actively engaged in the experience [49]. In this study, a sensor capturing participants' movement was mounted on an indoor bicycle to increase the effectiveness of exercise immersion in the virtual reality world. Wearing the HMD disconnected participants from the outside world, and they perceived the surrounding environment to be changed by their actions as if they were exercising in the real world, which increased exercise immersion and its effects.

There are several limitations to the study. While the duration of the intervention was the same as the exercise program, the prolonged experimental period made it difficult to control for differences in individual living environments and diets, which may have affected the variables. Furthermore, when applying immersive virtual reality, it was difficult for participants to observe surrounding objects, predisposing them to possible cybersickness and requiring the investigator's attention. For the virtual reality exercise program to be continuously applied and promotion of the continuation of exercise, it is necessary to further develop various programs.

5. Conclusions

The virtual reality exercise program used in this study effectively reduced the BMI and the level of depression, increased the level of exercise fun and exercise immersion, and the exercise effects in overweight middle-aged women. However, the continuity of these effects require further verification through repeated studies in the future. Nonetheless, increasing the fun of exercise and immersion can be used as an intervention for improving the BMI and reducing depression in overweight middle-aged women.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of University E (EUIRB 2020-063). The study was conducted after registration with the Clinical Research Information Service (ID: PRE20210219-009). The purpose of the study was explained in detail to all recruited participants before they agreed to participate. They were allowed to decide whether to participate or not. The consent form described the possibility of participation and withdrawal from the study, adverse effects, and how to cope with adverse effects. It was explained that the collected data will be coded according to the personal data guidelines, used for approximately 1 year, and be permanently deleted after a storage period of 3 years.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.
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