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ORIGINAL RESEARCH

Effects of a Mobile-Health Exercise Intervention on Body Composition, Vascular Function, and Autonomic Nervous System Function in Obese Women: A Randomized Controlled Trial

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Purpose: The present study verified the effect of an m-health exercise intervention using a 12-week exercise program on body composition, vascular function, and the ANS.

Patients and Methods: Thirty obese adult women participants were randomized (n = 15 each) into the experimental (EXP) group, those who performed mobile-health (m-health) exercises using a wearable device (Charge 4, Fitbit, USA) and AI-fit web page, or the control (CON) group, those who continued their daily activities as before. Muscle function, cardiorespiratory endurance, and flexibility were assessed during the exercise program using the AI-fit web page and wearable device. The EXP group participated in exercise interventions using the m-health system for 12 weeks, while the CON group was encouraged to maintain their normal daily routines. Body composition, vascular function, and autonomic nervous system (ANS) were evaluated before and after the intervention.

Results: Significant decreases were noted in fat mass (Post - Pre: −1.47 kg; $p < 0.001$) and percent body fat (Post - Pre: −2.11%; $p < 0.05$). Flow-mediated dilatation (Post - Pre: 2.63%; $p < 0.001$) was significantly increased, and brachial-ankle pulse wave velocity (Post - Pre: −91.49 cm·sec^{-1}; $p < 0.01$) was significantly decreased. RMSSD (Post - Pre: 10.43 ms; $p < 0.01$), NN50 (Post-Pre: 24.04; $p < 0.05$), pNN50 (Post - Pre: 7.70%; $p < 0.05$) and HF (Post-Pre: 179.60 ms^2; $p < 0.05$) increased significantly.

Conclusion: In conclusion, m-health exercise interventions using AI fit and wearable devices are effective in preventing obesity and improving vascular function, and ANS.

Keywords: mobile health, pulse wave velocity, flow-mediated dilation, autonomic nervous system, obese women

Introduction

The World Health Organization (WHO) defines obesity as a complex multifactorial disease characterized by excessive fat that can harm health and a risk factor for various diseases.[1] About a third of the world's population is classified as overweight or obese, and the incidence of obesity continues to increase.[1,2] Previous studies reported that the prevalence of obesity was higher in women than men, and women were expected to continue to be higher than men until 2025.[2,3] Obesity causes cardiovascular disease (CVD) complications, such as coronary artery disease, hypertension, type 2 diabetes, and dyslipidemia, the leading causes of early death.[4,5]

Atherosclerosis is a risk factor for CVD and all-cause death.[6] Obesity lowers the endothelial function of the arterial blood vessels, reducing the bioavailability of nitric oxide and causing various diseases such as vascular inflammation, vasoconstriction, and thrombosis.[7] Blood vessel elasticity decreases due to increased inflammation and decreased endothelial cell function

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due to obesity. As a result, blood vessel stiffness increases, causing arteriosclerosis, which can increase the prevalence of CVD.[7–9] CVD is a major cause of death whose prevalence is higher in women than that in men.[10]

Obesity can contribute to mental health issues such as depression and anxiety, which can further impact a woman's overall well-being and quality of life.[11] The autonomic nervous system (ANS) maintains homeostasis in response to internal and external stimuli.[12] However, obesity complicates the activation of the sympathetic and parasympathetic nerves (functions of the ANS) and decreases heart rate variability (HRV).[13] A decrease in HRV indicates impaired ANS function, which causes problems in cardiovascular control and leads to diseases such as hypertension, insulin resistance, and dyslipidemia.[4] Therefore, an effective method is needed to prevent CVD through vascular and ANS functional management by treating obesity.

Addressing obesity through lifestyle changes, such as a regular physical activity, can significantly reduce the risk of these health problems. Physical activity reportedly improves obesity, CVD, chronic diseases, and quality of life.[14–19] With the recent development of information and communication technology, these physical activities can be performed non-face-to-face through mobile health (m-health) offerings using wearable devices such as smartphones and smartwatches with the recent development of information and communication technology.[20,21] Wearable devices can continuously monitor an individual's physical activity and health status.[22] They can also provide customized interventions to increase physical activity in conjunction with various types of m-health offerings.[23] A previous study of a wearable device reported a decreased body weight and an increased amount of physical activity by intervention with moderate- to vigorous-intensity physical activity[24,25] while another study reported improved blood pressure and body mass index (BMI).[26]

Obese women must work with a healthcare professional to develop a tailored plan to achieve and maintain a healthy weight. Previous studies were limited by whether participants performed an exercise intervention in conjunction with mobile apps for wearable devices.[27] Feedback was provided using phone calls and e-mails to achieve exercise performance during non-face-to-face exercise interventions.[27] Therefore, this study verified the effect of an m-health exercise intervention using a 12-week exercise program on body composition, vascular function, and the ANS.

Materials and Methods

Participants

In this study, the sample size was selected as follows according to the intention to improve the power to 95% or more. According to the previous study, the effect size of the moderate- to high-intensity physical activity variable was 0.57.[28] On the G-power test with $\alpha = 0.05$, β (power) = 0.85, number of groups = 2, and number of repeated measurements = 2, a total of 10 sample sizes were calculated. However, 30 participants were selected considering the number of dropouts during the 12-week exercise intervention period. This clinical trial was conducted for 12 weeks from February 12, 2022, to May 30, 2022. The participants in this study were 30 obese adult women with a percent body fat ≥ 30% who were randomly assigned to the experimental (EXP) group or control (CON) group. All participants' health problems were identified using the Physical Activity Readiness Questionnaire for Everyone (Table 1). The exclusion criteria were as follows: limited physical activity by a doctor's prescription, scheduled to undergo surgery or rehabilitation, and current pregnancy (Figure 1). This study was approved by the Institutional Review Board of Konkuk University (7001355–202112-HR-491) and Clinical Research Information Service (KCT0007125).

Table 1 Subjects' Characteristics

Variable	EXP (n = 15)	CON (n = 15)	*p* value
Age (years)	39.70 ± 10.07	39.20 ± 11.63	0.910
Height (cm)	161.28 ± 6.19	160.49 ± 7.12	0.757
Weight (kg)	66.07 ± 10.67	66.79 ± 10.20	0.853
Percent body fat (%)	37.59 ± 5.62	36.52 ± 4.76	0.579

Note: Values are expressed as mean ± standard deviation.
Abbreviations: CON, control group; EXP, experimental group.

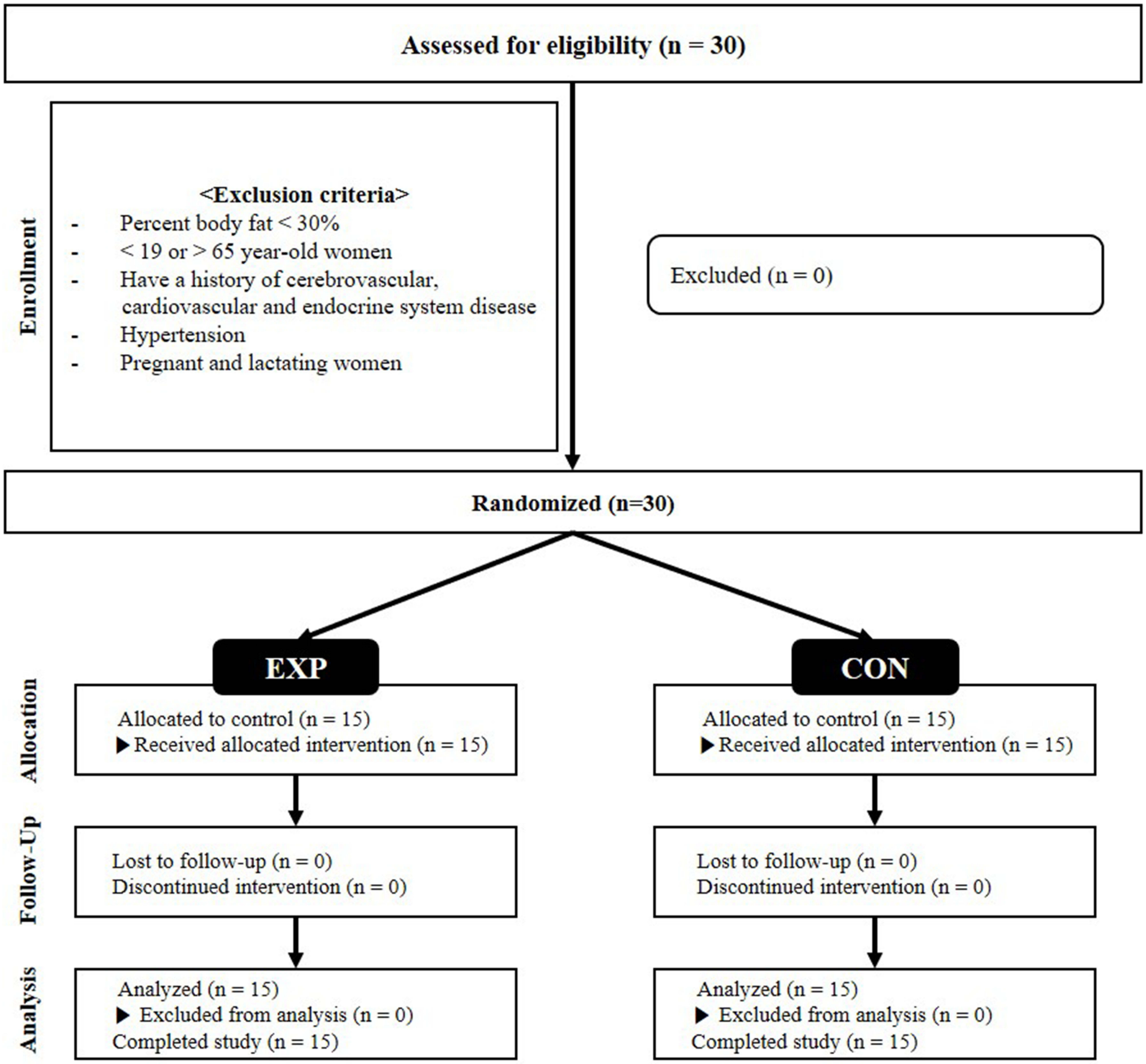

Figure 1 A brief outline of the study design.

Study Design and m-Health Exercise Intervention Program

The EXP was performed non-face-to-face using an m-health exercise intervention. The CON group was encouraged to maintain their normal daily routines during the intervention period. This study conducted a pre-test (0 weeks) and post-test (12 weeks) to examine the effects of the 12-week m-health exercise intervention. All subjects visited the laboratory after fasting for more than 8 h and underwent body composition, blood pressure, arterial stiffness, vascular endothelial function, and ANS measurements. The exercise program was designed with the goal of 3000 Metabolic Equivalent Tasks (MET)-min/week, which means high-intensity physical activity, among the MET-min values surveyed using the International Physical Activity Questionnaires-Short Form questionnaire, Korean version.[29] The participants achieved a high rate of 85% of their target physical activity. The exercise program provided muscle function (muscle strength and muscular endurance) (OMNI scale 7–8), cardiorespiratory endurance (60–85% of the maximal heart rate [HRmax]), and flexibility exercise.[30,31] Muscle function exercises were performed twice a week for 60 min (eg, 10 min of warm-up, 40 min of the main exercise, and 10 min of cool-down) and consisted of 10 movements.[30] Muscle function exercises included push-ups, side banding, arm curls, lunges, squats, donkey kicks, leg raises,

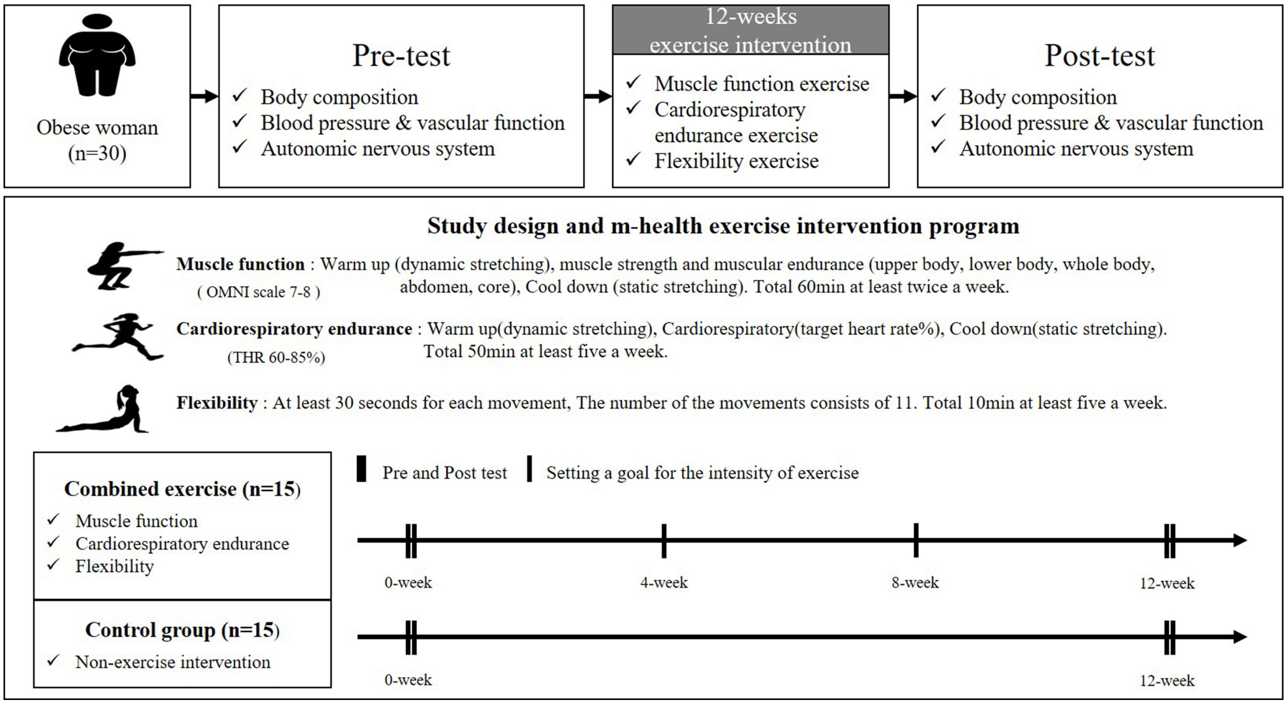

Figure 2 Overview of the study design.

burpee tests, bridging, and planks. Cardiorespiratory endurance exercises were performed five times a week for 50 min (eg, 10 min of warm-up, 30 min of the main exercise, and 10 min of cool-down). Cardiorespiratory endurance exercises included cycling and walking. Flexibility exercises were performed five times a week for 10 min (at least 30s for each movement) and included 11 movements. Flexibility exercises included stretching the inside of the legs, stretching the fronts of the legs, stretching the backs of the legs, stretching the hip, stretching the sides, stretching the stomach, stretching the lower arm, stretching in front of the chest/shoulder, stretching on the back/shoulders, and stretching the neck. The detailed study design and exercise program are shown in Figure 2.

In this study, participants' physical activity data (kcal/day) were tracked using the Fitbit Charge 4 and Fitbit app. The Fitbit Charge 4 has been validated by numerous studies and is a proven wearable device that can track HR, walking steps, and physical activity.[25,32,33] The data tracked using Fitbit were linked to the AI Fit webpage (AI-fit) through the synchronization process. The AI-fit implemented the linked data so that participants could check the amount of physical activity, HR during exercise, and exercise record (muscle function, cardiorespiratory endurance, and flexibility exercises). In addition, the EXP group performed exercise programs while watching videos and were able to exchange feedback on exercise performance through a mobile chat program (Kakao Talk, Korea; https://www.kakao.com/talk) linked to AI fit. In contrast to previous studies of non-face-to-face exercise interventions, physical activity can be tracked and feedback provided through AI-fit and Fitbit using the targeted exercise intensity.[34–36]

Body Composition

Body composition was measured using the Inbody 770 body composition analyzer (Inbody, Seoul, Korea) and a tape measure at the top and bottom of the light. Participants fasted for more than 8 h the day before the test and restricted their active physical activity for 48 h. Each participant was barefoot and metal material attached to the body was removed before the measurement. Height, body weight, BMI, fat-free mass (FFM), fat mass (FM), skeletal muscle mass (SMM), and percentage body fat (%BF) were measured.

The waist-to-hip ratio (WHR) was measured using a tape measure to determine waist and hip circumferences. Waist circumference was measured by asking the subject to stand upright with their arms crossed over their chest and then measuring the waist, the thinnest part between the ribs and long bones of the subject. The tape measure was placed on a horizontal plane and the circumference measured twice during the last stage of normal expiration, and a good score was recorded in units of 0.1 cm. The hip circumference was measured at the widest part of the back of the subject's buttocks after the subject crossed over arms over their chest and stood upright. The tape measure was placed on a horizontal plane and the circumference measured twice; a good score was recorded in units of 0.1 cm. WHR was calculated using the waist/hip circumference formula.

Blood Pressure and Vascular Function

Blood pressure, systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure (MAP), and pulse pressure (PP) were measured using a blood pressure monitor (HBP-9020; Omron, Tokyo, Japan). After resting for at least 5 min, the participants sat in a chair and their right arm was measured at the same height as the heart by automatic pressurization. Blood pressure was measured twice at 5-min intervals and the average value was used.

Brachial-ankle pulse wave velocity (baPWV) was measured using a VP-1000 plus (Omron, Tokyo, Japan). Each participant wore a sensor cuff on the upper arm and ankle after lying on the bed and resting for at least 30 min before the test.

In the case of vascular endothelial cell function in the arterioles, flow-mediated dilatation (FMD) was measured using a noninvasive Doppler ultrasound instrument (UNEXEF38G; Unex, Tokyo, Japan). After resting for at least 30 min before the test, each subject lay down on the bed and the diameter of the medial muscle artery was measured using a Doppler device by placing the ultrasound device on the brachial artery 3–5 cm above the right elbow. After the measurement, the blood flow was occluded for 5 min at an appropriate pressure (mmHg) for the person taking the measurement based on the blood pressure at rest. After 5 min, the pressure was removed and the blood flow velocity and vessel diameter of the brachial artery were automatically recorded for 2 min. The formula used was %FMD = (maximal diameter [mm] - resting diameter [mm]/resting diameter [mm]) × 100.

Autonomic Nervous System

HRV was measured using an HR monitor (Polar V800; Polar, Kempele, Finland). For 48 h before the test, the participants refrained from vigorous physical activity and alcohol intake. After the participant rested for at least 30 min before the measurement, the HR sensor was worn on the chest in a quiet room with no noise while sitting in a chair and resting for 5 min. The R-R interval was measured and stored for 15 min when the HR was maintained at a constant level. The measured R-R interval data were analyzed using the Kubios HRV (version 3.3.1) program. The analyzed data were the time domain (standard deviation of the interval [SDNN], the square root of the mean of the sum of the squares of differences between adjacent NN intervals [RMSSD], the number of interval differences of successive NN intervals greater than 50 ms [NN50 count], the proportion derived by dividing NN50 by the total number of NN intervals [pNN50]), and frequency domain (total power [TP], very low frequency [VLF], low frequency [LF], high frequency [HF]).

Statistical Analysis

For all data obtained in this study, the mean and standard deviation for each item were calculated using SPSS 26 (SPSS Institute, IBM Corp., Armonk, NY, USA). The assumptions of normality and equal variance for parametric statistical analysis were verified using the Shapiro–Wilk test for all dependent variables. Two-way analysis of variance by repeated measurements was conducted to verify the interaction effect before and after training and to the group. A paired *t*-test was conducted to examine changes according to training within the group. The significance level for all statistical treatments was set at $p < 0.05$.

Results

There were significant interactions and main effects on total energy consumption as well as group main effects on physical activity (Table 2). In the post-hoc analysis, the total energy expenditure (364.17 kcal/day, $p < 0.001$) of the EXP group significantly increased, while there was a significant intergroup difference in the amount of physical activity in the pre- (EXP - CON: 119.9 kcal, $p < 0.01$), middle- (EXP - CON: 158.24 kcal, $p < 0.001$), and post-intervention (EXP - CON: 181.54 kcal, $p < 0$ 0.001) tests.

There were interaction and main effects for FM, and interaction effects were observed in %BF and SMM (Table 3). The post-hoc analysis revealed a significant decrease in FM (Post - Pre: −1.47 kg, $p < 0.001$) and %BF (Post - Pre: −2.11%, $p < 0.05$) in the

Table 2 Changes in Total Energy Consumption and Physical Activity Among Obese Women During the Intervention Period

Variable	EXP			CON			p value (η^2)		
	Pre-Test	Middle-Test	Post-Test	Pre-Test	Middle-Test	Post-Test	T	G	I
Total energy expenditure (kcal/day)	2004.70 ± 337.00*	2240.51 ± 352.51***	2368.87 ± 245.77***	1679.31 ± 184.39	1801.50 ± 36.60	1749.19 ± 43.39	0.000† (0.397)	0.001† (0.212)	0.001† (0.580)
Physical activity (kcal/day)	348.35 ± 119.92**	395.20 ± 105.61***	409.58 ± 89.83***	228.45 ± 61.22	236.95 ± 39.94	228.04 ± 50.19	0.133 (0.072)	0.000† (0.593)	0.173 (0.062)

Notes: Values are expressed as mean ± standard deviation. †Significant interaction or main effect. *p < 0.05, **p < 0.01, ***p < 0.001, significant difference between groups.
Abbreviations: CON, control group; EXP, experimental group; G, group; I, interaction; T, time.

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Table 3 Changes in Body Composition Between Pre- and Post-Intervention Tests in Obese Women

Variable	EXP			CON			*p* value (η^2)		
	Pre-Test	Post-Test	Mean Difference (Lower, Upper)	Pre-Test	Post-Test	Mean Difference (Lower, Upper)	T	G	I
Weight (kg)	66.07 ± 10.67	65.23 ± 9.34	−0.85 (−2.03, 0.34)	66.79 ± 10.20	66.61 ± 9.45	−0.17 (−1.18, 0.83)	0.170 (0.066)	0.773 (0.003)	0.361 (0.030)
Percent body fat (%)	37.59 ± 5.62	35.47 ± 4.58	−2.11* (−3.62, −0.60)	36.52 ± 4.76	37.53 ± 4.47	1.01** (0.33, 1.69)	0.164 (0.068)	0.778 (0.003)	0.000† (0.369)
Body fat mass (kg)	23.89 ± 6.10	22.42 ± 5.70	−1.47*** (−2.14, −0.81)	24.69 ± 7.28	25.24 ± 6.62	0.55 (−0.12, 1.21)	0.044† (0.138)	0.447 (0.021)	0.000† (0.431)
Fat-free mass (kg)	41.25 ± 5.18	41.59 ± 4.57	0.34 (−0.42, 1.10)	42.09 ± 4.50	43.20 ± 6.03	1.11 (−2.50, 4.72)	0.406 (0.025)	0.463 (0.019)	0.658 (0.007)
Skeletal muscle mass (kg)	22.45 ± 3.18	22.65 ± 2.75	0.20 (−0.27, 0.67)	22.95 ± 2.69	22.53 ± 2.44	−0.42* (−0.82, −0.02)	0.444 (0.021)	0.852 (0.001)	0.039† (0.143)
BMI (kg/m^2)	25.46 ± 4.32	25.17 ± 3.91	−0.29 (−0.75, 0.16)	26.04 ± 4.58	25.95 ± 4.20	−0.09 (−0.81, 0.33)	0.193 (0.060)	0.666 (0.007)	0.489 (0.017)
WHR (%)	0.83 ± 0.06	0.82 ± 0.08	−0.01 (−0.29, 0.01)	0.86 ± 0.08	0.85 ± 0.07	−0.01 (−0.05, 0.03)	0.365 (0.029)	0.272 (0.043)	0.975 (0.000)

Notes: Values are expressed as mean ± standard deviation. †Significant interaction or main effect. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, significant difference between pre- and post-intervention tests.
Abbreviations: BMI, body mass index; CON, control group; EXP, experimental group; G, group; I, interaction; T, time; WHR, waist-to-hip ratio.

EXP group. SMM was significantly reduced in the CON group (Post - Pre: −0.42 kg, $p < 0.05$). However, no changes were observed in weight, FFM, BMI, or WHR.

There were interaction and main effects for FMD, and the main effect was demonstrated in baPWV (Table 4). In the post-hoc analysis, FMD (Post - Pre: 2.63%, $p < 0.001$) significantly increased, and baPWV (Post - Pre: −91.49 cm/sec, $p < 0.01$) significantly decreased in the EXP group. However, no changes were observed in SBP, DBP, PP, or MAP.

Main effects were found in RMSSD, NN50, PNN50, and HF (Table 5 and Table 6). The post-hoc analysis revealed a significant increase in RMSSD (Post - Pre: 10.43 ms, $p < 0.01$), NN50 count (Post - Pre: 24.04, $p < 0.05$), PNN50 (Post - Pre: 7.70%, $p < 0.05$), and HF (Post - Pre: 179.60 ms^2, $p < 0.05$). However, there were no changes in SDNN, VLF, LF, or TP.

Discussion

According to the World Health Organization's 2020 guidelines on physical activity and sedentary behavior, moderate-intensity aerobic and muscle-strengthening exercises can prevent obesity and chronic diseases.[37] Aerobic exercise improves body composition and CVD risk factors.[38] Resistance exercise also increases muscle strength, improves muscle function through hypertrophy, and reduces CVD-induced mortality.[39] In a previous study examining changes in body composition induced by non-face-to-face interventions, aerobic exercise (walking 10,000 steps per day) and diet management were interventions in 98 obese adults using pedometers and apps for 24 weeks.[40] As a result, weight (−10.8 kg), %BF (−5.64%), and BMI (−10.92%) reportedly decreased. In another study, 38 obese adults were asked to participate in an aerobic exercise program using a pedometer for 36 weeks.[41] As a result, weight (−4.5 kg), BMI (−1.6 kg/m^2), %BF (−3.2%), BF (−4.7 kg), waist circumference (−3.1 cm), and hip circumference (−2.9 cm) decreased. A previous study reported that non-face-to-face exercise interventions using apps achieved physical activity goals by motivating themselves through real-time monitoring as a positive cause of changes in body composition.[21,40] Similarly, our study used an m-Health program that allows real-time monitoring to achieve physical activity goals. Our findings showed a significant decrease in %BF (−2.11%) and BF (−1.47 kg) in the EXP group versus a significant increase in %BF (1.01%) and a decrease in SMM (−0.42 kg) in the CON group. Therefore, non-face-to-face exercise interventions using m-health effectively improve the body composition of obese women compared to traditional exercise interventions. The body composition changed dramatically in previous studies that combined diet and exercise in a non-face-to-face intervention.[40,41] In our study, it was found that non-face-to-face intervention had a positive effect on improving body composition, even though dietary intake was not controlled. In future studies, dramatic results will be obtained if non-face-to-face intervention studies are conducted in parallel with dietary intake.

Obesity can cause disorders in the sympathetic and parasympathetic nerves, increasing blood pressure and causing arteriosclerosis.[7,42,43] Regular exercise inhibits sympathetic nerve activity, reduces blood pressure, and prevents arteriosclerosis.[44–47] Huh et al reported that walking consumes at least 150 kcal/day as determined through a wearable device and telephone counseling for middle-aged adults with metabolic syndrome.[34] As a result, SBP (−9.2 mmHg) and DBP (−6.65 mmHg) were significantly decreased. Regular walking effectively controls blood pressure by improving vasodilator function and reducing tension in the vasodilator.[34] Additionally, sedentary individuals have been shown to positively impact metabolic syndrome by maintaining a moderately active level.[34] Previous studies that conducted physical activity and dietary interventions using phone and text messages reported weight loss, although there was no significant change in blood pressure.[36] The researchers concluded that although physical activity and dietary interventions did not result in significant changes in blood pressure, weight loss and improved dietary intake may prevent CVD.[36] In this study, SBP (−2.13 mmHg), DBP (−3.59 mmHg), and MAP (−3.10 mmHg) were not significantly different in the EXP group but showed a decreasing tendency. Non-face-to-face exercise intervention using m-Health has tended to lose weight and blood pressure and can further help prevent chronic and cardiovascular diseases caused by obesity.

Research on non-face-to-face exercise therapy using wearable devices to verify PWV and FMD, important indicators of vascular function, lacks scientific evidence. However, the positive effects of aerobic and resistance exercises on vascular function were scientifically verified in previous studies. Yang et al reported that obese women showed a decrease in BMI, waist circumference, SBP, DBP, and baPWV after 45 min of aerobic exercise and 20 min of resistance exercise five days a week at 60–70% of the HRmax for 12 weeks.[46] These results showed that the decrease in baPWV was due to the reduction in BMI, waist circumference, SBP, and DBP due to complex exercise and improved

Table 4 Changes in Blood Pressure and Vascular Function Between Pre- and Post-Intervention Tests of Obese Women

Variable	EXP			CON			p value (η^2)		
	Pre-Test	Post-Test	Mean Difference (Lower, Upper)	Pre-Test	Post-Test	Mean Difference (Lower, Upper)	T	G	I
SBP (mmHg)	120.87 ± 12.99	118.73 ± 12.46	−2.13 (−8.58, 4.31)	119.70 ± 10.95	119.36 ± 12.17	−0.34 (−5.52, 4.83)	0.525 (0.015)	0.947 (0.000)	0.646 (0.008)
DBP (mmHg)	75.63 ± 10.99	72.05 ± 10.39	−3.59 (−8.13, 0.95)	73.13 ± 8.51	72.80 ± 9.65	−0.33 (−4.40, 3.74)	0.179 (0.064)	0.796 (0.002)	0.262 (0.045)
MAP (mmHg)	90.71 ± 11.20	87.61 ± 10.75	−3.10 (−8.17, 1.97)	88.66 ± 8.42	88.32 ± 9.97	−0.34 (−4.43, 3.76)	0.267 (0.044)	0.843 (0.001)	0.370 (0.029)
PP (mmHg)	45.23 ± 7.14	46.65 ± 6.08	1.42 (−1.54, 4.37)	46.57 ± 8.85	46.55 ± 7.38	−0.01 (3.80, 3.78)	0.535 (0.014)	0.804 (0.002)	0.528 (0.014)
baPWV (cm/sec)	1285.30 ± 337.18	1193.81 ± 244.11	−91.49** (−160.02, −22.95)	1170.13 ± 185.70	1148.66 ± 197.21	−21.47 (−117.27, 74.33)	0.049† (0.131)	0.362 (0.030)	0.213 (0.055)
FMD (%)	7.436 ± 2.79	10.06 ± 2.79	2.63*** (1.54, 3.73)	7.61 ± 3.96	7.645 ± 3.20	0.03 (−1.21, 1.28)	0.002† (0.298)	0.323 (0.035)	0.002† (0.288)

Notes: Values are expressed as mean ± standard deviation. †Significant interaction or main effect. **$p < 0.01$, ***$p < 0.001$, significant difference between pre- and post-intervention tests. baPWV, brachial-ankle pulse wave velocity.
Abbreviations: CON, control group; DBP, diastolic blood pressure; EXP, experimental group; FMD, flow-mediated dilation; G, group; I, interaction; MAP, mean arterial pressure; PP, pulse pressure; SBP, systolic blood pressure; T, time.

Table 5 Changes in Heart Rate Variability Time-Domain Variables Between Pre- and Post-Intervention Tests in Obese Women

Variable	EXP			CON			*p* value (η^2)		
	Pre-Test	**Post-Test**	**Mean Difference (Lower, Upper)**	**Pre-Test**	**Post-Test**	**Mean Difference (Lower, Upper)**	**T**	**G**	**I**
SDNN (ms)	26.37 ± 17.05	30.59 ± 15.03	4.22 (−3.14, 11.59)	26.07 ± 11.12	26.73 ± 6.84	0.66 (−4.02, 5.34)	0.240 (0.049)	0.636 (0.008)	0.388 (0.027)
RMSSD (ms)	22.10 ± 14.21	32.53 ± 17.55	10.43** (3.63, 17.22)	26.11 ± 12.13	28.92 ± 12.49	2.82 (−5.37, 11.00)	0.013† (0.203)	0.965 (0.000)	0.136 (0.078)
NN50 (beats)	25.67 ± 41.61	49.71 ± 58.46	24.04* (6.45, 41.63)	27.53 ± 37.29	30.27 ± 34.82	2.73 (−18.23, 23.70)	0.045† (0.136)	0.556 (0.013)	0.106 (0.091)
PNN50 (%)	6.93 ± 11.54	14.63 ± 16.42	7.70* (2.06, 13.34)	7.84 ± 10.47	9.30 ± 11.60	1.47 (−5.47, 8.40)	0.036† (0.147)	0.599 (0.010)	0.146 (0.074)

Notes: Values are expressed as mean ± standard deviation. †Significant interaction or main effect. *p < 0.05, **p < 0.01, significant difference between pre- and post-intervention tests.

Abbreviations: CON, control group; EXP, experimental group; G, group; I, interaction; NN50 count, the number of interval differences of successive NN intervals greater than 50 ms; pNN50, the proportion derived by dividing NN50 by a total number of NN intervals; RMSSD, the square root of the mean of the sum of the squares of the difference between adjacent NN intervals; SDNN, standard deviation of the interval; T, time.

Table 6 Changes in Heart Rate Variability Frequency-Domain Variables Between Pre- and Post-Intervention Tests in Obese Women

Variable	EXP			CON			*p* value (η^2)		
	Pre-Test	**Post-Test**	**Mean Difference (Lower, Upper)**	**Pre-Test**	**Post-Test**	**Mean Difference (Lower, Upper)**	**T**	**G**	**I**
VLF (ms^2)	71.93 ± 87.67	45.44 ± 31.97	−26.49 (−67.58, 14.60)	40.92 ± 43.90	52.01 ± 42.99	11.09 (−19.30, 41.49)	0.524 (0.015)	0.467 (0.019)	0.126 (0.082)
LF (ms^2)	481.99 ±741.63	400.75 ± 439.82	−81.24 (−544.35, 381.87)	372.39 ± 554.33	202.71 ± 141.86	−169.68 (−448.19, 108.83)	0.328 (0.034)	0.284 (0.041)	0.728 (0.004)
HF (ms^2)	299.69 ± 464.47	479.29 ± 509.48	179.60* (34.85, 324.35)	295.18 ± 306.67	323.51 ± 242.18	28.33 (−114.14, 170.80)	0.037† (0.147)	0.562 (0.012)	0.121 (0.084)
TP (ms^2)	853.93 ± 1145.21	922.17 ± 766.97	68.24 (−509.59, 646.06)	708.71 ± 704.55	580.76 ± 272.73	−127.95 (−445.78, 189.88)	0.847 (0.001)	0.324 (0.035)	0.529 (0.014)

Notes: Values are expressed as mean ± standard deviation. †Significant interaction or main effect. *p < 0.05, significant difference between pre- and post-intervention tests.
Abbreviations: CON, control group; EXP, experimental group; G, group; HF, high frequency; I, interaction; LF, low frequency; T, time; TP, total power (VLF, LF, and HF components); VLF, very low frequency.

vascular endothelial function by increasing the nitric oxide utilization rate of vascular endothelial cells.[46] Accordingly, the researchers reported that the decrease in baPWV was due to the improvement of vascular endothelial function by increasing the utilization rate of NO in vascular endothelial cells due to exercise.[46] Another study reported an increase in endothelial progenitor cells and improvement in FMD that contribute to angiogenesis and vascular repair through a 12-week home training (45 min of aerobic exercise and 15 min of circuit training) intervention in 30 adults with intermittent lameness, a peripheral arterial disease of the lower extremities.[48] Similar to the results of previous studies, baPWV (−91.49 cm/sec) was significantly decreased in the EXP group, while FMD (2.63%) increased significantly. Arteriosclerosis damages FMD, and vascular endothelial cell dysfunction can predict CVD-inducing factors such as smoking and hypercholesterolemia.[49] Exercise plays an important role in improving vascular endothelial cell function.[49] Therefore, m-health exercise intervention using AI-fit and wearable devices can positively affect vascular function by effectively improving vascular endothelial cell function.

The ANS can be divided into sympathetic and parasympathetic nerves and is closely related to obesity.[13,50] A continuous increase in sympathetic nervous system activity at rest can lead to a decreased basal metabolic rate, weight gain, and obesity.[51,52] As an indicator of ANS function, the HRV test is an effective noninvasive evaluation method for investigating the relationship between obesity and ANS.[50] Exercise can also positively affect the ANS by reducing sympathetic nerve function and increasing parasympathetic nerve function.[19,44] Park et al reported an increase in mean RR, SDNN, and RMSSD, which are time domain indicators, an increase in TP and HF, which are frequency domains, and a decrease in LF/HF through aerobic exercise for 12 weeks among obese women. This suggests that 12 weeks of aerobic exercise improves sympathetic and parasympathetic nerve balance, which is highly correlated with obesity and disease in obese women.[50] In this study, RMSSD, NN50, and pNN50, indicators of parasympathetic nervous system activity in the time domain, were significantly increased in EXP after an m-health exercise intervention, which is similar to the results of previous studies. In the frequency domain, HF representing parasympathetic nervous system activity increased significantly, while LF indicating sympathetic nervous system activity tended to decrease, although not significantly. Therefore, non-face-to-face exercise intervention using m-health positively affects ANS function by improving sympathetic and parasympathetic nerve balance. Improvement of NO through exercise is a potential medium that affects endothelial function and autonomic nerve improvement.[53,54] In addition, improving obesity and vascular function improves autonomic nervous system function. Although NO was directly measured in our study, obesity and vascular function were improved through exercise intervention. The improvement of vascular function can be seen as an increase in NO bioavailability. These results confirm that non-face-to-face exercise intervention using m-health effectively improves endothelial function and ANS function by increasing NO bioavailability.

Conclusion

In our study, even though diet control was not combined, the effect of improving body composition was shown. In addition, it was confirmed that non-face-to-face exercise intervention using m-health could positively affect maintaining and lowering blood pressure and improving vascular and ANS function. A dramatic improvement effect would have been obtained if diet control was combined with m-health intervention research. Nevertheless, non-face-to-face exercise intervention using m-health that did not combine diet control showed sufficient improvement effects. Therefore, a customized exercise management system that uses m-health can effectively prevent and improve obesity. Additionally, the m-health program confirmed the possible efficacy of a telemedicine exercise program for patients with various diseases.

Data Sharing Statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics Approval and Informed Consent

This study was reviewed and approved by the Institutional Review Board of Konkuk University (7001355-202112-HR-491). It was registered with the Clinical Research Information Service (http://cris.nih.go.kr), conforming to the World Health Organization International Clinical Trials Registry Platform (registration number: KCT0007125). Written consent was obtained from all participants and conducted by the principles of the Helsinki Declaration.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest in this work.

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