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Original Research

Effects of Aerobic Exercise on Physical Fitness in Obesity Using Fox vs. Tanaka's Maximum Heart Rate and Percentage vs. Karvonen Methods

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Abstract

International Journal of Exercise Science 18(8): 695-711, 2025. https://doi.org/10.70252/XEPS8890 The intensity of aerobic exercise is influenced by maximum heart rate (MHR), which can be assessed through an incremental exercise test. However, this method requires specialized equipment and a level of fitness that individuals who are sedentary or overweight may lack. Therefore, estimating MHR using formulas is essential. Various methods exist to calculate MHR, but their effectiveness in real exercise programs for obese individuals remains unclear. This study aimed to investigate the effects of aerobic exercise using different intensity calculation methods, specifically comparing Fox's and Tanaka's maximum heart rate (MHR) equations, as well as the Percentage and Karvonen methods for target heart rate (THR). Seventy-eight men aged 20 to 30 with a body fat percentage of over 20% were divided into one control group and four aerobic exercise groups. EG1 and EG3 used Fox's and Tanaka's equations for MHR and THR from the percentage, while EG2 and EG4 applied the Karvonen method for THR. Participants engaged in 45 minutes of moderate-intensity walking or running on a treadmill four days a week for 12 weeks. Body weight, body fat percentage, BMI, resting heart rate (RHR), and VO_2 max were measured at baseline and after the intervention. After 12 weeks, all exercise groups demonstrated significant improvements in VO_2 max, as well as reductions in body weight, body fat percentage, BMI, and resting heart rate (RHR), whereas the control group showed no changes. No significant differences were found among the exercise groups. Aerobic exercise at various intensities effectively enhances cardiovascular fitness and body composition in obese individuals, indicating that these methods are equally beneficial.

Keywords: Aerobic exercise, maximum heart rate, exercise intensity, maximal oxygen consumption

Introduction

Obesity is a significant global health issue that contributes to serious noncommunicable diseases (NCDs), including cardiovascular disease, diabetes, hypertension, hyperlipidemia, and cancer.[1] Over the past 20 years, the prevalence of overweight and obesity has steadily increased. According to the World Health Organization, more than 1.9 billion adults worldwide were overweight in 2016, which comprised 39% of the global population. Among these, over 650 million were classified as obese.[2] Based on these trends, identifying effective and safe methods for weight loss is crucial for enhancing the health and quality of life for individuals affected by this condition. This goal aligns with the United Nations Sustainable Development Goals (SDGs), particularly those focused on the prevention and control of serious chronic non-communicable diseases (NCDs). Overweight and obesity are influenced by various factors, including genetics, excessive calorie intake, advanced age, decreased metabolic rate, reduced physical activity, and insufficient exercise.[3]

Aerobic exercise is low in intensity, allowing for prolonged activity, and is particularly suitable for individuals who are overweight or obese. This type of exercise can aid in weight loss by helping to reduce body fat.[4] Additionally, aerobic exercise enhances the circulatory and respiratory systems by increasing oxygen consumption.[4,5] Moreover, exercise promotes energy metabolism and improves hormonal function, ultimately leading to better body composition, including a reduction in body fat and waist circumference (WC).[5] Furthermore, increased aerobic physical activity is linked to a lower risk of developing type2 diabetes and cardiovascular diseases.[6] Exercise is appropriate for individuals across all age groups and has been shown to enhance the quality of life for both young and older individuals.[7]

To achieve weight loss, aerobic exercise should be performed at an appropriate intensity. Exercise intensity is defined as a percentage of an individual's maximum heart rate (MHR). In healthy individuals, a linear relationship exists between heart rate and exercise intensity during incremental exercise.[8] The American College of Sports Medicine (ACSM) recommends that for effective aerobic exercise, it should be performed at moderate intensity, typically between 46% and 63% of maximal oxygen consumption (VO_2 max), which corresponds to 40% to 59% of the heart rate reserve (HRR), or 64% to 76% of the MHR.[9] Individuals starting an aerobic exercise regimen should aim for an intensity level of 50% to 70% of their VO_2 max, which translates to 57% to 76% of their maximum heart rate (MHR) for light to moderate exercise.[9] However, the intensity range can vary among individuals due to differences in physical fitness levels and resting heart rates. Individuals with higher aerobic fitness typically exercise at intensities that exceed their oxygen consumption (VO_2).[10]

Exercise intensity is determined based on the individual's maximum heart rate (MHR), which represents a theoretical point of peak performance in circulatory and respiratory functions.[11,12,13] MHR serves as a reference to establish exercise intensity goals and helps determine the appropriate target heart rate range (THR) during aerobic exercise. The traditional method for calculating MHR involves the formula HR max = 220 - age. This formula has been utilized since the 1930s and gained popularity among exercise physiologists; however, the specific mechanism behind its development remains unclear. The formula has been extensively used in both teaching and research and was formally published by Fox III, Naughton, and Haskell in 1971.[12,14] After its introduction, it became common in textbooks and research and is presented in ACSM's Guidelines for Exercise Testing and Prescription.[15,9] However, several studies have suggested that this method may be off by 7–20 bpm.[15] Despite its widespread use, research into more accurate MHR formulas remains limited.[12,16] In 2001, Tanaka et al proposed an alternative calculation method for healthy individuals: HR max = 208 - (0.7 x age),[17] which is also widely used, particularly among athletes.[9]

Maximum heart rate is crucial for determining exercise intensity because it plays a vital role in calculating the target heart rate. Two popular methods are used to determine the target heart rate (THR) based on the maximum heart rate (MHR): 1) a direct calculation of THR as a percentage of MHR, a simple and widely used method in various heart rate monitoring contexts devices,[18] and 2) the Karvonen method, which calculates THR using heart rate reserve (HRR) and is the most commonly employed technique. This method was developed because the MHR percentage method often yields inaccurate estimates of exercise intensity, leading to either underestimation or overestimation.[18] As physical fitness varies among individuals, these differences should be taken into account when determining exercise intensity. The HRR, which is the difference between MHR and resting heart rate (RHR), is used to provide more specific and personalized calculations.[13] The percentage of HRR (%HRR) is closely correlated with the percentage of VO_2max and can effectively determine exercise intensity.[19] Although calculating THR using HRR is directly associated with the body's oxygen consumption, the %MHR method remains widely used for setting target heart rates during exercise.[9,18]

Although maximum heart rate (MHR) can be tested using an incremental exercise test, it requires significant equipment, such as a heart rate monitor or treadmill. This method may not be suitable for some individuals, including those who are overweight or obese. Therefore, estimating maximum heart rate using a formula is essential for determining the intensity of aerobic exercise. While several methods exist for calculating exercise intensity, further research is needed to understand how intensity, duration, and frequency impact fitness outcomes.[20] This study aimed to compare the effects of aerobic exercise on physical fitness in obese individuals by evaluating the differences in exercise intensity derived from Fox's and Tanaka's maximum heart rate equations, as well as comparing the percentage-based and Karvonen methods for setting target heart rates.

Methods

Participants

A sample size analysis was conducted using G*Power 3.1, which indicated that 59 participants were required (effect size = 0.5, power = 0.85, significance = 0.05). This effect size was hypothesized to suggest that the maximal oxygen uptake (VO_2max) would improve by 10%, which is reasonable based on determinations made in G*Power.[5] To account for potential sample loss or dropouts, the sample size was adjusted to 80 participants.

Participants in this study were male students and staff recruited from the University of Phayao, aged 20-30 years, with a body fat percentage exceeding 20%,[21] categorizing them as overfat. All participants were either sedentary or had not engaged in regular exercise for at least three months before the study. Furthermore, participants did not have any unusual health conditions that could hinder the training program. To ensure eligibility for the exercise intervention, participants were screened for any pre-existing health conditions that could affect their ability to safely participate in the training program, such as a history of heart disease or severe hypertension (blood pressure not exceeding 180/100 mmHg). Additionally, participants completed a health history questionnaire and disclosed any ongoing medication use. Written informed consent was obtained from all participants prior to their voluntary enrollment in the study. This study was approved by the University of Phayao Human Experimental Ethics Committee, Project No. UP-HEC 1.3/022/64. This research was conducted entirely in accordance with the ethical standards of the *International Journal of Exercise Science.*[22]

Protocol

This study used a 12-week randomized controlled trial (RCT) design. All participants were randomly assigned to five groups of 16 individuals, which included four experimental groups and one control group as follows:

1) G1 (220 @%MHR): The target heart rate (THR) was determined as a percentage of the formula MHR = 220 - age, with training at 65-75% MHR.

2) G2 (220 @%HRR): The THR was determined using the Karvonen method: THR = [(MHR - RHR) × %Intensity] + RHR, with training at 45-55% HRR, where MHR was adjusted using the formula 220-age.

3) G3 (208 @%MHR): The THR was determined as a percentage of the formula MHR = 208 - (0.7 × age), with training at 65-75% MHR.

4) G4 (208 @%HRR): The THR was determined using the Karvonen method: THR = [(MHR - RHR) × %Intensity] + RHR, with training at 45-55% HRR, where MHR was adjusted using the formula 208 - (0.7 × age).

5) Control Group: No exercise intervention; participants continued their normal daily activities.

The intensity of exercise was personalized and assessed using the following methods:

1) Maximum Heart Rate was calculated using either of two formulas:

1.1) Fox's Method: HRmax = 220 – Age[9,14]

1.2) Tanaka's Method: HRmax = 208 - (0.7 x Age)[9,17]

2) Target Heart Rate was calculated using either of two methods:

2.1) Percentage Method: %MHR (percentage of maximum heart rate) training intensity was set at 65–75% of HRmax, in line with ACSM recommendations for improving cardiovascular health and body composition.[9]

2.2) Karvonen Method: The training intensity was set at 45–55% of the HRR, according to the recommendations of the American College of Sports Medicine for exercise aimed at improving cardiovascular health and body composition.[9]

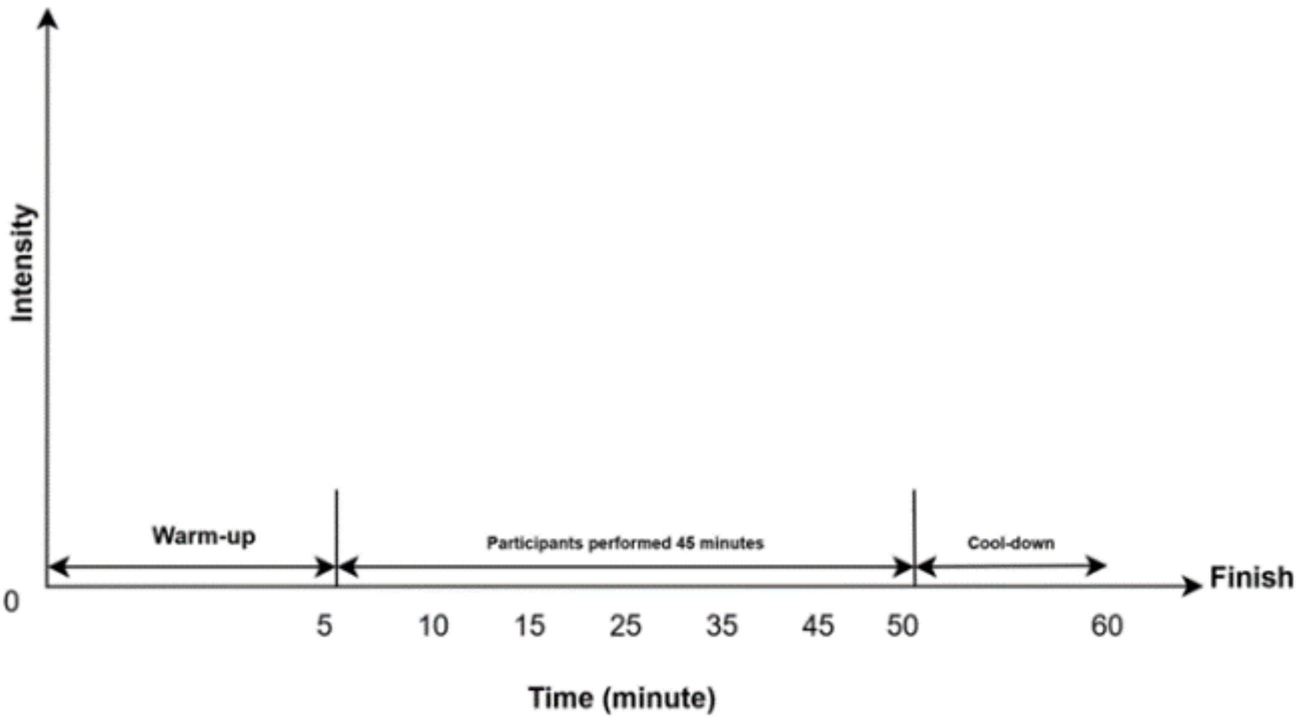

Figure 1. The 45-minute Training program. An individual velocity@ THR (km/hr.) was performed for low-intensity speed (65% HRmax in groups 1 and 3, and at 45% HRR for Groups 2 and 4) and high-intensity speed (75% HRmax in groups 1 and 3, and at 55% HRR for Groups 2 and 4). The velocity@ THR was adjusted at the beginning of each mesocycle.

The 12-week intervention program adhered to the guidelines set by the American College of Sports Medicine for continuous aerobic exercise, incorporating activities such as walking and running, which are suitable for overweight individuals.[5,9] This period was divided into three mesocycles, each incorporating adjustments to exercise intensity based on the target heart rate (THR) test. The velocity during the THR test was individualized according to each participant's HRmax and adjusted at the beginning of each mesocycle. The low-intensity speed was established at 65% of HRmax for Groups 1 and 3, and 45% of HRR for Groups 2 and 4, while the high-intensity speed was set at 75% of HRmax for Groups 1 and 3, and 55% of HRR for Groups 2 and 4. Participants were allowed to adjust their speed (increase or decrease) throughout the training period between low- and high-intensity levels as needed. Each training session began with a 5-minute warm-up, involving walking on the treadmill at an intensity of 40-50% HRmax or a speed of 3–4 km/h. Following the warm-up, participants engaged in 45 minutes of exercise at the intensity corresponding to their group assignment, either low or high, followed by a 10-minute cool-down period. The exercise intervention program was conducted at the same time every day at the fitness center within the Department of Exercise Science and Sport at the University of Phayao, in a controlled environment with a temperature range of 25-27 °C.

Participants were supervised by the researcher and the researcher's assistant regarding prescriptions and safety. They were instructed to maintain their regular routines throughout the intervention period, which involved no significant changes in eating habits, physical activity, or relaxation behaviors.

The total duration of the intervention comprises 48 exercise sessions. Participants can train between 3 and 5 sessions per week, with a minimum of 3 sessions and a maximum of 5 sessions allowed. However, over the last three weeks, participants may attend no fewer than two sessions and no more than six sessions per week. Additionally, participants who completed fewer than 38 sessions (i.e., less than 80%) were excluded from the analysis.

The physical fitness assessments were conducted 48 hours before the start of the training program. Participants were instructed to maintain their regular routine in the days leading up to the test, following specific guidelines to avoid strenuous physical activity, alcohol consumption, and smoking for at least 72 hours, and to abstain from eating for at least 2 hours before the fitness test. The testing protocol aimed to assess key components of health-related physical fitness, including cardiorespiratory endurance and body composition, both of which can be positively influenced by aerobic exercise.[4,9] The test sequence included measurements of body weight, body fat, and VO_2 max.

RHR was measured according to the guidelines of the International Society of Kinesiology (ISAK). Measurements were conducted in a quiet room after a 5-minute rest period in the supine position.[23] To ensure consistency, all RHR tests were scheduled in the morning between 8:00 and 9:00 a.m., before the subject's meal.

Body weight and body fat percentage were measured using Bioelectrical Impedance Analysis (BIA) with an ACCUNIQ BC380.[24] Participants were instructed to wear the same type of clothing for each measurement, refrain from wearing accessories or jewelry, and remove their shoes and socks. Measurements occurred in the morning, before eating or drinking.

Oxygen consumption was assessed using expired air collected every 15 seconds with the 5 L mixing chamber technique utilizing CardioCoach CO2. Modified Haldane equations were used to calculate VO_2 max (mL/kg/min), while CO_2 was measured directly by the device. Each participant completed a 3-minute exercise test at 50 W, followed by a 25 W increment every minute until reaching volitional fatigue (VO_2 max). Participants were required to maintain a pedal rate of 65 rpm at the specified workload. The test was terminated when participants could not keep 65 rpm.[25]

The research team included the researchers who designed the study, managed the testing and training program, collected data, and analyzed the results. Additionally, a fitness coach with a degree in sports science or physical education led the exercise training program and conducted assessments. Fitness coach assistants, who were in their fourth year of a sports science bachelor's degree program, assisted the fitness coach in delivering the training program and assessments, all under the supervision of the researchers.

Statistical Analysis

Data were analyzed using SPSS (version 22.0). The normal distribution was assessed using the Kolmogorov-Smirnov test. All variables (age, height, weight, RHR, fat (%), BMI, and VO2 max) are reported as means and standard deviations (SD). A one-way analysis of variance (ANOVA) was used to compare the mean values at baseline between groups. A paired samples t-test was employed to compare the mean difference between baseline and after 12 weeks of the exercise intervention (within-group time effect). A one-way analysis of covariance (ANCOVA) was used to compare mean differences among groups while controlling for covariance with baseline values. If significant interactions were identified, the Bonferroni test was applied to compare mean differences between the groups. Effect sizes from ANCOVA are reported as partial eta squared ($\eta^2 p$), with values of 0.01 indicating a small effect, 0.06 indicating a medium effect, and 0.14 indicating a significant impact.[5] The change from baseline to after 12 weeks of the exercise intervention is shown as a change score and % change.

Results

Participants and Intervention

This study included 80 volunteers who were randomly assigned to one of five groups: four experimental groups and one control group. The experimental groups underwent a 12-week exercise intervention, while the control group maintained a typical lifestyle without any exercise intervention. The exercise groups were categorized based on different methods for determining target heart rate (THR) during aerobic exercise. Group 1 (G1) utilized the maximum heart rate (MHR) method, setting the THR at 65–75% of MHR, calculated using the formula MHR = 220 – age. Group 2 (G2) employed the heart rate reserve (HRR) method, determining THR as 45–55% of HRR, with MHR again calculated using the formula MHR = 220 – age, alongside the Karvonen equation: THR = [(MHR − RHR) × %Intensity] + RHR. Group 3 (G3) utilized the MHR method, with the formula MHR = 208 – (0.7 × age), and trained at 65-75% of MHR. Group 4 (G4) adopted the HRR method, utilizing the MHR calculated via the formula MHR = 208 – (0.7 × age) and the Karvonen equation, with training conducted at 45–55% of the HRR. The control group continued their normal daily activities without any exercise intervention. After a 12-week exercise intervention, 78 volunteers completed the program. Two participants from Experimental Groups 1 and 4 withdrew due to personal reasons, leaving 62 participants in the exercise groups and 16 in the control group. The exercise intervention groups showed significant improvements in VO_2 max, body weight, and body fat percentage, whereas the control group exhibited no significant changes.

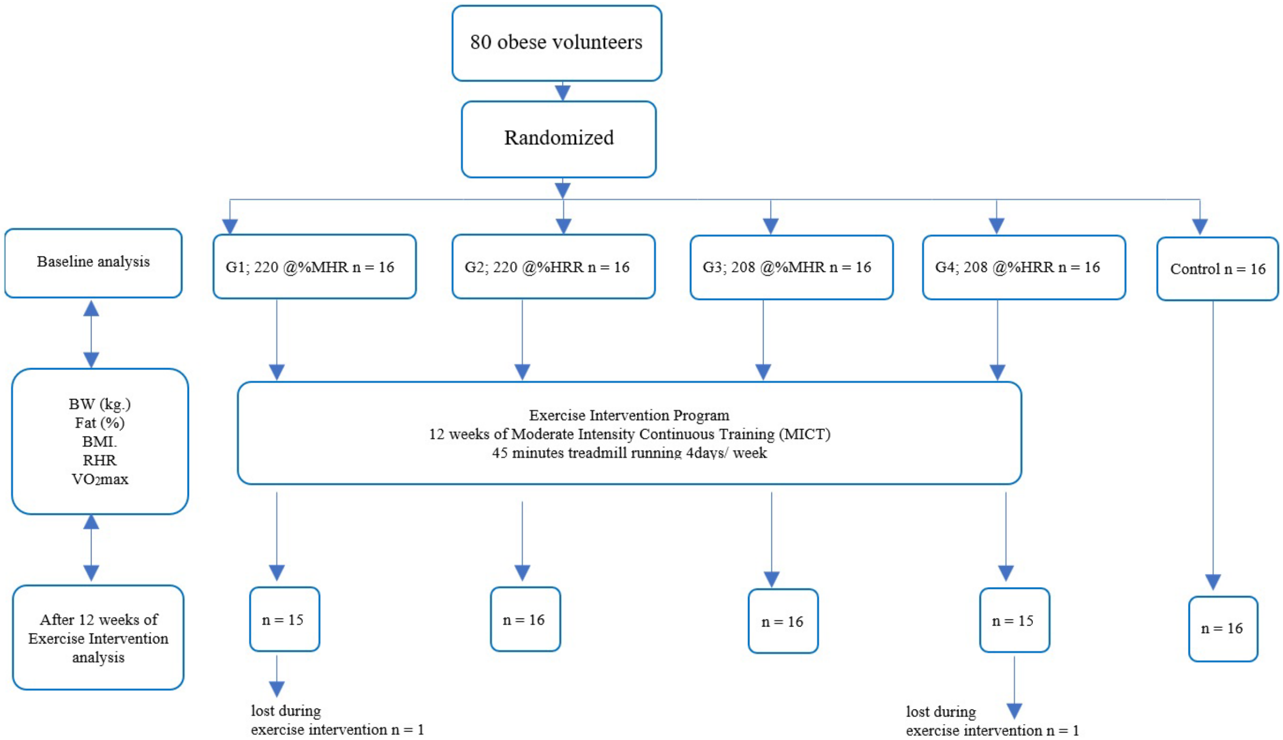

Figure 2. Flow diagram showing participants' enrollment and completion of the program over the 12-week intervention period.

Aerobic Exercise Directly Influences Body Weight

The paired-samples t-test revealed significant reductions in body weight across all experimental groups following the 12-week aerobic exercise intervention: [G1: 220@%MHR, baseline (M = 82.53, SD = 4.63) to post-test (M = 80.30, SD = 4.86), $t(14) = 6.170$, $p < .001$] [G2: 220@%HRR, baseline (M = 84.11, SD = 7.76) to post-test (M = 81.78, SD = 7.34), $t(15) = 5.700$, $p < .001$] [G3: 208@%MHR, baseline (M = 86.19, SD = 7.55) to post-test (M = 83.47, SD = 7.16), $t(15) = 5.365$, $p < .001$] [G4: 208@% HRR, baseline (M = 85.40, SD = 6.48) to post-test (M = 83.18, SD = 6.50), $t(14) = 8.928$, $p < .001$], with no significant differences noted in the control group. When baseline values were adjusted for ANCOVA, a large and significant between-group effect for body weight was observed ($F(4,72) = 9.662$, $p < 0.001$, $\eta^2 p = 0.349$). Post-hoc analysis revealed that, after 12 weeks of exercise intervention, body weight in all experimental groups was significantly lower than in the control group (Table 3). No significant differences were found between the exercise groups.

Aerobic Training Reduces Body Fat Percentage

All experimental groups demonstrated a statistically significant reduction in body fat percentage after 12 weeks of aerobic exercise intervention: [G1: 220@%MHR, baseline (M = 28.44, SD = 6.43) to post-test (M = 26.48, SD = 6.32), $t(14) = 5.556$, $p < .001$] [G2: 220@% HRR, baseline (M = 27.38, SD = 4.50) to post-test (M = 26.01, SD = 4.78), $t(15) = 4.906$, $p < .001$] [G3: 208@%MHR, baseline (M = 28.21, SD = 3.59) to post-test (M = 25.81, SD = 3.32), $t(15) = 10.477$, $p < .001$] [G4:

208@% HRR, baseline (*M* = 26.87, *SD* = 3.77) to post-test (*M* = 25.09, *SD* = 4.12), *t*(14) = 11.117, *p* < .001], while no significant differences were observed in the control group. A large and significant between-group effect for body fat percentage was noted ($F(4,72) = 15.320$, $p < 0.001$, $\eta 2p = 0.460$). Post-hoc analysis revealed that after 12 weeks of exercise intervention, body fat percentage in all experimental groups was significantly lower than in the control group (Table 3). No significant differences were identified between the exercise groups.

Table 1. Baseline Participant Characteristics

Variables	G1; 220@%MHR (n=15)		G2; 220@%RHR (n=16)		G3; 208@%MHR (n=16)		G4; 208@%RHR (n=15)		Control (n=16)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age (years)	20.67	± 0.82	20.69	± 0.79	20.81	± 0.83	19.93	± 0.70	21.44	± 0.51
Height(cm)	172.67	± 2.89	174.06	± 4.02	174.44	± 4.57	173.87	± 3.87	173.75	± 2.62
Weight(kg)	82.53	± 4.63	84.11	± 7.76	86.20	± 7.55	85.40	± 6.48	83.76	± 8.27
RHR (beat/ min^{-1})	74.20	± 5.48	73.50	± 5.36	76.50	± 4.70	73.40	± 5.19	75.44	± 4.08
MHR (220-age) (beat/ min^{-1})	199.33	± 0.82	199.31	± 0.79	-	-	-	-	-	-
MHR (208 (0.7 x age) (beat/ min^{-1})	-	-	-	-	193.43	± 0.58	194.05	± 0.49	-	-
THR (65%MHR) (beat/ min^{-1})	129.57	± 0.53	-	-	125.73	± 0.38	-	-	-	-
THR (75%MHR) (beat/ min^{-1})	149.48	± 0.59	-	-	145.07	± 0.43	-	-	-	-
THR (45%HRR) (beat/ min^{-1})	-	-	130.12	± 2.93	-	-	127.69	± 2.78	-	-
THR (55%HRR) (beat/ min^{-1})	-	-	142.70	± 2.40	-	-	139.76	± 2.25	-	-

MHR, Maximum Heart Rate (bpm); RHR, rated heart rate (bpm); THR = Target Heart Rate (bpm); HRR = Heart Rate Reserve (bpm)

Body Mass Index Decreases After Aerobic Training

The paired samples demonstrated a significant reduction in BMI across all experimental groups after 12 weeks of aerobic exercise intervention: [G1: 220@%MHR, baseline (*M* = 27.71, *SD* = 1.93) to post-test (*M* = 26.96, *SD* = 1.93), *t*(14) = 6.256, *p* < .001] [G2: 220@% HRR, baseline (*M* = 27.73, *SD* = 2.09) to post-test (*M* = 26.99, *SD* = 2.18), *t*(15) = 5.864, *p* < .001] [G3: 208@%MHR, baseline (*M* = 28.31, *SD* = 2.01) to post-test (*M* = 27.41, *SD* = 1.74), *t*(15) = 5.222, *p* < .001] [G4: 208@% HRR, baseline (*M* = 28.28, *SD* = 2.31) to post-test (*M* = 27.54, *SD* = 2.34), *t*(14) = 9.046, p < .001]. In contrast, no significant differences were noted in the control group. Baseline values were adjusted for ANCOVA, revealing a moderate and significant between-group effect for BMI ($F(4, 72) = 9.624$, $p < 0.001$, $\eta^2p = 0.348$). Post-hoc analysis indicated that following the 12-week exercise intervention, BMI in all experimental groups was significantly lower compared to the control group (Table 3). No significant differences were detected between the exercise groups.

Aerobic Training Decreases RHR

RHR showed significant reductions across all experimental groups: [G1: 220@%MHR, baseline (M = 74.20, SD = 5.48) to post-test (M = 72.53, SD = 5.50), $t(14)$ = 6.168, $p < .001$] [G2: 220@% HRR, baseline (M = 73.50, SD = 5.35) to post-test (M = 71.63, SD = 5.85), $t(15)$ = 5.960, $p < .001$] [G3: 208@%MHR, baseline (M = 76.50, SD = 4.69) to post-test (M = 74.63, SD = 4.83), $t(15)$ = 10.434, $p < .001$] [G4: 208@% HRR, baseline (M = 73.40, SD = 5.18) to post-test (M = 72.07, SD = 5.08), $t(14)$ = 4.641, $p < .001$]. In contrast, no significant differences were found in the control group. ANCOVA revealed a small yet significant between-group effect for RHR ($F(4, 72) = 4.942$, $p < 0.05$, $\eta^2 p = 0.215$). Post-hoc analysis revealed that, after 12 weeks of exercise intervention, resting heart rate (RHR) in all experimental groups decreased significantly compared to the control group (Table 3). No significant differences were noted among the exercise groups.

Table 2. Within-group differences (baseline versus after 12 weeks of aerobic exercise) in Body Weight, Body Fat, BMI, RHR, and VO_2 max After 12 Weeks of Aerobic Exercise.

Variables	G1; 220@%MHR (n=15)			G2; 220@%RHR (n=16)			G3; 208@%MHR (n=16)			G4; 208@%RHR (n=15)			Control (n=16)		
	Baseline	12weeks	%Change	Baseline	12weeks	%Change	Baseline	12weeks	%Change	Baseline	12weeks	%Change	Baseline	12weeks	%Change
BW (kg.)	82.53 ± 4.63	80.30** ± 4.86	-2.70%	84.11 ± 7.76	81.78** ± 7.34	-2.79%	86.19 ± 7.55	83.47** ± 7.16	-3.17%	85.40 ± 6.48	83.18** ± 6.50	-2.60%	83.76 ± 8.27	83.89 ±8.11	+0.16%
Fat (%)	28.44 ± 6.43	26.48** ± 6.32	-6.89%	27.38 ± 4.50	26.01** ± 4.78	- 5.00%	28.21 ± 3.59	25.81** ± 3.32	-8.51%	26.87 ± 3.77	25.09** ± 4.12	-6.62%	27.43 ± 3.62	27.64 ± 3.59	+0.77%
BMI	27.71 ± 1.93	26.96** ± 1.93	-2.71%	27.73 ± 2.09	26.99** ± 2.18	-2.67%	28.31 ± 2.01	27.41** ± 1.74	-3.18%	28.28 ± 2.31	27.54** ± 2.34	-2.69%	27.71 ± 2.22	27.76 ± 2.23	+0.18%
RHR (bpm)	74.20 ± 5.48	72.53** ± 5.50	-2.25%	73.50 ± 5.35	71.63** ± 5.85	-2.54%	76.50 ± 4.69	74.63** ± 4.83	-2.51%	73.40 ± 5.18	72.07** ± 5.08	-1.85%	75.44 ± 4.08	75.00 ± 3.92	-0.60%
VO_2 max **(ml/kg/min)**	30.13 ± 3.92	32.97** ± 3.66	+ 9.43%	30.47 ± 3.84	33.34** ± 4.24	+9.42%	28.08 ± 4.65	31.29** ± 4.74	+11.43%	29.56 ± 5.26	32.53** ± 6.68	+10.05%	28.23 ± 4.27	28.14 ± 4.02	-0.32%

%Change = Percentage change from baseline (after 12 weeks of intervention – baseline) x 100 / baseline, BW = body weight, fat % = body fat percentage, * = $p < 0.05$, ** = $p < 0.001$

Table 3. Differences between groups after 12 weeks of aerobic exercise in body weight, percentage of body fat, BMI, resting heart rate (RHR), and maximal oxygen consumption.

Variables	G1; 220@%MHR (n=15)		G2; 220@%HRR (n=16)		G3; 208@%MHR (n=16)		G4; 208@%HRR (n=15)		Control (n=16)		Ancova	
	12 weeks	Anc.Adj.	12 weeks	Anc.Adj.	12 weeks	Anc.Adj.	12 weeks	Anc.Adj.	12 weeks	Anc.Adj.	P-value, *F*	η^2_p
BW (kg.)	80.30	82.09(5)	81.76	82.07(5)	83.46	81.77(5)	83.18	82.24(5)	83.89	84.51(1,2,3,4)	.000, 9.662**	0.349
Fat (%)	26.48	25.72(5)	26.01	26.28(5)	25.81	25.28(5)	25.09	25.87(5)	27.64	27.88(1,2,3,4)	.000, 15.320**	0.460
BMI	26.96	27.18(5)	26.99	27.19(5)	27.41	27.06(5)	27.54	27.23(5)	27.76	28.00(1,2,3,4)	.000, 9.624**	0.348
RHR (bpm)	72.53	72.96(5)	71.63	72.75(5)	74.63	72.76(5)	72.07	73.92(5)	75.00	74.19(1,2,3,4)	.001, 4.942*	0.215
VO_2 max (ml/kg/min)	32.97	32.07(5)	33.34	32.09(5)	31.29	32.55(5)	32.53	32.24(5)	28.14	29.23(1,2,3,4)	.000, 19.390**	0.519

Anc.Adj. = ANCOVA adjustment for baseline covariates, BW = body weight, fat % = body fat percentage, * = p < 0.05, ** = p < 0.001, (1) = significate with 220@%MHR, (2) = significate with 220@%HRR, (3) = significate with 208@%MHR, (4) = significate with 208@%HRR, (5) = significate with Control Group

VO_2 max Increases Significantly with Aerobic Training

VO_2 max significantly improved in all experimental groups after 12 weeks of aerobic training [G1: 220@%MHR, baseline (M = 30.13, SD = 3.92) to post-test (M = 32.97, SD = 3.66), $t(14)$ = 8.713, $p < .001$] [G2: 220@% HRR, baseline (M = 30.47, SD = 3.84) to post-test (M = 33.34, SD = 4.24), $t(15)$ = 10.664, $p < .001$] [G3: 208@%MHR, baseline (M = 28.08, SD = 4.65) to post-test (M = 31.29, SD = 4.74), $t(15)$ = 10.683, $p < .001$] [G4: 208@% HRR, baseline (M = 29.56, SD = 5.26) to post-test (M = 32.53, SD = 6.68), $t(14)$ = 6.859, $p < .001$]. Therefore, no significant differences were found in the control group. When baseline values were adjusted for ANCOVA, a large and significant between-group effect for VO_2 max was observed ($F(4, 72) = 19.390$, $p < 0.001$, $\eta p^2 = 0.519$). Post-hoc analysis showed that after 12 weeks of exercise intervention, VO_2 max in all experimental groups improved significantly compared to the control group (Table 3). No significant differences were observed between the exercise groups.

Discussion

This study revealed several key findings after 12 weeks of aerobic exercise intervention. All exercise groups demonstrated significant improvements in maximal oxygen consumption, as well as decreases in body weight, body fat percentage, BMI, and resting heart rate (RHR). At the same time, these parameters remained unchanged in the control group. Furthermore, comparisons between the exercise groups and the control group revealed significant differences in body weight, body fat percentage, BMI, and resting heart rate (RHR). Lastly, no significant differences were observed among the exercise intervention groups. These findings highlight the efficacy of aerobic exercise in enhancing physical fitness and body composition in individuals with obesity, regardless of the specific formula used to calculate target heart rate zones.

Aerobic exercise improved cardiovascular and respiratory endurance, body composition, and muscular strength in all training groups. The absence of significant differences between the exercise interventions can be attributed to the concept of Co-Target Heart Rate Area (Co-THRA) (Figure 3). When calculating MHR and THR using various methods, some overlap in THR ranges may occur, resulting in similar exercise intensities across groups. In this study, the Co-THRA ranged from 130.12 bpm to 139.76 bpm. As a result, participants in all groups may train at similar intensities, resulting in insignificant differences in physical fitness between intervention groups.

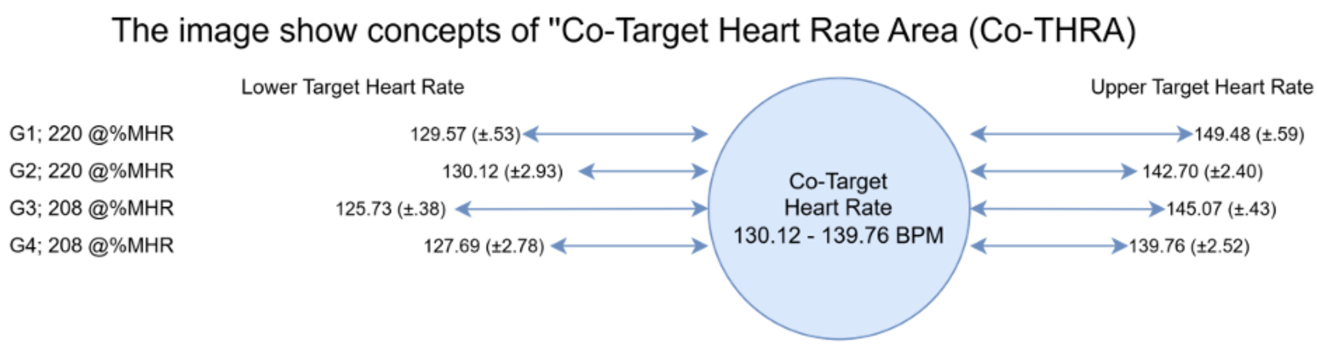

Figure 3. Co-Target Heart Rate Area (Co-THRA)

Body Composition Adaptation

Participants in the exercise intervention groups exhibited a statistically significant decrease in body weight, body fat, and body mass index (BMI). These reductions can be attributed to regular aerobic exercise four days a week for 12 weeks. This regimen promotes fat burning through a process called fat oxidation.[26] Increased energy expenditure during exercise and heightened lipoprotein lipase activity contribute to fat reduction not only through fat oxidation but also by stimulating catecholamine release, which enhances metabolic processes, boosts fat burning, and increases the secretion of growth hormones.[27-28] Post-exercise oxygen consumption also plays a role in prolonging fat oxidation after an exercise session.[29]

As body fat decreases, fat-free mass increases, which includes muscles and other lean tissues. Furthermore, aerobic exercise elevates resting energy expenditure, enabling the body to burn more calories even at rest and facilitating weight loss.[4] These findings align with previous studies that demonstrated a reduction in body weight and body fat percentage after aerobic training.[30] When comparing the exercise groups to the control group, the experimental groups exhibited significantly lower body weight and body fat levels, reinforcing the role of aerobic exercise in enhancing body composition.

These improvements also have significant health implications. Reducing body weight and fat lowers the risk of cardiovascular diseases and diabetes and helps alleviate the workload on the heart at rest. Overweight individuals have a higher resting heart rate (RHR), and the reduction in body weight through exercise contributes to lowering RHR.[31] To achieve changes in body composition, moderate-intensity continuous aerobic exercise should be performed at 60–76% of maximal heart rate (MHR) or 40–70% [27] of heart rate reserve (HRR). In this study, exercise intensity was set at 65–75% of MHR and 45–55 % of HRR. Our findings are consistent with previous studies, which demonstrate that exercise at 40–70% HRR significantly reduces body weight and fat.[27]

Although the results of this study demonstrate the positive effects of aerobic exercise on weight loss, previous studies have suggested that long-term exercise training may not necessarily lead to a continuous reduction in body weight. Although increased exercise initially resulted in more significant energy expenditure and fat burning, weight loss plateaued over time or resulted in modest weight loss (1.5–3 kg).[32] Adjustments to exercise programs may be necessary to achieve sustained weight loss over the long term.

While increased exercise may initially lead to more significant energy expenditure and fat burning, weight loss will eventually stabilize. Adjusting the exercise program might be necessary to achieve sustainable long-term weight loss.

Cardio-Respiratory Endurance

This study found a statistically significant increase in VO_2 max across all intervention groups, with no differences observed between them. VO_2 max, regarded as the gold standard for cardiovascular fitness, reflects improvements in both the circulatory and respiratory systems. Aerobic exercise enhances VO_2 max by increasing cardiac output, stroke volume, and arteriovenous O_2 differences.[33] Exercise also promotes vasodilation and angiogenesis.[34-36] These adaptations contribute to positive changes in maximal oxygen consumption in the exercise group.

The intensity of exercise in this study (40 – 55 %RHR and 64 - 70% MHR, four days per week for three months) is consistent with previous research, indicating that aerobic exercise at 50-75%

MHR positively influences maximal oxygen consumption.[37-38] Some studies suggest that higher exercise intensities may lead to more significant improvements in VO_2max, with moderate (50% VO_2 reserve), vigorous (75% VO_2 reserve), and near-maximal (95% VO_2 reserve) intensities resulting in increases in VO_2 max of 20.6%, 14.3%, and 10%, respectively.[38] In contrast, a meta-analysis of 28 studies suggests that any training intensity above 60% of the maximum oxygen uptake (VO_2 max) can enhance cardiorespiratory endurance.[39] Additionally, the appropriate duration of training may significantly impact the optimization of maximal oxygen consumption.[40]

In this study, resting heart rate (RHR) significantly decreased in all exercise groups, aligning with previous findings.[41-42] This reduction was attributed to an increased stroke volume, while cardiac output remained unchanged. Aerobic endurance training enlarges the left ventricle, which directly affects blood volume and contributes to the observed decrease in resting heart rate (RHR).[41-42] Therefore, regular moderate-intensity aerobic exercise, as highlighted in this study (65-75% of maximum heart rate or 45 – 55 % of heart rate reserve, performed four times a week for 45 minutes per session), effectively enhances cardiorespiratory fitness, regardless of the method used to calculate maximum heart rate and heart rate reserve.

Therefore, the increase in VO_2max, the decrease in resting heart rate (RHR), and the reduction in body fat and weight among the four sample groups align with the exercise intensity that encourages physical development, as previously mentioned. Although the four groups employed different methods to calculate exercise intensity, the resulting values were consistent with the intensities necessary for developing both the circulatory and respiratory systems, as well as body proportions. Exercise intensity in the four sample groups ranged from 130.12 bpm to 139.76 bpm, based on the combined values. If the groups exercised at an intensity that was neither too high nor too low, according to the combined values, the development of VO_2max, the decrease in RHR, and the reduction in body fat and weight would occur at a similar level, resulting in no statistical difference between the groups.

Furthermore, the development of VO_2max, the decrease in resting heart rate (RHR), and the reduction in body fat and weight are interconnected. The reduction in fat correlates with the decline in body weight, and lower body weight is generally associated with lower resting heart rate (RHR) values compared to those who are obese.[31] This study demonstrates that exercise training, by determining MHR using Fox and Tanaka's formulas and THR from the Percentage and Karvonen Methods, effectively enhances physical fitness related to health, particularly in the circulatory and respiratory systems and in body composition.

We identified some limitations in our study. First, although volunteers were advised not to alter their daily energy intake, we could not directly monitor their consumption; however, the observed reductions in body weight and body fat are assumed to result from the exercise intervention rather than changes in dietary habits. A second significant limitation was that participants did not continuously wear heart rate monitoring devices. This design, however, was intentional to enhance the study's ecological validity, as the protocol was aimed to be practical and reflective of real-world conditions where individuals may not use monitors due to cost, comfort, or personal preference. To mitigate this, we re-evaluated and adjusted the exercise intensity at the beginning of each mesocycle, ensuring an appropriate and progressive training stimulus throughout the experimental period. Finally, as this research was conducted with individuals with obesity—a population where exercise often elicits more pronounced changes—findings from this study may not apply to certain populations. This includes individuals with high physical fitness, those with strength training backgrounds, or athletes.

In summary, the findings of this study suggest that aerobic exercise, irrespective of the method used to calculate maximum and target heart rates, significantly enhances cardiovascular fitness and body composition in individuals with obesity. Participants who performed aerobic training showed better overall physical performance compared to those who did not exercise. While maximum heart rates can be measured through an incremental maximum exercise test, this method requires precise equipment, such as a heart rate monitor or exercise ergometer. Some organizations may not have access to such testing equipment. Additionally, the incremental maximum exercise test should only be performed on healthy individuals, as it can pose risks for those with a history of circulatory or respiratory diseases, the elderly, or obese individuals. Therefore, using a formula to estimate maximum heart rate is essential. The data from this research can be used to develop exercise programs for weight management, improve cardiovascular and respiratory fitness in clinical settings, and promote health in schools and communities. Although the study's results showed no significant differences in improvements to the circulatory and respiratory systems or body composition among the different groups, we recommend using simple formulas and calculation methods for children and older adults. Also, including resting heart rate (RHR) in assessments should be considered in clinical practice to help address obesity and support individuals with good physical fitness.

For future research, it is recommended to investigate the MHR formula by Miller et al ($200 - (0.48 \times \text{age})$), which was specifically developed for the obese population, in comparison to other formulas. However, this study has intentionally focused on comparing the Fox and Tanaka formulas due to their widespread prevalence and practical application in textbooks and various automatic calculation tools for designing weight-loss exercise programs. Importantly, this research addresses a significant gap in the literature, as no previous study has directly compared the effects of using both of these formulas in conjunction with the Karvonen method (%HRR) specifically within an obese population. Finally, the data from this study confirms the value of calculating maximum heart rate using both the Fox and Tanaka methods, as well as calculating target heart rate with the Percentage and Karvonen Methods, which are highly relevant in the fields of health and exercise science.

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