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Effects of Aerobic Versus Combined Aerobic-Resistance Exercise on Physiological Variables among Female University Students: An Eight-Week Experimental Study

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Abstract

Background: Physical inactivity among university students is associated with adverse cardiovascular and body composition outcomes. Although both aerobic exercise and combined aerobic–resistance exercise improves physiological health, evidence comparing their effectiveness among female university students remains limited.

Methods: A randomized pretest–posttest experimental study was conducted among 32 non-athlete female undergraduate students at Bahir Dar University, Ethiopia. Participants were randomly assigned to a moderate-intensity aerobic exercise group (MIAE; $n = 16$) or a combined aerobic–resistance exercise group (CEX; $n = 16$). Both groups participated in supervised exercise sessions three times per week for eight weeks. Resting systolic blood pressure (SBP), diastolic blood pressure (DBP), resting heart rate (RHR), body fat percentage (BF%), and lean body mass (LBM) were measured before and after the intervention. Data were analyzed using paired-samples t -tests and multivariate analysis of variance (MANOVA).

Results: Significant within-group improvements were observed in both interventions. The MIAE group demonstrated significant reductions in SBP ($p < 0.001$), DBP ($p = 0.002$), RHR ($p < 0.001$), and BF% ($p < 0.001$). The CEX group showed significant reductions in SBP ($p < 0.001$), DBP ($p = 0.002$), RHR ($p < 0.001$), BF% ($p < 0.001$), and a significant increase in LBM ($p < 0.001$). MANOVA revealed a significant overall intervention effect on the combined physiological variables (Wilks' $\Lambda = 0.411$, $F(10,21) = 3.003$, $p = 0.016$, partial $\eta^2 = 0.589$). Follow-up analyses indicated significant between-group differences in RHR ($p = 0.019$) and LBM ($p = 0.037$), whereas SBP, DBP, and BF% did not differ significantly between groups.

Conclusion: Both exercise modalities improved cardiovascular and body composition outcomes. However, moderate-intensity aerobic exercise produced greater reductions in resting heart rate, whereas combined aerobic–resistance exercise was superior for increasing lean body mass. Combined exercise may therefore provide broader physiological benefits among female university students.

Trial Registration: Pan African Clinical Trial Registry (PACTR; pactr.samrc.ac.za), PACTR202607782571116, registered on 31 July 2026. Retrospectively registered.

1. Introduction

1.1. Background of the Study

Physical inactivity has emerged as a major global public health concern and is recognized as one of the leading modifiable risk factors for premature mortality worldwide [1-3]. According to the World Health Organization, insufficient physical activity contributes substantially to the global burden of non-communicable diseases and premature deaths [2,3]. Physical inactivity is strongly associated with an increased risk of cardiovascular disease, hypertension, obesity, type 2 diabetes mellitus, certain cancers, and all-cause mortality [1,4-7]. Lack of regular physical activity has also been identified as a major contributor to the development and progression of several chronic diseases across the lifespan [5,6,8].

University students are particularly vulnerable to physical inactivity because of academic workload, prolonged sedentary behaviors, and reduced participation in structured physical activity [6,9,10]. Consequently, many students experience declines in cardiovascular fitness and overall physiological health during early adulthood [6,11]. Female university students may be especially susceptible to the adverse effects of physical inactivity because they often participate less frequently in structured exercise programs than their male counterparts [9,10]. The transition from secondary school to university is frequently accompanied by a decline in physical activity levels, which may negatively affect both physical and psychological well-being [9,11]. Studies conducted among university students from different countries have reported high levels of physical inactivity and sedentary behavior [1,10]. Reduced physical activity among university students has been associated with poor cardiovascular fitness, unfavorable body composition, metabolic dysfunction, and increased health risks later in life [4,12,13].

Sedentary behavior may adversely affect cardiovascular, metabolic, and musculoskeletal health, thereby increasing the likelihood of chronic disease development [4-6,14]. Sedentary behavior among female students has been linked to increased body fat accumulation, elevated resting heart rate, reduced cardiovascular endurance, and lower lean body mass, all of which may negatively affect health status, physical performance, and quality of life [5,15].

In Ethiopia, evidence regarding the comparative effects of aerobic exercise and combined aerobic–resistance exercise on physiological variables among sedentary female university students is scarce. Consequently, there remains insufficient evidence to determine which exercise modality is more effective for improving cardiovascular health and body composition in this population [16,17].

Regular physical activity improves cardiovascular health, body composition, muscular fitness, metabolic function, and psychological well-being while reducing the risk of obesity,

hypertension, cardiovascular disease, diabetes mellitus, and other chronic conditions [4,6,12,13]. Therefore, promoting physical activity among university students is essential for improving health outcomes and reducing the future burden of non-communicable diseases [3,10,12]. Aerobic exercise involves continuous rhythmic activities that engage large muscle groups and primarily rely on aerobic metabolism for energy production [18]. Regular aerobic exercise improves cardiorespiratory fitness, cardiovascular efficiency, oxygen utilization, and blood pressure regulation [19-21].

Combined aerobic–resistance exercise integrates aerobic and resistance training within the same program and is designed to simultaneously improve cardiovascular fitness and muscular strength [22]. Previous studies have reported favorable effects of combined exercise on body composition, metabolic health, cardiovascular fitness, and muscular performance [23-25]. Comparative studies have shown that both aerobic exercise and combined aerobic–resistance exercise improve physiological health outcomes; however, findings regarding their relative effectiveness remain inconsistent [26,27]. While some studies have reported superior improvements in body composition and cardiovascular fitness following combined exercise training [23,28,29], others have observed comparable benefits between the two exercise modalities [26,30].

Despite growing evidence on the physiological benefits of aerobic and combined exercise training, limited research has been conducted among healthy, non-athlete female university students in Ethiopia [16]. Most previous studies have focused on athletes, older adults, overweight individuals, or clinical populations [16,23]. Consequently, there is insufficient evidence regarding the comparative effects of aerobic exercise and combined aerobic–resistance exercise on physiological variables among Ethiopian female university students.

Therefore, the present study aimed to compare the effects of eight weeks of moderate-intensity aerobic exercise and combined aerobic–resistance exercise on resting heart rate, blood pressure, body fat percentage, and lean body mass among female undergraduate students at Bahir Dar University.

2. Methods

2.1. Study Area

The study was conducted at Bahir Dar University, located in Bahir Dar City, the capital of the Amhara National Regional State, Ethiopia. Bahir Dar is situated approximately 578 km northwest of Addis Ababa at an elevation of about 1,820 meters above sea level. Geographically, the city is located near the outlet of the Abbay River from Lake Tana at coordinates 11°36'N latitude and 37°23'E longitude. The study specifically took place at the university's main campus sports academy.

2.2. Research Design

A true experimental research design with a pretest–posttest randomized two-group approach was employed in this study. This design was selected because it enables the investigator to establish a stronger cause-and-effect relationship between the intervention and outcome variables [31]. The study compared the effects of moderate-intensity aerobic exercise and combined aerobic plus resistance exercise on selected physiological variables among female university students. Baseline measurements were recorded before the intervention, followed by reassessment after eight weeks of exercise intervention.

The independent variables of the study were aerobic exercise and combined exercise interventions, whereas the dependent variables included resting blood pressure, resting heart rate, body fat percentage, and lean body mass.

2.3. Study Population

The target population consisted of undergraduate third-year female students from the College of Science at Bahir Dar University. Participants were healthy non-athlete young adult females. University students were selected because they share relatively similar characteristics in terms of age, educational background, and lifestyle, which helps minimize confounding variables during the intervention [32]. Additionally, physiological adaptations to exercise are often more noticeable among previously sedentary individuals than among trained athletes [33].

2.3.1. Inclusion Criteria

Participants were included in the study if they fulfilled the following criteria:

- Healthy non-athlete female university students aged 21–24 years.
- Able and willing to provide informed consent.
- Sedentary (A lifestyle characterized by engaging in less than 150 minutes of moderate-intensity physical activity per week and spending ≥ 6 hours per day sitting or reclining during waking hours, excluding sleeping time or moderately physically active individuals [34].
- Free from cardiovascular, metabolic, or musculoskeletal disorders that contraindicate exercise participation [3].

2.3.2. Exclusion Criteria

Participants were excluded if they had any of the following conditions:

- Known cardiovascular, metabolic, or musculoskeletal disorders aggravated by exercise.
- Recent injury or surgery limiting physical activity participation.

- Pregnancy or breastfeeding status.
- Chronic illnesses requiring specialized medical management such as uncontrolled diabetes mellitus or severe asthma.
- Regular use of medications affecting physiological responses to exercise [3].

2.4. Sample Size Determination and Sampling Technique

A comprehensive sampling technique was used in this study due to limited source population. The source population initially consisted of 44 third-year female students from the College of Science at Bahir Dar University. After applying the inclusion and exclusion criteria, 32 eligible participants remained and were enrolled in the study.

The selected participants were randomly assigned into two equal experimental groups, each containing 16 participants. Group I participated in moderate-intensity aerobic exercise, while Group II participated in combined aerobic and resistance exercise training. Random allocation was employed to minimize selection bias and ensure comparability between groups [31]. The participant selection process involved screening for eligibility, excluding individuals who were unwilling to participate, physically active before the intervention, had chronic illnesses, or were using medications that could interfere with the intervention outcomes.

Following baseline assessment and confirmation of eligibility, participants were randomly assigned to either the Moderate-Intensity Aerobic Exercise (MIAE) group or the Combined Exercise (CEX) group. Randomization was performed by a research assistant who was not involved in outcome assessment using a simple lottery method. Each participant's identification number was written on identical slips of paper and placed in a sealed container. Participants were then randomly allocated to one of the two intervention groups by drawing the slips.

To ensure allocation concealment, group assignments were prepared in advance and placed in sequentially numbered, opaque, sealed envelopes. The envelopes were opened only after completion of baseline measurements and participant enrollment. Thus, neither the participants nor the assessor responsible for baseline measurements was aware of group assignment before allocation. Randomization was conducted after all baseline physiological measurements had been completed to prevent selection bias and ensure comparability between groups at the start of the intervention.

This study was reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) 2010 guidelines (Supplementary File 1).

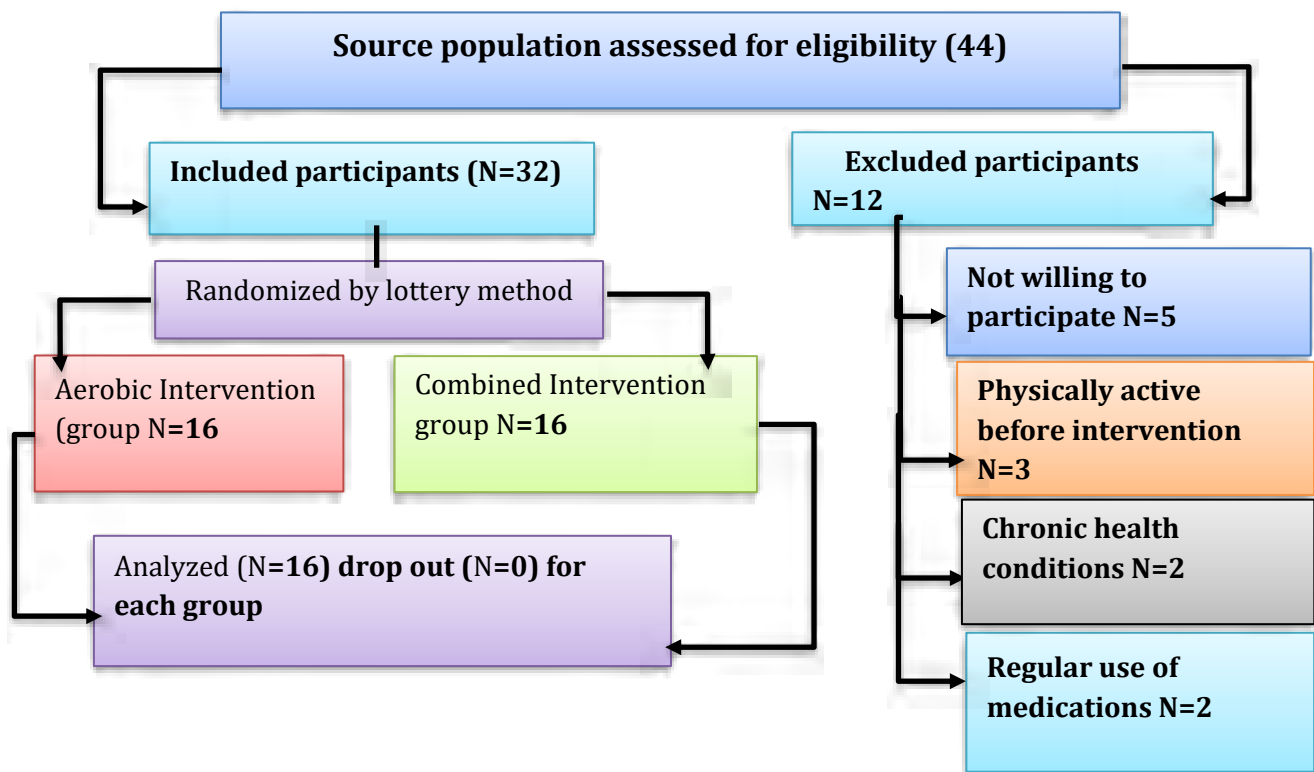


Figure 1: Sample Selection Criteria Flow Chart

3. Variables of the Study

3.1. Independent Variables

- Moderate-intensity aerobic exercise
- Combined aerobic and resistance exercise

3.2. Dependent Variables

- selected Physiologic variable
- Resting systolic blood pressure
- Resting diastolic blood pressure
- Resting heart rate
- Body fat percentage
- Lean body mass

3.3. Intervention Procedures

The intervention lasted for eight consecutive weeks, with exercise sessions conducted three times per week. Exercise intensity and duration were prescribed according to established exercise training recommendations for improving cardiovascular and physiological fitness [35-37].

Participants in the aerobic exercise group, a structured physical activity involving continuous rhythmic movement of large muscle groups performed at moderate intensity (60–85% of maximum heart rate) for 30–60 minutes per session, three times per week, for eight weeks, performed moderate-intensity aerobic activities such as jogging and aerobic workouts [34]. The combined exercise group, a training program that integrates aerobic exercise and resistance exercise within the same training session, performed three times per week for eight weeks, performed aerobic exercise

together with resistance training exercises within the same training session [23]. Participants in the aerobic exercise group performed moderate-intensity aerobic exercise at 64–76% of maximum heart rate (HRmax), three times per week for eight weeks. HRmax was estimated using the equation $220 - \text{age}$, and exercise intensity was monitored using heart rate reserve (HRR), calculated as $\text{HRmax} - \text{resting heart rate (RHR)}$. The combined exercise group performed aerobic exercise followed by resistance exercise within the same training session. Each exercise session lasted approximately 60 minutes, including warm-up and cool-down periods. Exercise intensity was maintained at approximately 60–85% of maximum heart rate reserve to ensure moderate-intensity training [15,38,39].

4. Data Collection Instruments and Procedures

Data collection was conducted before the initiation of the intervention (pre-test) and immediately after completion of the eight-week exercise intervention program (post-test). All measurements were performed under standardized conditions by trained personnel to ensure consistency and reliability of the collected data [31]. Participants were instructed to avoid vigorous physical activity, caffeine intake, alcohol consumption, and heavy meals for at least 12 hours before data collection sessions [32]. The physiological variables assessed in this study included blood pressure, resting heart rate, body fat percentage, and lean body mass. Standardized and calibrated instruments were used for all measurements.

4.1. Blood Pressure Measurement Procedures

Resting systolic blood pressure (SBP) and diastolic blood pressure

(DBP) were measured using a calibrated digital sphygmomanometer [33,40]. Blood pressure measurements were conducted in a quiet room under controlled environmental conditions to minimize external influences on cardiovascular responses [40].

Participants were instructed to sit comfortably on a chair with their back supported and feet flat on the floor for at least five minutes before measurement [40]. The participant’s arm was positioned at heart level during the procedure. Blood pressure measurements were taken from the left arm using an appropriately sized cuff according to standard clinical guidelines [33]. Two consecutive measurements were obtained at five-minute intervals, and the average value was recorded for analysis [6]. Blood pressure values were recorded in millimeters of mercury (mmHg) [41]. Resting systolic and diastolic blood pressure were measured using a BpTRU Blood Pressure Monitor (BpTRU Medical Devices, Coquitlam, British Columbia, Canada), an automated sphygmomanometer recommended for clinical and research blood pressure assessment.

4.2. Resting Heart Rate Measurement Procedures

Resting heart rate (RHR) was measured in beats per minute (bpm) using a digital heart rate monitor before the exercise intervention and after completion of the training program [15]. Participants remained seated quietly for five minutes before the measurement was taken to ensure stabilization of heart rate [42]. Measurements were conducted in the morning hours before exercise sessions to reduce the influence of fatigue and circadian variation [43]. Two measurements were recorded, and the average value was used

for data analysis [15]. Resting heart rate was measured using the BpTRU Blood Pressure Monitor (BpTRU Medical Devices, Coquitlam, British Columbia, Canada).

4.3. Body Composition Measurement Procedures

Body composition variables assessed in this study included body fat percentage and lean body mass. Measurements were taken while participants stood upright on the analyzer platform according to manufacturer instructions [44]. Participants were instructed to remove shoes, heavy clothing, jewelry, and metallic objects before measurement [45]. Measurements were taken while participants stood upright on the analyzer platform according to manufacturer instructions [44]. To improve measurement accuracy, participants were advised to avoid food intake, excessive fluid consumption, and strenuous exercise for several hours before testing [46]. Body fat percentage was recorded as the proportion of total body weight composed of fat tissue, while lean body mass represented non-fat body tissues including muscle, bone, and body water [47].

Body fat percentage was assessed using a Lange Skinfold Caliper (Beta Technology, Inc., Santa Cruz, California, USA), a widely used anthropometric instrument for measuring subcutaneous fat thickness at standardized body sites. Lean body mass (fat-free mass) was assessed using an Omron Body Composition Monitor Scale (Omron Healthcare Co., Ltd., Kyoto, Japan). The device utilizes bioelectrical impedance analysis (BIA) technology to estimate body composition variables, including lean body mass, expressed in kilograms (kg).

Variable Measured	Instrument	Manufacturer	Location
Resting blood pressure	BpTRU Blood Pressure Monitor	BpTRU Medical Devices	Coquitlam, BC, Canada
Resting heart rate	BpTRU Blood Pressure Monitor	BpTRU Medical Devices	Coquitlam, BC, Canada
Body fat percentage	Lange Skinfold Caliper	Beta Technology, Inc.	Santa Cruz, California, USA
Lean body mass	Omron Body Composition Monitor Scale	Omron Healthcare Co., Ltd.	Kyoto, Japan
Note: BpTRU = automated blood pressure monitor; BIA = bioelectrical impedance analysis			

Table 1: Instruments Used for Measurement of Physiological Variables

4.4. Exercise Intervention Monitoring Procedures

Participants in both intervention groups attended supervised exercise sessions three times per week for eight consecutive weeks [47,48]. Attendance and adherence were monitored throughout the intervention period. Exercise intensity was monitored using heart rate responses and the target heart rate method to ensure that participants exercised within the prescribed moderate-intensity

range of 60–85% of maximum heart rate [49]. Warm-up and cool-down activities were included in every session to minimize the risk of injury and improve exercise safety [50]. The aerobic exercise group performed continuous aerobic activities such as jogging and aerobic dance exercises. The combined exercise group performed aerobic exercise together with resistance training activities during the same session [23].

Component	MIAE Group	CEX Group
Intervention duration	8 weeks	8 weeks
Frequency	3 sessions/week	3 sessions/week
Session duration	60 min/session	60 min/session
Exercise intensity	64–76% HRmax (40–59% HRR)	64–76% HRmax (40–59% HRR)
Warm-up	10 min of light stretching and dynamic movements	10 min of light stretching and dynamic movements
Aerobic component	50 min of aerobic activities	30 min of aerobic activities
Aerobic activities	Brisk walking, jogging, aerobic dance, rhythmic movements	Brisk walking, jogging, aerobic dance
Resistance component	Not applicable	20 min of resistance exercises
Resistance exercises	Not applicable	Squats, lunges, push-ups, abdominal crunches, planks, resistance-band exercises
Sets	Not applicable	2–3 sets per exercise
Repetitions	Not applicable	10–15 repetitions per set
Rest interval	Not applicable	60–90 seconds between sets
Cool-down	10 min of walking and stretching exercises	10 min of walking and stretching exercises
Intensity monitoring	Heart rate monitored using HRmax and HRR methods	Heart rate monitored using HRmax and HRR methods
Supervision	Supervised by exercise instructors	Supervised by exercise instructors
HRmax = maximum heart rate estimated as 220 – age; HRR = heart rate reserve calculated as HRmax – resting heart rate. MIAE = Moderate-Intensity Aerobic Exercise; CEX = Combined Exercise (aerobic plus resistance exercise). Both intervention programs were conducted three times per week for eight consecutive weeks under supervised conditions.		

Table 2: Exercise Intervention Protocols for the Moderate-Intensity Aerobic Exercise (MIAE) and Combined Exercise (CEX) Groups

4.5. Data Recording and Quality Assurance Procedures

All collected data were recorded immediately using structured data collection sheets prepared specifically for the study [51]. Data completeness and consistency were checked daily by the investigator and supervisors before data entry [31,52].

To ensure reliability and validity of measurements, the following quality control measures were implemented:

- Calibration of all measuring instruments before data collection [53].
- Standardization of measurement procedures across all participants [53,54].
- Training of data collectors and exercise supervisors before commencement of the study [55].
- Conducting measurements at similar times of the day to minimize physiological variation [56].
- Repeating measurements when inconsistent values were observed [57,58].

These procedures were implemented to improve the accuracy, reliability, and validity of the collected physiological data.

5. Statistical Analysis

Data were entered, coded, and analyzed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means and standard deviations, were computed for all study variables.

Prior to inferential analyses, the assumptions of normality and homogeneity of variance were assessed. Normality of the data distribution was evaluated using the Shapiro–Wilk test, supplemented by visual inspection of histograms and Q–Q plots. The results indicated that all outcome variables were approximately normally distributed ($p > 0.05$). Homogeneity of variance between intervention groups was examined using Levene’s test, and the assumption was satisfied for all dependent variables ($p > 0.05$).

Within-group differences between pre- and post-intervention measurements were analyzed using paired-samples t-tests. To examine the overall effect of intervention type on the combined set of physiological variables, a multivariate analysis of variance (MANOVA) was conducted. Following a significant multivariate effect, tests of between-subjects effects were performed to identify the specific variables contributing to group differences. Bonferroni-adjusted pairwise comparisons were subsequently conducted to compare post-intervention outcomes between the Moderate-Intensity Aerobic Exercise (MIAE) and Combined Exercise (CEX) groups.

Statistical significance was established at $\alpha = 0.05$ for all analyses. Effect sizes were reported using partial eta squared (η^2) for MANOVA and univariate analyses to quantify the magnitude of intervention effects.

6. Result

6.1. Demographic characteristics of participants for aerobic exercise

A total of 16 non-athlete students from the College of Science,

Bahir Dar University Main Campus, participated in the study. The participants had a mean age of 22.19 ± 0.83 years, a mean body weight of 56.00 ± 4.23 kg, and a mean height of 161.50 ± 7.58 cm. All participants in this group were of the same sex (Table 3).

	No of participants	Mean	Standard Deviation
sex of students	16	1.00	.000
age of students in year	16	22.188	.8342
weight of student in kilograms	16	56.0000	4.22690
height of students in meters	16	161.5000	7.58068

Table 3: Demographic Characteristics of Participants for Aerobics Exercise

6.2. Demographic Characteristics of Participants for Combined Aerobic-Resistance Exercise

Similarly, experimental group two is also female active students who have a mean age of 22.13 ± 0.719 years, mean weight of

54.7500 ± 4.86484 kg and mean height of 161.2500 ± 7.17867 cm. This indicates that the selected populations were relatively similar in age, height, and weight at the beginning of the exercise program (table 4).

		N	Mean	Std. Deviation
sex of students	16	1.00	.000	
age of students in year	16	22.13	.719	
weight of student in kilograms	16	54.7500	4.86484	
height of students in meters	16	161.2500	7.17867	

Table 4: Demographic characteristics of participants for Combined Aerobic-Resistance Exercise

6.3. Baseline Descriptive Statistics of Physiological Variables in the Moderate-Intensity Aerobic Exercise and Combined Exercise Groups

The moderate-intensity aerobic exercise (MIAE) and combined exercise (CEX) groups exhibited comparable baseline

characteristics. The mean values of systolic blood pressure, diastolic blood pressure, resting heart rate, body fat percentage, and lean body mass were similar between the two groups, indicating homogeneity at pre-test and suggesting that the groups were well matched before the intervention (table 5)

Variables	Intervention	Mean	Std. Deviation	N
SBP	MIAE	119.5000	4.06612	16
	CEX	118.8750	3.32415	16
DBP	MIAE	79.5625	2.63233	16
	CEX	79.0625	2.76812	16
RHR	MIAE	74.5625	2.30850	16
	CEX	74.8750	2.12525	16
BF%	MIAE	23.0500	1.88644	16
	CEX	23.0875	2.00794	16
LBM	MIAE	42.8000	1.08074	16
	CEX	42.5750	1.03891	16

Table 5: Baseline Descriptive Statistics of Physiological Variables in the Moderate-Intensity Aerobic Exercise and Combined Exercise Groups

6.4. Descriptive Statistics of Multivariate Analyses of Pre-Post-Test Results of Two Intervention Groups

Table 6 and Figure 2 present the descriptive statistics of the pre- and post-test physiological variables for the moderate-intensity aerobic exercise (MIAE) and combined exercise (CEX) groups. In the MIAE group, post-intervention measurements showed reductions in systolic blood pressure, diastolic blood pressure, resting heart rate, and body fat percentage compared with baseline values. Lean body mass remained relatively unchanged following the 8-week

intervention. Similarly, the CEX group demonstrated reductions in systolic blood pressure, diastolic blood pressure, resting heart rate, and body fat percentage from pre-test to post-test. In addition, lean body mass increased following the intervention. Overall, both exercise programs were associated with favorable changes in cardiovascular and body composition variables, with the combined exercise program showing improvements in lean body mass alongside reductions in the other physiological measures.

Physiological variables	type of intervention	Mean	Mean	Std. Deviation	Std. Deviation	N
		Pre	Post	Pre	Post	
SBP	MIAE	119.5000	116.1250	4.06612	4.48516	16
	SEX	118.8750	114.5000	3.32415	3.70585	16
DBP	MIAE	79.5625	77.0000	2.63233	2.52982	16
	CEX	79.0625	76.3750	2.76812	2.47319	16
RHR	MIAE	74.5625	69.9375	2.30850	3.08693	16
	CEX	74.8750	72.5000	2.12525	2.73252	16
body fat %	MIAE	23.0500	22.2438	1.88644	1.70801	16
	CEX	23.0875	21.5188	2.00794	1.83565	16
LBM	MIAE	42.8000	42.7375	1.08074	1.02168	16
	CEX	42.5750	43.5625	1.03891	1.11647	16

Note: MIAE-moderate intensity aerobic exercise, CEX-combined exercise, SBP-systolic blood pressure, DBP-diastolic blood pressure, RHR –resting heart rate in bpm, body fat %-body fat percentages and LBM-lean body mass.

Table 6: Descriptive Statistics of Pre- and Post-Intervention Physiological Variables in the Moderate-Intensity Aerobic Exercise and Combined Exercise Groups

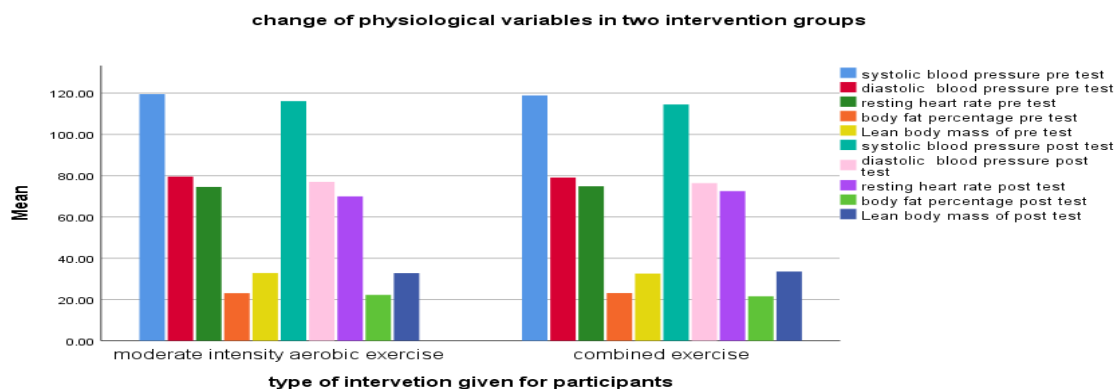


Figure 2: Graphical comparison of pre-post test results of the two groups

6.5. Paired-Samples t-Test Analysis of Pre- and Post-Intervention Physiological Variables in the MIAE and CEX Groups

The paired-samples t-test revealed significant improvements in most physiological variables following the interventions in both groups. In the moderate-intensity aerobic exercise (MIAE) group, significant reductions were observed in systolic blood pressure (mean difference = -3.38 mmHg, $p < 0.001$), diastolic blood pressure (mean difference = -2.56 mmHg, $p = 0.002$), resting heart rate (mean difference = -4.63 bpm, $p < 0.001$), and body fat

percentage (mean difference = -0.81% , $p < 0.001$). However, the change in lean body mass was not statistically significant (mean difference = -0.06 kg, $p = 0.729$).

Similarly, in the combined exercise (CEX) group, significant reductions were found in systolic blood pressure (mean difference = -4.38 mmHg, $p < 0.001$), diastolic blood pressure (mean difference = -2.69 mmHg, $p = 0.002$), resting heart rate (mean difference = -2.38 bpm, $p < 0.001$), and body fat percentage (mean difference = -1.57% , $p < 0.001$). In contrast to the MIAE group,

lean body mass increased significantly following the intervention (mean difference = 0.99 kg, $p < 0.001$). These findings indicate that both interventions were effective in improving cardiovascular

and body composition variables, while the combined exercise program produced additional benefits in increasing lean body mass (Table 7).

		Moderate-intensity aerobic group					T	F	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% CI of the Difference				
					Lower	Upper			
Pair 1	SBPB – SBPA	-3.37500	2.70493	.67623	-4.81636	1.9364	-4.991	15	.000
Pair 2	DBPB – DBPA	-2.56250	2.70724	.67681	-4.00509	1.11991	-3.786	15	.002
Pair 3	RHRB – RHRA	-4.62500	1.82117	.45529	-5.59543	-3.65457	-10.158	15	.000
Pair 4	BF%B – BF%A	-.80625	.61261	.15315	-1.13269	.47981	-5.264	15	.000
Pair 5	LBMB – LBMA	-.06250	.70699	.17675	-.43923	.31423	-.354	15	.729

Combined intervention groups

Pair 1	SBPB – SBPA	-4.37500	2.21736	.55434	-5.55655	-3.19345	-7.892	15	.000
Pair 2	DBPB – DBPA	-2.68750	2.82179	.70545	-4.19113	-1.18387	-3.810	15	.002
Pair 3	RHRB – RHRA	-2.37500	2.09364	.52341	-3.49062	-1.25938	-4.538	15	.000
Pair 4	BF%B – BF%A	-1.56875	1.08549	.27137	-2.14717	-.99033	-5.781	15	.000
Pair 5	LBMB – LBMA	.98750	.30083	.07521	.82720	1.14780	13.130	15	.000

Note: MIAE-moderate intensity aerobic exercise, CEX-combined exercise-test statistic, SBPB-systolic blood pressure posttest in mmHg, DBPB-diastolic blood pressure post-test in mmHg, RHRB –resting heart rate post-test in bpm, BF %B-body fat percentages post-test based on skin fold caliper result and LBMB-lean body mass post-test. SBPA-systolic blood pressure pre-test, DBPA-diastolic blood pressure pre-test, RHRA –resting heart rate pre-test in bpm, BF %A-body fat percentages pre-test based on skin fold caliper result, and LBMA-lean body mass pre-test.

Table 7: Paired-Samples t-Test Analysis of Pre- and Post-Intervention Physiological Variables in the MIAE and CEX Groups

6.6. Multivariate Effect of Training Group on the Combined Set of Physiological Parameters

the multivariate analysis of variance (MANOVA) examining the effect of exercise intervention on the combined set of physiological parameters. Among the four multivariate test statistics, Wilks' Lambda was selected for interpretation. The results showed a statistically significant multivariate effect of intervention on the combined physiological variables, Wilks' $\Lambda = 0.411$, $F(10, 21) = 3.003$, $p = 0.016$, partial $\eta^2 = 0.589$. The significant F-value indicates that the exercise intervention had a statistically significant effect on the combined physiological outcomes. Therefore, the

null hypothesis that the intervention groups did not differ on the combined set of physiological parameters was rejected. This finding suggests that the type of exercise intervention contributed to differences in participants' overall physiological responses. The Wilks' Lambda value of 0.411 indicates the proportion of variance in the combined dependent variables that remained unexplained by the intervention effect. In other words, approximately 41.1% of the variance in the combined physiological parameters was not attributable to differences between the intervention groups, while the remaining variance was associated with the intervention effect and other sources of variation (Table 8).

Effect		Value	F	Hypothesis df	Error df	Sig.	η^2
Intercept	Pillai's Trace	1.000	30987.63b	10.000	21.000	.000	1.000
	Wilks' Lambda	.000	30987.63b	10.000	21.000	.000	1.000
	Hotelling's Trace	14756.017	30987.63b	10.000	21.000	.000	1.000
	Roy's Largest Root	14756.017	30987.63b	10.000	21.000	.000	1.000
Intervention	Pillai's Trace	.589	3.003b	10.000	21.000	.016	.589
	Wilks' Lambda	.411	3.003b	10.000	21.000	.016	.589
	Hotelling's Trace	1.430	3.003b	10.000	21.000	.016	.589
	Roy's Largest Root	1.430	3.003b	10.000	21.000	.016	.589

“a” Design: Intercept + intervention;” b” Exact statistic, Key: F- F-ratio, Hypothesis df- Hypothesis Degrees of Freedom, Error df- Error degrees of Freedom, b -superscript- Exact Statistic and η^2 - Eta-squared

Table 8: Multivariate Effect of Training Group on the Combined Set of Physiological Parameters

6.7. Univariate Results of Individual Physiological Variables Between MIAE and CEX Groups

Following the significant multivariate effect of intervention observed in the MANOVA, univariate analyses were conducted to determine which specific physiological variables contributed to the overall group differences. The results indicated that systolic blood pressure (SBP), diastolic blood pressure (DBP), and body fat percentage (BF%) did not differ significantly between the Moderate-Intensity Aerobic Exercise (MIAE) and Combined Exercise (CEX) groups. For SBP, the intervention effect was not statistically significant, $F(1, 30) = 1.248$, $p = .273$, partial $\eta^2 = .040$. The effect size indicates that approximately 4.0% of the variance in SBP was associated with group membership, representing a small effect. Therefore, no significant difference in systolic blood pressure was observed between the two intervention groups. Similarly, no significant intervention effect was found for DBP, $F(1, 30) = 0.499$, $p = .485$, partial $\eta^2 = .016$. The effect size suggests that only 1.6% of the variance in diastolic blood pressure was associated with the intervention group, indicating a trivial to small effect. Thus, the two exercise interventions produced comparable outcomes with respect to diastolic blood pressure. Body fat percentage also showed no statistically significant difference between groups, $F(1, 30) = 1.338$, $p = .257$, partial $\eta^2 = .043$. The intervention accounted for approximately 4.3% of

the variance in body fat percentage, representing a small effect size. Consequently, the MIAE and CEX groups did not differ significantly in body fat percentage. In contrast, resting heart rate (RHR) demonstrated a statistically significant intervention effect, $F(1, 30) = 6.182$, $p = .019$, partial $\eta^2 = .171$. The p-value indicates a significant difference between the MIAE and CEX groups in resting heart rate. Furthermore, the effect size suggests that approximately 17.1% of the variance in resting heart rate was associated with the intervention group, representing a large effect according to commonly used benchmarks. This finding indicates that the type of exercise intervention had a meaningful influence on resting heart rate. Lean body mass (LBM) also showed a statistically significant intervention effect, $F(1, 30) = 4.755$, $p = .037$, partial $\eta^2 = .137$. Approximately 13.7% of the variance in lean body mass was associated with the intervention group, indicating a moderate-to-large effect size. This result suggests that participants in the MIAE and CEX groups differed significantly in lean body mass. Overall, the univariate analyses revealed that resting heart rate and lean body mass were the primary physiological variables contributing to the significant multivariate effect observed in the MANOVA. In contrast, systolic blood pressure, diastolic blood pressure, and body fat percentage did not show statistically significant differences between the intervention groups (Table 9).

Tests of Between-Subjects Effects							
Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	η^2
Intervention	SBPB	21.125	1	21.125	1.248	.273	.040
	DBPB	3.125	1	3.125	.499	.485	.016
	RHRB	52.531	1	52.531	6.182	.019	.171
	BF%B	4.205	1	4.205	1.338	.257	.043
	LBMB	5.445	1	5.445	4.755	.037	.137
Error	SBPB	507.750	30	16.925			
	DBPB	187.750	30	6.258			
	RHRB	254.938	30	8.498			
	BF%B	94.304	30	3.143			
	LBMB	34.355	30	1.145			
A. R Squared = .040 (Adjusted R Squared = .008)							
B. R Squared = .016 (Adjusted R Squared = -.016)							
C. R Squared = .171 (Adjusted R Squared = .143)							
D. R Squared = .043 (Adjusted R Squared = .011)							
E. R Squared = .137 (Adjusted R Squared = .108)							

Key: df - degrees of freedom, F- F-test, η^2 - Eta-squared

Table 9: Univariate Results of Individual Physiological Variables Between MIAE and CEX Groups

6.8 Pairwise Comparison Between MIAE and CEX Groups on Physiological Variables

For systolic blood pressure (SBP), the estimated mean difference between the MIAE and CEX groups was 1.625 mmHg (95% CI: -1.346 to 4.596). Although the MIAE group exhibited a slightly higher mean SBP value than the CEX group, the difference was not

statistically significant ($p = .273$). The confidence interval included zero, further indicating that the groups did not differ significantly in systolic blood pressure. Similarly, for diastolic blood pressure (DBP), the mean difference between the MIAE and CEX groups was 0.625 mmHg (95% CI: -1.181 to 2.431). The difference was not statistically significant ($p = .485$), suggesting that the two exercise

interventions produced comparable outcomes for diastolic blood pressure. For resting heart rate (RHR), a statistically significant difference was observed between the intervention groups. The mean difference was -2.562 beats per minute (95% CI: -4.667 to -0.458; $p = .019$). The negative mean difference indicates that the MIAE group had a lower estimated mean resting heart rate than the CEX group. Because the confidence interval did not include zero and the p -value was less than .05, the difference was considered statistically significant. For body fat percentage (BF%), the mean difference between the MIAE and CEX groups was 0.725% (95% CI: -0.555 to 2.005).

Although the MIAE group showed a slightly higher estimated mean body fat percentage than the CEX group, the difference was not statistically significant ($p = .257$). The confidence interval crossing zero further supports the absence of a significant group

difference. A statistically significant difference was also observed for lean body mass (LBM). The mean difference between the MIAE and CEX groups was -0.825 kg (95% CI: -1.598 to -0.052; $p = .037$). The negative mean difference indicates that the MIAE group had a lower estimated mean lean body mass than the CEX group. Since the confidence interval did not include zero and the p -value was below .05, the difference was statistically significant. Overall, the pairwise comparisons revealed significant differences between the MIAE and CEX groups for resting heart rate and lean body mass. Specifically, the MIAE group demonstrated a significantly lower resting heart rate, whereas the CEX group demonstrated a significantly greater lean body mass. In contrast, no statistically significant differences were observed between the groups for systolic blood pressure, diastolic blood pressure, or body fat percentage (Table 10).

Dependent Variable	(I) intervention	(J) intervention	Mean Difference (I-J)	Std. Error	Sig. ^b	95% CI for Difference	
						Lower Bound	Upper Bound
SBPB	MIAE	CEX	1.625	1.455	.273	-1.346	4.596
	CEX	MIAE	-1.625	1.455	.273	-4.596	1.346
DBPB	MIAE	CEX	.625	.884	.485	-1.181	2.431
	CEX	MIAE	-.625	.884	.485	-2.431	1.181
RHRB	MIAE	CEX	-2.562	1.031	.019	-4.667	-.458
	CEX	MIAE	2.563	1.031	.019	.458	4.667
BF%B	MIAE	CEX	.725	.627	.257	-.555	2.005
	CEX	MIAE	-.725	.627	.257	-2.005	.555
LBMB	MIAE	CEX	-.825*	.378	.037	-1.598	-.052
	CEX	MIAE	.825*	.378	.037	.052	1.598

Table 10: Pairwise Comparison Between MIAE and CEX Groups on Physiological

7. Discussion

The goal of the present study was to investigate the comparison effect of 8 weeks of aerobics and a combination of aerobic with resistance exercise on selected physiological variables among university students. The present study has focused on examining the comparable effects of the two different exercise interventions on a set of physiological outcome variables within each group and between the groups. The key physiological variables examined after the 8 weeks of training intervention programs included blood pressure (both systolic and diastolic), heart rate, body fat percentage, and lean body mass.

The variables that showed statistically significant effect changes in the MIAE group are systolic blood pressure, diastolic blood pressure, and resting heart rate. These three variables demonstrated statistically significant decreases, with p -values less than 0.05. On the other hand, the change in lean body mass within the MIAE group was not statistically significant, with a p -value of 0.729.

The Combined Exercise (CEX) group results also indicate a positive impact on multiple physiological measures in posttest results. Statistically significant decreases in systolic blood pressure, diastolic blood pressure, and resting heart rate (all $p < 0.05$). In

addition, the CEX group also showed a statistically significant decrease in body fat percentage ($p < 0.05$) and a statistically significant increase in lean body mass ($p < 0.05$).

7.1. Blood Pressure (Systolic and Diastolic Blood Pressure)

The present study found that both moderate-intensity aerobic exercise (MIAE) and combined exercise (CEX) significantly reduced systolic and diastolic blood pressure after the 8-week intervention period. However, no statistically significant difference was observed between the two intervention groups. These findings suggest that both exercise modalities are effective in improving blood pressure among healthy female university students.

The findings are consistent with previous studies reporting favorable effects of aerobic and combined exercise training on blood pressure regulation. A previous comparative trial reported significant reductions in blood pressure following combined aerobic and resistance training interventions, together with improvements in cardiovascular health indicators [59]. Similarly, an eight-week training study conducted among female university students demonstrated that an exercise program performed three times per week significantly improved cardiovascular parameters, including

systolic blood pressure, among this population [60]. Furthermore, prior clinical evidence reported that combining aerobic and resistance exercise effectively improves blood pressure control and cardiovascular function [61]. The absence of a significant difference between groups in the present study may indicate that both exercise modalities provide sufficient cardiovascular stimulus to induce similar blood pressure adaptations in healthy young adults.

7.2. Resting Heart Rate

Resting heart rate was significantly influenced by the type of exercise intervention. Although both groups experienced significant reductions in resting heart rate, the MIAE group demonstrated a significantly lower post-intervention resting heart rate compared with the CEX group. This finding suggests that moderate-intensity aerobic exercise may produce greater cardiovascular adaptations related to cardiac efficiency and autonomic regulation.

This finding is consistent with previous studies that have shown aerobic exercise to be highly effective in reducing resting heart rate. A prior comparative training intervention reported significant reductions in resting heart rate following aerobic, resistance, and concurrent training programs, with aerobic exercise producing the largest improvement [62]. Likewise, a related campus-based study found that moderate-intensity aerobic exercise significantly improved cardiorespiratory fitness and reduced resting heart rate among female students [60]. These improvements may be attributed to enhanced stroke volume, increased parasympathetic activity, and improved cardiac efficiency associated with aerobic conditioning.

7.3. Body Fat Percentage

Both intervention groups demonstrated reductions in body fat percentage following the intervention period. However, the difference between the MIAE and CEX groups was not statistically significant. This finding indicates that both exercise programs were similarly effective in improving body composition among the participants.

The result partially agrees with previous studies that have reported beneficial effects of aerobic and combined exercise on body fat reduction. A study reported that concurrent training was more effective than either aerobic or resistance training alone for improving body composition parameters [63]. Similarly, a 12-week concurrent training study found that combined aerobic and resistance exercise significantly reduced body fat percentage and improved physical fitness [23,64]. Although the CEX group in the present study demonstrated a greater numerical reduction in body fat percentage, the difference was insufficient to reach statistical significance. This may be explained by the relatively short intervention period and the healthy baseline status of the participants.

7.4. Lean Body Mass

Lean body mass was the second variable that differed significantly

between intervention groups. Participants in the CEX group achieved significantly greater lean body mass than those in the MIAE group following the intervention. This finding highlights the additional benefits of resistance training when combined with aerobic exercise.

The present finding is consistent with previous literature demonstrating that combined exercise programs are superior to aerobic exercise alone for increasing lean body mass. A study reported that combined aerobic and resistance training produced greater improvements in fat-free mass and overall physical fitness compared with isolated exercise modalities [64]. Similarly, another study found significant increases in lean body mass among females participating in endurance-strength training programs [65]. An 8-week concurrent strength and aerobic training study also reported that concurrent strength and aerobic training significantly improved total lean mass following an eight-week intervention program [66]. The resistance-training component of the CEX program likely stimulated muscle hypertrophy and neuromuscular adaptations, leading to greater improvements in lean body mass.

7.5. Comparative Effectiveness of MIAE and CEX

The multivariate analysis revealed a significant overall effect of intervention type on the combined physiological variables. Follow-up analyses showed that resting heart rate and lean body mass were the primary contributors to this difference. Specifically, MIAE produced greater improvements in resting heart rate, whereas CEX resulted in greater improvements in lean body mass.

These findings support previous evidence indicating that aerobic exercise is particularly effective for cardiovascular adaptations, while combined aerobic and resistance exercise provides additional benefits for body composition and muscular development [15,63,64, 66]. Therefore, exercise prescription should consider the primary physiological goal of the participant. Individuals aiming to improve cardiovascular efficiency may benefit more from moderate-intensity aerobic exercise, whereas those seeking improvements in lean body mass and overall body composition may benefit more from combined aerobic and resistance exercise.

8. Conclusion

Based on the findings of the study, it can be concluded that both Moderate-Intensity Aerobic Exercise (MIAE) and Combined Exercise (CEX) are effective exercise interventions for improving cardiovascular and body composition variables among non-athlete female university students. Both interventions produced significant reductions in systolic blood pressure, diastolic blood pressure, resting heart rate, and body fat percentage. However, when the two interventions were compared directly, significant differences were observed only for resting heart rate and lean body mass. Moderate-intensity aerobic exercise was more effective in reducing resting heart rate, indicating superior cardiovascular adaptation. In contrast, combined exercise, which incorporated both aerobic and resistance training, was more effective in increasing lean body mass.

The absence of significant differences in blood pressure and body fat percentage suggests that both exercise modalities are similarly effective for improving these physiological outcomes. Nevertheless, the significant multivariate effect observed through MANOVA indicates that the type of exercise intervention influences the overall pattern of physiological adaptation. Therefore, the selection of exercise modality should depend on the primary training objective. For improving cardiovascular efficiency and reducing resting heart rate, moderate-intensity aerobic exercise appears preferable. For enhancing lean body mass while simultaneously improving cardiovascular health, combined exercise is the more beneficial approach.

Limitations of the study

Several limitations should be considered when interpreting the findings of this study. First, the study included a relatively small sample size ($n = 32$), which may have limited the statistical power to detect small between-group differences and may reduce the generalizability of the findings. Second, all participants were healthy, non-athlete female undergraduate students from a single university in Ethiopia; therefore, the results may not be generalizable to male students, athletes, older adults, or other populations.

Third, the intervention period lasted only eight weeks. Although significant physiological adaptations were observed, a longer intervention and follow-up period may be necessary to determine the sustainability and long-term effects of the exercise programs. Fourth, dietary intake was not strictly monitored or controlled during the intervention period. Variations in nutrition and energy intake may have influenced changes in body composition outcomes, particularly body fat percentage and lean body mass.

Fifth, body composition was assessed using skinfold measurements and bioelectrical impedance analysis rather than more advanced methods such as dual-energy X-ray absorptiometry (DXA), which may have introduced measurement error. Finally, the study did not include a non-exercise control group; therefore, the observed changes cannot be attributed exclusively to the interventions without considering potential external influences such as lifestyle changes or daily physical activities outside the supervised exercise sessions.

Despite these limitations, the randomized experimental design, supervised training sessions, and complete participant retention strengthen the internal validity of the study and support the reliability of the findings.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

For University Students

- Female university students should regularly participate in structured exercise programs to improve cardiovascular health and body composition.
- Students seeking improvements in cardiovascular efficiency

and resting heart rate should prioritize moderate-intensity aerobic exercise.

- Students aiming to increase lean body mass while maintaining cardiovascular fitness should engage in combined aerobic and resistance exercise programs.

For Fitness Professionals and Health Practitioners

- Exercise professionals should prescribe both aerobic and combined exercise programs as effective non-pharmacological strategies for improving physiological health.
- Combined exercise programs should be recommended when improvements in lean body mass are desired.
- Aerobic exercise programs should be emphasized when reductions in resting heart rate are the primary goal.

For Bahir Dar University

- The university should strengthen physical activity promotion programs targeting female students.
- Appropriate facilities and organized exercise programs should be made available to encourage regular participation in physical activity.
- Awareness programs highlighting the health benefits of regular exercise should be conducted among students.

For Future Researchers

- Similar studies should be conducted using larger sample sizes to improve the generalizability of findings.
- Future investigations should include male participants and different age groups.
- Longer intervention periods should be considered to determine the long-term effects of aerobic and combined exercise interventions.
- Additional physiological and health-related variables such as aerobic capacity, muscular strength, lipid profile, blood glucose, and psychological well-being should be examined.
- Future studies should investigate the effects of different exercise intensities and training frequencies on physiological adaptations.
- It is recommended that subsequent investigations implement a standardized nutritional log or dietary control tracking variable to account for caloric intake, which acts as a known confounding variable in short-term body composition and metabolic interventions.

Declaration

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of Bahir Dar University (Approval No. IRB 123/2024). The study adhered to the ethical principles of the Declaration of Helsinki (59). Written informed consent was obtained from all participants before participation in the study. The ethical review process was overseen by the IRB committee, including Dr. Gashew Tesema and Dr. Haileyesus Gedefaw.

Data Availability

All data generated or analyzed during this study are included in this

published article and its supplementary materials. The extracted dataset and statistical code are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no conflicts of interest.

Authors Contributions

KA conceived and designed the study, conducted the literature search, and analyzed the data, and drafted the manuscript. ZD, YT contributed to study selection, quality assessment, data interpretation, and critical revision of the manuscript. All authors read and approved the final manuscript.

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