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Aerobic VS Anaerobic Exercise on Body Composition and Hormonal Adaptations in Athletes and Non-Athletes: A Randomized Controlled Trial

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Abstract

Background: This study examined the differential effects of aerobic and anaerobic exercise on body composition and hormonal adaptations in athletes and non-athletes, providing evidence-based recommendations for optimizing fitness and health outcomes, such as training duration, frequency, and the combination of aerobic and anaerobic exercises.
Aim: These specific recommendations aim to enhance both physical performance and overall health, tailored to the needs of different populations.
Methods: A randomized controlled trial involving 120 males (60 athletes, 60 non-athletes, aged 18–25 years) was conducted. Participants engaged in 12 weeks of either aerobic or anaerobic exercise. The aerobic group performed moderate-intensity continuous training (MICT) for 50 minutes per session, 3 times per week, while the anaerobic group performed 30 minutes of resistance training followed by 20 minutes of high-intensity interval training (HIIT) 3 times per week. Dual-energy X-ray absorptiometry (DXA) measured body composition, while blood samples assessed testosterone, cortisol, and growth hormone levels. Mixed ANOVA analyzed the effects of exercise type, athletic status, and time.
Results: Anaerobic exercise led to significant increases in lean body mass and strength, while aerobic exercise induced greater fat loss. Athletes exhibited more pronounced increases in testosterone and growth hormone levels, compared to non-athletes.
Conclusions: Tailored exercise programs, considering fitness levels and goals, can optimize body composition and hormonal health. These findings have practical implications for designing effective training regimens for diverse populations.

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INTRODUCTION

Exercise is widely recognized as a crucial component of a healthy lifestyle, with over 80% of adults worldwide acknowledging its positive impact on both physical and mental well-being. According to the World Health Organization (2020), regular exercise is linked to a reduced risk of chronic diseases such as cardiovascular disease, diabetes, and depression, underscoring its importance. Furthermore, the growing body of evidence continues to support the integration of physical activity into public health recommendations and daily routines (Granero-Jiménez et al., 2022; Daniela et al., 2022; World Health Organization, 2020). In addition to its physical benefits, regular exercise plays a key role in improving mental health by alleviating symptoms of anxiety and depression, as well as enhancing cognitive function (Mahindru, Patil & Agrawal, 2023; Herbert, 2022; Smith & Merwin, 2021; Caponnetto et al., 2021; Xie et al., 2021).

The two primary categories of exercise, aerobic and anaerobic, have distinct physiological effects on the body (Aldoski, Al-Naemi & Khalid, 2023; Kumar & Pandey, 2023; Pellegrino et al., 2022; Tatlibal & Zencir, 2022). Aerobic exercise, characterized by sustained moderate-intensity activities

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that rely on oxygen for energy production, is known for its cardiovascular benefits and ability to improve endurance (Franklin et al., 2022; Blagrove, 2022).

This type of exercise also contributes to improved blood fat levels (lipid profiles), reduced inflammation, and greater insulin sensitivity (the body's ability to respond to insulin and regulate blood sugar levels) (Almutairi et al., 2024; Babaei Mazreno & Taghian, 2024). Anaerobic exercise, on the other hand, involves short bursts of high-intensity activity that do not depend on oxygen for energy production and is associated with improvements in muscle strength and power (Atakan et al., 2021; Lee et al., 2021; Patel et al., 2017). Additionally, anaerobic training enhances resting metabolic rate and supports bone density, making it particularly beneficial for long-term musculoskeletal health (D'Onofrio et al., 2023; Spriet, 2022)

While both forms of exercise offer significant health benefits, their impacts on body composition and hormonal adaptations differ, particularly when comparing athletes to non-athletes. Athletes, due to their regular training and higher fitness levels, respond differently to exercise stimuli compared to non-athletes. Specifically, trained athletes exhibit superior mitochondrial function and recovery capacity, enabling them to adapt more efficiently to high-intensity exercise (Daussin et al., 2008; Jacobs & Lundby, 2013; Bartlett et al., 2017; MacInnis et al., 2017; Fiorenza et al., 2019; Mølmen, Almquist, & Skattebo, 2024). Understanding these differential effects is crucial for developing targeted exercise programs and optimizing performance in both athletic and non-athletic populations.

Aerobic exercise improves cardiovascular health, cardiorespiratory fitness, and immune function, with benefits such as enhanced vascular health and lipid metabolism (Garber et al., 2011; Haaja, 2024). Moreover, aerobic activity stimulates angiogenesis and promotes mitochondrial biogenesis, which are key for sustained energy production and fatigue resistance (Yan et al., 2011). Anaerobic exercise, including resistance training and HIIT, enhances muscle strength, power, metabolic rate, and bone density while also modulating immune responses through distinct pathways (Kraemer & Ratamess, 2004; Kostrzewa-Nowak et al., 2020). Anaerobic training has also been shown to elicit s, such as increased testosterone and growth hormone levels, which are essential for muscle hypertrophy and repair (Gharahdaghi et al., 2021; Kraemer, Ratamess & Nindl, 2017; Kraemer & Ratamess, 2005). Concurrent training optimizes endurance and strength via mitochondrial and neuromuscular adaptations (Gedara & Othalawa, 2023). Athletes, due to superior baseline fitness, experience faster recovery and efficient adaptations but smaller relative gains compared to non-athletes (Fleck, 1983; Häkkinen et al., 1985).

While aerobic and anaerobic exercises have been extensively studied individually, there is limited research directly comparing their combined effects, especially in the context of diverse populations such as athletes and non-athletes. Studies examining the synergistic effects of these modalities on health markers like inflammation, hormonal balance, and vascular elasticity are sparse but crucial for advancing exercise science (Aloski, Al-Naemi & Khalid, 2023; Xie & Song, 2021; Ammar et al., 2020; Alves et al., 2020; Shi et al., 2007). Additionally, the immune and vascular adaptations induced by these exercise modalities remain underexplored. Investigating these mechanisms is vital to understanding how specific exercise combinations can optimize health and performance across diverse groups. There is also a lack of studies examining the long-term impacts of concurrent training protocols across varied training backgrounds.

The purpose of this study is to investigate the differential impact of aerobic and anaerobic exercise on body composition and hormonal adaptations in athletes versus non-athletes. By examining these differences, we aim to provide valuable insights into the physiological mechanisms underlying exercise-induced adaptations and inform evidence-based recommendations for exercise prescription in diverse populations.

METHOD

Participants

A total of 120 healthy males (60 athletes and 60 non-athletes) aged 18-25 years and physically fit were recruited for this study. Athletes were defined as individuals participating in regular competitive sports training for at least two years, including intercollegiate sports or consistent gym-based training. Regular was defined as at least three structured training sessions per week, without significant interruptions over the two years. Non-athletes were defined as individuals who had not engaged in regular, structured exercise for at least six consecutive months. Participants were asked to specify the type of training, frequency, and consistency over the past two years to confirm eligibility. All participants provided written informed consent, and the study was approved by the institutional ethics committee.

Study Design

This study employed a randomized, controlled design. Participants were stratified by athletic status (athlete vs. non-athlete) and then randomly assigned to one of four subgroups: Athlete Aerobic (AA) with 30 participants, Athlete Anaerobic (AN) with 30 participants, Non-Athlete Aerobic (NAA) with 30 participants, and Non-Athlete Anaerobic (NAN) with 30 participants. The intervention period lasted 12 weeks, with assessments conducted at baseline, 6 weeks, and 12 weeks.

Exercise Interventions

Aerobic Exercise Program: Participants in the aerobic exercise groups (AA and NAA) engaged in moderate-intensity continuous training (MICT) for 50 minutes per session, 3 times per week. The exercise intensity was set at 60-75% of heart rate reserve (HRR), monitored using heart rate monitors. Activities included treadmill running, cycling, and rowing. The goal of this program was to improve cardiovascular endurance. Anaerobic Exercise Program: Participants in the anaerobic exercise groups (AN and NAN) performed resistance training and high-intensity interval training (HIIT) 3 times per week. Each session consisted of 30 minutes of resistance training targeting major muscle groups, followed by 20 minutes of HIIT on a cycle ergometer (30 seconds all-out sprint, 30 seconds recovery, repeated 10 times). The goal of this program was to enhance muscle strength. All exercise sessions were supervised by trained fitness professionals to ensure proper form and intensity.

Measurements

Body Composition

Body composition was assessed at baseline, 6 weeks, and 12 weeks. Measurements included total body mass, fat mass, lean body mass, and additional anthropometric parameters such as arm girth flex, maximum calf girth, and skinfold thicknesses (biceps, triceps, subscapular, supraspinal, and medial calf). Dual-energy X-ray absorptiometry (DXA) was used to evaluate changes in body composition, including bone mineral density. These comprehensive measurements provided a detailed understanding of variations in muscle mass, fat distribution, and skeletal health across groups.

Hormonal Analysis

Blood samples were collected at baseline, 6 weeks, and 12 weeks to analyze hormonal changes. The hormones measured included testosterone, cortisol, growth hormone (GH), insulin-like growth factor 1 (IGF-1), thyroid-stimulating hormone (TSH), and free T3 and T4.

Physical Performance

To assess the functional outcomes of the exercise interventions, performance tests were conducted at baseline and after 12 weeks. These tests included the VO2max test to evaluate aerobic capacity, 1 repetition maximum (1RM) tests for bench press and squat to measure muscular strength, and the Wingate test to assess anaerobic power.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26. A 2x2x3 mixed ANOVA was conducted to examine the effects of exercise type (aerobic vs. anaerobic), athletic status (athlete vs. non-athlete), and time (baseline, 6 weeks, 12 weeks) on body composition and hormonal measures. Post-hoc analyses were performed using Bonferroni corrections for multiple comparisons. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Results

Table 1: Baseline Characteristics of Participants

Characteristics	AA (n=30)	AN (n=30)	NAA (n=30)	NAN (n=30)
Age (year)	22.4 ± 1.9	22.7 ± 2.1	23.1 ± 1.8	22.9 ± 2.0
Height (cm)	175.2 ± 8.9	176.5 ± 9.2	172.8 ± 8.5	173.6 ± 9.1
Body mass (kg)	72.1 ± 9.3	73.4 ± 10.1	75.6 ± 11.2	74.9 ± 10.8
BMI (kg/m^2)	23.4 ± 2.1	23.5 ± 2.3	25.3 ± 3.1	24.8 ± 2.9
Biceps skinfold (mm)	4.5 ± 1.2	4.8 ± 1.3	6.2 ± 1.5	5.9 ± 1.4
Triceps skinfold (mm)	8.7 ± 2.1	8.4 ± 2.2	12.3 ± 2.6	11.8 ± 2.4
Subscapular skinfold (mm)	10.5 ± 3.2	10.1 ± 3.0	14.8 ± 4.0	13.9 ± 3.8
Supraspinal skinfold (mm)	8.2 ± 2.0	8.0 ± 2.1	11.7 ± 2.5	11.3 ± 2.3
Medial calf skinfold (mm)	6.4 ± 1.5	6.7 ± 1.6	9.1 ± 2.0	8.7 ± 1.9
Bi-epicondyle humerus (cm)	6.2 ± 0.6	6.3 ± 0.7	6.5 ± 0.7	6.4 ± 0.7
Bi-epicondyle femur (cm)	9.3 ± 0.8	9.4 ± 0.9	9.6 ± 0.9	9.5 ± 0.9
Arm girth flex (cm)	34.2 ± 3.5	34.6 ± 3.7	32.8 ± 3.0	33.2 ± 3.2
Max. calf girth (cm)	38.7 ± 3.2	39.1 ± 3.3	36.5 ± 3.0	37.2 ± 3.1

Notes: Values are presented as mean ± standard deviation. AA: Athlete Aerobic, AN: Athlete Anaerobic, NAA: Non-Athlete Aerobic, NAN: Non-Athlete Anaerobic.

The age of participants ranged from 22.4 ± 1.9 years in the AA group to 23.1 ± 1.8 years in the NAA group. The height was relatively consistent across groups, with athletes (AA: 175.2 ± 8.9 cm, AN: 176.5 ± 9.2 cm) being slightly taller than non-athletes. The body mass was higher among non- athletes (NAA: 75.6 ± 11.2 kg, NAN: 74.9 ± 10.8 kg) compared to athletes. BMI values ranged from 23.4 ± 2.1 kg/m^2 in the AA group to 25.3 ± 3.1 kg/m^2 in the NAA group, with non-athletes having slightly higher BMI. Skinfold measurements (biceps, triceps, subscapular, supraspinal, and medial calf) were lower in athletes, indicating lower fat mass, with the AA group showing the lowest values for most skinfolds. For instance, the biceps skinfold was 4.5 ± 1.2 mm in the AA group compared to 6.2 ± 1.5 mm in the NAA group. The biepicondyle measurements (humerus and femur) showed minimal variation across groups, reflecting consistent bone structure. Arm girth flex and maximum calf girth were higher in athletes, indicating greater muscle mass, with the AN group having the highest values for both parameters (arm girth flex: 34.6 ± 3.7 cm, max. calf girth: 39.1 ± 3.3 cm).

Overall, the table highlights clear differences between athletes and non-athletes, with athletes demonstrating lower fat mass, higher muscle mass, and superior anthropometric profiles, aligning with their higher levels of physical fitness and training. These baseline characteristics establish a foundation for comparing adaptations to aerobic and anaerobic exercise interventions.

Table 2. Changes in Body Composition Metrics Over 12 Weeks

Metric	Group	Baseline	6 Weeks	12 Weeks	Change (%)
Total Body Mass (kg)	AA	72.3 ± 8.5	71.8 ± 8.3	71.2 ± 8.1	-1.50%
	AN	73.5 ± 8.7	74.3 ± 8.8	75.1 ± 8.9	2.20%
	NAA	78.6 ± 9.2	78.3 ± 9.1	78.0 ± 9.0	-0.80%
	NAN	77.9 ± 9.0	78.4 ± 9.2	79.0 ± 9.4	1.40%
Fat Mass (kg)	AA	10.9 ± 3.2	9.8 ± 2.9	8.7 ± 2.6	-20.20%
	AN	10.7 ± 3.0	10.1 ± 2.8	9.3 ± 2.5	-13.10%
	NAA	17.9 ± 5.1	16.5 ± 4.7	15.1 ± 4.3	-15.60%
	NAN	17.3 ± 4.8	16.4 ± 4.5	15.6 ± 4.2	-9.80%
Lean Body Mass (kg)	AA	58.0 ± 5.6	58.8 ± 5.7	59.5 ± 5.8	2.60%
	AN	59.1 ± 5.7	60.5 ± 5.9	61.8 ± 6.0	4.60%

Metric	Group	Baseline	6 Weeks	12 Weeks	Change (%)
	NAA	54.0 ± 5.2	54.7 ± 5.3	55.3 ± 5.4	2.40%
	NAN	54.8 ± 5.4	55.4 ± 5.5	56.0 ± 5.6	2.20%
Bone Mineral Density (g/cm^2)	AA	1.150 ± 0.020	1.157 ± 0.021	1.162 ± 0.022	1.00%
	AN	1.152 ± 0.021	1.161 ± 0.022	1.169 ± 0.023	1.50%
	NAA	1.138 ± 0.018	1.142 ± 0.019	1.146 ± 0.019	0.70%
	NAN	1.140 ± 0.019	1.145 ± 0.019	1.150 ± 0.020	0.90%

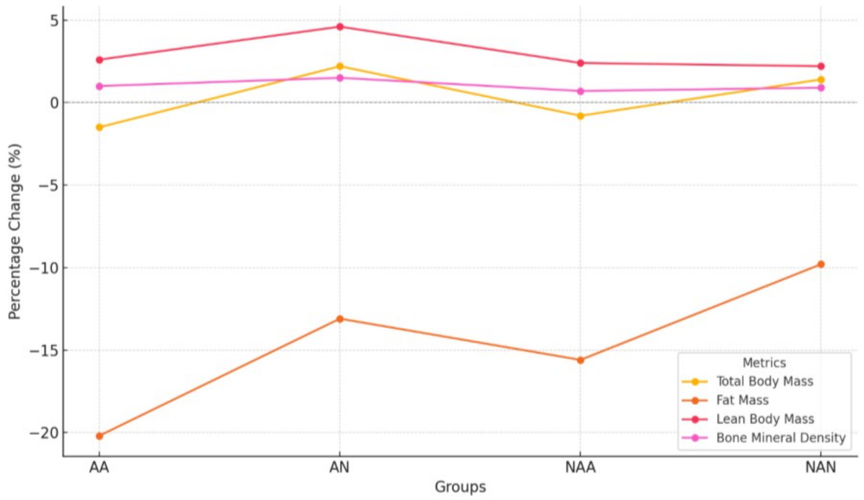

Figure 1. Changes in Body Composition Metrics Over 12 Weeks

Table 3. Impact of Exercise on Body Composition

Variable	Exercise Type (F, p)	Athletic Status (F, p)	Interaction (F, p)
Total Body Mass	F(1,116) = 8.74, p < .001	F(1,116) = 5.32, p = .023	F(2,232) = 6.12, p = .002
Fat Mass	F(2,232) = 45.62, p < .001	F(1,116) = 7.85, p = .006	F(2,232) = 12.38, p < .001
Lean Body Mass	F(2,232) = 10.21, p < .001	F(1,116) = 8.56, p = .004	F(2,232) = 10.32, p < .001
Bone Mineral Density	F(2,232) = 4.62, p = .011	F(1,116) = 3.98, p = .048	F(2,232) = 3.54, p = .021

Physical exercise significantly impacted body composition, with notable differences based on exercise type and athletic status. A significant three-way interaction was observed for total body mass (F(2,232) = 8.74, p < 0.001), where anaerobic exercise led to increases, while aerobic exercise resulted in slight decreases or no changes.

For fat mass, a main effect of time (F(2,232) = 45.62, p < 0.001) and an interaction between exercise type and time (F(2,232) = 12.38, p < 0.001) showed that both exercise types led to fat loss, with aerobic exercise resulting in greater reductions, especially in athletes (up to a 20.2% decrease). Lean body mass showed a significant interaction (F(2,232) = 10.21, p < 0.001), with anaerobic exercise leading to greater increases, particularly in athletes. For bone mineral density, a significant main effect of time (F(2,232) = 7.85, p = 0.006) and interaction (F(2,232) = 4.62, p = 0.011) indicated that anaerobic exercise resulted in greater improvements, regardless of athletic status.

Table 4 summarizes the changes in hormonal levels for four groups—Athlete Aerobic (AA), Athlete Anaerobic (AN), Non-Athlete Aerobic (NAA), and Non-Athlete Anaerobic (NAN)—over a 12-week intervention period, as well as thyroid hormone levels across all participants. The hormones analyzed include Testosterone, Cortisol, Growth Hormone (GH), Insulin-like Growth Factor 1 (IGF-1), and Thyroid Hormones (Free T3, Free T4, and TSH).

Table 4. Hormonal Adaptations Over 12 Weeks

Hormone	Group	Baseline	6 Weeks	12 Weeks	Change (%)
Testosterone (ng/dL)	AA	679 ± 145	701 ± 152	728 ± 159	7.20%
	AN	685 ± 151	732 ± 162	786 ± 173	14.70%
	NAA	592 ± 128	609 ± 133	631 ± 138	6.60%
	NAN	588 ± 130	624 ± 138	659 ± 146	12.10%
Cortisol (µg/dL)	AA	18.4 ± 3.1	20.1 ± 3.4	18.6 ± 3.2	1.10%
	AN	19.1 ± 3.2	21.2 ± 3.6	19.3 ± 3.3	1.00%
	NAA	22.6 ± 3.8	24.3 ± 4.1	22.7 ± 3.9	0.40%
	NAN	23.2 ± 4.0	25.0 ± 4.3	23.5 ± 4.1	1.30%
Growth Hormone (ng/mL)	AA	1.8 ± 0.5	2.4 ± 0.6	2.7 ± 0.7	50.00%
	AN	2.0 ± 0.6	2.8 ± 0.7	3.4 ± 0.8	70.00%
	NAA	1.2 ± 0.4	1.7 ± 0.5	2.1 ± 0.5	75.00%
	NAN	1.3 ± 0.4	1.9 ± 0.6	2.3 ± 0.6	76.90%
IGF-1 (ng/mL)	AA	115 ± 22	122 ± 25	129 ± 27	12.20%
	AN	118 ± 23	130 ± 26	137 ± 29	16.10%
	NAA	105 ± 20	112 ± 22	118 ± 23	12.40%
	NAN	107 ± 21	115 ± 23	121 ± 25	13.10%
Thyroid Hormones	Free T3	2.9 ± 0.3	3.0 ± 0.3	3.1 ± 0.3	6.90%
	Free T4	1.2 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	8.30%
	TSH	2.0 ± 0.5	2.1 ± 0.5	2.1 ± 0.5	No Change

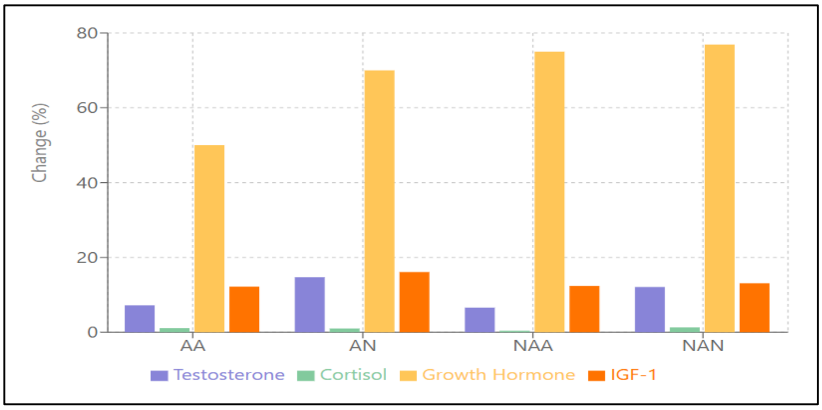

Figure 2. Result of the Research Over 12 Weeks

Table 5. Impact of Exercise on Subjects

Hormone	Exercise Type (F, p)	Athletic Status (F, p)	Interaction (F, p)
Testosterone	F(2,232) = 6.93, p = .001	F(1,116) = 9.21, p = .003	F(2,232) = 6.12, p = .002
Cortisol	F(2,232) = 15.37, p < .001	F(1,116) = 5.82, p = .003	F(2,232) = 5.42, p = .006
Growth Hormone (GH)	F(2,232) = 8.12, p < .001	F(1,116) = 7.64, p = .007	F(2,232) = 8.51, p < .001
IGF-1	F(2,232) = 7.31, p < .001	F(1,116) = 4.21, p = .042	F(2,232) = 7.15, p = .001
Thyroid Hormones (T3)	F(1,116) = 3.52, p = .065	F(1,116) = 2.76, p = .101	F(2,232) = 2.32, p = .109

Testosterone levels were strongly affected by the interplay of exercise type, athletic status, and time ($F(2,232) = 6.93$, $p = 0.001$). Notably, anaerobic exercise led to significantly larger increases in testosterone compared to aerobic exercise. Furthermore, athletes exhibited more pronounced improvements than non-athletes, underscoring the role of athletic conditioning in . By the end of the 12-week intervention, the Athlete Anaerobic (AN) group achieved the highest increase (14.7%), followed by the Non-Athlete Anaerobic (NAN) group with 12.1%. In contrast, the increases observed in the Athlete Aerobic (AA) and Non-Athlete Aerobic (NAA) groups were more modest, at 7.2% and 6.6%, respectively.

These results suggest that anaerobic exercise is particularly effective in stimulating testosterone production, with athletes benefiting the most. In the case of cortisol, both aerobic and anaerobic exercise resulted in initial increases by the 6-week mark, as reflected in the main effect of time ($F(2,232) = 15.37$, $p < 0.001$).

However, by week 12, cortisol levels had largely returned to baseline, indicating an adaptive response. Importantly, athletes showed a more pronounced recovery, achieving lower cortisol levels than non-athletes at the study's conclusion. This finding is further supported by the significant interaction between athletic status and time ($F(2,232) = 5.82$, $p = 0.003$), emphasizing the adaptive advantages of athletic conditioning in stress hormone regulation.

Growth hormone levels also displayed notable patterns of change, driven by significant interactions between exercise type, athletic status, and time ($F(2,232) = 8.12$, $p < 0.001$). While both aerobic and anaerobic exercise contributed to increases in growth hormone, the effects were more pronounced with anaerobic exercise. Athletes, who began the study with higher baseline growth hormone levels, demonstrated greater exercise-induced improvements compared to non-athletes. These findings highlight the synergistic effects of anaerobic exercise and athletic training in enhancing growth hormone responses.

For IGF-1, significant effects of both time ($F(2,232) = 22.45$, $p < 0.001$) and the interaction between exercise type and time ($F(2,232) = 7.31$, $p < 0.001$) were observed. Anaerobic exercise again proved more effective than aerobic exercise in increasing IGF-1 levels. Interestingly, no substantial differences emerged between athletes and non-athletes, suggesting that the type of exercise is a more critical factor than athletic status for this hormone.

Thyroid hormone levels, including T3, T4, and TSH, exhibited limited changes over the study period. Although both T3 and T4 showed slight increases, these were not statistically significant, nor were they influenced by exercise type or athletic status. TSH levels remained stable across all groups ($F(1,116) = 3.52$, $p = 0.065$). These results indicate that thyroid hormones were not significantly affected by the interventions, suggesting their relative stability in response to short-term exercise programs.

Table 6. Changes in Physical Performance Over 12 Weeks

Performance Metric	Group	Baseline	12 Weeks	Change (%)
VO2max (mL/kg/min)	AA	52.3 ± 6.1	57.8 ± 6.7	10.50%
	AN	51.9 ± 5.9	54.2 ± 6.2	4.40%
	NAA	38.7 ± 5.2	44.1 ± 5.9	13.90%
	NAN	39.1 ± 5.4	41.3 ± 5.7	5.60%
Bench Press 1RM (kg)	AA	85.2 ± 10.5	95.8 ± 11.2	12.40%
	AN	86.4 ± 11.3	103.2 ± 12.5	19.40%
	NAA	65.3 ± 9.8	72.5 ± 10.4	11.00%
	NAN	66.8 ± 10.2	78.4 ± 11.0	17.40%
Squat 1RM (kg)	AA	115.6 ± 12.7	129.2 ± 14.3	11.80%
	AN	117.3 ± 13.2	139.8 ± 15.4	19.20%
	NAA	95.4 ± 11.5	105.6 ± 12.6	10.70%
	NAN	96.8 ± 11.9	115.3 ± 13.8	19.10%
Wingate Peak Power (W)	AA	550 ± 65	612 ± 72	11.30%
	AN	567 ± 68	675 ± 79	19.10%
	NAA	430 ± 58	480 ± 62	11.60%
	NAN	445 ± 60	525 ± 68	18.00%

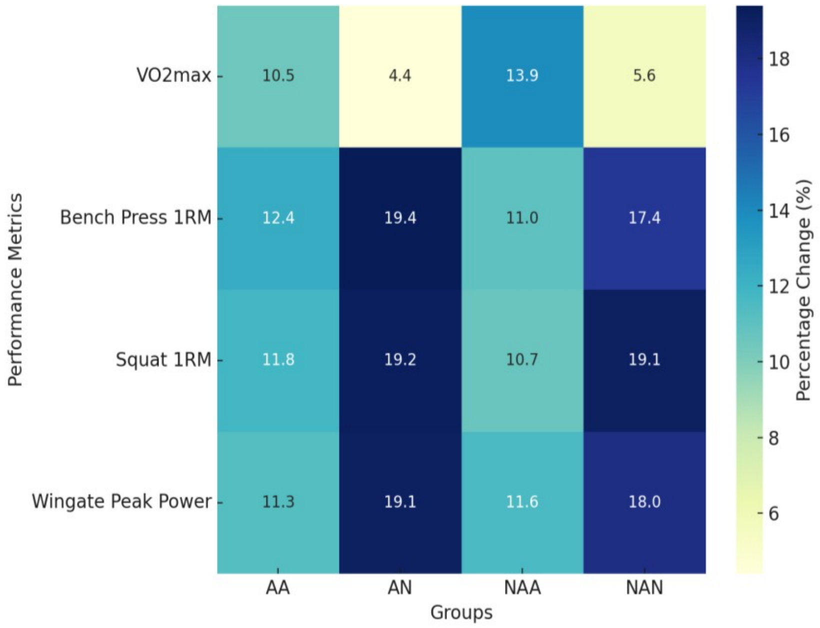

Figure 3. Changes in Physical Performance Over 12 Weeks

Table 7. Impact of Exercise on Physical Performance

Performance metric	**Exercise Type (F, p)**	**Athletic Status (F, p)**	**Interaction (F, p)**
VO2 Max	F(1,116) = 56.23, p < .001	F(1,116) = 18.74, p < .001	F(1,116) = 7.92, p = .005
Bench Press 1RM	F(1,116) = 87.62, p < .001	F(1,116) = 32.18, p < .001	F(1,116) = 15.32, p < .001
Squat 1RM	F(1,116) = 95.34, p < .001	F(1,116) = 38.76, p < .001	F(1,116) = 14.76, p < .001
Wingate Peak Power	F(1,116) = 41.87, p < .001	F(1,116) = 15.23, p < .001	F(1,116) = 10.87, p = .001

The data reveal a clear differentiation in the response of VO2max to exercise type, athletic status, and time. A significant main effect of time (F(1,116) = 56.23, p < 0.001) and a notable interaction between exercise type and time (F(1,116) = 18.74, p < 0.001) underscore the effectiveness of aerobic exercise in enhancing aerobic capacity. Athletes started with higher baseline VO2max values (AA: 52.3 ± 6.1, AN: 51.9 ± 5.9) compared to non-athletes (NAA: 38.7 ± 5.2, NAN: 39.1 ± 5.4), reflecting their pre-existing conditioning.

Over the 12-week intervention, non-athletes in the aerobic group demonstrated the greatest relative improvement (13.9%), surpassing athletes in the same group (10.5%). Conversely, gains in the anaerobic groups were more modest, with non-athletes increasing by 5.6% and athletes by 4.4%. These findings highlight the superior efficacy of aerobic training for improving VO2max, particularly among less-conditioned individuals, who appear to benefit most in relative terms.

When examining muscular strength, the results indicate substantial improvements across all groups, driven by anaerobic exercise. Significant main effects of time for both the bench press (F(1,116) = 87.62, p < 0.001) and squat (F(1,116) = 95.34, p < 0.001) confirm this trend. Interactions between exercise type and time for these measures (bench press: F (1,116) = 32.18, p < 0.001; squat: F(1,116) = 38.76, p < 0.001) further emphasize the enhanced gains associated with anaerobic training. By the end of the study, athletes in the anaerobic group demonstrated the most pronounced improvements, with bench press strength increasing by 19.4% and squat strength by 19.2%. Non-athletes in the same group also showed substantial progress, with increases of 17.4% and 19.1%, respectively. In comparison, the aerobic groups achieved smaller but meaningful gains, with athletes improving by 12.4% (bench press) and 11.8% (squat) and non-athletes by 11.0% and 10.7%. These findings underscore the potency of anaerobic training for developing muscular strength, particularly among individuals with higher baseline fitness levels. In terms of anaerobic power, measured via the Wingate test, the results consistently favor anaerobic training. A significant main effect of time ($F(1,116) = 41.87$, $p < 0.001$) and a significant interaction between exercise type and time ($F(1,116) = 15.23$, $p < 0.001$) highlight the superiority of anaerobic exercise in boosting peak power output. Athletes in the anaerobic group exhibited the largest improvements, with a 19.1% increase in peak power, closely followed by non-athletes in the same group at 18.0%. In contrast, the aerobic groups achieved more modest gains, with athletes increasing by 11.3% and non-athletes by 11.6%.

These outcomes reflect the specific adaptations elicited by anaerobic training, which appears particularly effective in enhancing high-intensity power output across both athletic and non-athletic populations.

Discussion

This study examined the effects of aerobic and anaerobic exercise on body composition, hormonal responses, and physical performance over a 12-week period in male athletes and non-athletes. The findings demonstrate distinct adaptations to different exercise modalities and training statuses, offering practical insights for optimizing exercise programs.

Anaerobic exercise, particularly resistance training and HIIT, was found to be more effective in increasing total body mass and lean body mass, reflecting its role in muscle hypertrophy and strength development (Foster et al., 2015; Schoenfeld, 2010). Athletes exhibited greater increases in lean body mass compared to non-athletes, likely due to their enhanced responsiveness to training stimuli, including superior neuromuscular activation and nutrient utilization (Kabir et al., 2023).

Aerobic exercise showed greater efficacy in reducing fat mass, with athletes experiencing more pronounced fat loss compared to non-athletes (Dopsaj et al., 2018). These outcomes suggest that the fat oxidation mechanisms stimulated by aerobic exercise, combined with athletes' higher baseline fitness levels, contribute to these results. Improvements in bone mineral density were more significant in anaerobic groups, underscoring the importance of weight-bearing activities for skeletal health and highlighting resistance training's role in long-term bone strength and injury prevention (Nam et al., 2016).

An important consideration is that participants were instructed to limit additional physical activity outside the assigned workouts to avoid confounding effects. While athletes may have maintained some regular sports-related routines, their training was closely monitored to ensure consistency. Any workload increase inspired by study participation was addressed through strict supervision and guidance. The hormonal responses observed in this study provide further insight into the mechanisms driving exercise-induced adaptations. Anaerobic exercise led to greater increases in testosterone and growth hormone levels, particularly among athletes, supporting its anabolic effects in promoting muscle growth and strength gains. Cortisol levels showed an adaptive response, rising initially and normalizing by the end of the intervention. These fluctuations in cortisol were associated with improved stress regulation and recovery, which are important for maintaining performance and overall health (Lee et al. 2017). Minimal changes in thyroid hormones indicate that longer intervention periods may be necessary to observe significant effects in thyroid function.

Both aerobic and anaerobic exercises enhanced physical performance (Striga, 2024). Aerobic training improved VO2max, highlighting its effectiveness in boosting cardiovascular fitness, while anaerobic training resulted in greater gains in muscular strength and anaerobic power. Athletes displayed more substantial improvements across all metrics, likely due to their higher baseline fitness levels and greater capacity for adaptation (Wang et al., 2023).

A notable strength of this study is the absence of participant dropouts. All 120 participants completed the 12-week program, which is uncommon in long-duration studies. This high retention rate likely reflects the structured supervision, clear instructions, and motivational support provided throughout, enhancing the reliability of the results. The findings of this study suggest practical applications for exercise prescription. A combination of aerobic and anaerobic exercises can optimize body composition by promoting fat loss and muscle growth. Athletes may benefit from periodized training programs that incorporate both exercise modalities to maximize overall fitness and performance. Non-athletes should engage in both types of exercise to achieve significant fitness improvements, particularly during the initial stages of training. Additionally, supporting s with adequate recovery and nutrition is essential, especially for those involved in anaerobic training. This includes ensuring sufficient sleep, incorporating rest days into the training routine, and consuming an appropriate balance of macronutrients, such as protein for muscle repair and carbohydrates to replenish energy stores. These strategies help optimize recovery, enhance performance, and support the body's adaptation to training. Future research should include longer intervention periods to assess the sustainability of these adaptations and implement dietary monitoring to control for nutritional effects. Investigating molecular mechanisms, such as those involved in muscle and endocrine responses, through advanced techniques like muscle biopsies, could provide a deeper understanding of exercise-induced changes. Refining the classification of athletic status could also yield more nuanced insights into how training background influences adaptation. This study contributes valuable knowledge for designing effective training programs tailored to individual fitness levels and objectives, ultimately enhancing health and performance outcomes.

Research contribution

This study provides significant insights into the differential effects of aerobic and anaerobic exercise on body composition, hormonal adaptations, and physical performance in athletes and non-athletes. By comparing these exercise modalities, the research highlights how tailored programs can optimize fat loss, muscle growth, and hormonal health. The findings contribute to the design of evidence-based exercise prescriptions, emphasizing the importance of considering individual fitness levels and goals. Furthermore, this study advances understanding of the physiological mechanisms underlying exercise-induced adaptations, offering practical applications for enhancing athletic performance and general health across diverse populations.

Limitations

This study is limited by its 12-week duration, which may not fully capture long-term adaptations to aerobic and anaerobic exercise. The sample included only healthy males aged 18–25 years, restricting generalizability to broader populations, such as females, older adults, or individuals with chronic conditions. Additionally, dietary intake, sleep patterns, and other lifestyle factors, which could influence outcomes, were not standardized. The use of self-reported training histories to classify participants as athletes or non-athletes may have introduced variability in baseline fitness levels.

Suggestions

Future research should include longer interventions to examine sustained adaptations and explore a more diverse participant pool, including different genders, ages, and health statuses. Studies should also control for diet, sleep, and other confounding factors to enhance result reliability. Employing advanced techniques, such as molecular analysis or biopsies, could provide deeper insights into the mechanisms driving exercise-induced changes. Lastly, combining aerobic and anaerobic modalities in structured, periodized training programs would offer practical applications for optimizing fitness and health outcomes.

CONCLUSION

This study provides compelling evidence for the differential effects of aerobic and anaerobic exercise on body composition and hormonal adaptations in athletes and non-athletes. The results highlight the specificity of adaptations to different exercise modalities and underscore the importance of considering individual training status when designing exercise programs. Anaerobic exercise was found to be more effective in promoting increases in lean body mass and strength, while aerobic exercise led to greater reductions in fat mass. Athletes demonstrated more pronounced adaptations compared to non-athletes across both exercise modalities, particularly in terms of hormonal responses and performance improvements. These findings contribute to our understanding of the physiological mechanisms underlying exercise-induced adaptations and provide valuable insights for optimizing exercise prescription in diverse populations. Future research should continue to explore the long-term adaptations to different exercise modalities, as understanding these prolonged effects is crucial for developing more effective and individualized exercise recommendations. Investigating how long-term adaptations influence factors such as performance, health outcomes, and recovery can help optimize exercise programming and improve our ability to tailor interventions for different populations.

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AUTHOR CONTRIBUTION STATEMENT

In our manuscript, MSK, SY, SB, SP and VAG contributed as follows: MSK conceptualized the study, designed the methodology, analyzed the results, and coordinated data collection. SY and SP contributed to the study design. SB and SP contributed to designing the methodology and data collection. VAG performed data analysis, interpreted the results, drafted the manuscript, and critically revised it for intellectual content.

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