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The Effect of Aerobic and Anaerobic Exercise on Physical Fitness as Seen from the BMI of Chemical Engineering Students at the Veteran National Development University in Yogyakarta

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ABSTRACT
This study aims to analyze the effect of exercise methods (aerobic and anaerobic) and Body Mass Index (BMI) categories on the improvement of physical fitness in students, measured through VO_2max, using a 2 × 2 quasi-factorial experimental design on 28 Chemical Engineering students at UPN Veteran Yogyakarta who took the Sports II course in volleyball. The results indicated that the aerobic exercise group with low BMI experienced the greatest increase in VO2max (3.94), while the anaerobic exercise group with high BMI recorded the smallest increase (2.27). The two-way ANOVA test showed that the exercise method did not have a significant effect on the increase in VO2max(F(calculated) 0.362 < F(table) 4.26), while the BMI factor had a significant effect (F(calculated) 6.392 > F(table) 4.26), where students with low BMI obtained higher increases than students with high BMI. The interaction test between exercise method and BMI was not significant (F(calculated) 0.021 < F(table) 4.26), indicating that both factors worked independently. Thus, it can be concluded that BMI status is a dominant factor in the increase in students' VO2max, while both aerobic and anaerobic exercise types are equally effective but not significantly different.

Keywords: Aerobic Exercise, Anaerobic Exercise, Body Mass Index, Physical Fitness

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INTRODUCTION

Physical fitness is a fundamental aspect that plays an important role in supporting daily activities, especially for students who face high academic demands. Good physical condition has been proven to increase endurance, strength, and overall physical capacity, which ultimately has a positive impact on academic achievement and mental health (Nurhasan, 2017; Zhang et al., 2025). Recent studies on students show that physical fitness, including VO2maxand muscle strength, is more accurate in predicting cardiometabolic risk than BMI (Peterson et al., 2025).

Physical fitness encompasses several key components such as cardiovascular endurance, muscle strength, flexibility, speed, and balance, all of which are important aspects of physical health (Raghuveer et al., 2020). One of the

objective indicators often used in fitness research is VO2max, which is the body's maximum ability to utilize oxygen during high-intensity activities. A high VO2maxlevel has been shown to be associated with better cardiorespiratory health and longevity, even in individuals who are overweight or obese (Weeldreyer et al., 2025).

Common methods used to improve physical fitness are aerobic and anaerobic exercises. Aerobic exercises are performed for long durations at light to moderate intensity, involving the cardiovascular system and using oxygen as the primary energy source. Examples include long-distance running, cycling, and swimming (Harsono, 2015). Recent research shows that at least 150 minutes of aerobic exercise per week significantly reduces body fat and waist circumference and improves cardio endurance. An experimental study of young women found that aerobic exercise improves insulin sensitivity, upper body strength, and cardiovascular performance (Sellami et al., 2025).

Meanwhile, anaerobic exercise is a high-intensity, short-duration physical activity, such as sprinting, weight lifting, and muscle strength training. This exercise uses energy without oxygen and aims to increase muscle strength, speed, and explosive power (Widiastuti, 2016).

Recent studies show that anaerobic exercise is more dominant in increasing muscle mass and strength, while aerobic exercise is more effective in reducing body fat (Kabir et al., 2025). In fact, a combination of both is reported to improve VO2max, arterial elasticity, insulin sensitivity, and body composition better than conventional exercise (Yue, 2025).

The results of this study also support these findings, where the anaerobic exercise group experienced an average increase in VO2maxof 2.91 points. Although this figure is lower than the increase in the aerobic group of 3.23 points, it still shows that anaerobic exercise contributes significantly to improving the physical fitness of students.

In addition to the type of exercise, nutritional status as measured by Body Mass Index (BMI) also affects physical fitness. BMI is calculated based on the ratio of weight to height and is then categorized as underweight, normal, overweight, or obese (Nuttall, 2015). Recent studies show that students with a normal BMI have

better physical fitness levels than overweight or obese students (Sun et al., 2024). Aerobic and resistance exercise-based interventions have also been shown to be effective in reducing BMI, lowering body fat percentage, and increasing VO2maxin overweight/obese adolescents (Liu et al., 2024).

Although many studies have examined the effects of aerobic and anaerobic exercise on physical fitness, most have focused on athletes or adolescents, rather than non-athletic students with high academic workloads. In addition, most studies examine physical exercise separately without considering BMI as an important variable that can affect the effectiveness of exercise. This has led to limited research on the relationship between the type of physical exercise and BMI in the context of physical fitness among college students, especially in fields of study that require intensive study time, such as chemical engineering.

This study presents a novelty by analyzing the effectiveness of aerobic and anaerobic exercise on physical fitness in terms of BMI categories. The focus on chemical engineering students at UPN Veteran Yogyakarta is an added value, as this group has received relatively little attention in physical fitness research despite being prone to low physical activity. With this background, this study offers novelty by assessing the effectiveness of aerobic and anaerobic exercise on physical fitness in terms of BMI categories. The focus on chemical engineering students at UPN Veteran Yogyakarta provides a new contribution, considering that this group has received relatively little attention in physical fitness research. The results of this study are expected to enrich the literature on the relationship between physical exercise and nutritional status, as well as provide practical recommendations for developing exercise programs tailored to the characteristics of students.

The objectives of this study are formulated as follows: (1) to examine the effect of anaerobic exercise on the physical fitness of students; (2) to examine the effect of aerobic exercise on the physical fitness of students; (3) to analyze the role of BMI in influencing physical fitness; and (4) to examine the interaction between exercise type and BMI in improving the physical fitness of chemical engineering students at UPN Veteran Yogyakarta.

METHODS

This study applied a quasi-experimental approach with a 2 x 2 factorial design. This design was chosen to examine the effect of aerobic and anaerobic exercise, as well as Body Mass Index (BMI) categories, on improving the physical fitness of students. The exercise program in this study was designed systematically to ensure it could be replicated by other researchers. The intervention lasted for 8 weeks with a frequency of three times per week. The aerobic group underwent moderate- to long-distance running exercises with an initial duration of 20 minutes per session, which was gradually increased to 40 minutes in the eighth week, with an intensity of 60–75% of the maximum heart rate (HRmax). The anaerobic group performed exercises such as 100-meter sprints, circuit training (push-ups, sit-ups, and squat jumps), and light to moderate weight lifting. Each session consisted of 3–4 sets with 8–12 repetitions at an intensity of 75–85% of maximum load or speed, with a rest period of 1–2 minutes between sets. The entire training program was designed progressively, with an increase in training load every two weeks to encourage physiological adaptation without causing excessive fatigue.

Through a 2 x 2 factorial model, researchers can not only assess the effect of each treatment variable separately but also identify interactions between exercise type and BMI classification. The research population included active students of the Chemical Engineering Study Program at UPN Veteran Yogyakarta in the 2024–2025 academic year. From this population, 28 individuals were selected as research samples through purposive sampling with specific criteria, namely, enrollment in the Sports II course in volleyball. Research subjects were selected from chemical engineering students who were taking the Sports II course in volleyball, due to considerations of participant availability and ease of program supervision. This selection was recognized as having the potential to affect the initial fitness level, considering that these students may have higher physical activity than chemical engineering students in general. To anticipate this, the researcher conducted a pre-test measurement of BMI and VO2maxbefore the treatment so that the participants' baseline conditions could be controlled in the research results analysis. For this reason, the selected samples were then grouped into four categories, each consisting of seven people. The four groups included (1) anaerobic exercise with low BMI, (2)

anaerobic exercise with high BMI, (3) aerobic exercise with low BMI, and (4) aerobic exercise with high BMI.

The data sources for this study came from direct measurements of the subjects, namely chemical engineering students who were the sample. The main data collected were Body Mass Index (BMI) and VO2maxas indicators of physical fitness. BMI measurements were taken by dividing body weight (kg) by height squared (m^2) according to the WHO Asia classification standard. Physical fitness was measured using the Multistage Fitness Test (Bleep Test) introduced by Léger & Lambert, which involves running back and forth 20 meters following a signal at a progressive speed. The final level that participants were able to complete was used as the basis for estimating VO2maxas an indicator of cardiorespiratory capacity. Data collection was conducted through direct observation and physical measurements before and after the exercise treatment. The data obtained were analyzed using two-way Analysis of Variance (ANOVA) at a significance level of 5%, and if the test results showed a significant F value, it was followed by the Newman-Keuls test. The prerequisite tests for analysis were conducted using the Liliefors method for normality and the Bartlett test for homogeneity. All stages of the study were carried out under controlled conditions so that the results obtained were valid and scientifically accountable.

RESULTS AND DISCUSSION

This study aims to analyze the effect of anaerobic and aerobic exercise and *Body Mass Index (BMI)* on improving the physical fitness *(VO2max)* of students in the Chemical Engineering Study Program at UPN Veteran Yogyakarta.

Table 1. Description of VO2max Test Results

Treatment	BMI	Statistics	Pretest	Posttest	Improvement
		Total	300.6	325.4	24.8
	Low	Mean	42.94	46.48	3.54
Anaerobic		SD	6.41	5.74	1.63
Exercise		Total	306.8	322.7	15.9
	Height	Mean	43.82	46.1	2.27
		SD	9.21	8.17	1.70
		Amount	299.1	326.7	27.6
	Low	Mean	42.72	46.67	3.94
Aerobic		SD	3.11	3.81	0.98
Exercise		Total	275.9	291.3	17.6
	Height	Mean	39.41	41.61	2.51
		SD	3.45	2.74	1.20

Data from each treatment variable was then accumulated into a set of initial and final test results. A comparison of these two results was used to assess the improvement in students' VO2maxcapacity. Thus, the VO2maxvalue obtained after treatment reflects the development of physical fitness compared to the initial condition before training was given.

In the group of students with low BMI, the average initial VO2maxvalue was 42.94, increasing to 46.49 after training, resulting in an increase of 3.54. Conversely, in the group with high BMI, the average initial VO2maxvalue was 43.83, increasing to 46.10, with an average increase of only 2.27. This shows that even though they both received anaerobic training, students with low BMI obtained a greater increase than those with high BMI.

The group of students with low BMI who participated in aerobic exercise experienced an average increase in VO2maxfrom 42.73 to 46.67, an increase of 3.94. Meanwhile, in the group of students with high BMI, the average initial VO2maxof 39.41 increased to 41.61, with an increase of 2.51. This means that aerobic training is more effective in increasing VO2max, especially in students with low BMI.

When compared overall: 1) The aerobic exercise group showed a higher average increase (3.94 and 2.51) than the anaerobic exercise group (3.54 and 2.27). The difference in the average increase in VO2maxbetween aerobic and anaerobic exercise was approximately 0.32 points. 2) The BMI factor also had a significant effect. The group with low BMI experienced an average increase of 3.74, while the group with high BMI only experienced an increase of 2.39. The difference in increase between low BMI and high BMI was 1.35 points.

The distribution of VO2maxincrease values based on treatment categories is presented in the following table, which facilitates analysis of the differences in results between groups.

Table 2. Average Increase in VO2maxCapacity.

No	Treatment Group	VO2max Capacity Increase Values
1	A1B1	3.54
2	A1B2	2.27
3	A2B1	3.94
4	A2B2	2.51

Four treatment groups, the highest increase occurred in the low BMI aerobic exercise group (A2B1) at 3.94, while the lowest increase was in the high BMI anaerobic exercise group (A1B2) at 2.27.

Hypothesis testing was performed using a 2 x 2 factorial analysis of variance (ANOVA) with the following results (A1 as Anaerobic Exercise, A2 as Aerobic Exercise, B1 as Low BMI, and B2 as High BMI):

Table 3. Summary of VO2max Ability Average Results

Average of VO2max capacity	A1		A2	
	B1	B2	B1	B2
Pretest results	42.94	43.82	42.72	39.41
Posttest results	46.48	46.12	46.67	41.61
Improvement	3,542	2.271	3.94	2.51

Table 4. Summary of Two-Factor Analysis of Variance Results

Source of variation	df	SS	RMSQ	$F_{calculated}$	F_{table}
Treatment average	1	263.52	263.52		
A	1	0.72	0.72	0.362*	
B		12.75	12.75	6.392*	4.26
AB	1	0.04	0.04	0.021*	
Error	24	47.89	1.99		
Total	38	324.95			

Hypothesis analysis using 2x2 factorial ANOVA showed variation in the mean increase in VO2maxbetween treatment groups. Descriptively, the group of students with aerobic exercise and low BMI (A2B1) had the largest increase, namely 3.94. Conversely, the smallest increase was recorded in the group of students who underwent anaerobic training with high BMI (A1B2), which was 2.27. These findings provide preliminary indications that aerobic training is more effective than anaerobic training and that students with low BMI tend to increase their VO2maxcapacity more easily than their peers with high BMI.

The statistical test results show that the exercise method factor (aerobic and anaerobic) produced an F-count of 0.362, which is smaller than F(table) of 4.26 at a significance level of 5%. This condition implies that there is no significant difference between the two types of exercise in terms of increasing VO2max. In other words, both aerobic and anaerobic exercise can increase maximum oxygen capacity, although the difference in increase is not large enough to be considered statistically significant. This can be understood because both forms of exercise

involve the cardiovascular and respiratory systems, even though the mechanisms of energy supply are different.

Meanwhile, the BMI factor showed different results. The calculated F value of 6.392, which is greater than the table F value of 4.26, indicates a significant difference between the groups of students with low BMI and high BMI. Physiologically, students with low BMI are more advantaged because they have a more proportional body composition, a lighter cardiovascular load, and more efficient energy metabolism, so that adaptation to exercise is more optimal. Conversely, individuals with high BMI tend to carry excess body mass that can limit aerobic capacity and result in a relatively lower increase in VO2max.

The interaction test between the exercise method and BMI category produced an F calculated of 0.022, which is smaller than the F table of 4.26. This indicates that there is no significant interaction between the two factors. Thus, the effect of the exercise method is not influenced by the BMI category, and conversely, the effect of BMI on VO2maxalso does not depend on the type of exercise given. Both variables work independently in influencing the increase in VO2maxcapacity of students.

Overall, the results of this study confirm that the BMI factor has a more dominant influence on the increase in VO2maxability than the type of exercise given. Although aerobic exercise tends to provide higher increases than anaerobic exercise, the difference is not statistically significant. Therefore, efforts to improve students' physical fitness, particularly VO2maxcapacity, should not only depend on the chosen exercise method but also consider nutritional status and body composition, specifically BMI, as critical factors determining the success of physiological adaptation to the exercise program.

The results of this study indicate that both aerobic and anaerobic exercises are equally effective in improving students' VO2max. The average increase in VO2maxin the aerobic group reached 3.23, while in the anaerobic group it was 2.91. Although aerobic exercise provided a slightly higher increase, the two-way ANOVA test showed that the difference was not significant (Fcount 0.362 < Ftable 4.26). Thus, both training methods can be considered to have relatively equal effectiveness in increasing maximum oxygen capacity. This finding can be

explained because both aerobic and anaerobic exercise involve the cardiovascular and respiratory systems, even though the mechanisms of energy supply are different. These results are in line with the research by Scribbans et al. (2016), which confirms that various intensities of aerobic exercise can increase VO2max, as well as Helgerud et al. (2007), who found that high-intensity aerobic intervals can increase VO2maxmore optimally. On the other hand, the contribution of anaerobic exercise to physical fitness is also supported by Harsono's (2015) theory that this exercise emphasizes muscle strength and explosive power, which indirectly supports an increase in cardiovascular capacity.

The Body Mass Index (BMI) factor has a more dominant influence on the increase in VO2max. The ANOVA test results showed a significant difference between students with low BMI and high BMI (F calculated 6.392 > F table 4.26). Students with low BMI experienced an average increase in VO2maxof 3.74, while the group with high BMI only experienced an increase of 2.39. This difference can be understood because individuals with low BMI have a more proportional body composition, a lighter cardiovascular load, and more efficient energy metabolism, so that physiological adaptation to exercise is more optimal. Conversely, students with high BMI tend to experience limitations in aerobic capacity due to carrying excess body mass. These findings are consistent with reports by Kalyanshetti & Veluru (2017), Shah et al. (2022), and Regima et al. (2016), who found a negative correlation between BMI and VO2max. Kumari et al. (2025) further emphasized that a high BMI is closely associated with reduced metabolic efficiency, which can hinder improvements in aerobic capacity.

Meanwhile, the results of the ANOVA test, namely the interaction test between the training method and BMI, were not significant (Fcalculated = 0.021 < Ftable = 4.26). This means that the effect of the training method on VO2maxwas not influenced by the BMI category, and conversely, the effect of BMI did not depend on the type of exercise given. In other words, the two factors worked independently. This finding supports Widiastuti's (2016) statement that the success of an exercise program is greatly influenced by the individual's initial physical condition, particularly their BMI status. Therefore, strategies for improving students' physical fitness should not only depend on the type of exercise chosen but

also take into account nutritional status and body composition as key factors determining the success of physiological adaptation to the exercise program.

CONCLUSIONS

This study concludes that Body Mass Index (BMI) status has a significant effect on the increase in VO2maxin students, while the type of exercise method, whether aerobic or anaerobic, does not show a significant difference. Although aerobic exercise tends to provide a higher average increase in VO2maxcompared to anaerobic exercise, the difference is not statistically significant. Students with low BMI achieved more optimal increases in VO2maxcompared to students with high BMI, confirming that ideal body composition is crucial for successful physiological adaptation to physical exercise. The analysis also showed that there was no significant interaction between exercise method and BMI, indicating that these two factors work independently in influencing improvements in students' physical fitness. Thus, ideal BMI status proved to be a dominant factor supporting increases in maximum oxygen capacity, while both aerobic and anaerobic exercise remained effective in improving fitness, even though there was no significant difference.

Based on these findings, students are encouraged to maintain an ideal BMI through a healthy diet, regular physical activity, and a balanced lifestyle, as a proportional body condition has been proven to support more optimal VO2maximprovement. Aerobic exercises such as jogging, running, cycling, or swimming are still recommended as the primary choice because they have been proven to be beneficial for physical fitness, even though they are not statistically significantly different from anaerobic exercises. To support the success of the exercise program, students also need to adopt a healthy lifestyle, such as getting enough sleep, maintaining nutritional quality, and avoiding smoking and staying up late. This study is expected to serve as a basis for the development of exercise programs on campus that are more focused and effective in improving students' physical fitness.

However, this study has limitations that need to be considered. The sample size was relatively small, only 28 people, so the generalization of the results is still limited to the population of chemical engineering students at UPN Veteran

Yogyakarta. In addition, the variety of exercise methods used was still simple, only comparing aerobic and anaerobic exercises without considering different combinations or intensities. Other factors that can affect VO2max, such as diet, sleep quality, and lifestyle habits, were also not strictly controlled in this study. Therefore, future research should involve a larger sample size, use a more diverse range of exercise methods, and control for other external factors in order to obtain a more comprehensive picture of strategies for improving students' physical fitness.

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