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Regular exercise has a beneficial effect on increasing aerobic capacity in army students

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Abstract

Military preparation requires aerobic capacity (VO2max) and physical condition. Studies show that Indonesian Air Force personnel are overweight (34.9%) and obese (9.1%), which may impede task performance. This study examines how stair ascending and descending improve aerobic capacity (VO2 max) in Skadron Pendidikan 404 (Skadik 404) cadets, with BMI as a supportive factor. A quasi-experimental study included 40 cadets aged 19-22 with a BMI of 18.5-24.9 kg/m², divided into four groups: POK 1 (stair climbing), POK 2 (stair descending), POK 3 (stair climbing), and POK 4 (stair descending). This study uses 'POK' to refer to each study group. Data was collected using the 12-minute Cooper Test to measure VO2max. The data was analyzed using pairwise t-tests and two-way ANOVA with 5% significance. The study found significant differences in aerobic capacity ($p < 0.05$), with the stair-climbing group achieving larger VO_2max improvements than the descending group. These results show that army students may benefit more from stair climbing for aerobic training. This study supports military fitness studies by showing that stair climbing is better than stair descending and suggesting time-efficient, high-intensity training routines to improve soldiers' physical readiness.

Keywords: Aerobic capacity, stair climbing exercise, stair descending exercise, Skadik 404 cadets.

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INTRODUCTION

Physical fitness is crucial for maintaining the operational readiness of military personnel, especially for tasks that demand high stamina and prolonged physical endurance (Keaney et al., 2024; Sari et al., 2024). In military operations, optimal physical performance, particularly aerobic capacity measured by maximum oxygen uptake (VO_2max), is a key indicator of a soldier's ability to sustain intense and extended physical

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activity (Lee & Zhang, 2021). Low fitness levels can decrease task efficiency and compromise a soldier's readiness for deployment. For instance, studies conducted within the Indonesian Air Force indicate that approximately 34.9% of personnel are overweight, while 9.1% are classified as obese. These findings emphasize the need for enhanced fitness programs to mitigate potential health and performance issues among military personnel.

Several studies have highlighted the critical role of aerobic capacity in optimizing physical performance, especially for high-demand occupations such as the military, where endurance and cardiovascular efficiency are vital. For instance, research by Hudain et al. (2024) found that aerobic training tailored to individual fitness levels significantly improves VO_2 max and reduces fatigue during prolonged physical tasks. Similarly, Held (2023) demonstrated that structured aerobic exercises, such as interval running or uphill sprints, enhance oxygen uptake efficiency and recovery time, which are essential for soldiers during missions requiring sustained physical effort. In military training, effective exercise should take into account the physical conditions of personnel, including Body Mass Index (BMI), as body proportion can affect physical performance and training efficiency (Turnquist et al., 2024; Wiriawan, 2022). Previous studies indicate that a high BMI can enhance muscle strength but tends to reduce agility and cardiovascular endurance, both crucial for supporting VO_2 max. Research on soldiers has also shown that physical performance can be optimized by tailoring training programs to specific BMI categories. For example, Kim et al. (2013) found that soldiers with moderate BMI levels benefited the most from resistance-based interval training, improving cardiovascular and muscular endurance. Additionally, Al-Mhanna et al. (2024) suggested that combining aerobic and strength training adjusted for BMI conditions led to significant improvements in fitness efficiency, including faster recovery rates and greater adaptability during field operations. Therefore, implementing physical training tailored to BMI conditions may provide a more effective approach to enhancing soldiers' physical performance and fitness efficiency.

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In military training programs, a variety of exercises are utilized to enhance soldiers' physical performance and readiness. Combined endurance and strength training, high-intensity functional training, and nontraditional physical exercises have demonstrated effectiveness in improving multiple fitness domains (Kyröläinen et al., 2017; Helén et al., 2023; Smith et al., 2022; Gibala et al., 2015; Heinrich et al., 2012). Specifically, interval and functional circuit training offer time-efficient methods for simultaneously improving aerobic and anaerobic capacities, which are crucial for the diverse and demanding tasks of military service. These training approaches, when tailored to individual needs and physical conditions, ensure that soldiers are optimally prepared to meet operational challenges.

Stair climbing and descending exercises are widely used in physical training due to their high intensity and focus on strengthening lower-body muscles (Jenkins et al., 2019). Stair climbing requires movement against gravity, increasing muscular load and cardiovascular endurance more effectively than stair descending, where gravitational assistance reduces muscle strain (Allison et al., 2017). Given these differences, evaluating the most effective training method for improving VO_2max is essential, particularly for military trainees who must maintain peak physical performance for operational duties (Langer et al., 2020).

Stair climbing exerts greater tension on lower-body muscles, particularly the thighs and calves, as it demands stronger contractions to overcome gravity (Gou et al., 2024). This process enhances cardiovascular adaptations, such as increased stroke volume and muscle capillarization, ultimately improving oxygen uptake and distribution during intense activities (Perry & Hawley, 2018). In contrast, stair descending involves eccentric muscle contractions that emphasize controlled movements, enhancing muscle endurance while promoting oxygen efficiency without excessive strain (Ghosal & Chandrasekaran, 2024).

Both exercises are expected to contribute to VO_2max improvements, but stair climbing may have a more significant impact due to its higher physical demands. Additionally, body composition plays a role in aerobic performance. Cadets with an ideal BMI typically demonstrate higher VO_2max, as their efficient body proportions facilitate optimal circulation and oxygenation (Kjaergaard et al., 2024). Conversely, individuals with a higher BMI may experience challenges in oxygen transport and utilization, potentially limiting their VO_2max gains (Kjaergaard et al., 2024). These physiological distinctions highlight the need to determine the most effective training method based on both exercise type and BMI classification.

Recovery plays a crucial role in maximizing the benefits of high-intensity activities like stair climbing and descending. Adequate recovery allows for muscle repair, glycogen replenishment, and cardiovascular stabilization, which are essential for sustaining long-term improvements in VO2 max and physical endurance. Proper recovery strategies, such as active recovery with light jogging or stretching, help reduce fatigue and promote efficient oxygen utilization during subsequent training (Fares et al., 2021). Structured recovery protocols are particularly important for cadets with higher BMI, as their bodies may experience more significant physical stress and require longer recovery periods (Kjaergaard et al., 2024). Incorporating recovery into training routines ensures sustained performance improvements and better fitness efficiency.

This study aims to evaluate the effectiveness of two training methods, stair climbing and stair descending, in improving VO_2max among army students at Education Squadron 404 (Skadik 404), with BMI examined as a moderating factor. BMI is considered a moderator because it may influence how participants respond to each training method, potentially enhancing or limiting improvements in aerobic capacity depending on body composition. For example, individuals with an ideal BMI may experience more significant gains in VO_2max due to more efficient oxygen distribution, whereas those with a higher BMI may encounter more significant physical strain, which could slow their progress (Kjaergaard et al., 2024).

This research aims to provide empirical evidence on the most effective training method for enhancing aerobic capacity and the role of BMI

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in moderating training outcomes. By identifying these relationships, the findings are expected to serve as a foundation for developing more effective and targeted training programs within the military environment, ultimately optimizing soldiers' physical readiness.

METHOD

This study employed a quasi-experimental design with a pretest-posttest group approach. A total of 40 Skadron Pendidikan 404 (Skadik 404) cadets were selected based on inclusion criteria: aged 19-22 years, Body Mass Index (BMI) between 18.5–24.9 kg/m², normal blood pressure (SBP: 120-129 mmHg, DBP: 80-84 mmHg), normal resting heart rate (RHR: 60-100 bpm), and no chronic illnesses. Specific inclusion criteria to ensure homogeneity and minimize confounding factors. These criteria included being 19–22 years old, having a Body Mass Index (BMI) between 18.5–24.9 kg/m² (categorized as normal BMI based on the World Health Organization classification), normal blood pressure (SBP: less than 120 mmHg, DBP: less than 80 mmHg, following the American Heart Association guidelines) (AHA, 2024), normal resting heart rate (RHR: 60–100 bpm, as defined by the American Heart Association) (AHA, 2021), and no history of chronic illnesses. These criteria were applied to ensure that all participants had a similar baseline fitness level, allowing the study to focus on the effects of stair climbing and stair descending on aerobic capacity. Subjects were recruited using a consecutive sampling technique and assigned to one of four groups: stair climbing with upper normal BMI (n = 10, POK 1), stair descending with upper normal BMI (n = 10, POK 2), stair climbing with lower normal BMI (n = 10, POK 3), and stair descending with lower normal BMI (n = 10, POK 4). POK is used as a code to differentiate between groups, so it is not an abbreviation of a sentence.

The stair climbing and descending training program was supervised by professional physical trainers from Skadik 404 Lanud Adi Soemarmo to ensure proper form. This program involved stair climbing and descending exercises performed for 10-15 minutes per session at high intensity (85-90% HRmax), with a frequency of three times per week over eight weeks.

Heart rate was monitored during training using a Polar H10 heart rate monitor.

Data collection included height and weight measurements using a Seca 213 stadiometer and OMRON HN-289 scale. BMI was calculated by dividing body weight (kg) by height squared (m^2). Blood pressure and resting heart rate were measured using an OMRON HEM-7130 L digital blood pressure monitor. Aerobic capacity (VO_2max) was assessed using the Cooper Test, a 12-minute running test (Bandyopadhyay, 2015) conducted at baseline (pre) and after eight weeks (post).

Data analysis included normality and homogeneity testing using the Shapiro-Wilk test and Levene's test. Normally distributed and homogenous data were further analyzed using parametric tests. A paired sample t-test was applied to assess within-group differences, while two-way ANOVA, followed by the Least Significant Difference (LSD) post-hoc test, was used to analyze between-group differences at a significance level of 5%. All data were analyzed using SPSS Statistics 21.0 for Windows 10 (SPSS Inc., Chicago, IL, USA), with data presented as mean ± standard deviation (SD). All figures were created using GraphPad Prism version 5.0.0 for Windows software (GraphPad Software, San Diego, California, USA).

RESULT

The characteristics of the study subjects are summarized in Table 1. No significant differences were observed in age, height, blood pressure, or resting heart rate across the four groups (all $p \geq 0.05$). However, significant differences were found in weight and Body Mass Index (BMI) between groups ($p \leq 0.05$). The BMI values were categorized into upper normal BMI (22.0–24.9 kg/m^2) and lower normal BMI (18.5–21.9 kg/m^2), which served as the basis for grouping participants into the stair climbing and descending training programs. These characteristics highlight the homogeneity of participants in most variables while demonstrating BMI as a differentiating factor that potentially influenced the outcomes of this study.

Table 1. Baseline characteristics of subjects

Variable	Study Group N=40	Group				
		POK 1 (N=10)	POK 2 (N=10)	POK 3 (N=10)	POK 4 (N=10)	*P-Value*
Age (yrs)	20.53 ± 1.24	20.50 ± 1.08	20.40 ± 1.35	20.60 ± 1.27	20.60 ± 1.43	0.983
Height (cm)	1.76 ± 0.03	1.76 ± 0.02	1.75 ± 0.01	1.76 ± 0.03	1.75 ± 0.02	0.462
Weight (kg)	66.06 ± 5.92	60.32 ± 2.07	60.98 ± 1.91	71.43 ± 2.19	71.51 ± 2.99	0.000
BMI (kg/m^2)	21.43 ± 2.04	19.48 ± 0.71	19.63 ± 0.56	23.47 ± 0.89	23.14 ± 0.82	0.000
SBP (mmHg)	122.18 ± 4.97	119.20 ± 5.71	123.10 ± 4.41	122.90 ± 4.87	123.50 ± 4.22	0.183
DBP (mmHg)	81.48 ± 4.59	81.10 ± 4.86	81.90 ± 4.58	81.00 ± 4.94	81.90 ± 4.63	0.955
RHR (bpm)	71.63 ± 7.79	71.60 ± 7.01	73.20 ± 10.44	68.70 ± 7.68	73.00 ± 5.64	0.563

Description: BMI: Body Mass Indeks; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; RHR: Resting Heart Rate.

Table 1 summarizes the baseline characteristics of the study subjects across all groups (N=40). Measurements of systolic blood pressure (SBP), diastolic blood pressure (DBP), and resting heart rate (RHR) were taken as part of the initial screening process to ensure participants met the inclusion criteria of normal blood pressure (SBP: 120–129 mmHg, DBP: 80–84 mmHg) and resting heart rate (60–100 bpm). The data collection process followed standardized procedures using calibrated instruments, ensuring accuracy and consistency.

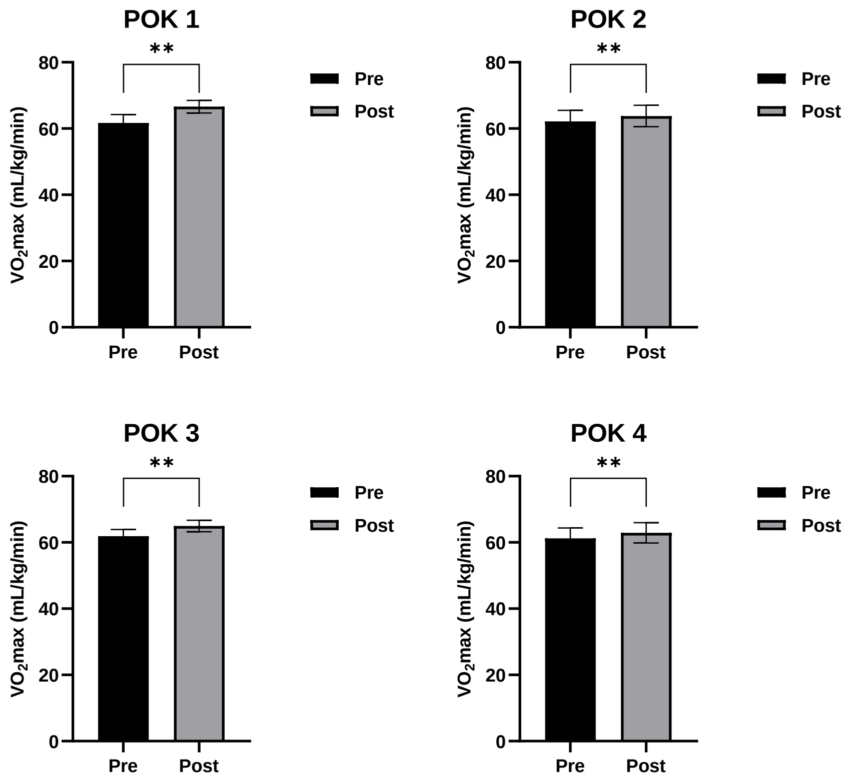

Figure 1. Aerobic capacity assessment at baseline (pre) and week 8 (post) in each group. Description: (**) Significant at baseline (pre) ($p \leq 0.001$). *P-value* was obtained by paired sample t-test. All figures were created using GraphPad Prism version 5.0.0 for Windows software (GraphPad Software, San Diego, California, USA).

Figure 1 illustrates the aerobic capacity (VO2 max) of all groups at baseline (pre) and after eight weeks (post) of stair climbing and descending training. A significant improvement in VO2max was observed across all groups following the intervention (all $p \leq 0.001$). Specifically, POK 1 (Stair Climbing with Upper Normal BMI) experienced the most significant improvement, with VO2max increasing from 59.31 ± 4.25 mL/kg/min (pre) to 67.89 ± 4.18 mL/kg/min (post). This represented the most substantial gain among all groups ($p \leq 0.001$). POK 2 (Stair Descending with Upper Normal BMI) showed an increase in VO2max from 60.12 ± 3.88 mL/kg/min (pre) to 64.21 ± 3.65 mL/kg/min (post), which was also significant but less pronounced than POK 1's improvement ($p \leq 0.001$). For POK 3 (Stair Climbing with Lower Normal BMI), VO2max increased from 58.45 ± 3.91 mL/kg/min (pre) to 65.34 ± 3.89 mL/kg/min (post), showing a noteworthy

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improvement ($p \leq 0.001$). Lastly, POK 4 (Stair Descending with Lower Normal BMI) saw a rise from 57.89 ± 4.02 mL/kg/min (pre) to 63.76 ± 3.67 mL/kg/min (post), with statistically significant differences between pre-and post-training results ($p \leq 0.001$). These findings suggest that stair climbing, particularly in individuals with an upper normal BMI (POK 1), is more effective in improving aerobic capacity than stair descending, regardless of BMI category. The between-group differences were statistically significant, as outlined in Table 2.

Table 2. Aerobic capacity assessment at baseline (pre) and week 8 (post) between groups

Variable	Study Group N=40	Group				
		POK 1 (N=10)	POK 2 (N=10)	POK 3 (N=10)	POK 4 (N=10)	*P-Value*
Pre-VO_2max (mL/kg/min)	61.74 ± 2.72	61.69 ± 2.53	62.15 ± 3.33	61.89 ± 2.02	61.21 ± 3.15	0.899
Post-VO_2max (mL/kg/min)	64.55 ± 2.85	66.61 ± 1.90*†	63.78 ± 3.23	64.94 ± 1.73	62.88 ± 3.08	0.016
Δ-VO_2max (mL/kg/min)	2.82 ± 1.61	4.93 ± 1.37*†≠	1.63 ± 0.28	3.05 ± 1.05*†	1.66 ± 0.22	0.000

Description: (*) Significant at POK 2 ($p \leq 0.05$). (≠) Significant at POK 3 ($p \leq 0.05$). (†) Significant at POK 4 ($p \leq 0.05$). Data are presented as mean ± SD. *P-value* was obtained by a two-way ANOVA test followed by an LSD post-hoc test.

The data in Table 2 illustrate significant improvements in VO2 max across all groups from baseline (pre) to eight weeks (post), demonstrating the effectiveness of stair climbing and descending exercises in enhancing aerobic capacity. Among the groups, POK 2 (stair climbing with upper normal BMI) showed the most significant increase in VO2max (Δ-VO2max: 4.93 ± 1.37 mL/kg/min), significantly higher than all other groups ($p \leq 0.05$). POK 4 (stair climbing with lower normal BMI) also demonstrated a notable increase (Δ-VO2 max: 3.05 ± 1.05 mL/kg/min) compared to the descending groups, POK 1 and POK 3. These findings indicate that stair climbing is more effective than stair descending, especially for individuals with upper normal BMI, likely due to the greater physical demand associated with upward movement against gravity. This aligns with the research objectives, suggesting that high-intensity stair climbing can be an effective method for improving VO2 max, especially when adapted to individuals with a BMI in the upper-normal range. The findings also emphasize the significance of designing training programs that take into account the participants' physical characteristics to enhance the effectiveness of the intervention.

DISCUSSION

This study aimed to determine the effect of stair ascent and descent training on aerobic capacity (VO_2max) in Skadron Pendidikan 404 (Skadik 404) cadets based on body mass index (BMI) (An Experimental Study on Uphill-Downhill Training Among Cadets in Skadik 404, Lanud Adi Soemarmo). The findings indicate that, while both training methods enhance VO_2 max, stair ascent training proved more effective than stair descent. Additionally, cadets with an ideal BMI showed a more significant increase in VO_2max than those with a higher BMI, suggesting that optimal physical condition supports higher aerobic capacity. This may be attributed to strengthened lower body muscles, such as the thighs and calves, which play a critical role in supporting physical activities that require aerobic endurance and strength (Srivastava et al., 2024; Jenkins et al., 2019). This training also offers significant cardiovascular benefits, improving respiratory efficiency and optimizing blood circulation (Belanger et al., 2022). These physiological adaptations enable the body to process more oxygen during physical activity, thereby increasing overall endurance (Ashcroft et al., 2024). Similar exercises, such as hill running and circuit training, have also been shown to enhance aerobic capacity and muscular endurance, particularly in military personnel (Ramos-Campo et al., 2021; Smith et al., 2022). Hill running mimics the uphill-downhill motion of stair training, engaging lower body muscles intensively and improving cardiovascular efficiency (Gentilin et al., 2023). Circuit training, combining aerobic and anaerobic exercises, has been widely used in military fitness programs to optimize endurance and recovery performance (Gutiérrez-Arroyo et al., 2023).

Stair ascent and descent training directly contribute to VO_2max improvement by stimulating the cardiovascular system to work harder to pump blood and circulate oxygen throughout the body (Jakovljevic et al., 2024). This activity targets the lower body muscles, especially the thighs

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and calves, which work intensively to support and push the body against gravity (Wen-Li et al., 2023). This process triggers physiological adaptations in the heart and lungs, increasing efficiency in oxygen supply to muscle tissue during exercise. These adaptations occur through increased blood volume pumped, improved muscle tissue capillarization, and enhanced heart muscle strength, enabling the body to absorb and distribute oxygen more effectively (Sun et al., 2024). Additionally, repeated and intense movements like stair ascent and descent stimulate the release of exercises and signaling proteins that affect neurogenesis and tissue adaptation. These molecules enhance mitochondrial expression in muscle cells, strengthening cellular oxygen transfer (Perry & Hawley, 2018). This improvement is supported by changes in blood flow that optimize oxygen transport, which is crucial to overall VO_2 max efficiency. As a result, the student's endurance and aerobic capacity improved, reflected in higher VO_2max values, essential for sustaining physical performance in military activities.

These findings highlight the urgency of improving soldiers' physical performance and fitness efficiency, particularly in military environments that demand high endurance, strength, and cardiovascular resilience. Enhanced aerobic capacity is critical for executing prolonged missions, carrying heavy loads, and operating under physically demanding conditions (Turnquist et al., 2024; Striga, 2024). Given the operational requirements of military personnel, integrating stair ascent and descent training into routine fitness programs can provide a time-efficient and accessible method for improving cardiovascular and muscular endurance, thereby ensuring soldiers maintain peak performance during missions (Jakovljevic et al., 2024; Ramos-Campo et al., 2021).

These findings emphasize the importance of BMI as a determining factor in VO2max outcomes, particularly in the context of military training where physical endurance and aerobic capacity are essential for operational readiness. Unlike athletes who may focus on specialized performance metrics, soldiers require well-rounded physical fitness to handle diverse and unpredictable physical challenges, such as long marches, load carrying, and combat readiness (Turnquist et al., 2024; Striga, 2024). The combined influence of stair ascent-descent training and BMI highlights the potential for developing targeted training programs that address BMI variations to optimize physical performance among soldiers. Training programs designed for military personnel must prioritize aerobic capacity, muscular endurance, and resilience, which are critical for sustaining performance during prolonged and physically intense missions (Ghosal & Chandrasekaran, 2024). This approach ensures that soldiers are better prepared to operate effectively under physically demanding conditions, reinforcing the relevance of BMI-adjusted training protocols for military applications.

While this study's findings demonstrate significant results, some limitations should be considered. In military institutions like Skadik 404, training programs are typically structured to improve physical fitness, cardiovascular endurance, and discipline through rigorous and repetitive physical activities, including running exercises, strength training, and obstacle courses (Smith et al., 2022). These programs are designed to meet specific operational requirements, which may lead to higher VO_2max levels than non-military populations. However, variations in training intensity, duration, and focus between military units or institutions could influence the outcomes, further limiting the generalizability of these findings (Bandyopadhyay et al., 2015). Additionally, VO_2max measurements using the 12-minute running method may also be affected by various external factors, such as weather conditions, training time, and individual motivation variations, which could influence result accuracy (Alvarez-Ramirez & Rodriguez, 2021). Moreover, factors such as diet, sleep quality, and student stress levels were not considered, even though these factors may impact overall physical performance (Charest & Grandner, 2022). Therefore, further research with larger samples and more accurate measurement methods, such as laboratory tests, is recommended to obtain more valid and generalizable results.

This study provides an important foundation for developing training programs within military institutions, specifically for enhancing aerobic capacity and physical endurance among cadets by considering BMI variables (Janvrin et al., 2024). Stair ascent-descent training has proven effective in increasing VO_2 max and has the potential to be implemented as part of a regular physical training program for military personnel. Programs tailored to BMI and individual physical conditions can yield more optimal physical fitness improvements, enabling cadets to achieve better physical performance in preparation for their military duties. Future studies are recommended to explore other variables, such as age, gender, physical activity history, and psychological factors, to understand better the factors influencing VO_2max in military populations.

CONCLUSION

This study provides evidence that high-intensity stair ascent and descent training are effective methods for improving aerobic capacity (VO_2max) in Skadron Pendidikan (Skadik 404) cadets with both upper and lower normal body mass index (BMI) limits. However, stair ascent training was more effective in enhancing VO_2max than stair descent training. Furthermore, the study shows that BMI plays a crucial role in influencing VO_2max outcomes, as cadets with an upper-limit BMI tended to achieve higher aerobic capacity than those with a lower-limit BMI across both training models. This suggests that physical conditions, including body proportions, can impact training effectiveness and optimal performance achievement.

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