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Profile of aerobic capacity (VO_2 max) of student athletes: a comparative study based on gender and sports group

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ABSTRACT
Problems: Aerobic capacity (VO_2 Max) is a fundamental component of physical condition that supports athletic performance in various sports. Grouping sports based on their physiological characteristics, such as martial arts, games, and measurable sports, can help in analyzing athlete fitness profiles. Furthermore, established physiological differences between genders are known to significantly influence aerobic capacity. **Purpose:** This study aims to map the profile and analyze differences in aerobic capacity among student athletes based on gender and sports classification. **Methods:** This study used a descriptive-comparative design with 57 student-athletes (37 men, 20 women, aged 20.98 ± 0.6 years) from 18 sports at the Universitas Pendidikan Indonesia, selected using convenience sampling. Aerobic capacity data (VO_2 Max) were collected through the standard Multistage Fitness Test (MFT) instrument. Data analysis was performed using descriptive statistics, Independent Samples T-test, and One-Way ANOVA. **Results:** This study showed that male athletes had a significantly higher mean VO_2 Max (42.02 ± 5.14 ml/kg/min) than female athletes (30.91 ± 4.67 ml/kg/min). Further analysis of the male group found no significant differences in VO_2 Max between the Martial Arts (43.33 ± 4.09 ml/kg/min), Games (41.6 ± 4.87 ml/kg/min), and Measured (43.9 ± 3.12 ml/kg/min) groups. Similarly, in the female group, no significant differences were found between Martial Arts (31.5 ± 6.80 ml/kg/min), Games (30.0 ± 3.01 ml/kg/min), and Measured (37.7 ± 1.27 ml/kg/min). **Conclusion:** Gender is the most dominant differentiating factor for the aerobic capacity of student athletes in this study, while grouping based on sports clusters did not show significant differences. These findings indicate that the variation in athletic levels within each sport group is greater than the differences between sport groups themselves. Further research is recommended to conduct similar analyses by controlling for equivalent athletic levels to obtain a more specific picture of the physiological demands between sports.
Keywords: aerobic capacity, gender, sport group, student athletes, VO_2 max.

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Introduction

Cardiorespiratory capacity, physiologically measured as maximal oxygen uptake (VO_2 Max), is a fundamental indicator that reflects the body's ability to perform sustained physical activity and has been recognized as an important marker of general health status (Tomkinson et al., 2019). In the context of sports, a high VO_2 Max level is one of the main predictors of athletic performance, endurance and recovery, influenced by complex interactions between the pulmonary, cardiovascular, and muscular systems, especially in sports that require endurance (Deliceoğlu et al., 2024; Santisteban et al., 2022). The importance of aerobic capacity is not limited to pure endurance sports, but also forms a crucial foundation in sports involving intermittent activity, where the ability to recover quickly between bursts of anaerobic energy is critical to success (Julio & Franchini, 2021).

The physiological demands for achieving peak performance vary greatly between sports. These differences can be analyzed by grouping sports based on their energy metabolism characteristics. Studies show clear physiological differences between endurance athletes, team athletes, and power athletes, which validates the grouping approach for analysis (Degens et al., 2019). Based on this, this study uses a classification approach for sports groups, namely martial arts, such as Taekwondo and Kickboxing, which are characterized by intermittent activities of very high intensity and require a strong aerobic base for recovery between actions and rounds (Andreato et al., 2017; Julio & Franchini, 2021; Kim & Nam, 2021; Li, 2023). Then there are sports such as soccer and basketball that require the ability to sprint repeatedly with short recovery periods (Muñoz-Vásquez et al., 2023; Stanković et al., 2021), where aerobic endurance plays a role in delaying fatigue (Mooney et al., 2024; Öztürk et al., 2023), and measurable sports, such as rowing and athletics, which are definitively dominated by the aerobic energy system (Sihite et al., 2023; Zorn, 2017).

In addition to sport classification, gender is a very strong differentiating variable in cardiorespiratory capacity. Research consistently shows that men have higher VO_2 Max values than women, even after adjusting for body mass (Koons et al., 2019; Santisteban et al., 2022). This difference is due to various fundamental physiological factors, including total blood volume, hemoglobin mass, and greater red blood cell volume in men, which implies superior VO_2 Max capacity (Koons et al., 2019; Schultz et al., 2022). The 10-12% performance gap observed in various endurance sports is often directly attributed to fundamental differences in VO_2 Max (Santisteban et al., 2022). The population of student athletes is a unique research subject because they are at the peak of their performance development while balancing training demands with academic activities (Ambaum & Hoppe, 2025; Amfo, 2024; Gomez et al., 2018). This can lead to highly varied levels of fitness among them (Duquette & Adam, 2024). Although there is a wealth of normative data for elite athletes and the general population, comparative data that specifically maps the VO_2 Max profile of student athletes in Indonesia using a sport classification approach is still limited. Therefore, this study aims to describe and compare VO_2 Max profiles in student athletes based on gender and sports classification (Martial Arts, Games, and Measured) to provide a more comprehensive picture of physiological demands at the university competition level.

Method

This study uses a quantitative approach with a descriptive-comparative design. The descriptive approach is used to present an overview or profile of VO_2 Max for each sample group studied. Meanwhile, the comparative approach is used to analyze and compare the differences in average VO_2 Max between groups, namely comparisons based on gender variables (men and women) and sports group variables (martial arts, games, and measured). The population in this study was all active student athletes at the Universitas Pendidikan Indonesia. The research sample consisted of 57 student athletes (37 men and 20 women) with an average age of 20.98 ± 0.6 years, who came from 18 different sports. The participants were part of the physically active university-age population, an important demographic group for fitness monitoring (Duquette & Adam, 2024). The sampling technique used was convenience sampling, in which samples were recruited based on availability and voluntary participation at the time of data collection, which coincided with the lecture schedule. All participants provided written informed consent before participating in the study.

The main instrument used to measure aerobic capacity is the Multistage Fitness Test (MFT), also widely known as the Bleep Test or 20-meter Shuttle Run Test (20mSRT). This test is a field instrument designed to indirectly estimate VO_2 Max (Tomkinson et al., 2019). The selection of this test is based on its practicality as a more cost-effective alternative that can be applied to large groups simultaneously, compared to the gold standard laboratory method such as Cardiopulmonary Exercise Testing (CPET), which requires special facilities and expertise (Senanayake et al., 2024). This test protocol involves continuously running back and forth between two lines 20 meters apart, following the rhythm of an audio signal that increases in speed progressively every minute. The Bleep Test has been internationally recognized as one of the most widely used field tests and has been proven to have moderate criterion validity and high to very high reliability for populations of youth and young adults (Tomkinson et al., 2019). The equipment used in this test includes speakers to play the test audio, cones to mark the track, and a measuring tape to ensure the accuracy of the 20-meter distance.

The test was conducted according to standard MFT procedures. Participants ran according to audio signals, and the test was stopped for each individual when they failed to reach the line twice in a row or stopped due to voluntary fatigue. The level and number of the last shuttle successfully completed by each participant was recorded as the test score. This score was then converted into an estimated VO_2 Max value (in ml/kg/min) using a validated prediction equation (Tomkinson et al., 2019). After completing the test, participants were instructed to do a cool-down session in the form of a light walk. All raw data collected were processed and analyzed using SPSS statistical software version 25. Data analysis was carried out in several stages. First, descriptive statistics were used to calculate the mean and standard deviation (SD) of VO_2 Max data for each group (overall, men, women, and each cluster). Second, hypothesis testing was performed to answer the research questions. An Independent Samples T-Test was used to test the hypothesis of a difference in the mean VO_2 Max between two independent groups (men and women). Next, One-Way

ANOVA was used to test the hypothesis of differences in the mean VO_2 Max between the three sports groups. ANOVA analysis was performed separately for the male and female groups. The significance level used for all hypothesis tests was set at $p < .05$.

Results

The results of the research data analysis are presented systematically in this section, beginning with a description of descriptive statistics to provide an overview of the participants' VO_2 Max profile, followed by the results of hypothesis testing to answer the research question regarding differences in aerobic capacity based on gender and sports classification.

Table 1. Descriptive Statistics of Aerobic Capacity (VO_2 Max)

	N	Mean	Std. Deviation
Male	37	42.02	5.14
Combat	7	43.33	6.11
Game	26	41.34	5.18
Measured	4	44.02	2.33
Female	20	30.91	4.67
Combat	4	31.4	6.78
Game	14	29.81	3.59
Measured	2	37.6	1.41

Overall, the 37 male athletes who participated in this study had an average VO_2 Max of 42.02 ± 5.14 ml/kg/min. When broken down by sport group, the male group in the Measured group had the highest average VO_2 Max (44.02 ± 2.33 ml/kg/min), followed by the Martial Arts group (43.33 ± 6.11 ml/kg/min), and the Games group (41.34 ± 5.18 ml/kg/min). Meanwhile, 20 female athletes showed an average VO_2 Max of 30.91 ± 4.67 ml/kg/min. Similarly, in the female group, the Measured group showed the highest average VO_2 Max (37.6 ± 1.41 ml/kg/min), followed by the Martial Arts group (31.4 ± 6.78 ml/kg/min), and the Games group (29.81 ± 3.59 ml/kg/min). These descriptive data provide an initial overview of the cardiorespiratory fitness profile of the sample before further hypothesis testing is conducted.

Table 2. Result of Independent Samples T-Test

		Levene's Test for Equality of Variances	T-Test for Equality of Means		
		Sig.	t	df	Sig. (2-tailed)
VO_2 Max	Equal Variances Assumed	.670	8.027	55	.000

To answer the first research question regarding differences in aerobic capacity based on gender, an Independent Samples T-Test was conducted. Before performing the T-test, Levene's Test of homogeneity of variance showed that the variance of data between the male and female groups was homogeneous ($p = .800$). The T-test results showed that there was a statistically significant difference in the mean VO_2 Max between male athletes (42.02 ± 5.14 ml/kg/min) and female athletes (30.91 ± 4.67 ml/kg/min), with $t(55) = 8.027$, $p < .001$. These findings indicate that the first hypothesis is accepted.

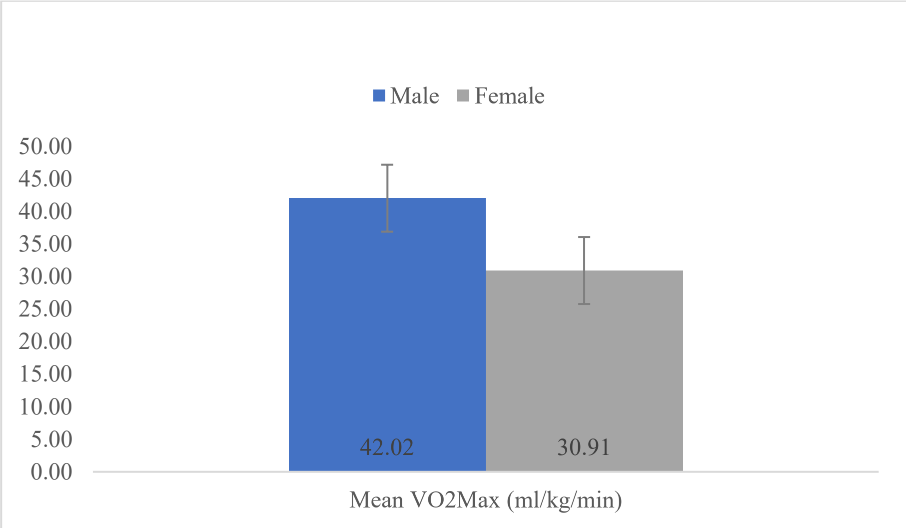

Figure 1. Comparison of Average VO_2 Max. between Male and Female

The results of the VO_2 Max comparison based on gender are presented in Figure 1. The graph shows a substantial difference between the average VO_2 Max of male and female athletes. The average VO_2 Max for the male group was recorded at 42.02 ml/kg/min, while for the female group it was 30.91 ml/kg/min. Statistical tests confirmed that this difference was highly significant ($p < .001$), indicating that the male athletes in this study sample had a much higher aerobic capacity than the female athletes.

Table 3. Result of One-Way ANOVA

		F	df	Sig.
Male	Between Groups	.780	2	.466
	Within Groups		34	
Female	Between Groups	2.967	2	.078
	Within Groups		17	

Next, to test the second hypothesis, a One-Way ANOVA analysis was conducted to compare the average VO_2 Max between sports groups. In the male group, the analysis results did not show any statistically significant differences in average VO_2 Max between the martial arts, games, and measured groups, with $F(2, 34) = .780$, $p = .466$. A similar pattern was found in the female group. The analysis results also showed no statistically significant differences between the three sports groups, with $F(2, 17) = 2.967$, $p = .078$. Thus, the second hypothesis was rejected for both groups.

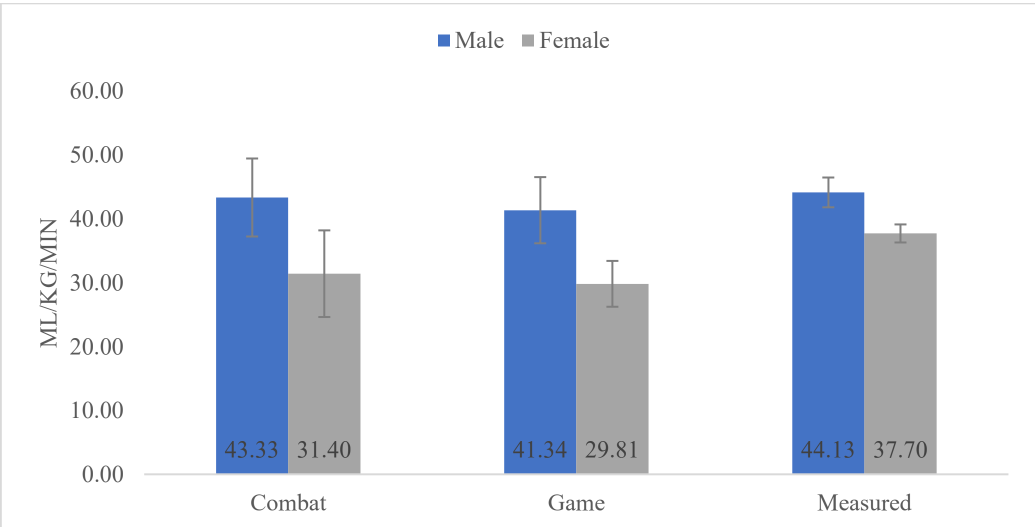

Figure 2. Comparison of VO_2 Max. between Sports Group

Figure 2 presents a comparison of the average VO_2 Max between three sports groups (Martial Arts, Games, and Measured) grouped by gender. In the male group, there were no significant differences between groups; the averages for Martial Arts, Games, and Measured were 43.33, 41.34, and 44.13 ml/kg/min, respectively. ANOVA analysis confirmed that these differences were not statistically significant. The same pattern was observed in the female group. Although the Measured category showed a numerically higher average value (37.70 ml/kg/min) compared to the Martial Arts (31.40 ml/kg/min) and Games (29.81 ml/kg/min) categories, this difference was also not statistically significant. Thus, it can be concluded that classification based on sports group does not show any significant differences in aerobic capacity in this study sample.

Discussion

The first and most consistent finding of this study was a highly significant difference ($p < .001$) in aerobic capacity between male (42.02 ± 5.14 ml/kg/min) and female (30.91 ± 4.67 ml/kg/min) student athletes. This average gap of more than 10 ml/kg/min reaffirms the physiological superiority of men in terms of maximum aerobic capacity, a phenomenon that has been widely documented in scientific literature (Santisteban et al., 2022). This fundamental difference is not only due to differences in average body size, but also to intrinsic factors that affect oxygen transport and utilization systems. Men tend to have greater total blood volume, red blood cell volume, and hemoglobin mass, which collectively increase the oxygen-carrying capacity of the blood (Koons et al., 2019). In addition, the larger average size of the heart and lungs in men allows for higher maximum cardiac output and greater ventilation potential during high-intensity physical activity (Santisteban et al., 2022). Differences in body composition, where men generally have greater muscle mass and lower body fat percentage, also contribute (Zorn, 2017). Although physical exercise can increase VO_2 Max in both sexes, evidence shows that the level of adaptation and physiological upper limits remain different due to these biological constraints (Santisteban et al., 2022). Normative data from the general student population also show similar patterns of gender differences, although average values among student athletes tend to be higher (Duquette & Adam, 2024). Therefore, the results of this study reinforce the understanding that gender differences are a very strong biological determinant of aerobic capacity, even in trained populations such as student athletes.

In contrast to the significant findings in the gender comparison, the ANOVA analysis did not show any statistically significant differences in VO_2 Max averages between the Martial Arts, Games, and Measured sports groups, either in the male ($p = .466$) or female ($p = .078$) groups. Theoretically, based on different energy system demands, a gradation in aerobic capacity between groups is expected. The Measured group, which includes endurance sports such as rowing, should show the highest VO_2 Max due to the dominance of aerobic metabolism and continuous nature of the effort (Degens et al., 2019; Purnamasari et al., 2021; Zorn, 2017). Martial arts and games, although intermittent, also require a strong aerobic base for recovery between high-intensity activities (Andreato et al., 2017; Julio & Franchini, 2021; Kim & Nam, 2021; Öztürk et al., 2023; Purnamasari et al., 2024; Ramadani et al., 2025). Similarly, game sports require aerobic endurance to sustain repeated sprint ability and delay fatigue over long match durations (Stanković et al., 2021). Comparative studies on elite athletes often confirm these differences; one study found that professional soccer players had higher VO_2 Max than handball players (Souza et al., 2018). However, in the context of this study, the absence of significant differences can be attributed to the specific characteristics of sample.

The research sample consisted of student athletes, a category that covers a broad spectrum ranging from recreational athletes at the student activity unit level to competitive athletes participating in the National Sports Week (PON). The large individual variation in terms of training history, actual fitness status, and genetic potential within each group created a wide standard deviation. This high internal variability likely masks any average differences that may theoretically exist between the three groups. This phenomenon of intra-group heterogeneity is supported by recent local studies. For example, within the Martial Arts cluster, aerobic requirements can differ drastically between "fight" and "art" categories, as shown by significant differences in VO_2 Max between Pencak Silat athletes in fight versus art categories (Ramadani et al., 2025). Similarly, within the Games cluster, significant differences have been found between futsal and volleyball players, suggesting that grouping them together might dilute specific characteristics (Purnamasari et al., 2024). Furthermore, a study that also found no significant differences in VO_2 Max between positions in amateur soccer players, suggesting that in non-homogeneous populations, individual variation can be more dominant (Öztürk et al., 2023). Additionally, factors such as muscle fiber composition (type I vs. type II), which has a strong genetic basis and influences aerobic and anaerobic potential, also contribute to performance variation between individuals within a single sport or group (Hopwood et al., 2023). Different training modalities (e.g., High-Intensity Interval Training vs. Continuous Training) employed by different sports also yield specific physiological adaptations that might not be fully captured by a single metric like VO_2 Max Body in a heterogeneous group (Peng et al., 2025; Sun et al., 2024). Body composition factors also play a significant role; athletes in the same sport may have different body compositions that affect relative VO_2 Max (Zorn, 2017). When compared to the general student population, the average VO_2 Max values of this athlete sample are indeed higher (Duquette & Adam, 2024), but their internal diversity prevents the detection of differences between sports.

The interpretation of these research results needs to take into account several methodological limitations. First, the use of convenience sampling techniques limits the generalization of findings to the entire population of student athletes, as the sample may not be fully representative. Second, the heterogeneous sample in terms of athletic ability is a major confounding factor, as discussed earlier. Third, aerobic capacity was measured using the Multistage Fitness Test (MFT), which is an indirect estimation method. Although the MFT is recognized for its validity and reliability (Tomkinson et al., 2019), validation studies show that this test tends to produce slightly higher estimates of VO_2 Max than direct measurements using respiratory gas analysis (Senanayake et al., 2024). Fourth, the sample size in some subgroups, particularly women in the Measured Group (N=2), was very small. This unbalanced and small sample size reduced the statistical power of the ANOVA analysis in the women's group and made the interpretation of results for this subgroup very cautious. Finally, this study did not control for other variables that could influence VO_2 Max, such as nutritional status, training phase at the time of testing, or environmental factors during testing.

Conclusion

This study concludes that gender is the most dominant differentiating factor for VO_2 Max in the population of student athletes studied, with male athletes consistently demonstrating higher capacity than female athletes. These findings emphasize the importance of considering fundamental physiological differences between genders in the context of athletic performance. On the other hand, classification of sports based on group (Martial Arts, Games, and Measured) did not show any significant differences in aerobic capacity in this sample. This indicates that variations in fitness levels and individual training histories within each group are likely to be greater than the average differences between groups themselves at the heterogeneous student athlete level. The important message from these findings is that although the general characteristics of sports provide an initial overview, the assessment and development of training programs need to focus more on the individual fitness level of athletes rather than relying solely on broad sports categorization. For further research, it is recommended that similar analyses be conducted with strict control of athletic level variables (e.g., only comparing athletes with equivalent competition levels) to obtain a more accurate picture of the specific physiological demands between sports and groups.

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