



The Influence of Body Mass Index, Hemoglobin, and Blood Pressure on VO₂max of Elite-Pro Karatekas in South Sulawesi

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Abstract

The lack of knowledge regarding the physical health aspects of karate athletes prompted this study, which examines direct and indirect causal relationships between Body Mass Index (BMI), Hemoglobin (Hb), and Blood Pressure (BP) on the VO₂max of Elite-Pro Karatekas. Path analysis was employed with BMI (X₁) and Hb (X₂) as independent variables, BP (X₃) as an intervening variable, and VO₂max (Y) as the dependent variable. Data were collected through BMI (height and weight), Hb (Easy Touch GCHB test), BP (digital sphygmomanometer), and VO₂max (Bleep Test). Results showed BMI affects BP ($r=0.267$, $p=0.036$), and Hb strongly affects BP ($r=0.687$, $p=0.000$), indicating more ideal Hb leads to more ideal BP. BMI also influences VO₂max ($r=0.467$, $p=0.000$), especially in overweight or high-BMI athletes with high muscle mass. Hb affects VO₂max ($r=0.551$, $p=0.000$), and BP also impacts VO₂max ($r=0.505$, $p=0.000$). Indirect effects were stronger: BMI affects VO₂max through BP ($0.601>0.467$) and Hb through BP ($0.897>0.551$). Karate coaching should emphasize nutrition, regular health monitoring of BMI, Hb, and BP, and reconsider excessive training habits. A deeper understanding of these health aspects can enhance athlete performance and reduce health risks.

Keywords: blood pressure; body mass index; hemoglobin; karateka; VO₂max

1. Introduction

Athletic success depends not only on technical, physical, mental, and tactical training but also on comprehensive physiological health management (Rusdiawan et al., 2020). One such predictor is a thorough understanding and maintenance of physical health aspects (Balyi et al., 2013); (Bompa & Buzzichelli, 2019); (Dahlan & Khemal, 2019). Physical health components such as cardiovascular system adaptation during physical activity are currently a primary concern among sports physiology specialists and sports physicians (Cherkesov et al., 2021). Clubs, coaches, and athletes striving for success must collaborate with health and nutrition experts, as a healthy lifestyle and balanced, adequate nutrition is crucial to athletic performance (Göbel, 2023).

This emphasis on physiological readiness is particularly relevant in high-intensity combat sports such as karate, where performance is closely tied to cardiovascular and metabolic health. The better the heart rate, heart rate reserve, cardiac output, blood pressure, and maximum oxygen uptake capacity,

the better the rest quality of elite-pro karatekas (Hayirl & Ayar, 2023). Height, body mass index (BMI), and body fat percentage are strongly related to the training performance of beginner karatekas (Arslan et al., 2024). There is a positive correlation between body fat percentage, muscle mass, and bone mass with the punching speed of karatekas (Mulia et al., 2024). Ideally, karatekas should maintain a normal blood pressure level to support their performance (Puspita Wati & Simanjuntak, 2020).

However, research on the importance of physical health aspects in karate remains limited and is recommended by various studies to be explored further and in more depth. The effects of karate on neurophysiology, dynamic balance reactions, and clinical health aspects still require further documentation (Dahmen-Zimmer & Jansen, 2017); (Jansen et al., 2017). More research is needed on blood pressure effects in karatekas, whether related to recovery phases or during and after training sessions (Guzii et al., 2021). Additionally, further study is required on the physiology (Chaabène et al., 2012), and anthropometric characteristics of karatekas (Vujacic et al., 2021).

This research gap is also evident in our literature review of 60 SINTA-indexed journals (Science and Technology Index) in the field of sports science. We found that the topic of physical health in karate is underrepresented compared to other themes: physical training (52 articles), technical training (21 articles), mental training (17 articles), and other topics such as management, instrument development, and talent scouting (14 articles). Only 3 articles specifically addressed physical health in karatekas: the effect of training on BMI and stamina (Prakoso, 2024), hemoglobin levels in athletes (including karate) at the Pre-PON level (Samodra et al., 2022), and the relationship between hydration status and VO₂max in karatekas (Sulastio et al., 2022).

Beyond the SINTA database, other studies have also addressed the importance of physical health in karate and other martial arts, relating to blood pressure; research related to blood pressure, prehypertension, and hypertension in elite-pro karatekas (Puspita Wati & Simanjuntak, 2020). Research related to anemia in adolescent karatekas (Cahyani et al., 2024). Research related to the effect of training on blood pressure (Guzii et al., 2021). Research related to blood pressure, cardiorespiratory functions, and heart rate (Youssef, 2021). Research related to systolic blood pressure and heart rate in adolescent Muay Thai athletes (Saraiva et al., 2022). In relation to body mass index; research related to the description of anemia, nutrient intake, and BMI in adolescent karatekas (Cahyani et al., 2024). Research related to cardiometabolic factors, oxidative stress, and obesity (de Souza et al., 2022). Research related to the relationship between height and body mass index (BMI) in beginner karatekas (Arslan et al., 2024). Research related to the influence of BMI on the technical skills of karatekas (Fadhila et al., 2024). Research related to body fat, muscle mass, bone mass, and technical ability in elite/professional karatekas (Mulia et al., 2024),

Regarding hemoglobin and VO₂max; research related to various relationships among somatotypes, anthropometric profiles, hemoglobin, menstruation, and VO₂max in karatekas (Vujacic et al., 2021). Research related to iron levels, menstruation, and VO₂max in female karatekas (Chania et al., 2022). Research related to the VO₂max consumption levels and injury risks in beginner karatekas (Kunabal et al., 2024). Research related to aerobic and anaerobic capacity in karate (Doria et al., 2009); (Nema et al., 2024a); (Nickytha et al., 2019); (Chaabène et al., 2012); (Chaabène et al., 2015); (Nema et al., 2024b). Relating to the neurophysiological and clinical health aspects of karateka (Dahmen-Zimmer & Jansen, 2017); (Jansen et al., 2017), and rest quality in elite-pro karatekas (Hayirl & Ayar, 2023).

This study addresses an urgent problem—namely, the lack of knowledge and limited research concerning the physical health aspects of karatekas. The variables deemed important and frequently studied include body mass index, hemoglobin, blood pressure, and VO₂max. Furthermore, several studies have analyzed or understood in depth the causal relationships, both direct and indirect, among these variables. We propose blood pressure as an intervening variable because research on

the relationship between blood pressure and VO₂max remains very limited and is generally approached through traditional scientific perspectives (Pesova et al., 2023). Therefore, this study aims to investigate the direct and indirect effects of body mass index and hemoglobin on VO₂max, with blood pressure proposed as a mediating variable, among elite-pro karatekas in South Sulawesi.

2. Method

This research adopted a quantitative, cross-sectional design using path analysis to examine the causal relationships among physiological variables. The variables proposed and tested in this study include: body mass index, denoted as BMI (X_1); hemoglobin, denoted as Hb (X_2); and blood pressure, denoted as BP (X_3), with VO₂max (Y) representing the dependent variable. In this model, BP (X_3) functions as an intervening variable, while BMI (X_1) and Hb (X_2) are considered independent variables, and VO₂max (Y) is the dependent variable.

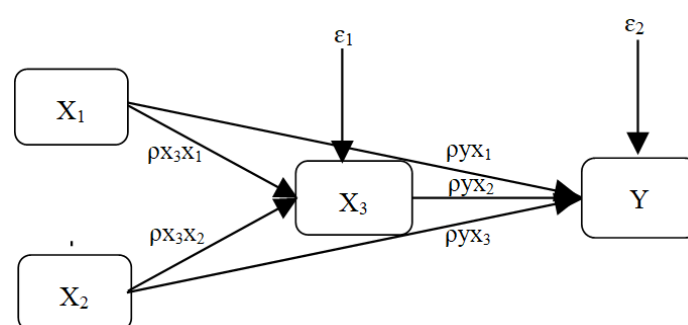


Figure 1. Theoretical Model

Given the limited number of elite-pro kumite karatekas in South Sulawesi Province, a total sampling technique was applied, allowing for the inclusion of all 30 eligible athletes to maximize statistical power and ensure population representation. All participants signed an informed consent form, and this study received ethical approval from the Ethics Committee of the State University of Makassar (Protocol No. 4064/UN36.11/LP2M/2024, Approval Date: 22 November 2024). The data collection was carried out from November 2024 to April 2025 at the Indonesian National Sports Committee (KONI) office in South Sulawesi Province. Data collection methods included: BMI (X_1) was calculated using standardized height and weight measurements with a digital stadiometer and scale, following WHO protocols; Hb (X_2) Hemoglobin levels were assessed using the EasyTouch GCHB test device, a validated portable hemoglobinometer suitable for field conditions; BP (X_3) Blood pressure was measured using an automatic digital sphygmomanometer, with participants in a seated, rested position after 5 minutes, and two readings were averaged.; and VO₂max (Y) was estimated using the multistage fitness (Bleep Test), a validated field measure for cardiorespiratory endurance. Data analysis was conducted using correlational regression tests with the help of SPSS version 24.

3. Result

The descriptive analysis results for the tested variables—BMI (X_1), Hb (X_2), BP (X_3), and VO₂max (Y) — are as follows:

Table 1. Descriptive statistics of BMI (X₁), Hb (X₂), BP (X₃), and VO₂max (Y) of elite-pro kumite karatekas in South Sulawesi Province

Statistics	Age	BMI (X ₁)			Hb (X ₂)	Mr (X ₃)			VO ₂ max (Y)	
		Height	Body Weight	Score (kg/m ²)		Systolic	Diastolic	Score	Level	Score
Mean	20.73	1.74	67.17	22.08	15.68	122.97	83.67	6.20	8.87	44.61
Standard Deviation	1.29	0.05	12.91	3.91	1.18	6.94	4.90	2.01	1.89	6.58
Maximum	23	1.80	90	30.48	17	139	90	9	12	55.99
Minimum	19	1.66	49	16.33	14	110	75	3	5	32.14

The average age of the sample we used was 20.73 years, with a standard deviation of 1.29, a maximum age of 23, and a minimum of 19 years. For BMI (X₁); the average height was 1.74, the average weight was 67.17, with an average BMI score of 22.08, a standard deviation of height of 0.05, a standard deviation of weight of 12.91, with a standard deviation of BMI score of 3.91, a minimum height value of 1.66, a minimum weight value of 49, with a minimum BMI score of 16.33, a maximum height value of 1.80, a maximum weight value of 90, with a maximum BMI score of 30.48. For Hb (X₂) has 15.68 mean, 1.18 standard deviation, 14 minimum value, 17 maximum. For BP (X₃) the average systolic is 122.97, the average diastolic is 83.67, with an average BP score of 6.20, a standard deviation of systolic 6.94, a standard deviation of diastolic 4.90, with a standard deviation of BP score of 2.01, a minimum systolic value of 110, a minimum diastolic value of 75, with a minimum BP score of 3, a maximum systolic value of 139, a maximum diastolic value of 90, with a maximum BP score of 9. VO₂max (Y) has 44.61 mean, 6.579 standard deviation, 32.14 minimum value, 55.99 maximum. Additional information related to BMI (X₁); of 30 samples, 5 people are underweight, 20 people are normal, 4 people are overweight, and 1 person is BMI Obesity stage 1. For BP (X₃); of 30 samples in diastolic BP, 9 people are normal, 16 people are hypertension stage 1, and 5 people are hypertension stage 2, in systolic BP, 9 people are normal, 16 people are elevated, and 5 people are hypertension stage 1.

Model Test

Substructure 1

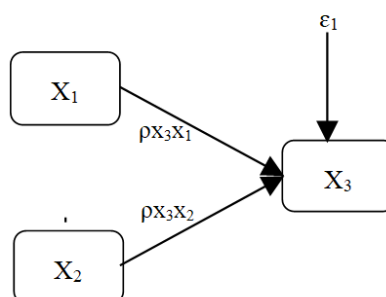


Figure 2. Substructure 1

Table 2. Coefficient of determination for substructure 1

Model	R	R Square	Adjusted Coefficient of determination	Std. Error
1	0.793a	0.629	0.602	1.266

Table 2 shows that the R-Square value is 0.629, indicating that the variables BMI (X₁) and Hb (X₂) simultaneously contribute 62.9% to explaining the variation in the BP (X₃) variable, while the remaining 37.1% is influenced by other variables outside the model. Based on the ANOVA (F-test), the independent variables collectively have a significant effect on the dependent variable of BP, with a significance value of 0.000b, which is less than the 5% alpha level.

Table 3. Analysis of multivariate regression model substructure 1

Model	Variable	Correlation Coefficient	T	P
1	X ₁	0.267	2.213	0.036 < 0.05
	X ₂	0.687	5.700	0.000 < 0.05
	Constanta			0.023

Table 3 shows that the coefficient value for the BMI (X₁) variable is 0.267, or approximately 26%, with a t-value of 2.213. Statistically, BMI (X₁) has a significant effect on the BP (X₃) variable, as indicated by a significance value of 0.036, which is less than the 5% alpha level. Another finding indicates that the coefficient value for the hemoglobin (Hb) variable (X₂) is 0.687 or 68%, with a t-value of 5.700. Statistically, Hb (X₂) has a significant effect on the BP (X₃) variable, as shown by a significance value less than the 5% alpha level (p = 0.000).

The effect of other variables outside the model can be determined using the following equation:

$$\epsilon_1 = \dots\dots\dots (R1)\sqrt{1 - R^2}$$

Thus, the path equation is as follows:

$$X_3 = \rho_{x_3x_1} + \rho_{x_3x_2} + \epsilon_1$$

$$X_3 = 0.267 X_1 + 0.687$$

Substructure 2

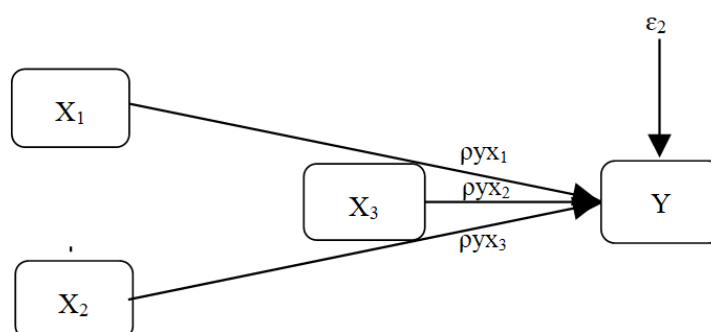


Figure 3. Substructure 2

Table 4. Coefficient of sbstructure determination 2

Model	R	R Square	Adjusted Determination Coefficient	Std. Error
2	0.929a	0.863	0.848	2.569

Table 4 shows that the R-Square value is 0.863, indicating that the variables BMI (X₁), Hb (X₂), and BP (X₃) collectively contribute 86.3% to explaining the variance in VO₂max (Y), while the remaining

13.7% is accounted for by variables outside the model. Based on the ANOVA (F-test), the independent variables simultaneously have a significant effect on the BP (X₃), with a significance value of 0.000b, which is less than the 5% alpha level.

Table 5. Multivariate Regression Analysis of Model 2 (Substructure 2)

Model	Variable	Correlation coefficient	T	P
2	X ₁	0.467	5.760	0.000 < 0.05
	X ₂	0.551	4.629	0.000 < 0.05
	X ₃	0.505	4.560	0.000 < 0.05
	Constanta			0.003

Table 5 shows that the coefficient value for the BMI (X₁) variable is 0.267, or approximately 46%, with a t-value of 5.760. Statistically, BMI (X₁) has a significant effect on the VO₂max (Y) variable, as indicated by a significance value of 0.000, which is less than the 5% alpha level. Furthermore, the coefficient value for the hemoglobin (Hb) variable (X₂) is 0.551 or 55%, with a t-value of 4.629. Statistically, Hb (X₂) has a significant effect on VO₂max (Y), as indicated by a significance value of 0.000, which is less than the 5% alpha level. Our next finding shows that the coefficient value for the Blood Pressure (BP) variable (X₃) is 0.505 or 50%, with a t-value of 4.560. Statistically, BP (X₃) has a significant effect on VO₂max (Y), as indicated by a significance value of 0.000, which is less than the 5% alpha level.

The influence of other variables outside the model (ε₁) can be determined by the following formula:

$$\varepsilon_1 = \frac{\dots\dots\dots}{(R^2)\sqrt{1 - R^2}}$$

Thus, the path equation is as follows:

$$Y = \rho_{yx1} + \rho_{yx2} + \rho_{yx3} + \varepsilon_2$$

$$Y = 0.467 \quad (2)$$

By combining Substructure Model 1 and Substructure Model 2, the resulting structure is shown in Figure 4.

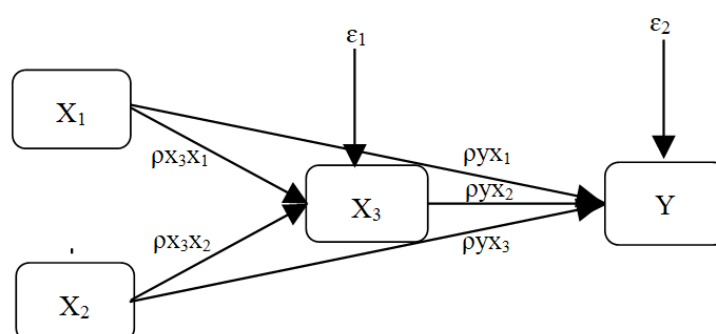


Figure 4. Test Result Model of Substructure 1 and Substructure 2

Based on the results of combining Substructure Model 1 and Substructure Model 2, the resulting structure is shown in Figure 4, and the substructure equations can be formulated as follows:

$$X_3 = \rho_{x3x1} + \rho_{x3x2} + \varepsilon_1$$

$$X_3 = 0.267 X_1 + 0.687 X_2 + 0.6092$$

$$Y = \rho_{yx1} + \rho_{yx2} + \rho_{yx3} + \epsilon_2$$

$$Y = 0.467 X_1 + 0.551 X_2 + 0.505$$

To understand the findings from the combination of Substructure Models 1 and 2, the results can be further formulated in the form of hypothesis testing, as presented in Table 5 below:

Table 6. Hypothesis testing results based on the combination of substructure model 1 and 2

Hypothesis	Coefficient β	α
1	0.267	0.036 < 0.05
2	0.687	0.000 < 0.05
3	0.467	0.000 < 0.05
4	0.551	0.000 < 0.05
5	0.505	0.000 < 0.05
6	0.601	0.000 < 0.05
7	0.897	0.000 < 0.05

Based on Table 5, it is known that the direct effect of BMI (X_1) on VO₂max (Y) is 0.467, while the indirect effect of BMI (X_1) on VO₂max (Y) through blood pressure (BP) (X_3) is the product of the β value of BMI (X_1) on VO₂max (Y) and the β value of BP (X_3) on VO₂max (Y) ($0.267 \times 0.505 = 0.134$). Subsequently, the direct effect of BMI (X_1) on VO₂max (Y) is added to the indirect effect of BMI (X_1) on VO₂max (Y) through BP (X_3) ($0.467 + 0.134 = 0.601$). This means that the indirect effect of BMI (X_1) on VO₂max (Y) through BP (X_3) is greater than the direct effect of BMI (X_1) on VO₂max (Y) ($0.601 > 0.467$). Therefore, BMI (X_1) through BP (X_3) has a significant influence on VO₂max (Y).

Furthermore, it is known that the direct effect of Hb (X_2) on VO₂max (Y) is 0.551, while the indirect effect of Hb (X_2) on VO₂max (Y) through BP (X_3) is the product of the β value of Hb (X_2) on VO₂max (Y) and the β value of BP (X_3) on VO₂max (Y) ($0.687 \times 0.505 = 0.346$). Subsequently, the direct effect of Hb (X_2) on VO₂max (Y) is added to the indirect effect through BP (X_3) ($0.551 + 0.346 = 0.897$). This means the indirect effect of Hb (X_2) on VO₂max (Y) through BP (X_3) is greater than the direct effect ($0.897 > 0.551$). Therefore, Hb (X_2) through BP (X_3) has a significant effect on VO₂max (Y).

4. Discussion

BMI Significantly Affects BP

Our findings show that there is a direct effect of BMI on BP ($r = 0.267$, $p = 0.036$), our findings strengthen previous findings using an athlete population which concluded that the more ideal the BMI, the more normal the BP (Arini & Wijana, 2020); (Battista et al., 2025); (Silado & Wirriawan, 2021); (Musyarofah et al., 2023). As well as research results using non-athlete samples (Chen et al., 2022); (Lubis, 2021); (Sinurat et al., 2023); (Guntara, 2022); (Melliya Sari et al., 2023). Based on our findings and previous findings, it is important for all parties involved in the development of sports (including karate) to pay attention to the allocation of training portions and nutritional intake for athletes. Another important effect is that a non-ideal BMI significantly contributes to various diseases, such as hypertension and elevated cholesterol levels (Rohkuswara & Syarif, 2017); (Aprilia & Saraswati, 2024).

Hb Significantly Affects BP

Our findings show that there is a direct effect of Hb on BP ($r = 0.687$, $p = 0.000$). Athletes who undergo intense training tend to experience increased hemoglobin levels and altered vascular properties, both of which are associated with changes in pulse wave velocity and systolic blood pressure, in both adult and junior athletes (Komka et al., 2022); (Grabitz et al., 2023). On the other hand, prolonged and excessive training loads can lead to a progressive and significant decrease in hemoglobin levels (hypohemoglobinemia), which may cause hypotension due to reduced oxygen-carrying capacity of red blood cells throughout the body (Liu & Liu, 2023). Therefore, regular health monitoring for athletes is essential, along with reconsidering the common practice of imposing high physical training loads on very young athletes, due to the associated risks of elevated blood pressure. High blood pressure in athletes has been shown to be the most common risk factor contributing to sudden cardiac death on the field (Purdom et al., 2023). Proper recognition and management of hypertension can improve athletic performance and reduce the risk of heart-related complications (Komka et al., 2022); (Afaghi et al., 2024).

BMI Significantly Influences VO₂max

Our findings indicate that there is a direct effect of BMI on VO₂max ($r = 0.467$, $p = 0.000$), our findings differ from previous findings in the athlete population that the more ideal the BMI, the more ideal the VO₂max, in other words BMI should have a negative effect on VO₂max (Wiecha et al., 2023); (Saputri et al., 2024); (Firda Nuzulia Aqmain & Machfud Irsyada, 2022); (Shabrina et al., 2022); (Rahadiani, 2022); (Nasrulloh et al., 2021); (Listyowati Ilyas et al., 2023); (Gawali et al., 2025). Because the more normal the BMI, the less visceral fat a person has, which can interfere with achieving higher maximum oxygen consumption (Rodríguez-García et al., 2024).

The results of our study are in line with other findings that also used athlete populations, which found no significant correlation between BMI and VO₂max (Pranata et al., 2024); (Gawali et al., 2025), but these two studies did not use athletes with Obese BMI at all, almost similar to our study which only involved 1 sample person with Obese BMI stage 1. Another factor that can be an argument for our findings is that high BMI does not always come from high fat composition, because it is also possible that it comes from high muscle mass composition and this does not always reduce VO₂max (Sari, 2019). This is reinforced by other research that athletes in martial arts (judo, taekwondo, and karate) in the heavyweight class generally have a normal to high BMI, but not all have a high fat composition and in fact more are found to have a high muscle mass composition so that it does not affect VO₂max (Baranauskas et al., 2022).

It can be concluded that high BMI is always associated with low VO₂max, but this is automatically true for obese individuals (>30.0), and not for overweight individuals, nor is it true for high BMI due to high muscle mass. Our findings should be considered as an important consideration for further study.

Hb Significantly Influences VO₂max

Our findings indicate that there is a direct effect of Hb on VO₂max ($r = 0.551$, $p = 0.000$). Our findings align with previous studies indicating a positive relationship between VO₂max, plasma concentration, white blood cells, red blood cells, and hemoglobin during and after exercise in both athletes and non-athletes (Gwotmut, 2023). Hemoglobin levels can predict cardiorespiratory endurance and muscular strength in athletes (Eli-Cophie et al., 2024). Hemoglobin and lung vital capacity together contribute to VO₂max capacity (Lawanis et al., 2024), and both hemoglobin concentration and its fluctuations positively influence VO₂max (Grzebisz-Zatońska, 2024). Absolute hemoglobin parameters—including hemoglobin concentration, mass, and hematocrit—are also

positively associated with VO₂max (Webb et al., 2023), A significant relationship between Hb levels, BMI, and VO₂max has been reported (Ningrum & Dewi, 2024).

However, our findings differ from studies that found no significant relationship between VO₂max and changes in hemoglobin and erythrocyte levels (Ming, 2024). Additionally, fat intake, body fat percentage, and hemoglobin levels were not statistically associated with VO₂max (Arisanty et al., 2024). These differences warrant further investigation, as VO₂max is influenced by multiple variables, such as genetics and gender affect VO₂max, although empirical evidence remains limited (Webb et al., 2023).

BP Significantly Influences VO₂max

Our findings indicate that there is a direct effect of Hb on VO₂max ($r = 0.505$, $p = 0.000$). Our results are consistent with previous research that found a relationship between blood pressure and hemoglobin levels with VO₂max among pencak silat athletes (Safitri, 2023). The link between BP and VO₂max can also be seen from studies showing that high-intensity VO₂max-dependent training can lead to reduced systolic blood pressure (Carlén et al., 2022). During prolonged aerobic activity, systolic blood pressure tends to increase to a peak and then gradually decrease due to vasodilation in active muscles (Pesova et al., 2023). Well-designed aerobic training programs have been shown to enhance skeletal muscle oxidative capacity and safely regulate blood pressure—and the reverse also holds true (Andrey V. Smolensky et al., 2022). Other factors that also strengthen the influence of BP on VO₂max, namely the occurrence of muscle perfusion (the amount of blood and oxygen that reaches the muscles) which depends on blood pressure (Levy et al., 2008); (Luu & Fitzpatrick, 2013); (Fitzpatrick et al., 1996).

We did not find any differences in the results of our research with previous research, based on our findings and the findings of previous research, it is important for all parties involved in the process of developing sports (especially martial arts) to pay attention to the direct influence of Hb on VO₂max, considering that there are two important events that influence VO₂max namely vasodilation and muscle perfusion, both of which are influenced by blood pressure. This certainly requires further in-depth study considering research on the relationship between BP and VO₂max is still very minimal and limited (Pesova et al., 2023).

BMI Significantly Influences VO₂max through BP

Our findings suggest that BMI has an influence on VO₂max max through BP ($0.601 > 0.467$). This finding is possible because the population we used was karate athletes with low-normal-overweight BMI, and only involved one sample with BMI Obesity stage 1. It is also possible because our study population came from a high BMI due to high muscle mass composition and not high fat composition. Regarding this, we admit that we did not predict in depth at the beginning of the study, we recommend understanding this in the future. Strengthened by several research results that illustrate that BP has an effect on VO₂max indirectly at the timevasodilation in active muscles (Pesova et al., 2023), and muscle perfusion (Levy et al., 2008); (Luu & Fitzpatrick, 2013); (Fitzpatrick et al., 1996).

Hb Significantly Influences VO₂max through BP

Our findings suggest that Hb has an influence on VO₂max through BP ($0.897 > 0.551$). Previous findings have shown that higher hemoglobin levels mean more oxygen can be transported to the muscles, increasing the capacity for oxygen uptake and utilization, thus contributing directly to VO₂max (Eli-Cophie et al., 2024); (Lawanis et al., 2024); (Grzebisz-Zatońska, 2024); (Webb et al., 2023); (Ningrum & Dewi, 2024). This effect occurs because the hemoglobin concentration (Hb)

influences the maximum arterial-mixed venous oxygen difference (Lundby et al., 2017); (Schierbauer et al., 2021); (Mancera-Soto et al., 2022). Consequently a change in Hb mass of 1 g is related to a change in VO₂max of ~4 ml min⁻¹ (Schmidt & Prommer, 2010); (Mancera-Soto et al., 2022). Strengthened by the indirect influence of BP on VO₂max at the moment vasodilation in active muscles (Pesova et al., 2023), and muscle perfusion (Levy et al., 2008); (Luu & Fitzpatrick, 2013); (Fitzpatrick et al., 1996).

Related to this, careful attention must be paid to exercise load, as fluctuations in BP can have negative consequences. Properly identifying and managing high blood pressure can enhance performance and reduce the risk of heart-related issues in athletes (Komka et al., 2022); (Afaghi et al., 2024). High blood pressure has been shown to be the most common risk factor contributing to sudden cardiac death among athletes during competition (Purdom et al., 2023). Therefore, alongside careful training, periodic health assessments for athletes should also be prioritized.

5. Conclusion and Recommendation

It is concluded that: (1) BMI has a significant influence on BP, where the more ideal BMI, the more ideal BP, therefore it is important to always pay attention to nutritional intake and check the athlete's health regularly. (2) Hb has a significant influence on BP, the more ideal Hb, the more ideal BP, but excessive physical training has been shown to cause hypotension, therefore it is very important to review the habit of providing excessive physical training. (3) BMI has a significant influence on VO₂max, our findings seem to contradict many other studies, but our findings are possible because low VO₂max automatically occurs in obese BMI (>30.0), does not automatically apply to overweight BMI, it is also possible because the athlete population we used came from athletes who had a high BMI due to high muscle mass composition (but this requires further investigation). (4) Hb has a significant influence on VO₂max, the more ideal Hb, the more ideal VO₂max, this further strengthens previous findings. (5) BMI has a significant influence on VO₂max through BP, we predict that our findings occurred because the population we used was only 1 person who came from an obese BMI (>30.0), it is also possible that it did not come from a high BMI due to high body fat composition, reinforced by an indirect influence by BP. (6) Hb has a significant influence on VO₂max through BP, our findings certainly come from the direct influence of Hb on VO₂max which has been proven by various studies and the additional effect of the indirect influence by BP.

In light of these conclusions, new information for stakeholders and those involved in karate development includes paying attention to nutritional intake, regularly checking athletes' health, and reconsidering the habit of excessive physical training. We also conclude that a wealth of knowledge about physical health aspects in karate can serve as a reference source for improving athlete performance and, at the same time, a marker for reducing the risk of injury, and most importantly, the risk of athlete death on the field due to sudden cardiac arrest.

A limitation of this study is that we did not classify the samples we used based on BMI, which are low-normal-overweight-obese stages 1, 2, and 3. High BMI due to high muscle mass composition and high BMI due to high body fat composition appear to have significant differences in the effects. Therefore, future research is expected to pay attention to or classify the samples used in relation to BMI. Another limitation is the small sample size (N=30), which risks producing unstable estimates. Therefore, a larger sample size is needed in future research.

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