Predictors of cardiorespiratory endurance in martial arts athletes: A path analysis of body composition, hemoglobin, and motivation

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ABSTRACT

Background: Cardiorespiratory endurance is vital to athletic performance, particularly in sports requiring sustained physical exertion such as martial arts.
Objectives: This study examined the predictive roles of body composition (BMI), hemoglobin concentration, and motivation on cardiorespiratory endurance among university-level martial arts athletes.
Methods: Using a quantitative path analysis design, data were collected from 20 purposively selected martial arts athletes who regularly trained. Cardiorespiratory endurance was assessed via the multistage fitness test, BMI was calculated using standard anthropometric measures, hemoglobin was measured using the Harenz scale, and motivation was evaluated with a validated Likert-scale questionnaire.
Results: The analysis showed that BMI ($\rho = 0.705$, $t = 3.071$, $p = 0.007$) and hemoglobin concentration ($\rho = 0.946$, $t = 4.672$, $p < 0.001$) had significant positive effects on cardiorespiratory endurance. Motivation, however, did not have a significant direct effect ($\rho = 0.087$, $t = 0.853$, $p = 0.203$). Additionally, BMI correlated positively with both hemoglobin ($\rho = 0.923$, $p < 0.001$) and motivation ($\rho = 0.670$, $p = 0.034$), suggesting indirect effects through physiological mechanisms.
Conclusions: The findings underscore that physiological indicators, specifically BMI and hemoglobin, are more critical predictors of aerobic capacity than psychological factors like motivation in this athletic population. Due to sport-specific demands, these results may not be generalizable to non-martial arts athletes. Future studies should incorporate additional mediators such as training intensity and account for potential self-report bias in motivation assessments.

Keywords: body composition, cardiorespiratory endurance, hemoglobin, motivation.

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INTRODUCTION

Cardiorespiratory endurance is one of the most critical indicators of physical fitness, reflecting the body's ability to perform sustained aerobic exercise. A combination of physiological and psychological factors influences this endurance. Among these, body composition, hemoglobin concentration, and motivation are often identified as potential predictors of endurance capacity. While body composition and hemoglobin are physiological markers that directly influence oxygen transport and utilization, motivation affects individuals' intensity and persistence in physical activity. Understanding how these variables interact is essential to developing holistic approaches to improving aerobic performance.

Numerous studies have evidenced that body composition, particularly the balance between fat and lean mass, significantly influences cardiorespiratory fitness. Higher body fat percentages are generally linked to reduced VO_2 max, a primary marker of aerobic capacity, with research showing a consistent negative correlation between fat mass and VO_2 max across various populations, including young adults, athletes, and university rugby players (Vargas et al., 2018; Dewi et al., 2015; Shalan et al., 2024). Conversely, lean body mass, especially skeletal muscle volume, demonstrates a positive relationship with peak oxygen consumption, underscoring its role in enhancing aerobic performance even when fat mass is controlled (Karlsson et al., 2024; Maciejczyk et al., 2014). Gender differences further complicate this relationship; for instance, waist circumference has been found to negatively correlate more strongly with respiratory exchange ratio in females than in males (Karlsson et al., 2024). In athletic youth populations, such as soccer players, reductions in fat percentage have been associated with improved aerobic endurance (Nalbant & Özer, 2018). However, individual differences, including age, activity levels, and genetics, also play a role, and the distribution and type of muscle fibers may influence how effectively lean mass contributes to VO_2 max. Thus, optimizing cardiorespiratory fitness requires a holistic consideration of body composition alongside other physiological and lifestyle factors.

The hemoglobin concentration is a critical physiological factor influencing aerobic performance due to its essential role in oxygen transport. Higher hemoglobin levels are positively associated with increased VO_2 max, a key indicator of aerobic capacity, as shown in multiple studies across diverse populations (Webb et al., 2023; Leoprayogo et al., 2020). For instance, research on endurance-trained cyclists has demonstrated that hemoglobin mass is linked to cardiac dimensions, further underscoring its impact on aerobic function. However, this relationship becomes less predictive when adjusted for lean body mass (Ahlgrim et al., 2009). Additionally, hemoglobin levels have been shown to correlate with muscular endurance in athletes, such as soccer players, and with overall functional capacity in young adults (Utami & Amani, 2023). These findings highlight the multifaceted influence of hemoglobin on physical performance, reinforcing its value as a biomarker in endurance sports.

However, aerobic performance cannot be fully explained by physiological parameters alone. Psychological factors, particularly motivation, are pivotal in shaping athletic outcomes. Motivation affects an individual's willingness to initiate and sustain physical effort and influences training consistency, which may amplify the physiological advantages conferred by high hemoglobin levels. Emerging research emphasizes integrating physiological and psychological metrics to develop a holistic understanding of endurance performance (Vyas & Khanvilkar, 2024).

Metabolomic-based models now support such integration, offering more profound insights into how internal and external factors interact to optimize performance. This comprehensive approach allows for personalized training strategies that address the body and mind, ultimately leading to more effective performance outcomes.

Despite established links between physical characteristics and aerobic performance, limited research has explored the combined predictive power of body composition, hemoglobin concentration, and motivation on cardiorespiratory endurance. Most existing studies analyze these variables in isolation, without a holistic understanding of their interrelationships. While the roles of body composition and hemoglobin in influencing VO_2 max are well-documented, the impact of psychological factors such as motivation on physiological performance remains underrepresented in the literature. This study aims to fill that gap by analyzing the individual and combined influence of body composition (including body fat and lean mass), hemoglobin concentration, and motivation on cardiorespiratory endurance in a single model path analysis. The research seeks to determine whether physiological and psychological variables can predict endurance performance more effectively when assessed together rather than separately. The findings are expected to offer valuable insights for sports scientists, coaches, and athletes by informing the design of more personalized and comprehensive training programs. Moreover, this research aligns with recent advancements in fitness science that promote the integration of biometrics, psychological factors, and metabolomic data to enhance performance prediction and optimization.

METHODS

Study Design and Participants

This study employed a quantitative research approach using a survey method combined with measurement and testing techniques. This design examined the causal relationships between multiple variables on cardiorespiratory endurance, specifically body composition, hemoglobin, and motivation. The research was conducted at Universitas Islam 45, Bekasi, Indonesia, involving athletes from the university's Pencak Silat student activity unit or Unit Kegiatan Mahasiswa (UKM). The total population consisted of 20 athletes who regularly participated in training sessions. Demographic data collected included age, gender, height, and weight, which are essential for calculating body composition and providing descriptive insights into the sample characteristics.

Ethical approval statement

Ethical clearance No. E.1.098/UNISMA.LPPM/E/V/2025 for this research was obtained from the LPPM Universitas Islam 45 Bekasi, Indonesia.

Research Instruments

Several standardized instruments were employed to measure the key variables in the study. Cardiorespiratory endurance was assessed using the multistage fitness test (bleep test). Body Mass Index (BMI) was calculated using the formula BMI = weight (kg) / height² (m^2) to represent body composition. Hemoglobin was measured using the Harenz scale, a field-appropriate method for quick hemoglobin assessment. Motivation was evaluated using a Likert-scale questionnaire, with a Cronbach's alpha of 0.80, indicating good reliability (Manouchehri et al., 2015), designed to

capture the participants' intrinsic and extrinsic motivation toward physical activity. All instruments were selected for relevance and practicality in a university sports setting.

Data Analysis

The data analysis technique used to analyze the causal relationships between multiple variables, specifically body composition, hemoglobin, and motivation, on cardiorespiratory endurance. The study utilized path analysis, a statistical technique suitable for evaluating the direct and indirect effects among variables within a multivariate framework.

RESULTS

In this study, the author took a sample of 20 athletes from the entire population, with the qualification that the athletes regularly train. The results of the calculations and measurements of the research variables' mean values and standard deviations can be seen in Table 1.

Table 1. Characteristics of Respondents

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Body Mass Index	20	19	25	22.10	1.774
Hemoglobin	20	12	18	14.40	2.010
Motivation	20	132	157	147.95	6.863
Cardiorespiratory Endurance	20	32	43	37.30	3.164

Table 2. Hypothesis Summary

Effect	p_{ij}	t B	p-value	Summary
X_1 on Y (ρ_{y1})	0,705	3,071	0,007	Sig
X_2 on Y (ρ_{y2})	0,946	4,672	0,000	Sig
X_3 on Y (ρ_{y3})	0,087	0,853	0,203	Not Sig
X_1 on X_3 (ρ_{31})	0,670	1,950	0,034	Sig
X_2 on X_3 (ρ_{32})	0,082	0,265	0,397	Not Sig
X_1 on X_2 (ρ_{21})	0,923	5,957	0,000	Sig

Thus, based on the results of hypothesis testing with the SPSS application, the empirical causal model X1, X2, X3 with Y is visualized as Figure 1.

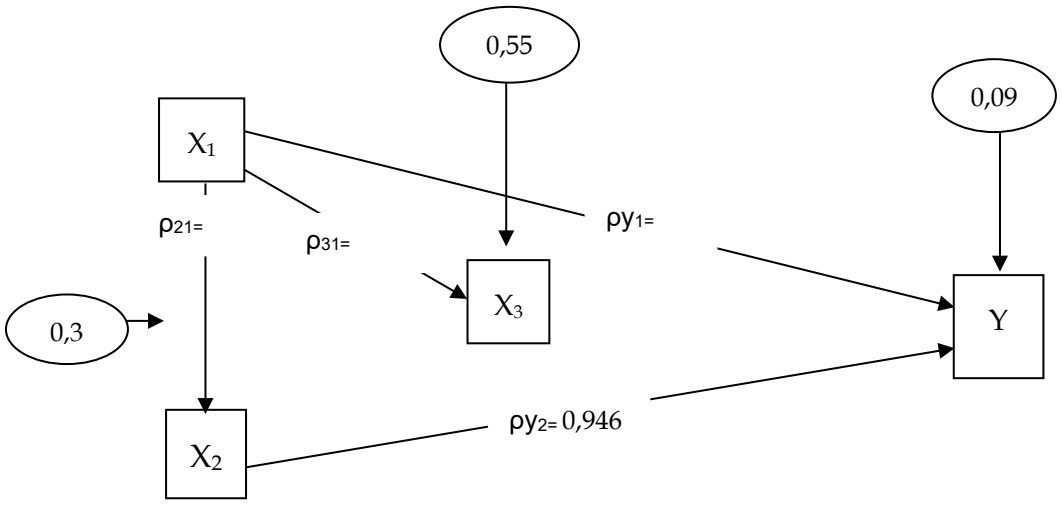

Figure 1. Summary of Average Scores for the Technical and Tactics Group

Model Fit

$H_0 : R = R(\theta)$

$H_0 : R \neq R(\theta)$

$$Q = \frac{1 - Rm^2}{1 - \mathrm{Re}^2}$$

$R^2_m = 1-(1- 0,663)\ (1- 0,452)\ (1- 0,909) = 0,983194$

$R_e^2 = 1-(1- 0,663)\ (1- 0,449)\ (1- 0,905) = 0,98236$

$$Q = \frac{1 - 0,983194}{1 - 0,98236} = 0,952707$$

With a sample size (n) = 20, and the number of insignificant path coefficients (d) = 2, the chi-square test statistic with W = -(n-d) ln Q = -(20-1) In (0.952707) = 0.920509582 from the chi square table with db = d = 2, at the significance level = 0.05, the tab price = (0.05; 2) = 5.99 is obtained. Because W = 0.920509582 < 9.49 or H0 is accepted. Thus, the model obtained is appropriate or suitable (model fit) with the data.

DISCUSSION

The relationship between various factors and cardiorespiratory endurance was investigated in a study. Body mass index was found to have a strong positive effect on cardiorespiratory endurance (ρy1 = 0.705), indicating that individuals with higher body mass indices tend to have better cardiorespiratory endurance. Research indicates a significant relationship between body mass index (BMI) and cardiorespiratory endurance in athletes, particularly martial arts athletes. Studies have shown that individuals with higher BMIs tend to have better cardiorespiratory endurance (Dharma et al., 2021). This association is further supported by findings that increased body mass correlates with decreased cardiorespiratory fitness (Bonney et al., 2018).

Additionally, BMI has been identified as a significant influencing parameter in cardiorespiratory endurance (Astuti et al., 2019). Moreover, the relationship between BMI and physical fitness, including cardiorespiratory fitness, has been explored in various studies (Eddolls et al., 2018; Chen et al., 2020; Firdausi & Simbolon, 2018). Higher cardiorespiratory fitness is linked to better quality of life, while overweight or obese individuals typically experience poorer quality of life (Eddolls et al., 2018). BMI correlates more with lean body mass than other anthropometric indices and is associated with better abdominal muscular and cardiorespiratory endurance (Chen et al., 2020). Maintaining an appropriate body weight and body fat rate in martial arts is crucial for athletes to perform well in competitions (Sadia, 2022). Athletes with higher body mass indices may experience decreased muscle strength and power, affecting their aerobic endurance during competitions (Mardiana et al., 2019). Therefore, optimizing BMI and cardiorespiratory fitness levels is essential for enhancing the performance of martial arts athletes. In conclusion, the evidence suggests a significant relationship between BMI and cardiorespiratory endurance in athletes, highlighting the importance of maintaining appropriate body weight and composition for optimal physical performance, especially in martial arts.

Similarly, cardiorespiratory endurance positively affected hemoglobin levels (ρy2 = 0.946), suggesting that individuals with higher hemoglobin levels may exhibit better cardiorespiratory endurance. Hemoglobin levels have been found to positively

affect cardiorespiratory endurance in martial arts athletes. Research indicates that cardiorespiratory endurance, which is the maximum capacity to utilize oxygen during physical activity, can be influenced by factors such as hemoglobin (Hb) levels and body mass index (BMI) (Astuti et al., 2019). Additionally, studies have shown that supplementing with beetroot juice may help mitigate the adverse effects of hypoxia on cardiorespiratory endurance in athletes, suggesting a potential link between certain supplements and improved endurance (Domínguez et al., 2017). Furthermore, genetic factors play a role in martial arts athletes' athletic performance, with those with higher total genetic scores demonstrating superior skill levels (Vostrikova et al., 2022). As supported by scientific literature, interval training has been shown to benefit athletes' endurance levels when practicing martial arts, emphasizing the importance of specific training methods in enhancing performance (Osipov et al., 2019). In addition to genetic and training factors, maintaining high levels of cardiorespiratory fitness has been associated with a reduced risk of conditions like type 2 diabetes, highlighting the importance of endurance training for overall health and performance in athletes (Someya et al., 2014). Core training has also been identified as a key factor in enhancing martial arts athletes' stability, strength, power, and endurance (Li & Du, 2023). Overall, a combination of factors, including genetic predisposition, appropriate training methods, and maintaining optimal cardiorespiratory fitness levels, can positively impact the endurance and performance of martial arts athletes. Further research is needed to explore this population's intricate relationship between hemoglobin levels, cardiorespiratory endurance, and athletic performance.

In contrast, motivation was found to have no direct effect on cardiorespiratory endurance ($\rho y3 = 0.087$), implying that motivation levels do not significantly impact an individual's cardiorespiratory endurance. Motivation has been a key factor studied in athlete performance in martial arts. While many studies have explored the impact of motivation on athletes' performance in various sports (Aftab et al., 2022), it was found that motivation does not have a direct effect on cardiorespiratory endurance in martial arts athletes (Setyawati et al., 2019). This finding suggests that factors other than motivation may significantly influence cardiorespiratory endurance in this specific group of athletes.

The lack of a significant link between motivation and cardiorespiratory endurance in athletes can be attributed to several interconnected factors, including sample homogeneity, the method of motivation assessment, and uncontrolled training variables. Athletes often demonstrate high baseline motivation due to their commitment to regular training, which may result in a homogeneous sample and mask individual differences in motivational levels (Röthlin, 2022). For instance, perseverance, a dimension of achievement motivation, has been linked to better endurance in young cyclists, yet such effects may be too subtle to detect in highly motivated populations (Röthlin, 2022). Additionally, motivation was measured using self-reported questionnaires, which were prone to response biases such as social desirability or lack of self-awareness, potentially compromising the accuracy of psychological assessments (Perry et al., 2017). This concern is supported by findings from McHugh (2017), who reported no significant relationship between pre-competition motivation scores and subsequent endurance performance in collegiate rowers. Another critical issue is the lack of control over training variables. Endurance adaptations are highly sensitive to training intensity and modality, and even when overall energy expenditure is equal, different training intensities can produce vastly

different outcomes (Reuter et al., 2024). Without accounting for these factors, the role of motivation may appear negligible. Moreover, standardized training regimens could lead to uniform endurance levels among athletes, further diminishing the observed effect of motivation (Usharani, 2017). Similarly, while some studies report a weak but significant correlation between physical activity and endurance, they underscore the more dominant influence of training intensity and specificity (Qhuzairi et al., 2023). Thus, while motivation is undoubtedly a component of athletic performance, its direct impact on cardiorespiratory endurance might be obscured by these methodological and contextual factors. Future research should include more robust, objective assessments of motivation and carefully controlled training conditions to elucidate better the interplay between psychological and physiological determinants of endurance.

Additionally, research has shown that youth athletes' physical fitness levels, particularly cardiorespiratory endurance, can vary significantly, with a considerable percentage classified in the "health risk" category (Pfeifer et al., 2019). This highlights the importance of addressing and improving cardiorespiratory fitness in athletes to ensure adequate endurance for sport participation and to mitigate potential health risks. Furthermore, studies have emphasized the importance of core strength training in enhancing flexibility, stability, and explosive strength in martial arts athletes (Feng, 2023). Core strength has been linked to improved overall strength quality and standardized execution of martial arts movements, indicating its significance in optimizing athletic performance. In conclusion, while motivation is a crucial aspect of athlete performance in sports, including martial arts, the direct impact of motivation on cardiorespiratory endurance in martial arts athletes may not be as pronounced as in other performance areas. Enhancing cardiorespiratory fitness levels and focusing on core strength training are essential components in improving martial arts athletes' physical capabilities and overall performance.

However, body mass index was positively correlated with motivation ($\rho 31 = 0.670$), indicating that individuals with higher body mass indices may also have higher motivation levels. Body mass index (BMI) positively correlates with motivation, suggesting that individuals with higher BMIs may exhibit higher motivation levels (Kaap-Deeder et al., 2014). This relationship was further supported by a study highlighting the positive effects of a task-oriented motivational climate and adherence to a Mediterranean diet on BMI (Castro-Sánchez et al., 2019). Additionally, a meta-analysis study indicated a positive correlation between high BMI and an increased incidence of pes planus in athletes (Resubun et al., 2022).

On the other hand, hemoglobin levels were not found to directly affect motivation ($\rho 32 = 0.082$), suggesting that hemoglobin levels do not play a significant role in determining an individual's motivation levels. On the other hand, hemoglobin levels were not directly linked to motivation levels (Kaap-Deeder et al., 2014). However, a study revealed a direct relationship between BMI and martial arts athletes' hemoglobin levels (Shah et al., 2008). Furthermore, the study revealed a direct relationship between body mass index and hemoglobin levels ($\rho 21 = 0.923$), indicating that individuals with higher body mass indices may also have higher hemoglobin levels. This finding suggests a potential link between body composition and blood parameters. Hemoglobin levels were associated with BMI and decreased renal function, indicating a complex interplay between these factors (Shah et al., 2008).

Overall, the results of this study highlight the complex interplay between body mass index, hemoglobin levels, motivation, and cardiorespiratory endurance. Further research is warranted to explore the underlying mechanisms driving these relationships and their implications for overall health and fitness.

Limitations of the study

This study only involved 20 Pencak Silat athletes from one university, so the generalizability of the results is limited. All participants were athletes with relatively similar motivational and fitness backgrounds, which may mask the influence of psychological variables such as motivation. Self-report measures of motivation are prone to social bias and do not always reflect actual motivation during training or competition. The study used a cross-sectional approach that only describes the relationship between variables at one point. Therefore, future research should include larger and more diverse samples from different institutions or sports to increase external validity, use data triangulation methods, such as direct observation or behavior-based measurement, to assess motivation more objectively, and longitudinal studies are recommended to identify long-term causal relationships between BMI, hemoglobin, motivation, and cardiorespiratory endurance.

CONCLUSIONS

This study concludes that body composition and hemoglobin levels significantly predict cardiorespiratory endurance among martial arts athletes, while motivation does not directly influence endurance outcomes. The strong correlation between BMI, hemoglobin, and motivation suggests an interdependent relationship among physiological and psychological variables. However, the physiological markers, particularly hemoglobin concentration and BMI, play a more decisive role in determining aerobic performance. These findings emphasize the need for targeted training and nutritional strategies to optimize body composition and blood oxygen-carrying capacity to enhance endurance. Further research with larger samples and more diverse athletic populations is recommended to generalize these results and explore deeper psychological dimensions that may indirectly impact physical performance. These findings may not be generalizable to non-bodybuilding athletes due to the specific demands of the sport.

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DATA AVAILABILITY

All data supporting the findings of this study are included in the article and its supplementary materials. Additional datasets are available from the corresponding author upon a reasonable request.

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CONFLICT OF INTEREST

The author hereby declares that this research is free from conflicts of interest with any party.

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