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Research Article

Body composition profiles and physical readiness among paragliding trainees: A cross-sectional study

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ABSTRACT

Background: Physical readiness is essential for performance and safety in paragliding. Body composition has been recognized as an important factor associated with physical performance; however, evidence regarding its collective influence on physical readiness among paragliding trainees remains limited. Objective: This study aimed to examine the role of body composition as an integrated correlate of physical readiness among paragliding trainees using a multiple regression analysis. Methods: A quantitative cross-sectional study was conducted involving 24 paragliding trainees selected through purposive sampling. Body composition variables, including body mass index (BMI), body fat percentage (PBF), skeletal muscle mass (SMM), and basal metabolic rate (BMR), were assessed using bioelectrical impedance analysis (BIA). Physical readiness was evaluated using a composite fitness score. Result: Descriptive analysis revealed moderate body composition profiles with substantial inter-individual variability. Multiple regression analysis showed that body composition variables collectively demonstrate a substantial association with physical readiness ($R^2 = 0.557$, Adjusted $R^2 = 0.464$, $F = 5.969$, $p = 0.003$). Conclusion: This study demonstrates that body composition is significantly associated with physical readiness among paragliding trainees. From a practical perspective, optimizing body composition, particularly reducing excess body fat and enhancing skeletal muscle mass, may be considered in training programs. This study contributes to the limited literature on aerial sports by providing evidence-based insights for individualized training strategies to improve both performance and safety in paragliding.

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Introduction

Paragliding is a high-risk aerial sport that requires not only technical proficiency but also optimal physical readiness to ensure both performance and safety. Unlike conventional sports, paragliding involves dynamic environmental interactions, including wind variability, altitude changes, and body positioning, which demand high levels of neuromuscular control, balance, and coordination (Feletti & Brymer, 2018; Niu et al., 2022). Physical readiness in aerial sports is strongly influenced by physiological and biomechanical factors, particularly body composition. Body composition has been widely recognized as a critical determinant of athletic performance across various sports disciplines (Martin-Rodriguez et al., 2024; Nugroho, Riyadi, & Haqiyah, 2025; Silva, 2019; Solikah et al., 2024). Excess body fat is associated with reduced movement efficiency, increased metabolic cost, and impaired performance outcomes (Jeukendrup & Gleeson, 2019; Ortega et al., 2016). Conversely, higher skeletal muscle mass contributes to enhanced strength, postural control, and movement stability, which are essential for maintaining equilibrium during flight (Suchomel et al., 2016; Wang et al., 2025).

Previous studies have consistently demonstrated the importance of body composition in athletic performance across various sports disciplines (Martin-Rodriguez et al., 2024; Ingebrigtsen, Jeffreys, & Rodahl, 2013). In endurance sports, lower body fat percentage has been associated with improved movement economy and aerobic performance. In football, skeletal muscle mass and lean body composition contribute to sprint ability, power production, and injury resilience. Similarly, research in combat sports has shown that body composition characteristics influence competitive performance and weight-management strategies. In aesthetic and aerial-related sports such as gymnastics, body composition has also been linked to balance control, movement efficiency, and technical execution. These findings collectively indicate that body composition plays a central role in athletic readiness across different sporting contexts. To our knowledge, no previous study has simultaneously examined BMI, body fat percentage, skeletal muscle mass, and basal metabolic rate as integrated correlates of physical readiness among paragliding trainees. Furthermore, existing research in aerial sports has largely focused on injury mechanisms, risk factors, and safety outcomes rather than physiological readiness indicators.

However, limited attention has been given to aerial sports, particularly paragliding, where body control and weight distribution play a more critical role in performance (Laver, Pengas, & Mei-Dan, 2017). This represents a significant gap in the sport science literature. Moreover, most existing studies have adopted a univariate or reductionist approach, analyzing physiological variables independently (Malina et al., 2004). Such approaches may fail to capture the complex interactions among body composition components, including fat mass, muscle mass, and metabolic rate, which collectively influence physical readiness (Chapman et al., 2025; Muller et al., 2016).

The novelty of this study lies in two aspects. First, this study extends body composition research into the context of paragliding trainees, a population that remains underrepresented in sport science literature. Second, this study conceptualizes body composition as an integrated physiological system rather than as separate variables, and evaluates its association with physical readiness using complementary multiple regression analysis techniques.

From a theoretical perspective, the findings contribute to the development of conceptual models explaining how multiple body composition components collectively relate to physical readiness in aerial sports, an area that remains insufficiently explored in sport science literature. Rather than conceptualizing body composition variables as isolated predictors, the findings support the view that physiological characteristics interact as an integrated system in shaping physical readiness. This perspective may help refine conceptual models linking body composition and performance in aerial sports.

Recent advances in sports science emphasize the importance of multivariable perspective to better understand performance determinants as integrated systems (Bourdon et al., 2017; Jianjun et al., 2025). In this context, examining body composition as a multidimensional construct provides a more comprehensive understanding of how physiological variables interact to influence performance outcomes. Therefore, this study adopts a multivariable perspective to investigate how body composition variables, including body mass index, body fat percentage, skeletal muscle mass, and basal metabolic rate, collectively relate to physical readiness among paragliding trainees. The findings are expected to contribute to evidence-based training strategies and provide practical insights for optimizing performance in aerial sports.

Method

Research Design

This study employed a quantitative cross-sectional design to examine the relationship between body composition and physical readiness among paragliding trainees. Cross-sectional studies are widely used in sport science to analyze physiological and performance-related variables at a single point in time, allowing for efficient identification of associations between variables (Setia, 2016; Wang & Cheng, 2020).

Participants

A total of 24 paragliding athletes (male and female) from the Central Java Provincial Training Center (Pemusatan Latihan Provinsi Jawa Tengah) participated in this study. At the time of data collection, all participants were actively preparing for national-level competitions under the official provincial training program. Participants were recruited using a purposive sampling technique to ensure that all athletes had formal paragliding training experience and were regularly involved in structured training sessions. Eligibility criteria included active membership in the Central Java Provincial Training Center, regular participation in scheduled training, and the absence of injury or medical conditions that could affect body composition assessment or physical fitness performance. Prior to participation, all athletes received detailed information regarding the study procedures and voluntarily provided written informed consent. The sample size is comparable to previous exploratory studies in sport science involving physiological profiling and performance assessment (Batterham & Hopkins, 2005).

The participating athletes represented the official Central Java provincial paragliding squad, making the sample appropriate for investigating the relationship between body composition and physical readiness in competitive paragliding athletes.

Ethical Approval Statement

Ethical approval for this study was obtained from the Institutional Review Board (IRB) of Universitas Negeri Malang, Indonesia (Permit Number: 6.5.16/UN32.14/PB/2026), dated March 11, 2026. Written informed consent was obtained from all participants before data collection, and the study was conducted in accordance with the Declaration of Helsinki.

Research Instruments

Body composition was assessed using an InBody 270 bioelectrical impedance analyzer (InBody Co., Seoul, South Korea). The device estimates body composition using multi-frequency bioelectrical impedance technology and has demonstrated high reliability and validity compared with dual-energy X-ray absorptiometry (DXA) in physically active populations. Participants were measured barefoot and in a fasting state according to manufacturer guidelines. BIA has been demonstrated to provide reliable estimates of body composition parameters, particularly when standardized measurement procedures are applied (Lukaski, 2013). This method allows for the simultaneous assessment of multiple physiological indicators relevant to performance and metabolic function. Several key body composition variables were obtained. Body Mass Index (BMI) was calculated as body mass divided by height squared (kg/m^2) and is commonly used as a general indicator of body composition and nutritional status (WHO, 2000). Although BMI does not distinguish between fat and lean mass, it remains a useful screening tool in population-based studies.

Body Fat Percentage (PBF) was measured to determine the proportion of fat mass relative to total body weight. PBF is considered a critical variable in sport performance, as excessive fat mass may negatively affect movement efficiency, increase energy expenditure, and reduce overall physical performance (Campa et al., 2021).

Skeletal Muscle Mass (SMM) was also assessed as an indicator of the amount of muscle tissue involved in force production and movement. Higher levels of SMM are associated with greater strength, stability, and neuromuscular control, which are essential for maintaining balance and performance in physically demanding activities (Janssen et al., 2000; Suchomel et al., 2016).

In addition, Basal Metabolic Rate (BMR) was measured to estimate the minimum energy expenditure required to sustain essential physiological functions at rest. BMR is closely related to body composition, particularly lean body mass, and serves as an important indicator of metabolic efficiency (Müller et al., 2016). Physical readiness was assessed using a composite Fitness Score derived from four physical fitness components considered relevant to paragliding performance: upper-body muscular endurance (push-up test), abdominal muscular endurance (sit-up test), cardiorespiratory endurance (20-m shuttle run test), and lower-body explosive power (standing long jump test). All assessments were conducted following standardized testing procedures commonly used in sport science. The push-up and sit-up tests measured the maximum number of correct repetitions completed within a specified time period, while the 20-m shuttle run test evaluated aerobic capacity through progressive running stages. Lower-body explosive power was assessed using the standing long jump test, with the best distance recorded for analysis. Raw scores from each test were converted into standardized scores based on normative performance criteria and subsequently averaged to generate a composite Fitness Score ranging from 0 to 100. Higher scores indicated greater overall physical readiness. Standardized scores were derived from age-adjusted normative criteria adapted from the Indonesian Physical Fitness Test (TKJI). This composite approach was selected to provide a multidimensional assessment of fitness, reflecting the combined muscular, aerobic, and neuromuscular capacities required for safe and effective paragliding performance (Bourdon et al., 2017).

Data Analysis

Initially, descriptive statistics were computed to summarize participant characteristics and examine the distribution of each variable. This included calculating the mean, standard deviation, minimum, and maximum values. Descriptive analysis is a fundamental step in quantitative research, providing insights into central tendency and variability before conducting inferential tests (Field, 2013; Hopkins et al., 2009). In sport science, descriptive statistics are essential for profiling physiological characteristics and performance indicators (Batterham & Hopkins, 2005).

Assumption testing confirmed that all variables satisfied the normality criterion (Ghasemi & Zahediasl, 2012; Razali & Wah, 2011). A significance value greater than 0.05 ($p > 0.05$) indicates that the data are normally distributed, while values below this threshold suggest deviations from normality.

To examine the association between body composition variables and physical readiness, multiple linear regression analysis was performed. Fitness Score was entered as the dependent variable, while body mass index (BMI), body fat percentage (PBF), skeletal muscle mass (SMM), and basal metabolic rate (BMR) were included as predictor variables. Multiple regression was selected because it enables the simultaneous evaluation of the contribution of several physiological variables to a single performance-related outcome. Prior to analysis, assumptions of normality, linearity, independence of errors, and multicollinearity were assessed. Statistical significance was established at $p < 0.05$. All analyses were conducted using JASP statistical software.

Results and Discussion

Results

The descriptive findings indicate that the paragliding trainees exhibited considerable heterogeneity in body composition despite presenting an overall moderate level of physical readiness (Table 1). The relatively large variability observed in body fat percentage (SD = 9.18%) compared with the other body composition indicators suggests substantial physiological differences among participants, whereas the average Fitness Score remained relatively consistent (73.90 ± 5.49). These findings indicate that individuals with similar levels of physical readiness may present markedly different body composition profiles, highlighting the importance of evaluating multiple physiological characteristics rather than relying on a single anthropometric indicator.

Table 1. Descriptive Statistics of Body Composition Variables and Fitness Score

	Valid	Mean	Std. Deviation	Minimum	Maximum
BMI	24	22.61	3.679	16.40	30.80
PBF (%)	24	24.20	9.181	8.000	46.60
SMM (kg)	24	24.48	5.959	16.30	35.90
BMR (kcal)	24	1,365.58	204.481	1,076	1,787
Fitness Score	24	73.90	5.494	59.20	81.30

Table 2. Summary of the Multiple Linear Regression Model Predicting Fitness Score

Model	R	R^2	Adjusted R^2	RMSE
M_0	0.000	0.000	0.000	5.494
M_1	0.746	0.557	0.464	4.024

Note. M_1 includes PBF (%), SMM (kg), BMI, BMR (kcal)

The regression model demonstrated a moderate-to-strong explanatory capacity, with body composition variables collectively accounting for 55.7% of the variance in physical readiness ($R^2 = 0.557$; Adjusted $R^2 = 0.464$) (Table 2). Moreover, the reduction in the prediction error from an RMSE of 5.49 in the null model to 4.02 in the regression model indicates that incorporating BMI, body fat percentage, skeletal muscle mass, and basal metabolic rate substantially improved the prediction of Fitness Score. These findings suggest that physical readiness is more accurately explained when body composition is considered as an integrated physiological profile.

Table 3. Analysis of Variance (ANOVA) for the Regression Model

Model		Sum of Squares	df	Mean Square	F	p
M_1	Regression	386.6	4	96.65	5.969	0.003
	Residual	307.6	19	16.19		
	Total	694.3	23			

Note. M_1 includes PBF (%), SMM (kg), BMI, BMR (kcal). The intercept model is omitted, as no meaningful information can be shown.

Table 4. Regression Coefficients of Body Composition Variables Associated with Fitness Score

Model		Unstandardized	Standard Error	Standardized	t	p	95% CI	
							Lower	Upper
M_0	(Intercept)	73.900	1.121		65.895	< .001	71.580	76.220
M_1	(Intercept)	75.429	26.687		2.826	.011	19.572	131.286
	PBF (%)	-0.052	0.348	-0.087	-0.149	.883	-0.781	0.677
	SMM (kg)	0.132	1.878	0.143	0.070	.945	-3.799	4.062
	BMI	-0.955	0.887	-0.640	-1.077	.295	-2.812	0.901
	BMR (kcal)	0.013	0.052	0.493	0.257	.800	-0.095	0.121

The ANOVA results confirmed that the regression model significantly explained the variability in physical readiness ($F = 5.969$, $p = 0.003$) (Table 3). This finding demonstrates that the body composition variables, when evaluated simultaneously, contributed meaningfully to the prediction of Fitness Score beyond random variation. Collectively, these results support the proposition that physical readiness among paragliding trainees reflects the combined influence of multiple physiological characteristics rather than isolated body composition indicators.

Although the overall regression model was statistically significant, none of the individual body composition variables independently predicted Fitness Score (all $p > 0.05$) (Table 4). Nevertheless, the standardized regression coefficients suggest that BMI ($\beta = -0.640$) and basal metabolic rate ($\beta = 0.493$) demonstrated relatively larger contributions than body fat percentage ($\beta = -0.087$) and skeletal muscle mass ($\beta = 0.143$). The discrepancy between the significant overall model and the absence of significant individual predictors implies that physical readiness is likely influenced by the interaction among body composition variables rather than by the independent effect of any single physiological measure.

Table 5. Collinearity Diagnostics of the Regression Model

Model	Dimension	Eigenvalue	Condition Index	(Intercept)	PBF (%)	SMM (kg)	BMI	BMR (kcal)
M_1	1	4.841	1.000	0	0	0	0	0
	2	0.140	5.871	0	0.039	0.001	0	0
	3	0.017	16.643	0.038	0.013	0.003	0.007	0
	4	0.001	63.323	0.002	0.885	0.025	0.965	0.006
	5	8.536×10-5	238.145	0.96	0.062	0.971	0.028	0.993
	1	4.841	1.000	0	0	0	0	0

Note. The intercept model is omitted, as no meaningful information can be shown

The collinearity diagnostics revealed substantial overlap among several predictor variables, as reflected by a maximum Condition Index of 238.15 and high variance proportions concentrated within the same dimensions (Table 5). These findings indicate the presence of considerable multicollinearity, suggesting that BMI, skeletal muscle mass, and basal metabolic rate share common physiological information. Consequently, the strong interrelationships among predictors may have reduced their unique statistical contributions in the regression analysis despite the significant explanatory power of the overall model.

Discussion

The present study demonstrated that body composition variables collectively accounted for a substantial proportion of the variance in physical readiness. The regression model explained approximately 55.7% of the variability in Fitness Score, indicating that body composition is an important factor associated with readiness for paragliding activities. This finding supports contemporary perspectives in sport science that emphasize the integrative nature of physiological systems in determining performance (Bourdon et al., 2017; Müller et al., 2016). Excess adiposity has been consistently associated with reduced movement efficiency, increased metabolic cost, and impaired biomechanical function (Jeukendrup & Gleeson, 2019; Ortega et al., 2016). In the context of paragliding, where body weight distribution and aerodynamic control are critical, higher body fat levels may be associated with reduced movement efficiency and lower levels of physical readiness.

Muscle mass is closely linked to force production, postural stability, and neuromuscular coordination, all of which are essential for maintaining control under dynamic flight conditions (Suchomel et al., 2016; Janssen et al., 2000). These findings reinforce the importance of muscular development as a key determinant of performance in physically demanding environments. Interestingly, the regression analysis revealed that although the overall model was statistically significant, individual predictors did not reach statistical significance. The absence of significant individual predictors may be partly explained by multicollinearity among body composition indicators, particularly variables that reflect overlapping physiological constructs such as body mass, muscle mass, and metabolic rate. As indicated by the collinearity diagnostics, several predictors shared substantial variance, which may have reduced their unique statistical contributions within the regression model. These findings suggest that physical readiness is not driven by a single dominant factor but rather emerges from the interaction of multiple interrelated physiological components, which aligns with systems-based perspectives in sport performance science (Hair et al., 2019; Tabachnick, Fidell, & Ullman, 2007).

BMI, in particular, has been criticized for its inability to distinguish between fat mass and lean mass, thereby limiting its usefulness in performance-related contexts (Müller et al., 2016). This further supports the need for comprehensive body composition assessment rather than reliance on simplistic indices. Importantly, this study contributes to the limited body of literature on aerial sports, particularly paragliding, by providing empirical evidence that body composition should be conceptualized as an integrated physiological system. This systems-based perspective offers a more comprehensive and ecologically valid understanding of performance readiness compared to traditional univariate approaches (Bourdon et al., 2017).

From a practical standpoint, the findings highlight the necessity of individualized training interventions. Given the substantial variability in body composition among participants, standardized training programs may not effectively address each trainee's specific physiological needs. Instead, training strategies should prioritize to support physical readiness for paragliding activities.

Limitations of Study

This study has several limitations. First, the cross-sectional design precludes causal inference regarding the relationship between body composition and physical readiness. Second, the relatively small sample size may have reduced statistical power and contributed to the absence of significant individual predictors. Third, participants were recruited through purposive sampling from a single training context, limiting generalizability to broader paragliding populations.

Conclusions

This study demonstrates that body composition is significantly associated with physical readiness among paragliding trainees. The multiple regression model showed that body composition variables collectively explained a substantial proportion of the variance in Fitness Score, highlighting the importance of considering body composition as an integrated physiological profile rather than as isolated indicators. Although none of the individual predictors reached statistical significance, the overall model suggests that physical readiness is associated with the combined contribution of multiple body composition components. These findings contribute to the limited body of knowledge on aerial sports and support the use of comprehensive body composition assessment in evaluating physical readiness among paragliding trainees. From a practical perspective, training programs may benefit from strategies aimed at maintaining healthy body composition profiles, including reducing excess body fat and promoting adequate muscle mass development to support overall physical readiness.

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Authors' contributions

N.I. conceived and designed the study, collected and assembled the data, performed the data analysis and interpretation, drafted the manuscript, critically revised the manuscript, and approved the final version of the article. A.S. and F.S. contributed to data collection and assembly, performed the data analysis and interpretation, and approved the final version of the article. D.C., J.A., and S.P. contributed to the study conception and design, participated in manuscript preparation, critically revised the manuscript, and approved the final version of the article. All authors read and approved the final manuscript.

Competing interests

The authors declare no competing interests.

AI Disclosure Statement

During the preparation of this manuscript, the authors used Grammarly to proofread the English text. All AI-generated outputs were critically reviewed and thoroughly edited by the authors to ensure factual accuracy, clarity of expression, and compliance with academic standards. The authors take full responsibility for the integrity and content of this manuscript.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request. The data are not publicly available because they contain information that could compromise participant privacy and confidentiality.

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