Journal Sport Area
http://journal.uir.ac.id/index.php/JSP
Vol. 10. No. 2. August, (2025)

Associations between body composition, macronutrient intake, and physical fitness in adolescent swimmers

Renaldy Carlos Gunawan[abcde,*] & **Satwika Arya Pratama**[acde]

Universitas Negeri Surabaya, Indonesia

Received: 27 March 2025; Accepted 12 July 2025; Published 16 August 2025
Ed 2025; *10*(2): 253-263

ABSTRACT

Background: Physical fitness plays a key role in the performance of adolescent swimmers. However, gaps remain in understanding how body composition and macronutrient intake jointly influence fitness when accounting for individual variability. **Research Objectives:** This study examines the correlation between macronutrients and body composition with physical fitness in adolescent swimming athletes from Bojonegoro. **Methods:** A cross-sectional study was conducted with 41 adolescent swimmers. Macronutrient intake was assessed using a Semi Quantitative Food Frequency Questionnaire (SQ-FFQ), body composition via Bioelectrical Impedance Analysis (BIA), and physical fitness through the Multistage Fitness Test. Spearman correlation and multiple linear regression were used to evaluate associations, adjusting for age, sex, weight, and height. **Findings/Results:** Physical fitness was positively correlated with skeletal muscle mass and intake of carbohydrates, protein, and fat ($p < 0.05$), and negatively correlated with total body fat. Demographic variables (age, sex, height) explained 42.7% of physical fitness variability (adjusted $R^2 = 0.427$, $p < 0.001$). Including exercise activities, body composition, and nutrient variables increased R^2 to 0.597, but the full model was not statistically significant (adjusted $R^2 = 0.404$, $p = 0.803$). **Conclusion:** Body composition and macronutrient intake are associated with physical fitness, but demographic factors remain the strongest predictors. Individualized training and dietary strategies may support performance optimization in adolescent athletes. Future studies with larger sample sizes and longitudinal designs are recommended to confirm and extend these findings.

Keywords: Adolescent swimmers; body composition; macronutrients; physical fitness; regression analysis

https://doi.org/10.25299/sportarea.2025.vol10(2).21886

Corresponding Author: Renaldy Carlos Gunawan, Department of Nutrition, Faculty of Sport and Health Sciences, Universitas Negeri Surabaya, Surabaya, Indonesia
renaldycg24@gmail.com

How to Cite: Gunawan, R.C., & Pratama, S.A. (2025). Body composition and macronutrients were correlate to physical fitness of adolescent swimming athletes. *Journal Sport Area*, *10*(2), 253-263. https://doi.org/10.25299/sportarea.2025.vol10(2).21886

Authors' Contribution: a – Study Design; b – Data Collection; c – Statistical Analysis; d – Manuscript Preparation; e – Funds Collection

INTRODUCTION

Swimming is a high-intensity sport that requires a combination of strength, endurance, and technical skill, engaging nearly all major muscle groups simultaneously (Espada et al., 2023). Optimal body composition and appropriate macronutrient intake are critical for enhancing propulsion efficiency, reducing hydrodynamic drag, and sustaining energy levels during training and competition (Dopsaj et al., 2020). Previous studies have shown that higher lean muscle mass and lower body fat percentages are associated with better swimming performance and reduced water resistance (Cortesi et al., 2020; Dopsaj et al., 2020). In addition, adolescent swimmers require sufficient intake of carbohydrates, proteins, and fats to meet the energy demands of intense training while supporting growth and recovery (Ferreira et al., 2024).

Physical fitness plays a crucial role in the performance of adolescent swimming athletes, influencing their endurance, strength, and overall athletic capabilities (Ferreira et al., 2024). Physical fitness, defined as the ability to perform daily tasks with vigor and alertness, is crucial in reducing the risk of metabolic disease (Sholihah & Mayasari, 2024). Among the key factors contributing to physical fitness, body composition, and macronutrient intake are particularly significant (Gonçalves et al., 2025). Body composition, encompassing the proportion of fat mass and lean mass, has been linked to athletic performance, with optimal ratios enhancing power, endurance, and efficiency in swimming movements (Espada et al., 2023). Similarly, Macronutrient intake provides essential energy and supports muscle recovery during training (Gonçalves et al., 2025).

Physical fitness is influenced by many factors, including genetics, gender, age, diet, body composition, smoking, and activity (Kurnia et al., 2020), this study focuses more on the factors of food intake and body composition (Macuh et al., 2023). Macronutrients carbohydrates, protein, and fats serve as the building blocks of an athlete's diet (Sasmarianto et al., 2021), playing distinct roles in fueling physical activity and recovery (Murray & Rosenbloom, 2018). Carbohydrates are essential for providing energy during prolonged training sessions, and replenishing glycogen stores that become depleted during exertion (Dhiman & Chand Kapri, 2023). Short distance swimming relies on the energy from phosphate stores in muscle and diet (Massini et al., 2021). Creatine phosphate is present in muscle but is only present for a short time. The creatine phosphate system is only active during a sprint swim, producing ATP. During long distance swimming, the lactic acid energy system is used when intake is insufficient (Hwang et al., 2023; Swinarew et al., 2020).

Body composition is the ratio of fat to lean mass. In swimmers, this is linked to better performance because it reduces water resistance and improves the power to weight ratio (Dopsaj et al., 2020). Research shows that more lean mass leads to better swimming performance. However, excess fat can be detrimental, increasing resistance in the water (Espada et al., 2023). Studies show elite swimmers have lower body fat percentages than non-elite swimmers. This affects physical fitness and endurance (Dopsaj et al., 2020). Normal body fat levels are important as excess fat can cause abnormalities. A lack of body fat can lead to weight loss and loss of muscle tissue, affecting performance (Kurnia et al., 2020).

In national athlete competitions or other sports competitions, athletes will need a large amount of energy intake to support their activities. In meeting energy needs, an athlete is generally advised to meet the needs with 55-65% through carbohydrate consumption, 20-35% fat, and 12-15% protein (Muharam, 2019). According to Maughan in research by Al Faruq and Adiningsih (2017) the energy needs of swimming athletes range from 3400 kcal to 4000 kcal if doing heavy intensity training. Adolescent swimming athletes need carbohydrates at least 3-8 g/kg body weight. Protein requirements for adolescent swimming athletes amount to 0.8-1.8g/kg body weight. Meanwhile, fat requirements are 20-25% of total calorie intake (Zahra & Muhlisin, 2020).

Previous research has investigated the correlation between nutrition, body composition, and physical fitness in adult or elite level swimmers and athletes (Dopsaj et al., 2020). For example, studies have shown that a well balanced diet with adequate macronutrient distribution positively impacts endurance, recovery, and performance outcomes (Espada et al., 2023). However, few studies have specifically examined how daily macronutrient intake correlates with body composition and physical fitness among adolescent swimmers, a group undergoing rapid growth and unique training loads. This study aims to fill this gap by analyzing the correlation between macronutrient intake, body composition, and physical fitness in adolescent swimmers in Bojonegoro. Understanding this correlation can help coaches and nutritionists design better training and dietary plans for young athletes.

METHOD

Type of Research and Participants

This study uses a quantitative method with a cross-sectional approach. In a cross-sectional approach, observations and assessments of risk variables and problems that emerge in the research subjects are conducted simultaneously to examine the correlation between body composition, macronutrient intake, and physical fitness in adolescent swimmers. The study was conducted at the Wana Dander tourist swimming pool, Bojonegoro Regency, on 25 August 2024. The population consisted of 50 adolescent swimmers (10-19 years). A total of 41 respondents who met the inclusion criteria were selected using total sampling.

Research Procedure and Instrument

Physical fitness was measured using the Multistage Fitness Test (MFT) or bleep test at a distance of 20 meters (Senanayake et al., 2024). The MFT was administered according to the established protocol to estimate VO_2max as an indicator of physical fitness. Macronutrient intake (carbohydrates, protein, and fat) was assessed using a Semi Quantitative Food Frequency Questionnaire (SQ-FFQ), which was then analyzed using Nutrisurvey software using the Indonesian Food Database. The SQ-FFQ was self administered under supervision to ensure accuracy in reporting dietary intake. The SQ-FFQ used in this study follows the standard Indonesian SQ-FFQ format commonly applied in adolescent nutrition surveys (Sakir et al., 2024), while no SQ-FFQ validation exists for Indonesian swimmers, previous international research has demonstrated its validity in adolescent swimming populations for example, a calcium specific SQ-FFQ achieved moderate classification accuracy and Pearson correlation (0.47) when compared with 24 hours recalls in adolescent swimmers (Almárcegui et al., 2015). Furthermore, Indonesian SQ-FFQ (e.g., urban Jakarta surveys) using 50+ items are also considered valid for assessing nutrient intake in adolescents (Sakir et al., 2024). While the instrument has been validated in general adolescent populations, no specific validation has been conducted for Indonesian adolescent swimmers. This limitation should be considered, as swimmer specific dietary patterns may differ from general adolescent habits. Future studies are encouraged to develop and validate sport specific dietary tools tailored to Indonesian athletic populations.

Macronutrient intake was calculated in both absolute amounts (grams per day) and relative to body weight (grams per kilogram per day, g/kg/day). All respondents were measured for body weight using calibrated digital scales and for height using a microtome while wearing light clothing and no shoes. Body composition data (total fat, visceral fat, skeletal muscle) were measured using Bioelectrical Impedance Analysis (BIA) with the Omron Karada Scan HBF-375 device. Body composition was assessed according to the standard procedures for BIA measurement. Exercise data, including training frequency (sessions per week), training duration (hours per session), and length of time in the club (years), were collected using a structured questionnaire. To improve data accuracy, self reported responses were cross verified with club training logs and confirmed by the trainer. This verification process was conducted to minimize recall bias and to ensure the reliability of training exposure data.

Data Analysis

Data was analyzed using SPSS software and presented descriptively. Descriptive statistics, including median, minimum, and maximum values, were calculated for all variables. The normality of continuous variables was tested using the Shapiro-Wilk test. Bivariate correlations between macronutrient intake, body composition, and physical fitness were analyzed using the Spearman correlation test, as the data were not normally distributed. Additionally, multiple linear regression analysis was conducted to examine the independent effects of macronutrient intake and body composition on physical fitness while controlling for potentially confounding variables such as age, sex, and height, with a significance level set at $p < 0.05$. The strength and direction of bivariate associations were assessed using the Spearman correlation coefficient (r_s). The strength of the multivariate association was evaluated using the R^2 value from the multiple linear regression model, with individual effects interpreted based on the unstandardized regression coefficients (B). Multicollinearity was tested using Variance Inflation Factor (VIF) and tolerance values, and no variable exceeded commonly accepted thresholds (VIF < 5, tolerance > 0.2).

Ethical Approval

All participants provided written informed consent, and data confidentiality was assured by the guidelines of the Research Ethical Clearance Commission. This study protocol was approved by the Research Ethical

Clearance Commission of Universitas Airlangga Faculty of Dental Medicine Health, number 0810/HRECC.FODM/VIII/2024.

RESULTS AND DISCUSSION

The population in this study consisted of male and female adolescent swimming athletes at Bojonegoro. The number of samples selected using total sampling consisted of 41 respondents who fit the inclusion criteria. Macronutrient intake was collected with a Semi Quantitative Food Frequency Questionnaire (SQ-FFQ), using the questionnaire obtained data on the results of carbohydrate, protein, and fat intake. Body composition data were collected using Bioelectrical Impedance Analysis (BIA) Omron Karada Scan HBF-375. Physical fitness data was collected using the Multistage Fitness Test (MFT) or bleep test method. Further discussion on the characteristics of the respondents is presented in Table 1 below:

Table 1. Description of Respondent Characteristics

Category	Minimum	Maximum	Median
Age (Years)	11.00	19.00	13.00
Weight (kg)	26.20	69.70	47.90
Height (cm)	130.00	180.00	153.00
Total Fat (%)	10.20	32.00	19.10
Visceral Fat (%)	0.50	3.00	1.50
Skeletal Muscle Whole Body (%)	27.30	40.50	36.00
Energy (kcal)	2366.26	5515.40	2875.00
Carbohydrates (g/day)	243.33	698.37	358.27
Protein (g/day)	66.23	214.30	107.00
Fat (g/day)	67.22	232.00	109.70
Physical Fitness (mL/kg/min)	24.30	43.60	34.60

The descriptive statistics of 41 adolescent swimmers are presented in Table 1. Participants had a median age of 13 years, reflecting early adolescence. The median VO_2 max, measured using the Multistage Fitness Test (MFT), was 34.6 mL/kg/min, indicating moderate aerobic capacity. This level is somewhat lower than the normative data reported in a recent Croatian study, which found mean Physical fitnessvalues of 45.7 ± 5.2 mL/kg/min among children and adolescents aged 7-14 years, using the same 20 meter shuttle run protocol (Sagat et al., 2023). These differences may be attributed to variations in training frequency, competitive level, or biological maturity. Nevertheless, the aerobic fitness observed in this sample remains consistent with expectations for developing swimmers at the early adolescent stage.

In terms of body composition, the respondents in this study exhibited a median total body fat percentage of 19.10%, visceral fat of 1.50%, and skeletal muscle mass of 36.00%. While these values fall within generally acceptable ranges for adolescents, the proportion of total fat remains a critical marker, especially in the context of dietary habits and training patterns. Elevated total fat levels are often linked to diets rich in saturated fats and excessive caloric intake, which promote adipose tissue accumulation (Panuganti et al., 2023). Moreover, energy imbalance where caloric intake exceeds energy expenditure due to insufficient physical activity further contributes to fat storage. This phenomenon may also occur in adolescent athletes who, despite engaging in training, may accumulate fat if the training volume or intensity is insufficient relative to their dietary intake (Shook et al., 2015). These findings underscore the importance of aligning nutritional intake with training demands to maintain optimal body composition in young athletes.

The macronutrient intake of our respondents had a median carbohydrate intake was 358.27 g/day, protein intake of 107.00 g/day, and fat intake of 109.70 g/day. According to Domínguez et al. (2017) the carbohydrate intake of swimming athletes dairy intake is 6.00g/kg/day, then the protein intake is 2.00g/kg/day, and the fat intake is 30-35% of energy intake. When looking at the macronutrient intake requirements above, it can be seen that the carbohydrate intake of our respondents is 7.48g/kg/day, then for the protein intake of our respondents is 2.23g/kg/day, and the fat intake of our respondents is already in the range of daily needs, namely at 30-35% of energy. Compared to previous findings from Larasati and Yuliana (2020) who examined athletes at the Central Java Student Sports Training and Education Centre (PPLOP) and reported lower macronutrient intakes, our data suggest a relatively better adherence to nutritional recommendations. These discrepancies may be influenced by differences in training supervision, nutritional education, or access to food between the study populations. Ensuring adequate macronutrient intake is essential to optimize physical performance and recovery in young athletes, particularly in endurance sports such as swimming.

In our analyses, we aimed to explore the potential correlation between body composition and macronutrient intake with physical fitness. Our results (refer to Table 2) showed that there were significant correlations between total fat, skeletal muscle, and macronutrients with physical fitness. However, there was no significant correlation between visceral fat and physical fitness.

Table 2. Correlation between Body Composition and Macronutrient Intake with Physical Fitness

Variables		r_s	p
Body Composition	Total Fat	-0.373	0.016
	Visceral Fat	-0.274	0.830
	Skeletal Muscle Whole Body	0.340	0.030
Macronutrient Intake	Carbohydrates	0.443	0.004
	Protein	0.318	0.043
	Fat	0.318	0.043

Note: "r_s" indicates the spearman correlation coefficient, while "$p < 0.05$" indicates significant correlation.

This study provides valuable insights into the correlation between body composition, macronutrient intake, and physical fitness in adolescent swimmers. The significant correlations observed between total fat, skeletal muscle mass, and various macronutrients with physical fitness are consistent with existing literature, but this study adds depth by controlling for key confounders such as age, sex, and height in a regression model. Importantly, the findings underscore the role of both internal (body composition) and external (nutrient intake) factors in shaping aerobic performance among youth athletes.

Our findings reveal that higher skeletal muscle and lower total fat are associated with better physical fitness among adolescent swimmers. This aligns with prior work by Roelofs et al. (2017) and Dopsaj et al. (2020), which showed that lean muscle mass enhances propulsion and cardiovascular efficiency in the water, while excess fat increases drag. Leaner body composition enhances endurance and agility by reducing hydrodynamic drag and supporting cardiovascular efficiency (Espada et al., 2023). The absence of a significant correlation with visceral fat is consistent with Setiaputri et al. (2017), suggesting that superficial fat may be a more performance-relevant measure in youth athletes.

Macronutrient intake, particularly carbohydrates and fats, also showed significant associations with physical fitness. These nutrients play distinct roles in energy metabolism during swimming, which relies on both aerobic and anaerobic pathways (Miguel-Ortega et al., 2024). The positive link between carbohydrate intake and physical fitness supports recommendations for pre training carbohydrate loading (Kitts et al., 2025), while dietary fats, especially unsaturated fats, support hormonal balance and recovery (Martín-Rodríguez et al., 2024). However, excess fat intake from low quality sources may compromise energy balance and performance.

The negative correlation between total fat and physical fitness highlights the physiological disadvantage of excess adiposity in swimming, a sport where hydrodynamic drag plays a critical role (Cortesi et al., 2020). Adipose tissue contributes to increased body volume and resistance in water, thereby reducing swimming efficiency. Conversely, skeletal muscle was positively associated with fitness levels, aligning with prior research indicating that greater lean mass enhances strength, propulsion, and muscular endurance in swimmers (Espada et al., 2023).

Although our results are supported by literature, caution is warranted. Self reported dietary intake may not fully capture true consumption, especially in adolescents. Future research should explore longitudinal designs or controlled interventions to clarify the direction of these associations and determine whether dietary adjustments can lead to measurable fitness improvements. Multiple linear regression was performed to assess the independent effects of body composition and macronutrient intake on physical fitness while controlling for age, sex, and height. The regression model was statistically significant ($p < 0.05$), indicating that macronutrient intake significantly predicted physical fitness levels (Table 4).

Table 3. Multiple Linear Regression Model Summary

Model	R	R^2	Adjusted R^2	Std. Error	F	p-value
1	0.696	0.427	0.427	3.392	8.440	0.000
2	0.744	0.558	0.458	3.298	1.695	0.187
3	0.773	0.597	0.404	3.459	0.499	0.803

Note: "R^2" indicates the proportion of variance in physical fitness explained by the model. "Model 1" includes demographic variables (age, sex, weight, height). "Model 2" further includes exercise activities (length of time in the club, frequency and duration of exercise). "Model 3" adds body composition variables (total fat, visceral fat, skeletal muscle) and macronutrient intake (carbohydrates, protein, and fat). "A p-value < 0.05" indicates statistical significance of the overall model.

Three hierarchical regression models were tested to better interpret the predictive strength of various factors on physical fitness. Model 1, which included only demographic variables (age, sex, and height), explained 42.7% of the variance in physical fitness (adjusted $R^2 = 0.427$, $p < 0.001$). All predictors were statistically significant, with older age, male sex, and greater height associated with higher aerobic capacity among adolescent swimmers (Table 4).

In Model 2, the addition of exercise activities (length of time in the club, frequency and duration of exercise) although this model slightly increased the explained variance (adjusted $R^2 = 0.458$), none of the additional predictors reached statistical significance, and only height remained significant, suggesting that training factors contributed minimally to physical fitness after accounting for demographic characteristics (Table 5).

Model 3 incorporated body composition (skeletal muscle, total fat, visceral fat) and macronutrient intake (carbohydrates, protein, fat) alongside all previous variables. Although the overall model was not statistically significant (adjusted $R^2 = 0.404$, $p = 0.803$), none of the individual predictors reached significance either. This discrepancy may be due to multicollinearity among predictors or insufficient statistical power due to the modest sample size. For instance, variables like skeletal muscle mass and carbohydrate intake, which were significant in bivariate analysis, lost significance in the multivariate model (Table 6).

These results indicate that demographic characteristics particularly age, sex, and height were the most consistent predictors of physical fitness, while exercise activities, body composition, and macronutrient intake factors contributed less when considered alongside one another. Of the three models tested, only Model 1 yielded statistically significant results (adjusted $R^2 = 0.427$, $p < 0.001$), highlighting the strong predictive role of demographic variables such as age, sex, and height. In contrast, Models 2 and 3, which incorporated exercise, body composition, and nutrient intake variables, did not significantly improve model fit and should be interpreted with caution. Therefore, conclusions should primarily reflect the findings from Model 1.

Table 4. Regression Model 1: Demographic Variables as Predictors of Physical Fitness in Adolescent Swimmers

Model 1	Unstandardized Coefficients		Standardized Coefficients	t	p-value	Collinearity Statistics	
	B	SE	β			Tolerance	VIF
(Constant)	3.079	9.558		0.322	0.749		
Age (Years)	0.783	0.344	0.386	2.277	0.029	0.498	2.007
Sex (Man and Woman)	-3.324	1.394	-0.311	-2.385	0.022	0.843	1.186
Weight (kg)	-0.066	0.094	-0.164	-0.698	0.490	0.261	3.828
Height (cm)	0.180	0.084	0.493	2.139	0.039	0.270	3.709

Note: "β" indicates standardized regression coefficients representing the effect of each predictor variable on physical fitness; SE = standard error. "A p-value < 0.05" denotes a statistically significant.

Table 5. Regression Model 2: Demographic and Exercise Activities as Predictors of Physical Fitness

Model 2	Unstandardized Coefficients		Standardized Coefficients	t	p-value	Collinearity Statistics	
	B	SE	β			Tolerance	VIF
(Constant)	8.221	10.443		0.787	0.437		
Age (Years)	0.356	0.407	0.176	0.876	0.387	0.337	2.971
Sex (Man and Woman)	-4.220	1.528	-0.395	-2.763	0.009	0.664	1.507
Weight (kg)	-0.098	0.096	-0.244	-1.028	0.311	0.240	4.168
Height (cm)	0.198	0.085	0.541	2.336	0.026	0.253	3.960
Length Of Time In The Club (Years)	0.495	0.398	0.360	1.245	0.222	0.162	6.156
Frequency Of Exercise (/Week)	-5.590	3.942	-1.245	-1.418	0.166	0.018	56.850

Model 2	Unstandardized Coefficients		Standardized Coefficients	t	p-value	Collinearity Statistics	
	B	SE	β			Tolerance	VIF
Training Duration / Session (Hours)	2.599	1.907	1.217	1.363	0.182	0.017	58.883

Note: "β" indicates standardized regression coefficients representing the effect of each predictor variable on physical fitness; SE = standard error. "A p-value < 0.05" denotes a statistically significant.

Table 6. Regression Model 3: Full Model Including Body Composition, and Macronutrient Intake Variables

Model 3	Unstandardized Coefficients		Standardized Coefficients	t	p-value	Collinearity Statistics	
	B	SE	β			Tolerance	VIF
(Constant)	25.974	18.971		1.369	0.182		
Age (Years)	0.484	0.463	0.239	1.045	0.305	0.286	3.502
Sex (Man and Woman)	-1.524	2.864	-0.143	-0.532	0.599	0.208	4.815
Weight (kg)	0.074	0.167	0.185	0.445	0.660	0.087	11.541
Height (cm)	-0.022	0.179	-0.060	-0.123	0.903	0.062	16.051
Length Of Time In The Club (Years)	0.333	0.469	0.242	0.710	0.484	0.128	7.799
Frequency Of Exercise (/Week)	-6.774	4.494	-1.508	-1.507	0.143	0.015	67.178
Training Duration / Session (Hours)	3.406	2.200	1.595	1.548	0.133	0.014	71.187
Total Fat (%)	-0.239	0.257	-0.295	-0.931	0.360	0.149	6.713
Visceral Fat (%)	-0.663	1.567	-0.086	-0.423	0.676	0.361	2.770
Skeletal Muscle Whole Body (%)	0.174	0.329	0.172	0.529	0.601	0.141	7.078
Carbohydrates (g/day)	0.001	0.009	0.022	0.094	0.926	0.281	3.560
Protein (g/day)	0.009	0.031	0.075	0.295	0.771	0.232	4.306
Fat (g/day)	0.000	0.029	-0.001	-0.006	0.996	0.227	4.402

Note: "β" indicates standardized regression coefficients representing the effect of each predictor variable on physical fitness; SE = standard error. "A p-value < 0.05" denotes a statistically significant.

The results of the hierarchical regression analyses are summarized in Tables 4 to 6. Model 1, which included demographic variables, revealed that age ($\beta = 0.386$, $p = 0.029$), sex ($\beta = -0.311$, $p = 0.022$), and height ($\beta = 0.493$, $p = 0.039$) were statistically significant predictors of physical fitness. These findings indicate that older adolescents, males, and those with greater height tended to have higher aerobic capacity. With an adjusted R^2 of 0.427, this model accounted for approximately 42.7% of the variance in physical fitness and provided the most robust explanation among the three models. In Model 2, training related variables length of time in the club, exercise frequency, and training duration were added. Although the total explained variance increased slightly (adjusted $R^2 = 0.458$), none of the newly included predictors reached statistical significance. Although training frequency and duration were not significant predictors in the regression models, these variables were included due to their theoretical relevance to physical fitness and VO_2 max. Prior research has emphasized the role of structured training in improving aerobic capacity in youth athletes. Including these variables allowed us to assess whether training exposure added predictive value beyond demographic characteristics. Model 3 incorporated additional predictors related to body composition (skeletal muscle, total fat, visceral fat) and macronutrient intake (carbohydrates, protein, and fat). However, the overall model was not statistically significant (adjusted $R^2 = 0.404$, $p = 0.803$), and none of the individual variables reached significance in this multivariate context. Variables such as skeletal muscle and carbohydrate intake, which were positively correlated with physical fitness in bivariate analysis, no longer showed independent associations. This inconsistency may be due to multicollinearity or insufficient statistical power due to the modest sample size.

While variance inflation factor (VIF) and tolerance values did not indicate severe multicollinearity, the presence of moderately correlated predictors such as between skeletal muscle and body weight, or between dietary fat and energy intake may have reduced the ability to detect unique contributions. Additionally, the modest sample size ($n = 41$) likely limited the statistical power to identify small to moderate effects in multivariate regression. Taken together, these findings suggest that only the demographic variables in Model 1 age, sex, and height were consistent and significant predictors of physical fitness in adolescent swimmers. The addition of training, physiological, and nutritional variables in Models 2 and 3 did not meaningfully enhance model fit and should be interpreted with caution. Future studies should consider using larger sample sizes, validated instruments tailored to adolescent athletes, and potentially longitudinal designs to better understand the complex interactions affecting aerobic performance.

This reinforces the central role of energy availability in supporting athletic performance, particularly in adolescents who face both developmental and sport specific metabolic demands (Ferreira et al., 2024). Carbohydrates serve as the primary fuel source during high intensity aerobic training (Miguel-Ortega et al., 2024). While dietary fats contribute to hormonal regulation and recovery (Noakes, 2022). Protein intake, while correlated with fitness in the bivariate analysis, did not remain a significant predictor in the regression model, which may suggest its role is more supportive (e.g., in recovery) than directly predictive of physical fitness levels (Dhiman & Chand Kapri, 2023). Controlling for confounding variables such as age, sex, weight, and height adds strength to the interpretation of our findings. In our final adjusted model, demographic variables were no longer statistically significant; however, they were significant in the baseline model (Model 1), suggesting that age, sex, and height are important predictors of physical fitness in adolescent swimmers.

This underscores the relevance of modifiable lifestyle factors, such as diet composition, in influencing aerobic performance (Kerksick et al., 2017). The inconsistency between significant bivariate correlations and non significant regression coefficients in Models 2 and 3 may reflect multicollinearity or insufficient statistical power due to the modest sample size (n = 41) (Kim, 2019). While multicollinearity did not appear severe based on VIF and tolerance statistics, the inclusion of interrelated variables such as skeletal muscle and body weight, or dietary fat and total energy intake may have reduced the apparent unique contribution of each predictor. Moreover, small sample sizes are known to reduce statistical power and increase the likelihood of type II errors, particularly in multivariable models (Lakens, 2022).

Nevertheless, this study is subject to several limitations. While our findings are in line with previous studies (Dopsaj et al., 2020), several important caveats must be acknowledged. First, the cross-sectional design limits causal interpretation. Although associations were statistically significant, it is not possible to determine whether improved nutrition leads to better fitness or if fitter athletes naturally tend to consume more appropriate nutrients (Ferreira et al., 2024). Second, although the sample size (n = 41) is comparable to previous studies involving adolescent athletes, it remains modest for multivariate regression. Due to the limited number of participants, some predictors may have lacked sufficient statistical power to reach significance, particularly in Models 2 and 3. Small sample sizes increase the likelihood of type II errors and may obscure meaningful relationships among variables. Third, the use of a self reported Semi Quantitative Food Frequency Questionnaire (SQ-FFQ) introduces the possibility of recall bias and misreporting, which is particularly relevant in adolescent populations (Almárcegui et al., 2015). Underreporting of caloric and fat intake is common among young athletes and may lead to an underestimation of true intake levels (Zahra & Muhlisin, 2020). Similarly, the use of Bioelectrical Impedance Analysis (BIA) for body composition while non invasive and practical can be affected by hydration status, recent physical activity, and other environmental conditions (Espada et al., 2023). Third, while we adjusted for age, sex, and height, other potentially relevant variables such as training volume, sleep quality, stress, and socioeconomic status were not included and may confound the observed associations (Kurnia et al., 2020). These unmeasured variables may explain some of the unexplained variance in physical fitness observed in the regression model.

Despite these limitations, the findings of this study hold practical value. Coaches and nutritionists working with adolescent swimmers should emphasize strategies that optimize body composition specifically reducing fat mass and increasing lean muscle through tailored training and dietary interventions (Espada et al., 2023). Nutritional programs should ensure sufficient carbohydrate and fat intake to meet training demands and support recovery (Martín-Rodríguez et al., 2024). Educational interventions aimed at adolescents and their caregivers may help foster long term habits that align with athletic and health outcomes (Ferreira et al., 2024).

Future research should consider longitudinal designs to better understand causal pathways between nutrition, body composition, and physical fitness (Dopsaj et al., 2020). In addition, incorporating objective biomarkers of dietary intake (e.g., urinary nitrogen, doubly labeled water) and including broader lifestyle variables such as sleep, hydration, and psychological stress would provide a more comprehensive picture (Noakes, 2022). Validation of dietary tools like the SQ-FFQ for swimmer specific contexts in Indonesia would also strengthen data accuracy in future studies (Sakir et al., 2024).

CONCLUSION

This study demonstrated significant bivariate associations between body composition, macronutrient intake, and physical fitness in adolescent swimmers. Higher skeletal muscle mass and intake of carbohydrates and fats were positively correlated with physical fitness, while higher total body fat showed a negative correlation. Although regression models identified demographic variables as primary predictors of physical fitness, bivariate analyses also revealed significant associations between skeletal muscle mass, total fat, and macronutrient intake with physical fitness. These relationships suggest the potential influence of body composition and dietary factors on aerobic performance, but should be interpreted with caution due to the cross-sectional design and limited statistical power.

Due to the cross-sectional design and modest sample size, these results should be interpreted cautiously. While correlations provide useful insights, causality cannot be established. Future studies with larger sample sizes and longitudinal designs are recommended to confirm and extend these findings. Nonetheless, the results highlight the importance of maintaining lean body mass and meeting appropriate dietary needs to support aerobic performance in adolescent swimmers.

ACKNOWLEDGEMENTS

The author would like to thank the parties who participated in this research. We also thank the coaches of the Taman Tirta Aquatic Bojonegoro Club and Zaki Trisna Hasta for their valuable support for this research.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

REFERENCES

Al Faruq, M. M., & Adiningsih, S. (2017). Pola Konsumsi Energi, Protein, Persen Lemak Tubuh dan Aerobic Endurance Atlet Renang Remaja. *Media Gizi Indonesia*, *10*(2), 117–122. https://doi.org/10.20473/mgi.v10i2.117-122

Almárcegui, C. J., Huybrechts, I., Bruton, A. G., Llorente, Á. M., Agüero, A. G., Cabello, A. G., Moreno, L. A., Casajús, J. A., & Rodríguez, G. V. (2015). Validity of a Food-Frequency Questionnaire for Estimating Calcium Intake in Adolescent Swimmers. *Nutricion Hospitalaria*, *32*(4), 1773–1779. https://doi.org/10.3305/nh.2015.32.4.9490

Cortesi, M., Gatta, G., Michielon, G., Di Michele, R., Bartolomei, S., & Scurati, R. (2020). Passive Drag in Young Swimmers: Effects of Body Composition, Morphology and Gliding Position. *International Journal of Environmental Research and Public Health*, *17*(6), 7–9. https://doi.org/10.3390/ijerph17062002

Dhiman, C., & Chand Kapri, B. (2023). Optimizing Athletic Performance and Post- Exercise Recovery: The Significance of Carbohydrates and Nutrition. *Montenegrin Journal of Sports Science and Medicine*, *12*(2), 49–56. https://doi.org/10.26773/mjssm.230907

Domínguez, R., Sánchez-Oliver, A. J., Cuenca, E., Jodra, P., Fernandes da Silva, S., & Mata-Ordóñez, F. (2017). Nutritional Needs in the Professional Practice of Swimming: A Review. *Journal of Exercise Nutrition & Biochemistry*, *21*(4), 1–10. https://doi.org/10.20463/jenb.2017.1

Dopsaj, M., Zuoziene, I. J., Milić, R., Cherepov, E., Erlikh, V., Masiulis, N., Di Nino, A., & Vodičar, J. (2020). Body Composition in International Sprint Swimmers: Are There any Relations with Performance? *International Journal of Environmental Research and Public Health*, *17*(24), 1–14. https://doi.org/10.3390/ijerph17249464

Espada, M. C., Ferreira, C. C., Gamonales, J. M., Hernández-Beltrán, V., Massini, D. A., Macedo, A. G., Almeida, T. A. F., Castro, E. A., & Pessôa Filho, D. M. (2023). Body Composition Relationship to Performance, Cardiorespiratory Profile, and Tether Force in Youth Trained Swimmers. *Life*, *13*(9). https://doi.org/10.3390/life13091806

Ferreira, F. A., Santos, C. C., Palmeira, A. L., Fernandes, R. J., & Costa, M. J. (2024). Effects of Swimming Exercise on Early Adolescents' Physical Conditioning and Physical Health: A Systematic Review. *Journal of Functional Morphology and Kinesiology*, *9*(3), 158. https://doi.org/10.3390/jfmk9030158

Gonçalves, S., Vicente, F., & Pereira, P. (2025). Energy and Key Micronutrient Intake in Amateur Swimmers: a Pilot Study. *Nutrients*, *17*(4), 664.. https://doi.org/10.3390/nu17040664

Hwang, E., Portillo, B., Grose, K., Fujikawa, T., & Williams, K. W. (2023). Exercise-Induced Hypothalamic Neuroplasticity: Implications for Energy and Glucose Metabolism. *Molecular Metabolism*, *73*(May), 101745. https://doi.org/10.1016/j.molmet.2023.101745

Kerksick, C. M., Arent, S., Schoenfeld, B. J., Stout, J. R., Campbell, B., Wilborn, C. D., Taylor, L., Kalman, D., Smith-Ryan, A. E., Kreider, R. B., Willoughby, D., Arciero, P. J., VanDusseldorp, T. A., Ormsbee, M. J., Wildman, R., Greenwood, M., Ziegenfuss, T. N., Aragon, A. A., & Antonio, J. (2017). International Society of Sports Nutrition Position Stand: Nutrient Timing. *Journal of the International Society of Sports Nutrition*, *14*(1), 1–21. https://doi.org/10.1186/s12970-017-0189-4

Kim, J. H. (2019). Multicollinearity and Misleading Statistical Results. *Korean Journal of Anesthesiology*, *72*(6), 558–569. https://doi.org/10.4097/kja.19087

Kitts, S., Stauffer, K., & Flink, T. (2025). Nutritional Preparation for an Ultra-Endurance Swimmer: A Case Report. *Journal of Exercise and Nutrition*, *8*(1), 1–6. https://doi.org/10.53520/jen2025.103190

Kurnia, D. I., Kasmiyetti, K., Dwiyanti, D., & Al, E. (2020). Pengetahuan Pengaturan Makan Atlet dan Persen Lemak Tubuh Terhadap Kebugaran Jasmani Atlet. *Sport and Nutrition Journal*, *2*(2), 56–64. https://doi.org/10.15294/spnj.v2i2.39001

Lakens, D. (2022). Sample Size Justification. *Collabra: Psychology*, *8*(1), 1–28. https://doi.org/10.1525/collabra.33267

Larasati, M. D., & Yuliana, S. (2020). Asupan Makanan, Status Gizi dan Ketahanan Kardiorespirasi Atlet Renang. *Jurnal Riset Gizi*, *8*(1), 37–43. https://doi.org/10.31983/jrg.v8i1.5763

Macuh, M., Levec, J., Kojić, N., & Knap, B. (2023). Dietary Intake, Body Composition and Performance of Professional Football Athletes in Slovenia. *Nutrients*, *15*(1). https://doi.org/10.3390/nu15010082

Martín-Rodríguez, A., Belinchón-deMiguel, P., Rubio-Zarapuz, A., Tornero-Aguilera, J., Martínez-Guardado, I., Villanueva-Tobaldo, C., & Clemente-Suárez, V. (2024). Advances in Understanding the Interplay Between Dietary Practices, Body Composition, and Sports Performance in Athletes. *Nutrients*, *16*(4), 571. https://doi.org/10.3390/nu16040571

Massini, D. A., Almeida, T. A. F., Vasconcelos, C. M. T., Macedo, A. G., Espada, M. A. C., Reis, J. F., Alves, F. J. B., Fernandes, R. J. P., & Pessôa Filho, D. M. (2021). Are Young Swimmers Short and Middle Distances Energy Cost Sex-Specific? *Frontiers in Physiology*, *12*(December), 1–13. https://doi.org/10.3389/fphys.2021.796886

Miguel-Ortega, Á., Calleja-González, J., & Mielgo-Ayuso, J. (2024). Endurance In Long-Distance Swimming And The Use Of Nutritional Aids. *Nutrients*, *16*(22), 3949. https://doi.org/10.3390/nu16223949

Muharam, R. R. (2019). Hubungan antara Pola Makan dan Status Gizi dengan Tingkat Kebugaran Atlet Dayung. *JOSSAE : Journal of Sport Science and Education*, *4*(1), 14-20. https://doi.org/10.26740/jossae.v4n1.p14-20

Murray, B., & Rosenbloom, C. (2018). Fundamentals of Glycogen Metabolism dor Coaches and Athletes. *Nutrition Reviews*, *76*(4), 243–259. https://doi.org/10.1093/nutrit/nuy001

Noakes, T. D. (2022). What is the Evidence that Dietary Macronutrient Composition Influences Exercise Performance? A Narrative Review. *Nutrients*, *14*(4), 862. https://doi.org/10.3390/nu14040862

Panuganti, K. K., Nguyen, M., & Kshirsagar, R. K. (2023). Obesity. In *StatPearls*. StatPearls. http://www.ncbi.nlm.nih.gov/pubmed/30811954

Roelofs, E. J., Smith-Ryan, A. E., Trexler, E. T., & Hirsch, K. R. (2017). Seasonal Effects on Body Composition, Muscle Characteristics, and Performance of Collegiate Swimmers and Divers. *Journal of Athletic Training*, *52*(1), 45–50. https://doi.org/10.4085/1062-6050-51.12.26

Sagat, P., Štefan, L., Petrić, V., Štemberger, V., & Blažević, I. (2023). Normative Values of Cardiorespiratory Fitness in Croatian Children and Adolescents. *PLOS ONE*, *18*(4), e0284410. https://doi.org/10.1371/journal.pone.0284410

Sakir, N. A. I., Hwang, S. Bin, Park, H. J., & Lee, B.-H. (2024). Associations between Food Consumption/Dietary Habits and the Risks of Obesity, Type 2 Diabetes, and Hypertension: A Cross-Sectional Study in Jakarta, Indonesia. *Nutrition Research and Practice*, *18*(1), 132. https://doi.org/10.4162/nrp.2024.18.1.132

Sasmarianto, Henjilito, R., Zulrafli, Kamarudin, & Nazirun, N. (2021). Understanding the Needs of Nutrition Intake on Athletes. *Journal Sport Area*, *6*(2), 244–253. https://doi.org/10.25299/sportarea.2021.vol6(2).6509

Senanayake, S. P., Dabare, P., Silva, A. R. N., Pushpika, S., & Maddumage, R. (2024). Validation Study to Assess the Concurrent Validity of the Beep Test as a Proxy for Cardiopulmonary Endurance, Using VO2 Max as the Criterion Standard. *European Journal of Sport Sciences*, *3*(1), 38–42. https://doi.org/10.24018/ejsport.2024.3.1.131

Setiaputri, K. A., Rahfiludin, M. zen, Suroto, & Al, E. (2017). Hubungan Konsumsi Zat Gizi, Persentase Lemak Tubuh dan Aktivitas Fisik dengan Kebugaran Jasmani pada Atlel Renang. *Jurnal Kesehatan Masyaraka*, *5*(3), 2356–3346. https://doi.org/10.14710/jkm.v5i3.17202

Sholihah, L., & Mayasari, N. R. (2024). Exploring Physical Fitness, Physical Activity, Nutritional Status, and Diet among Female Nutrition Students. *Journal Sport Area*, *9*(3), 459–467. https://doi.org/10.25299/sportarea.2024.vol9(3).14899

Shook, R. P., Hand, G. A., Drenowatz, C., Hebert, J. R., Paluch, A. E., Blundell, J. E., Hill, J. O., Katzmarzyk, P. T., Church, T. S., & Blair, S. N. (2015). Low Levels of Physical Activity are Associated with Dysregulation of Energy Intake and Fat Mass Gain Over 1 Year. *American Journal of Clinical Nutrition*, *102*(6), 1332–1338. https://doi.org/10.3945/ajcn.115.115360

Swinarew, A. S., Stanula, A. J., Gabor, J., Raif, P., Paluch, J., Karpiński, J., Kubik, K., Okła, H., Ostrowski, A., Tkacz, E., Skoczyński, S., Waśkiewicz, Z., Rosemann, T., Nikolaidis, P. T., & Knechtle, B. (2020). The Influence of Chlorine in Indoor Swimming Pools on the Composition of Breathing Phase of Professional Swimmers. *Respiratory Research*, *21*(1), 1–12. https://doi.org/10.1186/s12931-020-01350-y

Zahra, S., & Muhlisin, M. (2020). Nutrisi bagi Atlet Remaja. *Jurnal Terapan Ilmu Keolahragaan*, *5*(1), 81–89. https://doi.org/10.17509/jtikor.v5i1.25097