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The Relationship Between Nutritional Status And Hydration With Vo_2max In Swimming Athletes South Sulawesi

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ABSTRACT

VO_2max represents a central indicator of cardiorespiratory fitness and a primary determinant of endurance performance in competitive swimming. Adequate oxygen transport and utilization capacity are strongly influenced by physiological adaptations, body composition, and energy availability. However, suboptimal nutritional intake and inadequate hydration practices remain common among adolescent athletes and may compromise aerobic capacity and training adaptation. Empirical evidence examining the combined influence of nutritional status and hydration on VO_2max in regional swimming populations, particularly in South Sulawesi, remains limited. This study aimed to analyze the relationship between nutritional status, hydration status, and VO_2max among swimming athletes in South Sulawesi. A quantitative cross-sectional design was applied involving 20 adolescent swimmers selected through purposive sampling at the Mattoanging Stadium Swimming Pool, Makassar. Nutritional status was assessed using BMI-for-age (WHO standards), hydration status was evaluated through a urine color chart, and VO_2max was estimated using the multistage fitness (beep) test. Data were analyzed using Kendall's Tau correlation test. The findings revealed a significant relationship between nutritional status and VO_2max ($p = 0.002$), indicating that athletes with more optimal body mass profiles demonstrated superior aerobic capacity. Conversely, hydration status was not significantly associated with VO_2max ($p = 0.140$), suggesting that mild hydration variations may not directly affect maximal oxygen uptake under the study conditions. These results emphasize the critical role of optimal nutritional management in supporting cardiorespiratory endurance and swimming performance.

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A. Conception and design of the study;
B. Acquisition of data;
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INTRODUCTION

Physical fitness is a key determinant of athletic performance, particularly in swimming, which relies heavily on aerobic capacity and metabolic efficiency. Swimming is not only oriented towards competitive achievement but also contributes to improved physical and psychological health and musculoskeletal development in adolescents (Esih & Pramono, 2021). Physiologically, swimming performance is largely determined by the body's ability to maximally uptake, transport, and utilize oxygen (VO_2max), which is a key indicator of cardiorespiratory endurance (Firdausi & Sulistyarto, 2021; Amirzan et al., 2020). VO_2max

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reflects the integrated function of the heart, lungs, and hemoglobin, as well as the oxidative capacity of muscles in producing energy through the aerobic system, thus determining an athlete's ability to sustain high intensity for extended durations.

However, decreased VO_2max in adolescent athletes can be influenced by unhealthy lifestyles, including unbalanced nutritional intake, inadequate hydration, and poor eating habits (Syahputra et al., 2024). An imbalance between energy needs and nutrient intake can hinder physiological adaptation to exercise, reduce metabolic efficiency, and slow the recovery process (Rangga, 2020). National data shows that although most Indonesian adolescents have normal nutritional status, the prevalence of undernutrition and overnutrition remains a public health challenge (Ministry of Health of the Republic of Indonesia, 2023). This condition has the potential to impact the cardiorespiratory fitness of school-age athletes.

In addition to nutritional status, hydration is a crucial factor in maintaining homeostasis during physical activity. The National Athletic Trainers' Association emphasizes the importance of individualized hydration strategies before, during, and after exercise (Judge et al., 2021). A fluid deficit of as little as 2% of body weight has been shown to decrease aerobic capacity, lung function, and cardiac efficiency (Januszko & Lange, 2021). Recent studies have shown that mild to moderate dehydration can decrease VO_2max and increase the perception of fatigue in adolescent athletes (Umar et al., 2024). Thus, nutritional and hydration status are physiological determinants that directly and indirectly influence swimmers' aerobic capacity.

Recent literature in sports science confirms that VO_2max is a key predictor of performance in endurance sports, including competitive swimming (Joyner & Coyle, 2018; Sandbakk et al., 2021). Aerobic training adaptations increase capillary density, cardiac stroke volume, and oxidative enzyme activity, which cumulatively increase VO_2max (Poole & Jones, 2017). However, the effectiveness of these adaptations is highly dependent on adequate energy and micronutrient intake (Thomas et al., 2016; Burke et al., 2019).

Empirical research shows that optimal nutritional status is positively correlated with aerobic capacity and metabolic efficiency in adolescent athletes (Heikura et al., 2018; Desbrow et al., 2020). In swimming, a balanced body composition—including the proportion of fat-free mass—is associated with increased endurance and motor efficiency in the water (Morais et al., 2020). Meanwhile, hydration research confirms that fluid balance affects plasma volume, thermoregulation, and oxygen transport during high-intensity exercise (Casa et al., 2019; Goulet, 2020).

In Indonesia, several studies report that some adolescent athletes still have poor dietary habits and fluid intake below the recommended daily intake (Triningtyas et al., 2023; Kasmad et al., 2024). National regulations, through Indonesian Ministry of Health Regulation No. 28 of 2019, stipulate the daily fluid requirement for adolescents aged 16–18 years at 2,150–2,300 mL (Indonesian Ministry of Health, 2019), but compliance with this recommendation among athletes varies. Globally, a multidimensional approach integrating nutritional status, hydration, and aerobic capacity is gaining traction in sports performance research (Mountjoy et al., 2018; Maughan & Shirreffs, 2020).

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Although various studies have examined the relationship between nutritional status and VO_2max or between hydration and aerobic performance separately, studies investigating both variables simultaneously in adolescent swimmers are still limited, particularly in the context of Eastern Indonesia. Most previous research has focused on a single physiological determinant without considering the comprehensive interaction between nutritional balance and hydration status on cardiorespiratory capacity.

Furthermore, empirical data in South Sulawesi regarding the nutritional status, hydration levels, and VO_2max profiles of competitive swimmers remains minimal and systematically documented. Environmental factors such as temperature, humidity, and local dietary habits can influence athletes' energy and fluid needs. Initial observations at the Mattoanging Swimming Pool indicate a common habit of skipping breakfast, eating less than twice a day, and consuming less than two liters of fluid per day, potentially leading to energy deficits and mild dehydration. These conditions are suspected to impact aerobic capacity, but scientifically measurable empirical evidence is lacking.

Thus, there is a need for research that integratively analyzes the relationship between nutritional status and hydration levels and VO_2max in adolescent swimmers in the local context of South Sulawesi as a basis for evidence-based interventions.

This study aims to analyze the relationship between nutritional status and hydration levels and VO_2max in adolescent swimmers in South Sulawesi. Conceptually, this study integrates approaches from exercise physiology, nutrition science, and sport hydration science into one comprehensive analysis model. Empirically, this study presents regional data that has not been widely explored in the national and international literature.

The research's novelty lies in: (1) the simultaneous analysis of two key physiological determinants—nutritional status and hydration—on VO_2max in swimming; (2) the rarely studied context of the adolescent athlete population in Eastern Indonesia; and (3) the practical implications for formulating data-driven nutrition and hydration monitoring strategies to optimize swimmers' cardiorespiratory fitness.

With this approach, the research is expected to not only enrich the evidence-based sports science treasury, but also provide practical contributions for coaches, academics, and policymakers in improving the performance of swimming athletes through measurable and targeted nutrition and hydration interventions.

METHODS

This study employed a quantitative observational analytic approach using a cross-sectional design to examine the relationship between nutritional status, hydration status, and VO_2max among adolescent swimmers. A cross-sectional framework is appropriate for identifying associations between exposure variables and physiological outcomes measured simultaneously without experimental manipulation (Setia, 2016; Wang & Cheng, 2020). This design has been widely applied in sport nutrition and exercise physiology research to explore determinants of cardiorespiratory fitness in youth athletes (Heikura et al., 2018; Desbrow et al., 2020).

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The study was conducted in September 2025 at the Mattoanging Stadium Swimming Pool, Makassar, South Sulawesi. The population consisted of 55 registered swimmers actively training at the facility. A purposive sampling technique was used to recruit 20 athletes who met predefined inclusion criteria. Purposive sampling is frequently used in sport science research to ensure that participants possess specific training characteristics relevant to physiological measurement (Etikan & Bala, 2017). Inclusion criteria were: (1) registered and actively training swimmers; (2) aged 13–18 years, representing a developmental phase characterized by rapid physiological adaptation (Armstrong & McManus, 2017); and (3) written informed consent from both athletes and parents. Exclusion criteria included injury, illness, medication use affecting cardiovascular or fluid balance, and incomplete participation during testing sessions.

Three variables were examined: nutritional status and hydration status as independent variables, and VO_2max as the dependent variable. Nutritional status was assessed using Body Mass Index-for-Age (BMI-for-age) based on WHO z-scores, a standardized anthropometric indicator recommended for adolescents (WHO, 2017). BMI-for-age is widely used in epidemiological and sports health research to evaluate energy balance and growth status in youth athletes (Meyer et al., 2020; Indonesian Ministry of Health, 2023). Although BMI does not directly measure body composition, it remains a valid proxy for population-level nutritional assessment in adolescent cohorts (Nuttall, 2015).

Hydration status was evaluated using a urine color chart, a practical, non-invasive field method validated for estimating hydration in athletic settings (Armstrong et al., 2018; Casa et al., 2019). Urine color assessment correlates with urine specific gravity and osmolality, making it suitable for rapid screening in training environments (Goulet, 2020). Monitoring hydration is essential because even mild hypohydration (≥2% body mass loss) may reduce plasma volume, impair thermoregulation, and decrease aerobic performance (Maughan & Shirreffs, 2020; Januszko & Lange, 2021).

VO_2max was estimated using the multistage fitness test (beep test), a widely validated indirect measure of maximal aerobic capacity in adolescents (Tomkinson et al., 2018; Lang et al., 2018). The beep test demonstrates acceptable reliability and strong correlations with laboratory-based VO_2max assessments, making it suitable for field-based evaluation in youth sports populations (Mayorga-Vega et al., 2015; Sandbakk et al., 2021). VO_2max values were categorized into very poor, poor, moderate, good, and very good according to normative standards for adolescent fitness.

Data collection was conducted in three phases. In the preparatory phase, instruments were calibrated, anthropometric tools were standardized, and ethical procedures were completed in accordance with research guidelines for human participants (World Medical Association, 2018). In the implementation phase, body weight and height were measured using calibrated digital scales and stadiometers; urine samples were visually assessed using the standardized color chart; and the beep test was administered under controlled conditions to minimize environmental bias. In the final phase, the data were coded and analyzed using IBM SPSS Statistics version 27.

Univariate analysis was performed to describe frequency distributions and percentages of nutritional status, hydration status, and VO_2max categories. Bivariate analysis employed Kendall's tau correlation test, which is appropriate for ordinal and non-normally distributed data in small samples (McHugh, 2013). Statistical significance was set at $p < 0.05$. This analytical approach aligns with prior sport physiology studies investigating associations between anthropometric, hydration, and aerobic capacity variables in adolescent athletes (Morais et al., 2020; Umar et al., 2024).

RESULTS AND DISCUSSION

Result

Table 1.
Age Distribution of Respondents

Age	N	Percentage
13	7	35%
14	5	25%
15	4	20%
16	2	10%
17	2	10%
Total	**20**	**100%**

The characteristics of the respondents included age and sex, which are presented in Table 1. Based on the age distribution, the largest proportion of respondents were 13 years old, totaling 7 individuals (35%). This was followed by respondents aged 14 years, with 5 individuals (25%), those aged 15 years with 4 individuals (20%), and respondents aged 16 and 17 years, each totaling 2 individuals (10%). These results indicate that the majority of the athletes were in the age group of 13 years.

Table 2.
Gender Distribution of Respondents

Gender	N	Percentage
Male	12	60%
Female	8	40%
Total	**20**	**100%**

Based on gender, Table 2 shows that male respondents were more dominant than female respondents. Male athletes totaled 12 individuals (60%), while female athletes accounted for 8 individuals (40%). This distribution indicates that the number of male athletes in this study was higher than that of female athletes.

Table 3.
Frequency Distribution of Nutritional Status

Category	N	Percentage
Severely thinness	7	0
Thinness	5	0
Normal	4	85%
Overweight	2	10%
Obese	2	5%
Total	**20**	**100%**

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The distribution of respondents' nutritional status, hydration status, and VO_2max is presented in Table 3. The results of the univariate analysis showed that the majority of athletes had a good or normal nutritional status, totaling 17 individuals (85%).

Table 4.
Frequency Distribution of Hydration Status

Category	N	Percentage
Hydrated	0	0%
Mild dehydration	13	65%
Dehydration	6	30%
Severe dehydration	1	5%
Total	**20**	**100%**

The distribution of hydration status showed that the majority of athletes were in a condition of mild dehydration. A total of 13 athletes (65%) experienced mild dehydration, 6 athletes (30%) were in the dehydration category, and 1 athlete (5%) was classified as severely dehydrated.

Table 5.
Distribusi Frekuensi Variabel VO_2max

Category	N	Percentage
Very poor	0	0
Poor	0	0
Moderate	3	15%
Good	5	25%
Very good	12	60%
Total	**20**	**100%**

The distribution of the VO_2max variable showed that most athletes were in the very good category. Based on Table 5, a total of 12 athletes (60%) had VO_2max in the very good category, 5 athletes (25%) were in the good category, and 3 athletes (15%) were in the moderate category.

Table 6.
Correlation between Nutritional Status, Hydration, and VO_2max

Independent Variable	Dependent Variable	Kendall's Tau Correlation		
		N	r	p-value
Nutritional Status	VO_2max	20	-0,665	0,002
Hydration	VO_2max	20	-0,318	0,140

The analysis of the relationship between nutritional status and hydration status with VO_2max was conducted using Kendall's tau correlation test, as presented in Table 6. The results showed a significant relationship between nutritional status and VO_2max, with a correlation coefficient of $r = -0.665$ and a p-value of 0.002 ($p < 0.05$). The correlation coefficient was negative with a strong strength of association, indicating that an increase in nutritional status category was followed by a decrease in VO_2max values, and vice versa. Thus, nutritional status had a significant relationship with the cardiorespiratory fitness of swimmers.

In contrast, the analysis of the relationship between hydration status and VO_2max showed no statistically significant association. The correlation coefficient obtained was

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r = –0.318 with a p-value of 0.140 (p > 0.05). Although the direction of the relationship was negative, the p-value exceeding the significance threshold indicates that hydration status was not significantly associated with VO_2max among swimmers in this study.

Discussion

Nutritional Status of Swimmers in South Sulawesi

Findings indicate that most swimmers demonstrated generally adequate food intake; However, dietary patterns were not fully aligned with balanced nutrition principles, particularly in meal regularity and food diversity. Contemporary sports nutrition literature emphasizes that adolescent athletes require structured macronutrient distribution and micronutrient adequacy to support growth, metabolic adaptation, and training recovery (Thomas et al., 2016; Burke et al., 2019; Desbrow et al., 2020). Adolescence represents a critical anabolic phase characterized by accelerated somatic growth and hormonal maturation, increasing total energy expenditure and nutrient demands (Armstrong & McManus, 2017; Meyer et al., 2020).

Normal BMI-for-age observed in most athletes suggests a relative balance between energy intake and expenditure. However, normal BMI does not necessarily reflect optimal body composition or micronutrient sufficiency (Nuttall, 2015; Mountjoy et al., 2018). In competitive swimmers, lean body mass and optimal muscle-to-fat ratio are more predictive of performance than BMI alone (Morais et al., 2020; Sandbakk et al., 2021). The presence of overweight athletes in this study may be explained by chronic positive energy balance, where caloric intake exceeds metabolic and training demands, leading to increased adiposity (Utami et al., 2020). Excess fat mass can impair movement efficiency in water and increase physiological strain during endurance performance (Syahputra et al., 2024). These findings align with global evidence that inappropriate dietary habits in youth athletes may compromise aerobic efficiency despite apparently normal anthropometric indicators (Heikura et al., 2018).

Hydration Status of Swimmers in South Sulawesi

Most athletes exhibited suboptimal hydration status, indicating insufficient fluid replacement during intensive training. Exercise-induced sweat loss reduces plasma volume and increases cardiovascular strain, which may negatively influence endurance capacity if uncompensated (Casa et al., 2019; Maughan & Shirreffs, 2020). Even mild hypohydration (~2% body mass loss) has been associated with decreased aerobic performance and increased perceived exertion (Goulet, 2020; Januszko & Lange, 2021).

The high prevalence of dehydration among adolescents reported in recent meta-analytic findings (Papaoikonomou et al., 2025) supports the pattern observed in this study. Sex-based differences, where male athletes exhibit higher dehydration rates, are physiologically plausible given greater muscle mass, higher sweat rates, and greater metabolic heat production (Katz et al., 2021; Ani et al., 2025). Hydration status is inherently individual and influenced by environmental conditions, training intensity, and habitual fluid intake behaviors (Judge et al., 2021). These findings reinforce the importance of structured hydration monitoring strategies in youth swimming programs.

VO_2max of Swimmers in South Sulawesi

Most swimmers demonstrated good VO_2max levels, reflecting adaptive cardiorespiratory responses to systematic training. Aerobic conditioning increases stroke volume, capillary density, mitochondrial biogenesis, and oxidative enzyme activity, thereby improving oxygen transport and utilization (Poole & Jones, 2017; Joyner & Coyle, 2018). Structured swim training combined with supplementary conditioning has been shown to significantly increase aerobic capacity in adolescents (Alkaririn et al., 2022; Kolayis & Arol, 2020).

Conversely, lower VO_2max values are often associated with suboptimal body composition and lower habitual physical activity (Cahyono et al., 2021). Athletes with superior aerobic capacity demonstrate enhanced fatigue resistance and performance consistency during competition (Hita et al., 2020; Weraman et al., 2024). These physiological characteristics are essential in swimming, a sport heavily dependent on sustained aerobic metabolism, especially in middle- and long-distance events (Sandbakk et al., 2021).

Relationship Between Nutritional Status and VO_2max

A significant relationship was found between nutritional status and VO_2max. Athletes with normal nutritional status tended to demonstrate higher aerobic capacity, whereas overweight athletes showed relatively lower VO_2max values. Increased body mass—particularly from adipose tissue—raises the energy cost of movement and reduces relative oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$), explaining the inverse association (Sastra, 2022; Kurniawan et al., 2024). Excess fat mass may impair pulmonary mechanics and cardiovascular efficiency, limiting oxygen delivery to working muscles (Istiqomah et al., 2022).

These findings are consistent with studies in adolescent combat and aquatic sports demonstrating that optimal BMI and lean mass distribution positively correlate with aerobic fitness (Morais et al., 2020; Syahputra et al., 2024). VO_2max is influenced by cardiac output, hemoglobin concentration, and skeletal muscle oxidative capacity, all of which are indirectly affected by nutritional adequacy (Burke et al., 2019; Thomas et al., 2016). Thus, maintaining optimal nutritional status is essential for maximizing aerobic performance in swimmers.

Relationship Between Hydration and VO_2max

No significant relationship was found between hydration status and VO_2max. This suggests that acute hydration status, as assessed via urine color, may not directly reflect maximal aerobic capacity measured through the beep test. VO_2max is primarily determined by chronic physiological adaptations—cardiac function, mitochondrial density, and training status—rather than short-term hydration fluctuations (Joyner & Coyle, 2018; Ahmad et al., 2020).

Physical activity level remains a dominant predictor of aerobic capacity (Abduh et al., 2020; Adhianto & Arief, 2023). Similar findings were reported in youth sport studies where hydration status did not independently predict VO_2max when training load was controlled (Harfika & Hidayat, 2022). However, contrasting evidence indicates that

severe dehydration can impair endurance performance (Oktavrianto & Noordia, 2020; Goulet, 2020). The absence of association in this study may indicate that dehydration levels were mild and insufficient to significantly alter maximal oxygen uptake.

Overall, these findings underscore that while hydration is critical for performance sustainability and thermoregulation, long-term aerobic capacity in adolescent swimmers is more strongly influenced by nutritional status and structured training adaptations.

CONCLUSION

This study concludes that most swimmers in South Sulawesi demonstrated normal nutritional status, indicating an adequate balance between energy intake and expenditure to support growth, training adaptation, and performance. Importantly, a significant relationship was identified between nutritional status and VO_2max, confirming that athletes with more optimal body mass profiles tend to exhibit superior cardiorespiratory endurance. From a physiological perspective, adequate macro- and micronutrient intake supports hemoglobin synthesis, mitochondrial function, and cardiac output, all of which contribute to efficient oxygen transport and utilization during high-intensity swimming. Conversely, excess body fat may reduce relative oxygen uptake and increase metabolic load, thereby lowering aerobic capacity.

In contrast, no significant association was found between hydration status and VO_2max under the measurement conditions applied. This finding suggests that mild variations in hydration, as assessed in this study, may not directly influence maximal aerobic capacity, which is predominantly determined by long-term cardiovascular and muscular adaptations. Nevertheless, hydration remains essential for maintaining plasma volume, thermoregulation, and performance sustainability.

Therefore, systematic monitoring of nutritional and hydration status is recommended to optimize athlete development. Future research should involve larger samples and incorporate objective hydration biomarkers, training load, and body composition analysis to better elucidate their interaction with VO_2max.

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