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Assessment of serum electrolytes, nutritional status, and oxygen saturation among athletic Senior High School students

Penilaian elektrolit serum, status gizi, dan saturasi oksigen pada Siswa SMA yang berolahraga

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Abstract

Adolescent athletes have a higher risk of dehydration than adult athletes do. This increased risk results from the greater absorption of environmental heat and heightened body heat, which affects electrolyte balance and oxygen saturation. This study aimed to analyze electrolyte values and oxygen saturation in students at SMA Keberbakatan Aceh in 2024 using an observational analytical approach with a cross-sectional design. A total of 43 respondents were selected for this study. The intensity of physical exercise was assessed using the International Physical Activity Questionnaire (IPAQ) score, of which two respondents had hyponatremia, 40 had normal sodium levels, and one respondent had hypernatremia related to the intensity of physical exercise (p= 0,381). Potassium levels were not significantly affected, as all 43 respondents had normal potassium levels (p= 0,740). Regarding chloride levels, one respondent had hypochloremia, 40 had normal levels, and two had hyperchloremia. While previous results showed no effect, exercise intensity was found to have a significant influence on respondents' nutritional status (p= 0,034). All respondents maintained levels within normal limits in the assessment of oxygen saturation. Conclusion: Physical exercise intensity had no significant effect on serum electrolytes or oxygen saturation levels. However, a significant relationship was observed between the physical exercise intensity and nutritional status.

Keywords: Serum Electrolytes, Physical Exercise, Oxygen Saturation, IPAQ Score, Nutritional Status

Abstrak

Atlet remaja memiliki risiko dehidrasi yang lebih tinggi dibandingkan atlet dewasa, karena penyerapan panas lingkungan yang lebih besar dan peningkatan suhu tubuh, yang dapat mengganggu keseimbangan elektrolit dan saturasi oksigen. Penelitian ini bertujuan untuk menilai kadar elektrolit serum dan saturasi oksigen pada siswa SMA Keberbakatan Aceh tahun 2024. Penelitian ini menggunakan pendekatan analitik observasional dengan desain potong lintang dan melibatkan 43 responden. Intensitas aktivitas fisik diukur menggunakan skor *International Physical Activity Questionnaire (IPAQ)*. Hasil menunjukkan dua responden mengalami hiponatremia, 40 dengan kadar natrium normal, dan satu mengalami hipernatremia, namun tidak terdapat hubungan yang signifikan antara kadar natrium dan intensitas aktivitas fisik (p = 0,381). Seluruh responden memiliki kadar kalium normal tanpa hubungan yang signifikan (p = 0,740). Terkait kadar klorida, satu responden mengalami hipokloremia, 40 dalam batas normal, dan dua mengalami hiperkhloremia. Meskipun intensitas aktivitas fisik tidak berpengaruh signifikan terhadap kadar elektrolit, terdapat hubungan signifikan antara intensitas aktivitas fisik dan status gizi (p = 0,034). Semua responden menunjukkan saturasi oksigen dalam batas normal. Kesimpulan, intensitas aktivitas fisik tidak berpengaruh signifikan terhadap kadar elektrolit serum maupun saturasi oksigen, tetapi memiliki hubungan signifikan dengan status gizi.

Kata Kunci: Elektrolit Serum, Latihan Fisik, Saturasi Oksigen, Skor IPAQ, Status Gizi

Introduction

Adolescence is a period of rapid growth and psychosocial development that typically occurs between the ages of 10 and 20. Etymologically, the term refers to the transitional stage between childhood and adulthood. This stage is commonly divided into three phases: early adolescence (10–14 years), middle adolescence (14–17 years), and late adolescence (17–20 years) (Dieny & Putriana, 2016). During this period, growth occurs at a markedly faster rate than during childhood; for example, adolescents may experience growth spurts of 7–12 cm per year, especially during puberty. Adolescent athletes face unique physiological challenges in the context of sports and physical activity. Compared to adult athletes, they are more susceptible to dehydration due to a combination of factors such as a higher surface area-to-body weight ratio, lower efficiency of heat dissipation through sweating, increased metabolic heat production during exercise, and insufficient fluid intake to match sweat loss (Pamungkas, 2022) These vulnerabilities can impact fluid-electrolyte balance and overall performance, necessitating special attention to hydration strategies in this population.

The primary electrolytes excreted through sweat include sodium, potassium, and chloride, whereas magnesium and calcium are present in smaller amounts. Among these, sodium and potassium are lost at the highest concentrations, with reported values ranging from 480 mg/L to 1840 mg/L for sodium and approximately 195 mg/L for potassium (Dieny & Putriana, 2016).

The human body constantly regulates electrolyte concentrations in body fluids through homeostatic mechanisms to maintain internal stability. This regulatory process is essential for sustaining physiological functions, particularly during physical exertion. However, when fluid and electrolyte losses from sweating are not adequately replaced, an imbalance may occur, leading to disruptions in cellular function and thermoregulation. For adolescent athletes whose bodies are still undergoing physiological maturation, such imbalances may pose greater risks. These include reduced endurance, impaired neuromuscular coordination, and heightened vulnerability to heat-related illnesses (López de Lara et al., 2022; Pamungkas, 2022).

During physical exercise, the body undergoes several physiological adaptations to accommodate increased energy and oxygen demand. One of the primary responses is the enhancement of ventilation and circulation, which facilitates greater oxygen diffusion into pulmonary capillaries and promotes oxygen binding to hemoglobin. Simultaneously, physical exertion leads to elevated carbon dioxide production, lactic acid accumulation, and a decrease in blood pH. This acidic environment causes a rightward shift in the oxygen–hemoglobin dissociation curve, a phenomenon known as the Bohr effect. As a result, the affinity of hemoglobin for oxygen decreases, leading to reduced oxygen saturation even when the partial pressure of oxygen remains unchanged. This decline in oxygen saturation can impair muscular performance and endurance, especially in adolescent athletes, whose bodies are still adapting to physiological stressors and who may have less efficient thermoregulation and oxygen transport mechanisms (Aslan & Kahraman, 2023; Martín-Escudero et al., 2021).

A study in Turkey involving 36 athletes performing acute aerobic exercise found decreased oxygen saturation after exercise, while heart rate increased significantly (Eroğlu et al., 2018). Domestic research has examined students undergoing basketball training and has reported a significant increase in oxygen saturation levels after physical exercise (Simanjuntak et al., 2016).

Therefore, this study aimed to analyze serum electrolyte levels and oxygen saturation among students at a Sports Senior High School who represent an adolescent athlete population undergoing intense physical training. These students are particularly vulnerable to fluid and electrolyte imbalances as well as oxygen transport inefficiencies due to the combined demands of growth, development, and athletic activity. The findings of this study are expected to provide valuable insights into the physiological responses of adolescent athletes during exercise. Specifically, the results will help clarify the relationship between serum electrolyte status and oxygen saturation, which may inform more targeted strategies for hydration, recovery, and performance optimization in this age group.

Methods

This analytical observational study employed a cross-sectional design and was conducted in

September of 2024. The target population consisted of students from Sports Senior High School who met the predefined inclusion and exclusion criteria. The inclusion criteria were as follows: willingness to participate, present during the study period, and no physical or mental disabilities. The exclusion criteria were students who were absent during data collection or who withdrew consent. A total of 43 respondents were selected using simple random sampling.

The sample size determination was based on a minimum requirement for correlational analysis, with a targeted sample of at least 40 respondents. Owing to incomplete documentation and the absence of detailed parameters in the original formula, the sample size formula has been omitted for clarity.

$$n = \left(\frac{Z\alpha + Zß}{0{,}5\ln[(1+r)/(1-r)}\right)^2 + 3$$

$$n = \left(\frac{1{,}96+0{,}842}{0{,}5\ln(1+0{,}5)/(1-0{,}5)}\right)^2 + 3 = 40$$

$Z\propto$ = standard deviation of the error rate

$Zß$ = power

r = estimated correlation coefficient

ln = natural logarithm

All the participants provided written informed consent. Demographic and anthropometric data, including age, sex, height, weight, and body mass index (BMI), were recorded. Physical activity intensity was measured using the International Physical Activity Questionnaire (IPAQ), which assesses activity levels over the past seven days. The IPAQ includes items on light (e.g., walking and sitting), moderate (e.g., jogging and light cycling), and vigorous (e.g., running and aerobics) activities. Metabolic equivalent of task (MET) scores for light, moderate, and vigorous activities were calculated as follows: MET = 3,3, light, 4,34 for moderate, and 8,0 for vigorous activity, respectively. Total physical activity was expressed in MET-min/week and categorized as light (<300 MET-min/week), moderate (600–3000 MET-min/week), or high (>3000 MET-min/week). Following the questionnaire, oxygen saturation (SpO_2) was measured noninvasively using a fingertip pulse oximeter (ChoiceMMed MD300C2). Peripheral blood samples were collected to assess serum electrolyte levels, including sodium (normal range: 135–145 mmol/L), potassium (3,5–5,1 mmol/L), and chloride (96–106 mmol/L), using an automated biochemical analyzer (Roche Cobas C111).

Data normality was assessed using the Shapiro–Wilk test (p > 0,05, normal distribution). For bivariate analysis, the independent t-test was used to compare normally distributed continuous variables between groups. If the data were not normally distributed, the Mann–Whitney U test was applied. Correlation analysis employed Pearson's correlation for normally distributed variables and Spearman's rank correlation for non-normal data. Statistical analyses were performed using SPSS version 23. The results are presented in a narrative form, tables, and graphs.

This study received ethical approval from the Ethics Committee of the Faculty of Medicine, Syiah Kuala University (Reference No: 133/EA/FK/2024).

Result and Discussion

Characteristics and Physical Exercise

Table 1. Basic characteristics and physical exercise intensity of respondents

Variable	n	%
Gender		
Male	25	58,1
Female	18	41,9
Age (years)		
15	2	4,7
16	21	48,8
17	13	30,2
≥ 18	7	16,3
Weight (kg)		
40–49	8	18,6
50–59	18	41,9
60–69	17	39,5
Height (cm)		
145–159	13	30,2
160–169	24	55,8
170–180	6	14,0
Nutritional Status		
Underweight	4	9,3
Normal	33	76,7
Overweight	5	11,6
Obese	1	2,3
Physical Activity (MET)		
Moderate (600–3000)	7	16,3
High (>3000)	36	83,7

A total of 43 respondents participated in the study. Table 1 presents the combined basic characteristics and physical activity intensity levels of the participants. The majority were male (58%), aged 16 years (49%), with an average body weight of 50–59 kg (42%) and a height between 160 and 169 cm (56%). Most participants (77%) had a normal nutritional status. In terms of physical activity, 84% of the respondents engaged in high-intensity exercise, whereas 16% performed moderate-intensity activities. None of the participants reported light-intensity activity.

Serum Electrolyte Levels

Table 2 summarizes the effects of physical exercise intensity on the serum electrolyte levels and nutritional status. Most respondents maintained normal sodium, potassium, and chloride levels regardless of activity intensity. Two cases of hyponatremia and one case of hypernatremia were observed in the high-intensity group. All the participants had normal potassium levels. For chloride, one respondent in the moderate group had hypochloremia and two in the high group had hyperchloremia. No significant differences were observed between physical activity intensity and serum electrolyte levels: Sodium: p = 0,381 (95% CI: -3,14 to 2,88); Potassium: p = 0,740; Chloride: p = 0,240 (95% CI: -6,90 to -5,57).

However, physical exercise intensity was significantly associated with nutritional status (p= 0,038). All underweight respondents performed moderate-intensity activities, whereas 88% of normal-weight respondents engaged in high-intensity activities. Overweight and obese participants also tended to perform high-intensity activities.

The present study demonstrated that most adolescent athletes exhibited normal serum electrolyte levels, suggesting adequate physiological regulation and adaptation to exercise-induced demands. These findings are in agreement with those of previous studies by Koccedil (2009), Raj et al. (2014), and Hazar et al. (2013), which highlighted that regular physical activity, when supported by proper hydration and acclimatization, can maintain homeostasis of key electrolytes such as sodium, potassium, and chloride. The observed cases of hyponatremia and hyperchloremia, although limited in number, did not reach statistical significance and may reflect transient, self-limiting deviations, rather than pathological disruptions. Hormonal mechanisms, such as the action of aldosterone and antidiuretic hormone (ADH), likely contribute to the maintenance of fluid-electrolyte balance during intense exercise (Shirreffs & Sawka, 2011).

Interestingly, the analysis revealed a significant association between physical activity intensity and nutritional status (p = 0,038), which is consistent with the findings of Roring et al. (2020) and Rizk et al. (2019). These studies emphasized that high-intensity physical activity can enhance metabolic rate, increase energy expenditure, and improve fat oxidation, leading to a healthier body composition. In our study, a larger proportion of students with normal or higher BMI engaged in high-intensity activities. This may reflect the role of structured training programs in regulating the energy balance and optimizing nutritional outcomes in young athletes (Junita et al., 2024).

Table 2. Effect of physical exercise intensity on electrolyte levels and nutritional status

Variable	Category	Moderate Intensity		High Intensity		Total		p-value
		n	%	n	%	n	%	
Sodium Level	Hyponatremia	0	0,0	2	100,0	2	100,0	0,381
	Normal	7	17,5	33	82,5	40	100,0	
	Hypernatremia	0	0,0	1	100,0	1	100,0	
Potassium Level	Normal	7	16,3	36	83,7	43	100,0	0,740
Chloride Level	Hypochloremia	1	100,0	0	0,0	1	100,0	0,240
	Normal	6	15,0	34	85,0	40	100,0	
	Hyperchloremia	0	0,0	2	100,0	2	100,0	
Nutritional Status	Underweight	4	100,0	0	0,0	4	100,0	0,038
	Normal	4	12,1	29	87,9	33	100,0	
	Overweight	3	60,0	2	40,0	5	100,0	
	Obese	0	0,0	1	100,0	1	100,0	

Oxygen Saturation

All respondents had an oxygen saturation level of 100%, making statistical testing between groups impossible. This finding aligns with prior studies showing that oxygen saturation tends to remain stable during physical activity owing to improved cardiovascular function and oxygen utilization.

Regarding oxygen saturation, all participants maintained an SpO_2 level of 100%, suggesting efficient respiratory and cardiovascular responses to physical exertion. This observation is consistent with the findings of Simanjuntak et al. (2016) and Rompas & Martín-Escudero et al. (2021), who showed that trained adolescents typically sustain or even improve oxygen saturation post-exercise due to improved ventilation-perfusion matching and increased oxygen extraction at the tissue level. While no statistical analysis could be performed owing to the uniformity of the data, this trend reinforces the notion that adolescent athletes are physiologically equipped to maintain oxygenation even under intense physical demands (Desbrow, 2021).

Although several associations were not statistically significant, the observed directional trends may have physiological relevance. For instance, mild deviations in serum sodium or chloride could indicate an underlying susceptibility to electrolyte shifts during prolonged or extreme exertion (Rowlands et al., 2022), which was not captured due to the limited exercise duration in this study. Moreover, the relatively small sample size could have reduced the power to detect subtle differences, underscoring the need for larger-scale investigations with extended follow-up and the inclusion of confounding variables such as hydration status, sweat rate, dietary intake, and hormonal markers.

Overall, the findings support the growing body of evidence indicating that adolescent athletes exhibit robust physiological adaptations to exercise, but may still benefit from structured monitoring of electrolyte status and nutritional outcomes, particularly when exposed to high-intensity training regimens.

Conclusion

The findings indicated that physical exercise intensity had no statistically significant effect on sodium, potassium, or chloride levels, nor on oxygen saturation, which remained consistently at 100% across all respondents. However, a significant association was observed between physical activity intensity and nutritional status, with higher-intensity levels corresponding to healthier body composition profiles. Adolescent athletes exhibit stable electrolyte regulation and oxygenation during physical activity, likely due to physiological adaptation and training exposure. However, the observed link between exercise intensity and nutritional status underscores the potential role of targeted physical activity in supporting optimal body composition during adolescence, which is a critical period for growth and metabolic development.

Several limitations must be acknowledged, including the relatively small sample size, cross-sectional design, and lack of control over confounding factors, such as hydration status, dietary intake, and hormonal fluctuations. These factors may limit the generalizability of the findings and constrain causal interpretations.

The practical implications of this research include the need for regular monitoring of nutritional status in adolescent athletes, especially those involved in high-intensity training. Coaches, educators, and healthcare providers should incorporate individualized hydration and nutrition strategies into youth sports programmers. Future research should consider longitudinal designs with larger, more diverse cohorts, and integrate additional biomarkers to better elucidate the physiological adaptations associated with adolescent athletic training.

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