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Correlation of energy intake and availability with aerobic endurance performance

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ABSTRACT

Futsal is a high-intensity intermittent sport demanding optimal aerobic endurance and adequate nutritional support, particularly for adolescent athletes during growth. This study aimed to determine the relationship between nutrient intake, energy availability (EA), and aerobic endurance among futsal athletes in Bandung. A total of 47 male athletes aged 13-21 years from Futsal 15 Bandung participated in this cross-sectional study. Data collection included three 24-hour food recalls for dietary intake, anthropometric measurements, and the Multistage Fitness Test (Beep Test) for estimating VO_2 max. Energy availability was calculated by subtracting exercise energy expenditure (EEE) from energy intake, normalized per fat-free mass (FFM). The results showed significant positive correlations between aerobic endurance, VO_2 max, and intake levels of energy ($p = 0.003$, $r = 0.427$), carbohydrates ($p = 0.003$, $r = 0.427$), protein ($p = 0.000$, $r = 0.514$), and fluids ($p = 0.002$, $r = 0.446$). However, no significant correlation was found between EA ($p = 0.700$) or fat intake ($p = 0.465$) and VO_2 max. Most athletes had low EA values (< 30 kcal/kg FFM/day), indicating potential nutritional risks. These findings highlight the importance of adequate macronutrient and fluid intake to support aerobic performance and professional nutritional intervention in athlete development programs.

Key words: Energy availability; nutritional intake; aerobic endurance performance.

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INTRODUCTION

Futsal is an indoor soccer game played by two teams, with each team consisting of five players (Stochi de Oliveira & Borin, 2021). This game requires players to have good physical qualities, in addition to mastery of techniques, strategies, and mental strength (di Fronso & Budnik-Przybylska, 2023). These physical qualities include endurance, speed, leg muscle strength, and agility (Imram et al., 2022). Endurance plays an important role as this ability allows players to stay fit and not tire easily when playing at high intensity and long duration (Zambak & Toktas, 2024).

Various studies reveal that the endurance of futsal players is still classified as less than optimal. Research at AFTA Tulungagung Futsal Club showed that players had low endurance, inadequate power, and moderate speed and agility (Novianti & Winarno, 2023). An evaluation of the SMK Nasional Malang team also showed that some players had below-average endurance (Mbadi et al.,

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2023). These findings confirm the importance of a targeted physical training program, particularly to improve endurance capacity (Haqiqi et al., 2022).

Improved endurance depends not only on proper training patterns, but also on adequate nutritional intake. Effective training requires appropriate dietary support in terms of the type, amount and timing of nutrient consumption (Hasanpouri et al., 2023; Zwaard et al., 2021). Before exercise, carbohydrate consumption is important for glycogen synthesis. During exercise, carbohydrates and electrolyte fluids are needed to maintain performance, while after exercise, protein plays a role in muscle recovery and repair (Ravindra et al., 2022). Several studies have also shown that adequate fluid intake and hydration play an important role in maintaining aerobic endurance and preventing performance decline during prolonged and high-intensity exercise. Several studies have also shown that adequate fluid intake and hydration status play an important role in maintaining aerobic endurance and preventing performance decline during prolonged and high-intensity exercise (Apriandi et al., 2023).

However, many athletes experience an imbalance between their high energy requirements and insufficient energy intake, leading to the condition of Low Energy Availability (LEA) (Mountjoy et al., 2018). LEA is common in endurance athletes due to the tendency to restrict energy intake to maintain body weight. This condition can result in decreased muscle strength and changes in lactate metabolism during competition (Jurov et al., 2022a).

As far as is concerned, the research that is directly examining the relationship between consumption levels and energy availability with aerobic endurance performance is limited. Most previous studies have focused on the impact of LEA on athletes' metabolic and reproductive health (Kettunen et al., 2023; Stellingwerff et al., 2019). Meanwhile, some studies only addressed the relationship between nutrient intake and performance in general without linking it to specific physical aspects such as aerobic endurance (Fernanda et al., 2021; Lee, 2024; Maulida et al., 2023; Rachma et al., 2024). Overall, existing studies have not adequately examined the direct relationship between nutrient intake, energy availability, and aerobic endurance performance, as research has mainly focused on health outcomes of low energy availability or general athletic performance rather than specific aerobic capacity.

Based on the Bandung standings data in the 2024 Futsal Championship, Futsal Club 15 Bandung was ranked as the club with the lowest total points. To date, this club has not received professional supervision related to nutritional intake. A preliminary survey conducted by the authors among 16 players of Futsal Club 15 Bandung revealed that 11 athletes had irregular eating patterns, 13 athletes did not receive guidance from a nutritionist and frequently consumed food from outside sources, and 15 athletes regularly consumed fast food and fried foods. These findings indicate that the dietary practices of futsal athletes

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still require improvement, considering the important role of sports nutrition in supporting athletic performance and physical activity (Sasmarianto & Nazirun, 2022).

Based on these findings and the limited research that examines the relationship between nutrient consumption and energy availability with aerobic endurance performance, this study was conducted to fill the gap. This study specifically aims to examine the relationship between the level of energy consumption and energy availability on aerobic endurance performance in Futsal Club 15 Bandung player.

METHOD

Research this study used a quantitative approach with a cross- sectional design to determine the relationship between the level of nutrient consumption and energy availability (EA) on aerobic endurance performance in futsal athletes. The research was conducted at the 15 Bandung Futsal Club located in Cimahi, West Java, for two weeks, from February 14-28, 2025.

The researcher used the Slovin formula to calculate the number of samples needed in this study, with a confidence level of 90% and a margin of error of 10%. Based on these calculations, the minimum number of samples needed is 41 athletes from the Bandung 15 Futsal Club. However, to anticipate the possibility of dropouts during the research process, the researcher added the number of samples to better suit the conditions in the field. Thus, the total sample used in this study was 47 futsal athletes and had participated in regional or national championships.

The types of data used are primary and secondary data. Primary data was obtained through interviews and direct measurements of athletes using a 3×24-hour food recall, identity questionnaire, height measurement using a stadiometer, body composition using a BIA Omron HBF-375, and implementation of the Beep Test. Secondary data in the form of membership data of Futsal Club 15 Bandung and other complementary documents. The instruments used include questionnaires, stadiometers, BIA tools, stopwatches, and cones as a barrier to the Beep Test area.

The data collected was analyzed using SPSS software version 21. Univariate analysis was performed to describe the variables studied. Bivariate analysis was performed with the Spearman Rank test to determine the relationship between energy consumption levels and EA on VO_2 max performance. The significance test was determined with a p value < 0.05. Calculations energy availability using the formula:

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$$\text{Energy Availability (EA)} = \frac{\text{Energy Intake (kcal)} - \text{Exercise Energy Expenditure (kcal)}}{\text{Fat Free Mass (kg)}}$$

Figure 1. Energy Availability Assessment Formula

Energy Availability (EA) refers to the amount of energy left to sustain bodily functions and physiological processes after accounting for the energy expended during training. It is determined by subtracting the energy used for training from total energy intake (EI= ((body weight x exercise duration (hours/day) x exercise frequency (1)) x (METS x intensity)), and then dividing the result by the individual's fat-free mass (FFM=Body Fat × (100 − %Body Fat)/100) in kilograms. Calculations VO_2 max Score using the formula:

$$VO_2 \text{ max} = 18.043461 + (0.3689295 \times \text{TS}) + (-0.000349 \times \text{TS} \times \text{TS})$$

Figure 2. VO_2 max Scoring Assessment Formula

VO_2 max calculation can be calculated using the following formula with a possible error of ± 0.3 mls/kg/minute where TS is the total shuttle for each player.

FINDINGS AND DISCUSSIONS

Findings

The average age of the respondents was 16.43 ± 1.95 years. The mean body weight of athletes was recorded at 56.73 ± 11.78 kg, with an average height of 164.74 ± 5.26 cm. Body mass index (BMI) had an average of 20.79 ± 3.86 kg/m², and body fat percentage showed an average value of 12.97 ± 5.11%. The average subject training duration was 2.2 ± 0.60 hours per day, with a training frequency of 4.02 ± 1.21 times per week. The athlete's coach reported the intensity of the exercise given was 80% at the time of data collection for 3 days.

Table 1. Overview of Athletes' Characteristics, Nutritional Requirements, and Energy Availability

Variable	Average±SD	Range
Age (years)	16.43 ± 1.95	13 – 21
Body weight (kg)	56.73 ± 11.78	43 – 99
Height (cm)	164.74 ± 5.26	155 – 176
Body Mass Index (BMI kg/m^2)	20.79 ± 3.86	15 – 33
Body Fat (%)	12.97 ± 5.11	6 – 26
Training duration (hour)	2.2 ± 0.60	1 – 3

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Training frequency (/weeks)	4.02 ± 1.21	2 – 7
Intensity of the exercise	80%	80 – 80
VO_2 max (mL/kg/min)	45.84 ± 4.37	34 – 56
Energy Intake (kkal/hari)	2024.93 ± 418.86	1003.8 – 3087.2
Exercise Energy Expenditure (EEE kkal)	476.51 ± 98.97	363.72 – 831.6
Energy Availability (EA kkal/kg FFM)	31.15 ± 8.53	15 – 48

VO_2 max values reflect moderate aerobic endurance capacity. Aerobic endurance performance was measured through VO_2 max values obtained from the Beep Test. The average VO_2 max value was 45.84 ± 4.37 mL/kg/minute. More than half of the athletes (57.4%) had aerobic performance in the moderate category. The athletes' Total Daily Energy Expenditure (TDEE) values were high, indicating their intense physical activity. The results showed that the average total daily energy expenditure (TDEE) in subjects was greater than the needs of adolescent males aged 13-19 years of 2400 and 2650 kcal (Permenkes RI, 2019).

Energy intake for athletes is represented through the Basal Metabolic Rate (BMR) and Total Daily Energy Expenditure (TDEE) values. The energy intake consumed by athletes has an average of 2024.93 ± 418.86 kcal/day. Meanwhile, the average Exercise Energy Expenditure (EEE) was recorded at 476.51 ± 98.97 kcal/day. Based on the calculation of Energy Availability (EA), an average value of 31.15 ± 8.53 kcal/kg FFM/day was obtained, which indicates that most athletes have not reached the ideal EA value.

Table 2. Overview of Athletes' Nutrient Consumption Levels and Energy Availability

Variables	Amount (n)	Percentage (%)
Energy Consumption	26	55.3%
	21	44.7%
Protein Consumption	26	55.3%
	21	44.7%
Fat Consumption	12	25.5%
	35	74.5%
Carbohydrate Consumption	26	55.3%
	21	44.7%
Water Consumption	28	59.6%
	19	40.4%
Energy Availability (EA)	41	87.2%
	6	12.8%

The results of consumption showed that as many as 55.3% of subjects had energy consumption below 90% of daily requirements (TDEE), and only 44.7% were sufficient. Similar conditions were found in protein and carbohydrate consumption, where 55.3% of respondents had insufficient consumption each. Fat consumption was mostly met, with 74.5% of respondents meeting daily

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requirements. In contrast, fluid consumption was still lacking in most athletes, with 59.6% of respondents not reaching 90% of daily requirements. In terms of Energy Availability, 87.2% of subjects recorded low EA values (< 30 kcal/kg FFM/day). This low result will certainly affect the athlete's performance.

Table 3. Relationship between Nutrition Consumption Level and Energy Availability with VO_2 max

Variable	p-value	$r_{corellation}$	Exp
Energy Consumption	0.003	0.427	Medium correlation
Protein Consumption	0.000	0.514	Medium correlation
Fat Consumption	0.003	0.427	Medium correlation
Carbohydrate Consumption	0.465	–0.109	Very weak correlation
Water Consumption	0.002	0.446	Medium correlation
Energy Availability (EA)	0.700	–0.058	Very weak correlation

There is a significant and positive relationship between energy, protein, carbohydrate and water consumption and aerobic performance as measured by VO_2 max. Unlike the other nutrients, the level of fat consumption did not show a significant relationship with aerobic endurance performance. This correlation was negative and very weak. The results showed no significant relationship between energy availability (EA) and aerobic performance. This is most likely due to the long term.

Discussion

This study involved 47 male adolescent futsal athletes with an age range of 13-21 years old from Futsal Club 15 Bandung. Most of whom are in an active growth period. Adolescence is an important phase in physiological and psychosocial development, which also affects physical performance. Accelerated growth in height and increased muscle mass during this period not only reflects biological maturity but also signals a surge in metabolic demand that must be matched by adequate nutritional intake (Sarfika et al., 2024).

Based on the American College of Sports Medicine (2018) categories, more than half of the subjects (59.6%) fell into the adequate body fat category for male athletes. However, to date, there is no definitive consensus on the ideal body fat percentage to achieve optimal health risks. An athlete body fat range of 10%-22% for male athletes and 20%-32% for female athletes has long been referenced as a range considered adequate to support general health (Riebe, 2018). Other research suggests that body fat percentage has a significant impact on athletic performance. A higher body fat percentage was negatively correlated with aerobic capacity (VO_2 max) in professional soccer players (Shabrina et al., 2022). In calculating EEE by indirect energy expenditure, it is necessary to know several things, including metabolic equivalent intensity levels (METs), training

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duration in a day, training frequency in a week, and current body weight (Supit et al., 2021).

Aerobic endurance performance was assessed using VO_2 max values obtained from the Beep Test, which reflect the body's ability to transport and utilize oxygen during prolonged and high-intensity physical activity. This capacity is one of the important indicators in assessing cardiorespiratory fitness, especially in soccer athletes who rely heavily on aerobic endurance during matches (Shabrina et al., 2022).

The athletes' Total Daily Energy Expenditure (TDEE) values were high, indicating their intense physical activity. The results showed that the average total daily energy expenditure (TDEE) in subjects was greater than the needs of adolescent males aged 13-19 years of 2400 and 2650 kcal (Permenkes RI, 2019). This high TDEE is consistent with the profile of adolescent athletes who undergo intensive and regular training and illustrates the need for adequate energy and nutrient intake to support optimal growth and performance (Pontzer et al., 2021).

An imbalance between TDEE and energy intake can lead to energy deficits that impact performance and long-term health. High energy expenditure without adequate energy intake can lead to Low Energy Availability (LEA), which risks metabolic and hormonal disturbances. Thus, an understanding of TDEE is essential in planning the nutritional needs of athletes, especially during the growing years of adolescence (Mountjoy et al., 2018).

Energy intake for athletes is represented through the Basal Metabolic Rate (BMR) and Total Daily Energy Expenditure (TDEE) values. Researchers compared the consumption of these nutrients with the needs of different athletes. Most of the subjects still had insufficient energy intake.

The analysis showed that the Energy Availability (EA) values of most respondents were below the recommended minimum (30 kcal/kg FFM/day), although the Exercise Energy Expenditure (EEE) calculation method was adjusted to avoid overestimation. This finding indicates that the low EA was mainly due to the low daily energy intake of the respondents. Low energy availability can affect aerobic performance indirectly through decreased muscle mass, hormonal imbalances and impaired recovery. If these conditions occur chronically, then adaptations to training, including improvements in VO_2 max, may be inhibited (Jurov et al., 2022b; Melin et al., 2019). Some studies show that long-term energy deficits can reduce cardiorespiratory performance, especially if not balanced with adequate nutritional intake (Wulansari et al., 2021).

Athletes who receive adequate and balanced nutrition tend to have better focus, more stable energy, and better mental performance when facing the challenges of training and competition (Sinaga et al., 2024). Sufficient nutritional

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intake is essential for optimal athletic performance, and athletes require specific guidance and monitoring to meet the recommended daily macronutrient needs necessary for success in sports (Irbatunnisa et al., 2025). Various studies have shown that inadequate protein intake can have a negative impact on athletes' fitness and performance. Adequate macronutrient intake, including protein, is essential for maintaining and improving athletes' physical fitness (Listianasari et al., 2022).

Fat consumption was mostly met, with 74.5% of respondents meeting daily requirements. Fat is an important source of energy for athletes, especially in prolonged training, and serves as a vitamin solvent and protector of vital organs (Sasmarianto & Nazirun, 2022). In contrast, fluid consumption was still lacking in most athletes, with 59.6% of respondents not reaching 90% of daily requirements. In terms of Energy Availability, 87.2% of subjects recorded low EA values (< 30 kcal/kg FFM/day). This low result will certainly affect the athlete's performance.

How effectively the heart, lungs, and blood vessels deliver oxygen throughout the body during prolonged physical activity is reflected in VO_2 max (Setyowati & Lani, 2024), which was assessed through the Multistage Fitness Test (Beep Test), a commonly used and validated method for estimating aerobic endurance performance and adolescents' aerobic fitness (Malau et al., 2025). Adequate energy consumption is also very important in supporting the work of the muscles and cardiovascular system during training and competition, as described by (Burke et al., 2011) and (Rachma et al., 2024). Adequate protein intake plays a role in muscle synthesis, post- exercise tissue recovery, and increased oxygen transport efficiency, which has an impact on increasing VO_2 max. This is reinforced by El Ghina et al. (2023) which states that protein intake is significant in increasing the aerobic capacity of athletes. In addition, carbohydrates as the main source of energy in high-intensity activities also show a positive relationship with aerobic performance, in line with research by (Jeukendrup & Gleeson, 2018). Fluid intake also contributes importantly to maintaining heart function, body temperature, and blood flow, so good hydration status can maintain and even increase VO_2 max, as revealed by (Hidayatulloh & Gandasari (2023).

Unlike the other nutrients, the level of fat consumption did not show a significant relationship with aerobic endurance performance. This correlation was negative and very weak. This can be explained through metabolic mechanisms, where fat tends to be a source of energy in light to moderate activities and does not dominate in high-intensity activities such as VO_2 max tests. Research by Fitrah and Putriningtyas (2024) also confirmed that fat consumption was not significantly correlated with VO_2 max. In addition, moderate fat intake does not

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appear to play a sufficient role in influencing aerobic capacity when compared to carbohydrates and protein.

The results showed no significant relationship between energy availability (EA) and aerobic performance. This is most likely due to the long term. Study design cross-sectional nature of the study design did not capture the long-term effects of low EA on aerobic capacity. Literature such as Mountjoy et al. (2018) and Loucks et al. (2011) explain that the negative effects of chronic energy deficits only become significant when they last for a long period of time, such as decreased muscle mass, hormonal disruption and poor recovery.

Other factors that may contribute to these results are the complexity of EA, which is influenced by many factors, such as energy intake and expenditure and individual metabolic status, as well as reporting bias or variation in estimation of energy expenditure during exercise. The limited number of participants with sufficient EA also influenced the results. Even so, the distribution of the data showed that many athletes experienced low EA, which deserves further attention.

Therefore, although most athletes in this study had low EA, it cannot be statistically concluded that there was a direct impact on VO_2 max. The data distribution still showed a tendency for athletes with sufficient EA to perform better, albeit in small numbers. This finding confirms the importance of adequate macronutrient fulfillment and hydration in supporting the aerobic performance of adolescent athletes, as well as the need for further evaluation of energy availability in futsal athletes. Thus, the focus of nutrition interventions should be on improving the adequacy of daily consumption and eating habits of athletes, especially during growth and intensive training (Jurov et al., 2022a; Melin et al., 2019).

This study has several limitations, including the use of a cross-sectional research design. Ideally, studies on energy availability (EA) should be conducted with a longitudinal approach to observe changes in energy intake and expenditure and their impact on athletes' performance and physiological status on an ongoing basis. In addition, the estimation of energy expenditure during exercise (EEE) was based solely on reports of frequency, duration and type of exercise provided by athletes and coaches, without the use of objective measurement tools such as the more accurate Polar heart rate monitor. The use of the 24-hour food recall method to collect food consumption data also relies on respondents' memory, which is prone to bias and recall errors.

CONCLUSION

This study shows that most athletes have adequate nutritional status, but the intake of energy, protein and carbohydrates is still below the needs, while the consumption of fat and liquid is relatively sufficient. The majority of athletes

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also experience low energy availability, which is caused by daily energy intake that is not optimal. The performance of most athletes was in the moderate category based on VO_2 max values. There were significant relationships between energy, protein, carbohydrate and fluid consumption levels and aerobic endurance performance, with protein intake showing the strongest correlation. However, no significant relationship was found between fat consumption and energy availability with aerobic performance. Thus, adequate consumption of certain macronutrients and hydration play an important role in supporting the aerobic performance of futsal athletes, while short-term energy availability has not shown a significant effect in the context of this study.

Futsal athletes are advised to improve their diet by avoiding irregular eating habits and adjusting their intake to the body's needs, including consumption of complex carbohydrates, animal protein, and a minimum of 2-3 liters of fluid per day. It is advisable to work with a nutritionist so that athletes can consult regularly for nutritional evaluation according to training intensity. For future researchers, this study can be developed with a longitudinal approach, using intensity measurement tools such as heart rate monitors or fitness trackers, as well as more accurate nutritional assessment methods such as food weighing, so that the relationship between energy availability and physiological performance can be analyzed more comprehensively.

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