nutrición clínica y Dietética Hospitalaria

Artículo Original

Nutr Clín Diet Hosp. 2025; 45(3):296-304
DOI: 10.12873/453hamid

The potential of local fish-based snacks to improve the performance of adolescent football school students in Ternate city

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Recibido: 15/julio/2025. Aceptado: 12/septiembre/2025.

ABSTRACT

Background: Adolescents require comprehensive and balanced nutrition to support their growth, development, and physical activities.

Objective: This study aimed to evaluate the impact of a snack intervention utilizing mackerel scad (*Decapterus sp.*) and tuna liver on body composition, hemoglobin (Hb) levels, and VO_2max in male adolescents.

Methods: Employing a *one-group pretest-posttest* design, the study included 32 male adolescents aged 13–15 from two soccer schools, who were randomly selected from a pool of 134 screened subjects. The intervention snack, provided three times weekly over a 10-week period, had a nutritional composition per 90 grams of: 194.99 kcal of energy, 15.09 grams of protein, 14.81 grams of carbohydrates, 6.21 grams of total fat, 3.09 grams of iron, and essential amino acids. Food intake was assessed using a *24-hour food recall*, body composition with Bioelectrical Impedance Analysis (BIA), Hb levels via the cyanmethemoglobin method, and VO_2max with the Cooper Test. All data were analyzed using IBM SPSS version 25.

Results: Muscle mass increased significantly from 14.32% to 16.86% (p=0,001 <0,05), representing a 17.79% gain. Hemoglobin levels also rose from 11.37 g/dL to 11.93 g/dL (p=0.03 < 0,05), a 4.92% increase. Furthermore, VO_2max saw a notable improvement, increasing from 36.93 mL/kg/min to 41.84 mL/kg/min (p=0.001< 0,05), or a 13.29% gain. Conversely, a significant increase in fat mass was also observed, rising from 14.86% to 15.75% (p=0.04 <0,05), which corresponds to a 5.99% increase.

Conclusion: The local fish-based snack intervention significantly impacted body composition, hemoglobin levels, and VO_2max of adolescent football players.

KEYWORDS

Adolescent Athletes, Aerobic Endurance, Functional Snacks, Iron, Nutritional Interventions.

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INTRODUCTION

Nutritional problems among adolescents are primarily caused by insufficient food intake, poor dietary quality, and low levels of physical activity, which are the dominant factors contributing to malnutrition in this age group[1]. In Indonesia, the prevalence of stunting (short stature) and underweight remains high among adolescents aged 13-15 years, recorded at 24% and 7.5%, respectively. In North Maluku, the same prevalence rates are observed, 24% for stunting and 7.5% for underweight[2].

Malnutrition issues such as inadequate nutrient intake, anemia, and impaired growth are still frequently found among children attending Football Schools *(in Indonesia: Sekolah Sepak Bola/SSB)* across Indonesia. For example, a study at Ganesha Putra Football School in Purwodadi, Semarang, reported that 41% of the children had inadequate protein intake[3]. Similarly, a study conducted at a boarding Football Training and Education Center *(In Indonesia: Sekolah Sepak Bola-Pusat Pendidikan dan Latihan Pelajar/SSB-PPLP)* showed energy macronutrient intake deficiencies; carbohydrates, fats, and proteins were all below adequate levels by 81.2%. In another case, Tugu Muda Football School in Semarang recorded inadequate intake in 93.8% of students for carbohydrates, 75% for fats, and 87.5% for proteins[4]. Furthermore, hemoglobin measurements among football athletes in Sleman Regency, Yogyakarta, revealed that 29.7% suffered from anemia[5].

These data highlight the ongoing nutritional challenges faced by adolescent football students in Indonesia. If left unaddressed, such deficiencies may impair physical growth and athletic performance. Carbohydrates, fats, and proteins are essential energy-yielding nutrients[6] and serve as key substrates for muscle energy metabolism during physical activity[7]. Addressing these nutritional gaps is essential for optimizing the growth and performance of adolescents engaged in high physical activity, particularly in structured sports environments such as football schools.

Adolescents require adequate protein and amino acids to support tissue growth and to increase insulin-like growth factor I (IGF-I) levels, which stimulate endochondral ossification for normal linear growth[8]. Sufficient intake of carbohydrates, fats, proteins, iron, and high-quality nutrients is essential to ensure optimal physical development, endurance, and VO_2max capacity in adolescent football school students, key physiological components for young athletes.

Nutritional interventions are a crucial short-term strategy to address growth-related deficiencies in adolescents, particularly through the provision of nutrient-rich supplementary foods. Snack products formulated as sources of key nutrients can help fulfill the unmet nutritional needs of this population. The development of fish-based snack products is one approach to improve dietary variety and prevent consumption fatigue among adolescents[9].

In Indonesia, early talent scouting and athlete development are mandated by the national government (Peraturan Pemerintah Pusat No. 95 2017), emphasizing the importance of early interventions across multiple domains, including nutrition. Improving adolescent athletes' nutritional status can be a measurable and strategic component of early athletic development.

This study aims to examine the effects of a snack intervention made from locally sourced mackerel scad *(Decapterus sp.)*, enriched with tuna liver, as a supplementary source of energy, fat, protein, and iron. Specifically, the research investigates the impact of this intervention on body composition, hemoglobin levels, and VO_2max in adolescent football school students in Ternate City.

METHODS

This study employed a quasi-experimental design using a one-group pretest–posttest approach[11]. The research was conducted between August and October 2024 at two football schools in Ternate City: Indonesia Muda (IM) and Tunas Gamalama/Mayoma. Ethical clearance for the study was granted by the Ethics Committee of the Health Polytechnic of the Ministry of Health in Semarang, under approval number 0188/EA/KEPK/2024. Informed consent was obtained from the parents of all participating children, and the children provided their voluntary assent to participate.

The sample size was calculated based on data from a previous study, which reported a mean post-intervention body weight (X_1) of 45.75 kg and a control value (X_2) of 40.73 kg with a standard deviation (S_2) of ±10.4 [12]. The calculation used a two-tailed $Z\alpha$ of 1.96, a $Z\beta$ of 0.84 (β = 20%), and a significance level (α) of 5%, providing a statistical power of 80%. Based on these parameters, a minimum of 26 participants aged 13–15 years was required. To anticipate possible dropout, an additional 20% (5 participants) was included, resulting in a total sample of 32 subjects. The study involved 32 male adolescents aged 13–15 from two soccer schools who met the inclusion and exclusion criteria, who were randomly selected from a pool of 134 screened subjects.

The study subjects were selected using strict inclusion and exclusion criteria. Inclusion criteria required participants to be (a) male adolescents aged 13–15 enrolled in soccer schools; (b) actively involved in weekly training sessions; (c) willing to volunteer for and complete the study; (d) have low hemoglobin (Hb) levels (<12 g/dL for ages 13–14 and <13 g/dL for age 15); and (e) have a physical fitness level rated as very poor, poor, or moderate based on initial screening. In contrast, subjects were excluded if they had (a) a history of cardiovascular or pulmonary diseases, or (b) an allergy to fish or any food ingredients in the study snack.

The snack intervention consisted of a formulation containing 90 grams per portion and was administered three times per week for 10 weeks. Each portion provided approximately 14.81 grams of carbohydrates, 6.21 grams of total fat, 194.99 kcal of energy, 15.09 grams of protein, 3.09 mg of iron, and essential amino acids including 0.54 grams of isoleucine, 0.96 grams of lysine, and 0.90 grams of valine.

The snack product, formulated from mackarel scad fish *(Decapterus sp)* (locally known as *ikan layang*) enriched with tuna liver, was prepared weekly to minimize the risk of food safety issues. The snacks were served warm. Parents are asked to ensure no food is given to the children two hours before and after practice. Concurrently, coaches and assistant coaches are to help monitor the children's food consumption during practice for the duration of the research.

The intervention was administered to youth football players aged 13-15 years, 60 minutes after training sessions. Post-exercise protein intake has been shown to be more effective for enhancing muscle protein synthesis[13]. The snacks were provided three times per week for 10 consecutive weeks[14]. To ensure the quality and consistency of consumption, participants were required to consume the snack at the training location under supervision.

Demographic data, including age, sex, and training frequency, were collected through interviews. Nutrient intake was assessed using 2×24-hour dietary recalls covering one regular day and one non-training day, collected via structured interviews. Using the food composition conversion table from the Ministry of Health of the Republic of Indonesia, daily consumption data from a 2x24-hour recall is converted into grams to calculate nutritional values.

Body composition was measured using a Bioelectrical Impedance Analyzer (BIA) scale (InBody Dial) and a Microtoise stadiometer, employing standard anthropometric procedures. Prior to a medical examination, soccer school students who fast and decrease their physical activity are given a three-day rest period to restore their bodies to a normal state. Body weight and height are measured in the morning. Hemoglobin levels were assessed using the Cyanmethemoglobin photometric method at Nita Medical Laboratory. VO_2max was measured using the Cooper 2400-meter run test, and the results were converted into estimated VO_2max values using standard conversion formulas. This method, validated and supervised by expert athlete physical development coaches, is tested in the morning on a 320-meter track.

Data were processed using Microsoft Excel and IBM SPSS version 25. Prior to analysis, the data underwent coding, entry, and cleaning procedures to ensure accuracy. Quantitative data were analyzed using both univariate and bivariate methods to describe frequency distributions, means, and standard deviations (SD) for each variable.

Body mass and hemoglobin levels were compared against standard reference values. VO_2max was estimated using the Cooper 2400-meter run test and calculated using the formula: $VO_2max = (483 / \text{time in minutes}) + 3.5$

To evaluate the effect of the mackarel scad fish and tuna liver-based snack intervention, statistical comparisons between pre- and post-intervention values were conducted. Data normality was assessed using the Shapiro-Wilk test. For normally distributed data, the paired samples t-test was applied, while the Wilcoxon signed-rank test was used for data that did not meet normality assumptions.

RESULTS AND DISCUSSION

Participant Characteristics and Nutrient Intake

Performance outcomes in this study were assessed through two main indicators: body composition (muscle mass and body fat mass) and fitness (hemoglobin levels and VO_2max capacity). The characteristics of study participants are presented in Table 1. A total of 32 adolescent male participants aged 13 to 15 years were recruited from two football schools in Ternate City based on inclusion criteria.

Table 1. Baseline characteristics of adolescent soccer players participating in the intervention with fish snack in Ternate (n = 32)

Variable	Min-Max	Mean±SD
Age (years)	13–15	13.19 ± 0.47
Muscle mass (%)	10.20–18.90	14.32 ± 2.38
Body fat mass (%)	9.50–19.30	14.84 ± 2.38
Hemoglobin (g/dL)	10.50–12.40	11.37 ± 0.39
VO_2max (ml/kg/min)	30.00–44.00	36.59 ± 4.58

The average muscle mass of participants was 14.32 ± 2.38%, ranging from 10.20% to 18.90%, while body fat mass averaged 14.84 ± 2.38%, with a range of 9.50% to 19.30%. Hemoglobin levels ranged from 10.50 to 12.40 g/dL, with a mean value of 11.37 ± 0.39 g/dL, indicating mild anemia in several participants. The average VO_2max was 36.59 ± 4.58 ml/kg/min, placing participants in the "below average" fitness category for this age group (Table 1).

Based on the two-day dietary recall results presented in Table 2, the nutritional adequacy levels of the adolescent football players revealed significant deficiencies in several key nutrients. Carbohydrate intake ranged from 47.30% to 92.69% of the recommended dietary allowance (RDA), with a mean adequacy of 72.48 ± 11.60%. For this age group, the recommended daily intake of carbohydrates is 350 grams[15].

Table 2. Nutritional intake and percentage adequacy with respect to dietary recommendations in adolescent soccer players (based on 24-hour reminders)

Variable	Min-Max	Mean±SD
Carbohydrates (g)	165.55–324.29	253.70 ± 40.60
Fat (g)	41.28–68.41	54.35 ± 6.63
Protein (g)	44.28–63.04	55.19 ± 5.45
Energy (kcal)	1,468–2,240	1,897 ± 188.97
Iron (mg)	8.03–10.89	9.66 ± 0.82
% RDA Carbohydrates	47.30–92.69%	72.48 ± 11.60
% RDA Fat	51.60–90.05%	67.94 ± 8.29
% RDA Protein	63.26–90.05%	78.85 ± 7.78
% RDA Energy	61.18–93.33%	79.04 ± 7.87
% RDA Iron	72.95–98.98%	87.85 ± 7.46

These data indicate a carbohydrate deficit of approximately 27.58%, which could impair energy availability for high-intensity physical activity and recovery.

Fat intake ranged from 63.26% to 90.05% of the RDA, with a mean adequacy of 67.94 ± 8.29%, showing a moderate shortfall from the expected intake. Protein adequacy ranged between 63.26% and 90.05%, with an average of 78.85 ± 7.78%. This suggests a protein deficit of 21.15%, equivalent to approximately 14.81 grams per day. Previous study found that adolescent athletes require between 1.2 and 2.0 grams of protein per kilogram of body weight to support muscle development and exercise recovery, reinforcing the importance of addressing this gap[16]. The average energy intake covered only 79.04 ± 7.87% of the RDA, with values ranging from 61.18% to 93.33%, reflecting a substantial energy deficiency of 20.96%. Iron intake ranged from 72.95% to 98.98% of the RDA, with a mean of 87.85 ± 7.46%, indicating an average deficit of 12.15%. Suboptimal iron intake is particularly concerning given its role in oxygen transport and aerobic capacity, both of which are critical for athletic performance.

To address these nutritional inadequacies, a protein- and iron-rich snack was developed as part of this intervention. The snack was formulated using locally sourced, nutrient-dense ingredients including mackarel scads *(Decapterus spp.)*, chicken eggs, and tuna liver, which are known for their high protein and micronutrient content[17]. The final product contained 18.69 grams of protein per 100 grams. The protein content was primarily derived from layang fish (22 g/100 g), tuna liver (5.65 g/50 g), and chicken eggs (6.2 g/30 g), contributing significantly to the overall nutritional value of the snack.

As a protein source, the snack contributed 34.18% of its total caloric content from protein, approaching the 35% benchmark required to be classified as a "high-protein food" according to Indonesia's National Agency of Drug and Food Control[18]. Although it fell slightly short of the threshold, the snack can still be considered a functionally significant protein-rich product, especially suitable for adolescent athletes who have increased protein needs.

In addition to its protein content, the snack also provided a meaningful amount of iron, measuring 3.49 mg per 100 grams. The iron content was contributed by all three main ingredients: layang fish (2 mg/100 g), chicken eggs (3 mg/30 g), and tuna liver (0.45 mg/50 g). Other minor ingredients such as flour and seasonings also contributed to the total iron content. Based on these values, the snack was calculated to contribute more than 15% of the daily iron RDA, qualifying it as a source of iron-rich food in accordance with BPOM regulations[18].

Table 3 presents the macronutrient and micronutrient composition of the developed snack formulated with layang fish (Decapterus spp.). The carbohydrate content ranged from 400.19 to 493.83 grams, with a mean intake of

Table 3. Average Nutritional Composition of Snacks Made With (Decapterus Sp) Enriched With Tuna Liver

Variable	Range	Mean ± SD
Carbohydrate (g)	400.19–493.83	471.31 ± 31.33
Fat (g)	167.16–206.28	196.87 ± 13.08
Protein (g)	408.94–504.63	481.61 ± 32.01
Energy (kcal)	4741–5850	5583 ± 371
Iron (Fe, mg)	76.36–94.23	89.93 ± 5.97
Isoleucine (g)	13.01–16.05	15.31 ± 1.01
Lysine (g)	23.39–28.86	27.54 ± 1.83
Valine (g)	21.81–26.92	25.69 ± 1.70

471.31 ± 31.33 grams. Fat content varied from 167.16 to 206.28 grams, averaging 196.87 ± 13.08 grams. The protein content was notably high, ranging between 408.94 and 504.63 grams, with a mean of 481.61 ± 32.01 grams. Energy content spanned from 4,740.52 kcal to 5,849.82 kcal, with an average of 5,583.05 ± 371.17 kcal.

In terms of micronutrients and essential amino acids, the snack was found to contain iron (Fe) in amounts ranging from 76.36 to 94.23 mg, with a mean of 89.93 ± 5.97 mg. The isoleucine content ranged from 13.01 to 16.05 grams (mean 15.31 ± 1.01 g), lysine ranged from 23.39 to 28.86 grams (mean 27.54 ± 1.83 g), and valine ranged from 21.81 to 26.92 grams (mean 25.69 ± 1.70 g). These values indicate that the snack is not only energy- and protein-dense but also rich in key amino acids and iron, which are essential for adolescent growth, muscle development, and oxygen transport.

The effects of the intervention on body composition, hemoglobin levels, and VO_2max are illustrated in tabel 4 and Figure 1. After consuming the intervention snack over the study period, participants showed a significant improvement in muscle mass. The percentage of muscle mass increased from a range of 12.10% to 20.80%, with a mean of 14,32±2,38% to 16.86 ± 2.41% and a net gain of 2.55%. Statistical analysis confirmed that this change was significant ($p = 0.00^{(a*)} < p\ 0.05$), indicating a positive impact of the protein-rich snack on muscle development.

A slight but statistically significant increase was also observed in fat mass percentage, which rose from 11.60% to 18.90%, with a post-intervention mean of 14,84±2,38 to 15.75 ± 1.94% and a mean difference of 0.91%. This change was statistically significant ($p = 0.04^{(a*)} < 0{,}05$), although the increase in fat was within acceptable physiological limits and may reflect im-

Table 4. Body composition, hemoglobin) and VO_2max, children of the Football School in Ternate City before and after the intervention

Variabel	Before Mean±SD	After Mean ±SD	*Δ(e-b)*	*P*
Muscle mass(%)	14,32±2,38	16,86±2,41	2,55	0,00[a*]
Fat mass (%)	14,84±2,38	15,75±1,94	0,91	0,04[a*]
Hemoglobin (gr/dL)	11,37±0,39	11,93±0,54	0,56	0,03[a*]
VO_2max (ml/Weight/minute)	36,59±4,58	41,31±4,01	4,72	0,00[b*]

Average±SD, difference (e-b), paired samples t-test([a*]) and Wilcoxon Signed Ranks Test results([b*]). *different ($p<0.05$).

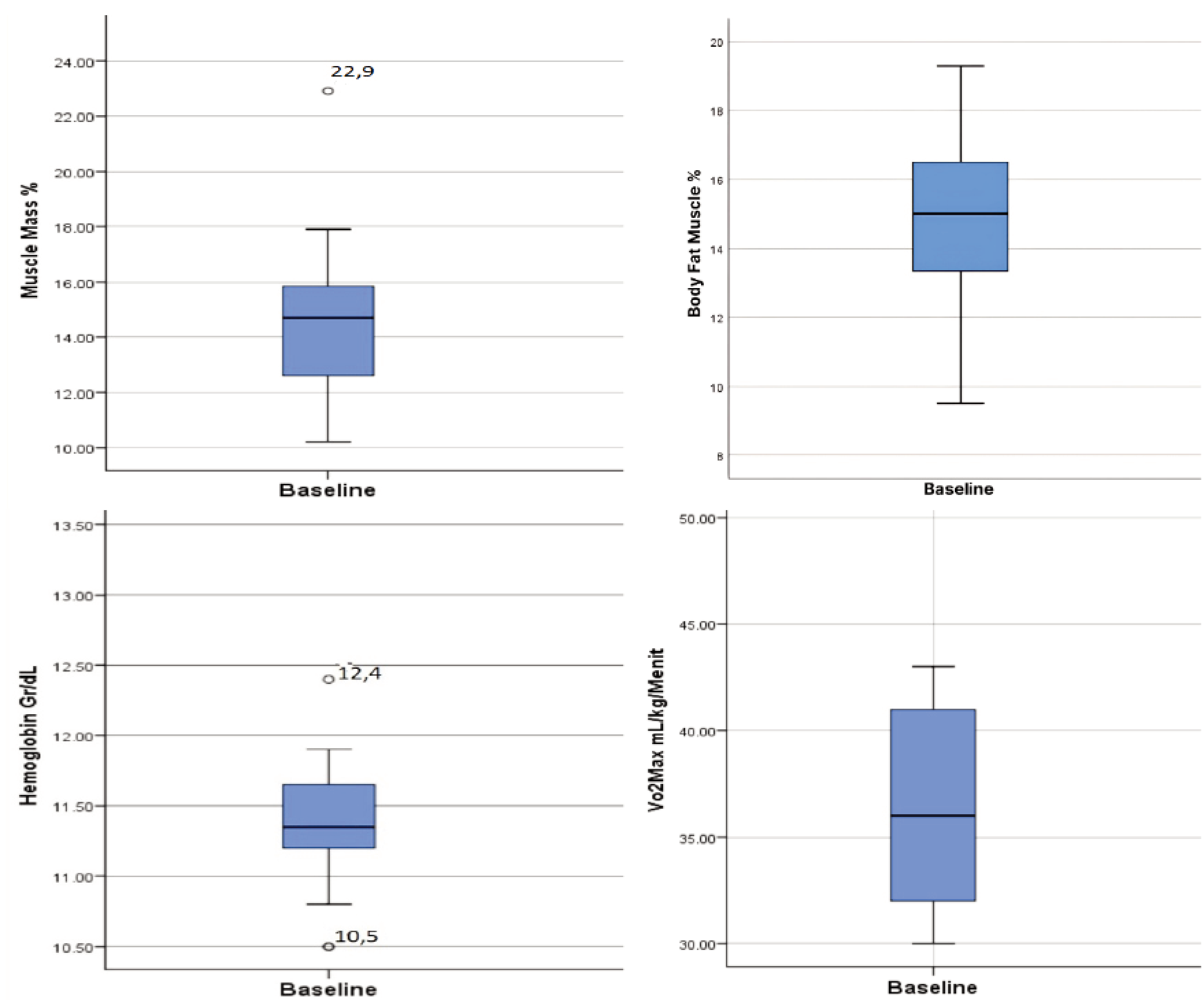

Figure 1. Impact of intervention on muscle mass, body fat muscle, hemoglobin, and VO_2max

proved energy balance in undernourished adolescent athletes. Hemoglobin levels also improved post-intervention, rising from 11.30 g/dL to 13.10 g/dL, with an average of 11,37±0,39 to 11.93 ± 0.54 g/dL and a mean increase of 0.56 g/dL. This improvement was statistically significant ($p = 0.03^{(a*)} < 0,05$), suggesting the snack's iron content was sufficient to support hematological status, potentially enhancing oxygen-carrying capacity. Furthermore, the intervention led to a significant improvement in aerobic capacity as measured by VO_2max. Values increased from 35 to 47 ml/kg/min, with an average post-intervention VO_2max of 36,59±4,58 to 41.31 ± 4.01 ml/kg/min and a net increase of 4.72 ml/kg/min. The statistical test yielded a significant difference ($p = 0.02^{(b*)} < 0,05$), indicating enhanced cardiorespiratory fitness, which may be attributed to the improved intake of energy, protein, and iron all of which play roles in endurance and performance.

Impact of Snack Consumption on Body Composition

Adequate energy intake, primarily from quality carbohydrates, is crucial for meeting the body's energy demands. When energy needs are not met, the body may catabolize other macronutrients, such as fat and protein, for energy, potentially leading to a decrease in muscle mass, particularly in adolescents[19]. In this study, the percentage of muscle mass increased from an average of 14.32±2.38% before intervention to 16.86±2.41% after. The intervention resulted in a 17.79% increase. While this represents a positive increase, the ideal muscle mass for adolescent football players is typically in the range of 30% to 40% of body weight[20]. Despite the current muscle mass of participants (16.86% of body weight) still being below this ideal, the observed positive trend indicates ongoing improvement.

The essential amino acids, such as leucine, isoleucine, and valine, provided by the snacks are crucial for protein synthesis and the formation of new muscle cells[21]. The snack intervention delivered average intakes of isoleucine (15.31±1.01 grams), lysine (27.54±1.83 grams), and valine (25.69±1.70 grams) (Table 3). These amino acids are utilized by the body to synthesize Insulin-like Growth Factor 1 (IGF-1). In muscle tissue, IGF-1 promotes protein synthesis and muscle regeneration by stimulating the differentiation and proliferation of muscle satellite cells, which are vital for muscle mass growth and tissue repair following injury. Consequently, IGF-1 contributes significantly to the development and maintenance of healthy muscle[8].

The protein derived from the fish, egg, and tuna liver-based snacks, in particular, appears to have effectively contributed to increased muscle mass in the young football players. Beyond protein, the iron (Fe) content of the snacks also played a significant role. Iron is essential for the formation of hemoglobin, which facilitates oxygen transport to all body tissues for metabolic processes. Hemoglobin profoundly impacts the formation of body cells, especially muscle cells[22]. Conversely, the percentage of body fat mass increased to 15.75±1.94% after the intervention. The intervention resulted in a 5.99% increase. This finding places the body fat mass of the football academy students above the maximum standard for adolescent football players, which typically ranges from 10−15% of body weight[20]. While the body utilizes fat as an energy source during prolonged physical activity, contributing to increased muscle mass and a more ideal body composition[23], an indirect relationship exists between iron and fat metabolism. Iron deficiency can reduce the body's capacity to efficiently burn fat, potentially leading to an increase in fat mass.

Impact of Snack Consumption on Hemoglobin Levels

The average protein intake of 481.61±32.01 grams over 10 weeks significantly increased hemoglobin levels. A mean increase of 0.53 g/dL was observed, with post-intervention hemoglobin levels averaging 11.93±0.54 g/dL. The intervention resulted in a 4.92% increase. This improvement is directly linked to the protein content in the snacks, as protein plays a crucial role in hemoglobin synthesis. Specifically, the globin component of protein directly binds with iron to form hemoglobin[24]. Proteins like transferrin and ferritin are also essential for iron transport. A deficiency in these proteins can hinder iron transport, leading to reduced hemoglobin levels and potentially iron deficiency[25].

Protein is integral to hemoglobin formation, serving as its primary structural component. Hemoglobin comprises four polypeptide chains, known as globin (typically two alpha and two beta chains in adults), which are all types of protein. These globin chains are synthesized from amino acids derived from dietary protein intake and then fold into a three-dimensional structure that forms the "framework" of hemoglobin. Each globin chain contains a heme group, which holds an iron atom. The globin protein supports and protects this heme group, enabling hemoglobin to reversibly bind and release oxygen. Without an adequate supply of protein, the body cannot produce sufficient globin chains, thereby inhibiting the formation of complete and functional hemoglobin molecules, which can lead to a decrease in hemoglobin levels.

The intervention, which included an average iron (Fe) intake of 89.93±5.97 mg over 10 weeks, also contributed to increased hemoglobin. While this amount improved hemoglobin levels, the effect may not be maximal within a short timeframe. Studies suggest that an iron intervention of 5 mg administered over three to six months can effectively increase and improve hemoglobin levels[26]. Within the body, iron is a critical component of hemoglobin formation, with its primary role in the heme group, the non-protein part of hemoglobin that binds oxygen.

The iron content from scads and tuna liver in the form of heme iron is significantly more effective in hemoglobin formation due to its high bioavailability and efficient absorption mechanism. Heme iron is absorbed intact by intestinal cells through specific pathways without requiring modification. Once heme iron is available, the body utilizes it for hemoglobin synthesis in the bone marrow. This is because the iron atom is the central component of the heme group, which then binds to globin proteins to form a functional hemoglobin molecule. This efficiency of absorption and direct utilization makes heme iron consumption highly effective in increasing blood hemoglobin levels in school-aged football players. The iron in the snacks serves as a supplementary source to iron obtained from staple foods, aiding in meeting the body's iron requirements. The significant increase observed was also partly due to improved consumption of staple foods by the children, facilitated by their parents.

Impact of Snack Consumption on VO_2max

The protein intervention from the snacks indirectly enhanced the VO_2max capacity in the football academy students. Protein contributes to hemoglobin formation, which is vital for transporting oxygen from the lungs to all tissues. Additionally, protein supports muscle adaptation, tissue repair, and metabolic efficiency, all of which facilitate an increase in VO_2max through sustained and appropriate training[27]. Following the intervention, participants showed an average increase of 4.72 mL/kg/minute, reaching a mean VO_2max of 41.31±4.01 mL/kg/minute. The intervention resulted in a 13.29% % increase. This improvement is attributable to the positive effects of protein and amino acids sourced from fish, eggs, and tuna liver.

Beyond protein, the iron intervention of 89.93±5.97 mg directly influenced VO_2max. Iron plays a crucial role in oxygen transport via hemoglobin, oxygen storage in muscles through myoglobin, and oxygen utilization in the mitochondria by respiratory enzymes. Iron deficiency can diminish the body's capacity to use oxygen efficiently, leading to a decrease in VO_2max, even if the lungs and heart are healthy[28].

The observed increase in VO_2max capacity is directly linked to the improvement in hemoglobin levels among the football academy students. Hemoglobin is critical for boosting VO_2max because it directly determines the body's capacity to transport and deliver oxygen to working muscles during physical activity. VO_2max, the maximum amount of oxygen the body can utilize per minute, is highly dependent on oxygen availability. Hemoglobin, found in red blood cells, serves as the primary transporter for this oxygen. Each hemoglobin molecule binds four oxygen molecules in the lungs, meaning higher hemoglobin levels allow for more oxygen to be bound and transported from the lungs to muscle tissues. During intense and prolonged muscle contractions, a constant and abundant oxygen supply is crucial for generating energy through aerobic metabolism.

An increase in hemoglobin levels allows for more oxygen to be delivered per unit of time to muscle mitochondria. This higher oxygen availability enables muscles to sustain aerobic energy production at higher intensities and for longer durations, thereby enhancing overall VO_2max [29].

CONCLUSION

This study observed significant increases in muscle mass, fat mass, hemoglobin levels, and VO_2max capacity following the intervention. The administration of snacks made from mackerel scads *(Decapterus sp.)* with added tuna liver had a significant positive impact on these body composition and physiological parameters.

RECOMMENDTIONS

Based on these findings, these snacks can serve as a valuable source of protein and iron, meeting a percentage of the Recommended Dietary Allowance (RDA) to support the nutritional adequacy of school-aged football players. Further research with a larger sample size and extended intervention period is recommended to explore the long-term effects on muscle mass, total muscle weight, and hemoglobin in anemic, underweight toddlers.

STRENGTHS

A key strength of this study is that the 90-gram intervention snack, made from fish with added tuna liver, contributed 26.5% of the daily protein and 25.75% of the daily iron requirements for school-aged football players aged 13-15 years, supplementing their main meals.

LIMITATIONS

A limitation of this study was a primary weakness of the study is its quasi-experimental one-group pre-test-post-test design, as it lacks a control group. The inability to fully control and monitor the subjects' dietary patterns, as all participants resided with their parents rather than being centrally housed.

ACKNOWLEDGMENTS

The researchers extend their gratitude to the Ministry of Health and PT Antam Tbk (North Maluku Branch) for their financial support of this research.

REFERENCES

1. UNICEF. Communication Strategies for Social and Behavioral Change: Improving Adolescent Nutrition in Indonesia. Unicef [Internet]. 2021; 1–66. Available from: https://sl1nk.com/yPRrS
2. Ministry of Health 2023. In numbers in numbers. Ski Lap of the Ministry of Health of the Republic of Indonesia [Internet]. 2023; 1–908. Available from: https://l1nk.dev/2uD1U

3. Sa'adah U, Hardiansyah A, Darmuin D. The Relationship between Nutritional Knowledge and Macronutrient Intake with the Physical Fitness Level of Football Athletes at SSB Ganesha Putra FC Purwodadi. J Indonesian Nutrition Science [Internet]. 2023; 4(1). Available from: https://jurnal.umitra.ac.id/index.php/JIGZI/article/view/1026

4. Dieny FF, Widyastuti N, Fitranti DY, Tsani AFA, J FF. Nutrient intake profiles, nutritional status, and hydration status are related to the performance of Football School Athletes in Semarang City. Indonesian J Hum Nutr [Internet]. 2020; 7(2):108–19. Available from: https://ijhn.ub.ac.id/index.php/ijhn/article/view/358

5. Listianasari Y. Fe Intake, Hb and Vo2Max Levels in Football Athletes in Sleman Regency Yogyakarta. Nutr J Food, Nutrition, Health [Internet]. 2020; 1(2):35–41. Available from: https://ejournal.poltekkes-pontianak.ac.id/index.php/PNJ/article/view/919/404

6. Podlogar T, Wallis GA. New Horizons in Carbohydrate Research and Application for Endurance Athletes. Sport Med [Internet]. 2022;52(s1):5–23. Available from: https://doi.org/10.1007/s40279-022-01757-1

7. Henselmans M, Bjørnsen T, Hedderman R, Vårvik FT. Henselmans, M.; Bjørnsen. T,; Hedderman R i wsp. The Effect of Carbohydrate Intake on Strength and Resistance Training Performance: A Systematic Review 2022. [Internet]. Vol. 14, Nutrients. 2022. Available from: https://pubmed.ncbi.nlm.nih.gov/35215506/

8. Inzaghi E, Pampanini V, Deodati A, Cianfarani S. The Effects of Nutrition on Linear Growth. Nutrients [Internet]. 2022;14(9):1–12. Available from: https://pubmed.ncbi.nlm.nih.gov/35565716/

9. Putri MP, Dary D, Mangalik G. Protein Intake, Iron and Nutritional Status in Adolescent Women. J Nutr Coll [Internet]. 2022; 11(1):6–17. Available from: https://ejournal3.undip.ac.id/index.php/jnc/article/view/31645

10. Central Government. Presidential Decree No. 95 concerning the improvement of national sports achievements. 2017; 1–15. Available from: https://setkab.go.id/wp-content/uploads/2017/10/Perpres-Nomor-95-Tahun-2017.pdf

11. Ratnawati M, Probowati R, Sawitri Prihatini M, Ningtyas SF, Ulfa AF. Feeding Modified Supplementary Feeding on the Nutritional Status of Toddlers. J Heal Science [Internet]. 2023; 4(2):104–11. Available from: http://www.jasapublishjurnal.com/jurnal.healthsains.co.id/index.php/jhs/article/view/801

12. Fauziah F, Kusharto CM, Setiawan B. Effect of high protein milk administration and compliance level on weight gain and nutritional status of children aged 15-17 years. AcTion Aceh Nutr J [Internet]. 2022; 7(1):41. Available from: https://ejournal.poltekkesaceh.ac.id/index.php/an/article/view/532

13. Van Loon LJC. Role of dietary protein in post-exercise muscle reconditioning. Nestle Nutr Inst Workshop Ser [Internet]. 2013;75:73–83. Available from: https://pubmed.ncbi.nlm.nih.gov/23765352/

14. Alhussain MH, ALshammari MM. Association Between Fish Consumption and Muscle Mass and Function in Middle-Age and Older Adults. Front Nutr [Internet]. 2021;8(December):1–8. Available from: https://pubmed.ncbi.nlm.nih.gov/34966766/

15. Ministry of Health. Ministry of Health of the Republic of Indonesia, 2019 [Internet]. Vol. 1, Duke Law Journal. 2019. Available from: http://hukor.kemkes.go.id/uploads/produk_hukum/PMK_No__28_Th_2019_ttg_Angka_Kecukupan_Gizi_Yang_Dianjurkan_Untuk_Masyarakat_Indonesia.pdf

16. Garcia-Iborra M, Castanys-Munoz E, Oliveros E, Ramirez M. Optimal Protein Intake in Healthy Children and Adolescents: Evaluating Current Evidence. Nutrients [Internet]. 2023; 15(7):1–24. Available from: https://pubmed.ncbi.nlm.nih.gov/37049523/

17. Boateng EF, Nasiru MM, Agyemang M. Meat: Valuable Animal-Derived Nutritional Food. A Review. Asian Food Sci J [Internet]. 2020;15(1):9–19. Available from: https://journalafsj.com/index.php/AFSJ/article/view/297

18. BPOM. Regulation of the Food and Drug Supervisory Agency Number 1 of 2022 concerning Claims Supervision on Labels and Advertisements of Processed Foods. BPOM Regulation [Internet]. 2022; 11:1–16. Available from: https://shorturl.at/vyrpc

19. Öneş E, Sağlam D. Do Locus of Control Affect Anthropometric Measurements, Food Intake and Diet Quality in Adolescent Soccer Players ? Adölesan Futbolcularda Denetim Odağı Antropometrik Ölçümleri, Besin Alımını ve Diyet Kalitesini Etkiler mi? 2023;51(1):61–8. Available from: https://sl1nk.com/tQOnz

20. Sebastiá-Rico J, Martínez-Sanz JM, González-Gálvez N, Soriano JM. Differences in Body Composition between Playing Positions in Men's Professional Soccer: A Systematic Review with Meta-Analysis. Appl Sci [Internet]. 2023;13(8). Available from: https://www.mdpi.com/2076-3417/13/8/4782

21. Hannon MP, Close GL, Morton JP. Energy and Macronutrient Considerations for Young Athletes. Strength Cond J [Internet]. 2020;42(6):109–19. Available from: https://journals.lww.com/nsca-scj/abstract/2020/12000/energy_and_macronutrient_considerations_for_young.11.aspx

22. Medise BE. The Role of Iron for Supporting Children's Growth and Development. World Nutr J [Internet]. 2021;5(1–1):16–24. Available from: https://worldnutrijournal.org/OJS/index.php/WNJ/article/view/265

23. Hernandez-Martin A, Garcia-Unanue J, Martinez-Rodriguez A, Manzano-Carrasco S, Felipe JL, Carvalho MJ, et al. The effects of football practice on nutritional status and body composition in children: A systematic review and meta-analysis. Nutrients [Internet]. 2021;13(8). Available from: https://pubmed.ncbi.nlm.nih.gov/34444722/

24. Valenzuela PL, Alejo LB, Montalvo-Pérez A, Ojanguren D, Górriz M, Pagola I, et al. Pre-sleep protein supplementation in professional cyclists during a training camp: a three-arm randomized controlled trial. J Int Soc Sports Nutr [Internet]. 2023;20(1). Available from: https://doi.org/10.1080/15502783.2023.2166366

25. Gomaa MAE, Allam MG, Haridi AAIM, Eliwa AEM, Darwish AMG. High-Protein Concentrated Pro-Yogurt (Pro-WPI) Enriched With Whey Protein Isolate Improved Athletic Anemia and Performance in a Placebo-Controlled Study. Front Nutr [Internet]. 2022; 8(January):1–10. Available from: https://pubmed.ncbi.nlm.nih.gov/35127786/

26. Rehman T, Agrawal R, Ahamed F, Das S, Mitra S, Kumar D, et al. Optimal dose and duration of iron supplementation for treating iron deficiency anaemia in children and adolescents: A systematic review and meta-analysis. PLoS One [Internet]. 2025;20(2): e0319068. Available from: http://dx.doi.org/10.1371/journal.pone.0319068

27. Bagheri R, Kargarfard M, Sadeghi R, Scott D, Camera DM. Effects of 16 weeks of two different high-protein diets with either resistance or concurrent training on body composition, muscular strength and performance, and markers of liver and kidney function in resistance-trained males. J Int Soc Sports Nutr [Internet]. 2023;20(1):2236053. Available from: https://doi.org/10.1080/15502783.2023.2236053

28. Purwanto S, Ockta Y. Sports Nutrition and Gross Motor Skill Development in Youth Athletes: A Literature Review. J Penelit Pendidik IPA [Internet]. 2024;10(8):572–9. Available from: https://jppipa.unram.ac.id/index.php/jppipa/article/view/8991

29. Webb K, Wiggins C, Secomb T, Joyner M, Roy T. The dependence of maximum oxygen uptake on hemoglobin-oxygen affinity and altitude: a computational modeling approach. Physiology [Internet]. 2023;38(S1):1–11. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10569622/