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ORIGINAL ARTICLE

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Sport and Exercise Nutrition

Does sex differ the relationship between macronutrients adequacy and aerobic power?

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ABSTRACT

Background: Sex is a recognized factor influencing physiological and biochemical changes in response to physical activity and nutrient intake. Dietary intake may impact athletic performance, including aerobic power. However, these effects may be sex-dependent. **Aims:** to evaluate pattern and adequacy of macronutrient intake; to evaluate predicted VO_2max, and investigate potential correlations between macronutrients and aerobic power, stratified by sex. **Subjects and Methods:** A correlational design was employed, targeting recreational athletes. Participants (n = 52) were recruited using purposive sampling (aerobic dancers n = 15, runners n = 18, pesilat n = 10, badminton players n = 9). Three-day food records were collected and analyzed using the NutriSurvey application to determine dietary intake and macronutrient composition. Predicted VO_2max was assessed via the Beep Test. The study protocol was approved by the Institutional Health Research Ethics Commission. Bivariate correlation analysis was conducted to explore associations between macronutrients and aerobic power. **Results:** Mean daily energy intake was 1,417.19 ± 56.12 kcal/day distributed as carbohydrate (46%), fat (40%), and protein (14%). The majority of participants (57.69%, n=30) demonstrated average VO_2max, while the remaining 42.31% (n = 22) exhibited below-average values. Interestingly, a significant negative moderate correlation (r -.565 as $p < 0.05$) was observed between fat intake and predicted VO_2max in females only. No significant correlations were identified between carbohydrate or protein intake and predicted VO_2max for either sex. **Conclusion:** Despite consuming a low-carbohydrate, high-fat (LCHF) diet, participants maintained adequate energy intake. Notably, fat intake in females displayed a strong negative association with predicted VO_2max.

Keywords: Sports for all, public health nutrition, cardiorespiratory endurance, physical fitness.

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1 Introduction

Maximal aerobic power (VO_2max) is one of key parameters for assessing the aerobic fitness of endurance athletes. Research demonstrates a significant relationship between VO_2max and agility, power, balance, and flexibility in both adolescent males and females. Additionally, long-term aerobic exercise training has been associated with increased leg muscle power [1,2]. Aerobic power improvement reflects the enhanced ability of muscles to utilize oxygen delivered by the lungs and heart for energy production. In essence, it represents the functional capacity of the cardiorespiratory system, defined as the maximum rate of oxygen consumption during intensive physical activity [3]. Besides training programs, another crucial factor that is believed to be able to affect physical performance is nutrition. Macronutrients, the primary building blocks of various tissues, contribute to total caloric intake and serve as the main energy source for the human body [4]. Carbohydrates, proteins, and lipids are the three main categories of macronutrients. Deficiencies in any of these can significantly compromise overall bodily function and physiology [5,6]. Nutrient timing is a strategy employed in sports nutrition to enhance athlete performance, recovery, and adaptations. Nutrient timing involves strategically manipulating nutrient intake around training session [7,8]. Another widely recognized strategy in sports nutrition is carbohydrate loading. This technique aims to super compensate muscle glycogen stores by manipulating dietary intake, training duration and intensity, and any accompanying exercise.

During prolonged endurance-type of exercise, the body relies primarily on carbohydrates and fat as fuel sources. Carbohydrates are stored as endogenous glycogen, while fats contribute through β-hydroxyacyl-CoA dehydrogenase and citrate synthase activity. A greater availability of fat during exercise can improve performance via the carbohydrate-sparing effect of "fat loading". While robust evidence shows protein intake induces protein fractional synthesis rate. Additional protein sources on carbohydrate supplementation have also been reported to extend time to exhaustion on cycling 85% of VO_2max in trained cyclists. This finding suggests that a higher plasma insulin response, potentially stimulated by protein intake, may contribute to muscle glycogen sparing [9]. Therefore, accurate assessment of an athlete's nutritional adequacy is crucial. This can be achieved by evaluating the individual's dietary program to ensure they are consuming sufficient quantities of essential nutrients [10].

Studies investigating the dietary intake and nutritional status of athletes in emerging sports such as CrossFit have highlighted potential deficiencies. Gogojewicz et al. (2020) [11] reported that both male and female CrossFit athletes exhibited energy intake below recommended levels. Notably, this deficit was specific to carbohydrate intake, iron, and calcium [11]. Meanwhile, a study by Oukheda et al. [12] demonstrated a significant association between macronutrient intake status and physical fitness, body mass index (BMI), and body fat percentage. Their findings suggest that individuals with a normal weight tend to exhibit superior physical performance compared to those who are underweight, overweight, or obese [12]. Moreover, physical performance (the slalom kayakers) has proved to correlate with percent body fat, energy intake, protein, carbohydrate, vitamin B6, vitamin A, thiamine, riboflavin, magnesium, and phosphorus [13].

Emerging evidence suggests potential sex-based difference in the adaptive response to physical training. While regular training program (e.g., 3 times per week for 6 weeks) can improve aerobic capacity in both men and women, research indicates that insulin sensitivity may only improve in males [14]. However, in slow-twitch muscle fibers females utilize less glycogen (42%) compared to males, during high-intensity training, as evidenced by lower blood lactate accumulation [14]. These findings suggest potential sex-based variations in metabolic responses to exercise. Furthermore, studies have demonstrated that nutritional strategies can modulate training adaptations. It becomes a potential aspect of the adaptive response at the recovery stage, which leads to improved physiological adaptations from time to time [15,16]. Therefore, this study aimed to evaluate the pattern of macronutrient intake and their association with predicted VO_2max in male and female recreational athletes.

2 Subjects and Methods

Study Design and Participants

This quantitative study employed a correlational design to investigate the relationships between macronutrient intake and aerobic power in recreational athletes from four different sports. The targeted sports (aerobic dance, running, pencak silat, and badminton) were selected based on the Indonesian Sports Grand Design (Desain Besar Olahraga Raga Nasional, DBON), which identifies sports with high medal potential for Indonesia in international competitions. These sports are also widely practiced throughout the country.

The study population consisted of recreational athletes recruited from four sports clubs participated in Indonesia: 1) Cempaka Obic Lovers (aerobic dance club) Plumbon District, Cirebon County, 2) Komunitas Brebes Runners (running club) Brebes District, Brebes County, 3) Perguruan Silat Persaudaraan Setia Hati - Terate Kuningan Terate Silat Center (pencak silat club) Northern Semarang District, Semarang City, and 4) Persatuan Bulu Tangkis Pendowo Semarang (badminton club) Gajahmungkur District, Semarang City.

Purposive sampling technique was employed, with inclusion criteria including: 1) voluntary participation by the sports club was willing (documented in written agreements); 2) informed consent from individual participants; 3) good health with no ongoing medical treatment, 4) willingness to complete a three-day food record, and 5) w willingness to participate in a multistage fitness test. A total of 52 subjects participated, with representation from each of the four sports (15 aerobic dance, 18 runners, 10 pencak silat, and 9 badminton).

Data Collection

Macronutrient adequacy data was collected using a self-reported three-day food record. Participants were instructed to record all consumed food and beverages over three randomly selected days (including two weekdays and one weekend day). A Google Form facilitated easier data entry for participants. NutriSurvey software was used to analyze the food records data, providing information on nutrient composition, energy requirements, and macronutrient content (in grams), energy requirements calculation, diet planning, diet history, meal frequency, nutrient search in foods, recipe handling, and other information [17]. Macronutrient values were then converted to kilocalories using standard conversion factors (4 kcal/g for carbohydrates, 9 kcal/g for fat, and 4 kcal/g for protein). Additionally, BMI was calculated using an online application (www.calculator.net) based on self-reported weight (kg), height (cm), sex, and age. No specific dietary interventions were implemented, ensuring the data reflected the participants' typical dietary patterns. Therefore, this common data could be representative of all major populations with similar diets, especially in Indonesia.

Predicted VO2max, an indicator of aerobic power, was assessed using the Multistage Fitness (Beep) Test. This widely used submaximal test involves continuous running back and forth over a 20-meter distance within a time frame dictated by progressively shortening audio beeps. Subjects needed to maintain the pace until they could no longer keep up, reflecting the increasing difficulty level. A standardized protocol with an initial speed of 8.5 km/h and increments of 0.5 km/h per minute was employed [18]. Raw data from the beep test were then calculated to find the predicted VO_2max through an online VO_2max calculator [19,20]. The predicted VO_2max scores were categorized into seven levels (excellent, good, above average, average, below average, poor, and very poor). It's important to note that participants did not undergo any specific training interventions for this study; their regular physical activity routines were maintained.

The study protocol was approved by the institutional health research ethics committee of Universitas Negeri Semarang (Ethical Clearance Numbers: 110/KEPK/EC/2022; 134/KEPK/EC/2022; 090/KEPK/EC/2022; 125/KEPK/EC/2022). These approvals adhered to the principles outlined in the Declaration of Helsinki (1975). There were three stages in this study: 1) Stage One: This stage involved participant education about the study literacy, instrument arrangement, active observation for partnership with the sports club (including signing of agreements), and subject screening; 2) Stage Two: During this stage, participants received a brief study explanation, completed the three-day food record (Google Form), and participated in the multistage fitness test; 3) Stage Three: This stage focused on data tabulation, analysis, presentation and interpretation, discussion, and preparation of the manuscript for publication.

Descriptive statistics (mean ± standard deviation, error of the mean, and percentage) were performed to analyze demographic data, macronutrients intake, and predicted VO_2max. The Kolmogorov–Smirnov test was conducted to assess data normality for subsequent bivariate correlation analysis. All statistical analyses were performed using IBM SPSS Statistic 21. Karl Pearson's correlation coefficient was used to determine the strength and direction of correlations between variables. Correlation coefficients were interpreted using established categories (negligible = 0.00-0.10; weak= 0.10-0.39; moderate= 0.40-0.69; strong= 0.70-0.89; very strong= 0.90–1.00) [21]. Squaring the Pearson correlation coefficient provided an estimate of the contribution of each macronutrient to VO2max.

3 Results

The study included a total of 52 participants (29 males and 23 females) (Table 1). The mean age for males 16.28 ± 0.52 years while females had a mean age of 21.04 ± 1.40. All participants fell within the normal body mass index (BMI) range (kg/m2). The average BMI for males was 19.99 ± 0.53 and 21.73 ± 1.17 for females. Participants were recruited from various sports clubs, including aerobic dance (female, n=15), running (male, n=18), pencak silat (male, n=5; female, n = 5), and badminton club (male, n= 6; female n= 3).

Table 1. Subjects' characteristic and distribution of sports (*Source: primary research data*)

Variables	Males (n= 29)	Females (n= 23)
Age (year)	16.28 ± 2.84	21.04 ± 6.75
Height (cm)	165.24 ± 11.93	155.39 ± 3.55
Weight (kg)	55.45 ± 13.07	52.26 ± 7.82
BMI (kg/m^2)	19.99 ± 2.88	21.73 ± 3.40
Aerobic Dance	0/52	15/52
Running	18/52	0/52
Pencak Silat	5/52	5/52
Badminton	6/52	3/52

Pattern of Macronutrients Intake and Adequacy

Data macronutrients were collected via a three-day food record administration. The daily intake patterns of macronutrients displayed a high degree of similarity across all three days, as evidenced by both average values and the detailed breakdown provided in Figure 1. Similarly, the adequacy of macronutrient intake remained consistent throughout the recording period (Table 2). On day one, the average daily intake consisted of 664.19 ± 38.64 kcal (46%), from carbohydrates, 574.98 ± 55.64 kcal (40%) from fat, and 200.32 ± 9.84 kcal (14%) from protein. Day two showed a

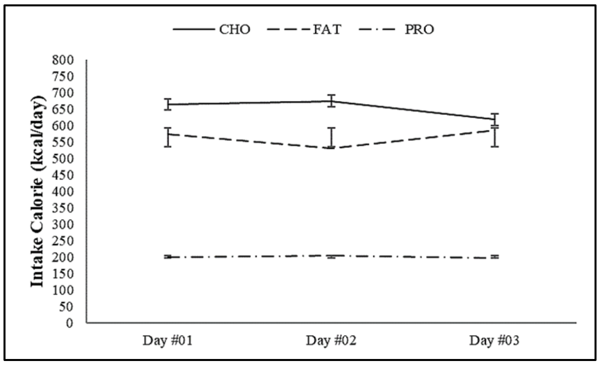

Figure 1. Pattern of Macronutrient intake (*Source: primary research data*)

Table 2. Macronutrient's adequacy (*Source: primary research data*)

Macronutrients	Recommended Range (%)	Day #01		Day #02		Day #03	
		M (n= 29)	F (n= 23)	M (n= 29)	F (n= 23)	M (n= 29)	F (n= 23)
Carbohydrate	55 – 65	43	50	47	49	42	48
Fat	15 – 25	44	34	39	36	45	36
Protein	10 – 15	13	16	14	15	13	16
Total (%)		**100**	**100**	**100**	**100**	**100**	**100**

Table 3. Distribution of predicted VO_2max among subjects in percentage (*Source: primary research data*)

Classification	Aerobic dancer	Recreational runner	Pencak silat (Pesilat)		Badminton player	
	Females (n= 15)	Males (n= 18)	Males (n= 5)	Females (n= 5)	Males (n= 6)	Females (n= 3)
Excellent	0.00%	16.67%	0.00%	0.00%	83.33%	66.67%
Good	0.00%	16.67%	20.00%	60.00%	0.00%	33.33%
Above Average	0.00%	5.55%	0.00%	0.00%	16.67%	0.00%
Average	0.00%	27.77%	80.00%	20.00%	0.00%	0.00%
Below Average	6.67%	16.67%	0.00%	20.00%	0.00%	0.00%
Poor	0.00%	16.67%	0.00%	0.00%	0.00%	0.00%
Very Poor	93.33%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

slight decrease in total calorie intake but maintained a similar macronutrient distribution. Carbohydrate intake averaged 674.39 ± 39.20 kcal (48%), fat intake averaged 532.19 ± 41.04 kcal (38%), and protein intake averaged 203.97 ± 15.55 kcal (14%). Day three followed a similar pattern, with an average intake of 618.14 ± 39.27 kcal (44%) from carbohydrate, 586.38 ± 47.76 kcal (42%) from fat, and 197.00 ± 12.08 kcal (14%) from protein. Considering the three-day average, the total daily energy intake was 1,417.19 ± 56.12 kcal. This comprised 652.24 ± 28.52 kcal (46%) from carbohydrates, 564.52 ± 31.59 kcal (40%) from fat, and 200.43 ± 8.42 kcal (14%) from protein.

Table 3 presents the distribution of predicted VO_2max values (ml/kg/min) for the participants. Due to variations in age categories, VO_2max data is categorized rather than presented as raw scores. This categorization is analogous to using percentiles. The majority of subjects (30/52, 57.69%) achieved an average VO_2max classification (10/30 from the recreational runner and Pencak silat). Additionally, the following classifications were observed: above average (2/30 from the recreational runner and badminton player), good (8/30 subjects from the recreational runner, Pencak silat and badminton), and excellent VO_2max (10/30 from recreational runner and badminton player). Meanwhile, the remaining subjects 22/52 (42.31%) fell into the below average (5/22 from the aerobic dancer, recreational runner, and Pencak silat), poor (3/22 from recreational runner), and very poor (14/22 from aerobic dancer).

Macronutrients and Aerobic Power

Referring to the data in table 4, the correlation between total energy intake and predicted VO_2max was weak and non-significance for both in males and females. Interestingly, fat intake exhibited a significant negative correlation with VO_2max in females ($p <0.05$) but not in males. This suggests a potential opposite different when it falls into carbohydrate. Further, the weak correlation between protein and VO_2max shows close to significant as $p > 0.05$ in males but not in females. BMI was included as a control variable in the correlation analysis. BMI showed a significant negative correlation with VO2max in females ($p < 0.05$) but not in males. Additionally, the contribution of each macronutrient to VO2max levels was estimated by squaring the Pearson correlation coefficients. Carbohydrates contributed approximately 12.88% to VO2max variation, fat contributed 31.92%, and protein contributed 12.18%.

Table 4. Correlation between macronutrients and aerobic power (*Source: primary research data*)

Variables	VO$_2$max (mL/kg/min)			
	Males		Females	
	r	*p*-value	r	*p*-value
Total Energy (kcal)	**.161**	**.405**	**-.341**	**.112**
Carbohydrates (kcal)	.359	.056	-.119	.589
Fat (kcal)	**-.146**	**.450**	**-.565****	**.005**
Protein (kcal)	.349	.064	-.150	.493
BMI (kg/m2)	**-.268**	**.159**	**-.583****	**.003**

**, r indicates Pearson correlation index; correlation is significant at the p <0.05 level (2-tailed).*

4 Discussion

Macronutrient intake plays a crucial role in determining VO$_2$max, a key indicator of aerobic fitness. This study investigates potential sex-based differences in this relationship. Our findings reveal a significant negative correlation between fat intake and VO$_2$max in females ($p < 0.05$), but not in males. This suggests a potential sex-specific interaction between fat metabolism and aerobic power in females. Females may exhibit a higher reliance on fat oxidation during exercise, potentially explaining the observed correlation between fat intake and VO$_2$max. Adequate fat intake may, therefore, support sustained aerobic performance in females [22]. Meanwhile, males displayed a trend towards a positive correlation between carbohydrate intake and VO$_2$max levels. This aligns with the established role of carbohydrates as the primary fuel source during high-intensity exercise. Additionally, males generally possess greater muscle mass and glycogen storage capacity compared to females. This increased capacity for glycogen storage may contribute to the observed association between carbohydrate intake and VO2max in males [23].

This study included participants with an average BMI within the normal range. BMI is a commonly employed anthropometric index that categorizes adults based on their height and weight ratio. It serves as a convenient method for obtaining a general assessment of body composition [24]. However, BMI has limitations: it does not directly measure body fat percentage and may not be an accurate indicator of health status for specific populations such as growing children, pregnant women, and athletes [25]. Notably, athletes often possess a greater proportion of lean muscle mass compared to the general population. This can lead to BMI overestimations of body fat in athletes and individuals with a muscular build. Therefore, body fat percentage may be a more precise indicator of both health and athletic performance compared to BMI [26].

To the best of our knowledge, the present study contributes novel findings to the understanding of macronutrient adequacy in athletes. First, we observed that all participants adhered to a high-fat dietary pattern (defined as exceeding 35% of total energy intake from fat [27]. This dietary approach is hypothesized to provide ketone bodies, primarily β-hydroxybutyrate, as an alternative fuel source for athletes [28]. Interestingly, our data revealed a significant, albeit moderate, correlation between fat intake and predicted VO2max. These findings warrant further investigation. A pilot study by Zdzieblik et al. [29] stated that a four-week LCHF diet ≥ 65% is able to improve the metabolic flexibility and additional benefits regarding exercise performance in male athletes.

This study revealed a daily average energy intake of 1,417.19 kcal across all subjects, representing approximately 70.8% adequacy compared to the Recommended Dietary Allowance (RDA) for the 10 to 29-year-old population. This translates to a daily deficit of Δ 582.81 kcal equivalent to roughly two missed snacks, when benchmarked against the daily energy requirements established by the Indonesian Ministry of Health, (Permenkes RI No. 28, 2019). Adequate energy intake is considered a cornerstone of an athlete's nutritional foundation [30]. Low energy availability, a condition arising from either insufficient dietary intake or excessive exercise expenditure, results in a deficit that hinders the body's ability to maintain normal physiological functions [31]. Early research conducted on humans and animals suggests that during periods of energy deprivation, the body prioritizes fuel conservation for cell survival, potentially at the expense of growth and reproductive processes [32].

Dietary patterns in Indonesia exhibit significant variation in sugar, salt, and oil consumption. The Indonesian Ministry of Health regulations (Permenkes RI No. 28, 2019) recommend a fat intake range of 20 – 25% of total daily energy intake. However, data from the 2013 Indonesian Riskesdas (National Health Research) survey indicates that 29.7% of the population exceeds these recommendations for sugar, salt, and fat intake. Provinces like Central Java reported even higher consumption levels compared to the national average [33]. Subsequent Riskesdas data from 2018 revealed that 58.4% of individuals in Central Java consume fried or fatty foods more than once daily, exceeding the national average of 41.7%. which is higher than the national consumption of fatty foods, which is 41.7%. These findings suggest a strong influence of taste and texture preferences on dietary choices, as fat often contributes to palatability.

High-fat diets have been linked to obesity prevalence and the development of non-communicable diseases. Conversely, low-carbohydrate, high-fat (LCHF) diets are often utilized for weight management and symptom control in various clinical conditions. Interestingly, for active individuals like athletes, LCHF diets may enhance fat oxidation as a primary energy source, potentially influencing physical performance [34]. Typically, a high-fat diet is defined as one where less than 25 % energy comes from carbohydrates and more than 60% comes from fat. The initial rationale for adopting high-fat diet in sports was to ensure a sustained energy supply and minimize glycogen depletion during exercise [35].

The percentage of dietary energy derived from fat can vary considerably. However, within the context of a healthy dietary pattern, understanding the type of fat consumed is crucial. Numerous health organizations consistently advocate for limiting saturated fat intake, typically to less than 10% of total energy intake. Trans fats demonstrably elevate the risk factors associated with a diverse range of cardiovascular diseases (CVD). Consequently, health recommendations advise minimizing trans-fat intake as much as possible [36]. In contrast, polyunsaturated fatty acids (PUFAs), such as n-6 and n-3, play beneficial roles in human health. Replacing saturated fats with increased PUFA consumption may offer anti-inflammatory properties, influence immune function positively, reduce CVD risk, and potentially improve athletic performance by promoting muscle adaptation, energy metabolism, muscle recovery, and injury prevention [37–39].

Performance in long-duration sporting events (endurance sport) depends on an individual's maximum aerobic power, the percentage of sustainable power, and the availability of carbohydrates and fats as energy sources [35]. Carbohydrates are well-recognized for their role in glycogen resynthesis during endurance exercise [40]. A high carbohydrate intake can optimize athletic performance for both power athletes and endurance athletes. Carbohydrates are stored as glycogen in the liver and skeletal muscle for later utilization. Low muscle glycogen stores are associated with increased fatigue levels due to the role of glycogen in enabling muscle ATP resynthesis during high-intensity endurance exercise [41]. Consuming sports drinks containing approximately 14 g of carbohydrates before exercise is considered beneficial for enhancing aerobic performance, especially VO_2max, and preserving blood glucose concentration during graded exercise testing. Furthermore, ingesting high carbohydrate liquids (120 g/h) can minimize neuromuscular fatigue and accelerates recovery at 24 h post-marathon and high-intensity running [42].

Emerging evidence suggests that iso-caloric high-fat diets (42% to 55% of total energy intake) with adequate carbohydrate (CHO) levels may be more effective for endurance athletes compared to low-fat diets (10% to 15% of total energy intake). This potential benefit may be attributed to the ability of high-fat diets to promote fat oxidation while preserving intramuscular glycogen stores during exercise [29]. There is emerging evidence that the metabolic changes induced by LCHF diets enhance endurance performance [34]. The present study's findings regarding the association between fat intake and aerobic power in female athletes contribute to this growing body of research, potentially prompting a reevaluation of the benefits of high-fat diets for athletic performance (Table 4).

While protein can serve as an energy source, its primary functions lie in structure, function, and regulation of cellular processes. The current study demonstrates within the overall macronutrient ratio, with no significant correlation observed between protein intake and aerobic power in either sex. High protein diets exceeding the RDA may improve fat-free mass when combined with exercise within a calorie-restricted diet [43]. Proteins provide amino acids, which are the building blocks for protein synthesis and contribute to maintaining a positive protein balance after endurance training. Endurance athletes typically require a protein intake in the range of 1.2 – 1.6 g protein/kg body weight/day, with potentially lower needs for female athletes compared to males. In contrast, bodybuilders and strength/power athletes often consume higher protein intakes ranging from 2 – 2.5 g/kg body weight/day, and may even reach up to 3.5 g/kg body weight/day, which carries the risk of excessive protein intake [44].

VO_2max, a well-established indicator of aerobic capacity, can vary depending on the specific sport. For instance, football players typically demonstrate higher VO_2max compared to volleyball players. Notably, regardless of the exercise modality (running, cycling, swimming, etc.), short sprint interval training programs have been shown to be highly effective in improving VO_2max, leading to enhanced aerobic and anaerobic performances in both young healthy adults and athletes [45]. Athletes, engaged in endurance sports tend to exhibit higher VO_2max compared to heir sedentary counterparts. Peak VO2max, aerobic threshold, and pulmonary ventilation values in athletes are influenced by a complex interplay of factors, including the specific characteristics of each sport (e.g., pitch dimensions, duration, tactical systems), sex, and individual morphology [46].

VO_2max is a widely used metric for assessing individual fitness level and prescribing exercise intensity. When implemented carefully and tailored to an individual's aerobic capacity, exercise programs based on VO_2max can yield significant benefits for both physical and cognitive health [47]. For example, high-intensity endurance training programs (reaching 83% maximum heart rate) have been shown to improve cardiovascular health (including up to a 15% increase in VO_2max) and promote metabolic adaptations in healthy elderly individuals after a 108-session training program.

The observed differences in correlations between VO_2max in nutrient intake (carbohydrates in males and fat in females) may be attributed to a multitude of factors, including: training program, the nutrients themselves, the physiological designs (fat depositions), and especially the hormonal roles in males versus females. Endogenous steroid hormones (testosterone and progesterone) play critical role in sustaining energy stores, building muscle, improving oxygen capacity/aerobic power, preventing fatigue, easing the recovery time, and optimizing hand-eye coordination. Other hormones. Other hormones such as estradiol and cortisol also contribute to physical performance. Proper thyroid function, influenced by progesterone production, is essential for maintaining energy availability, protein synthesis, cardiac function, and calcium balance. Conversely, hypothyroidism and hyperthyroidism are associated with poor sports performance and capacity due to weight loss and tachycardia [48]. During puberty, sex differences become more pronounced. Males tend to develop a larger and stronger physique with a more anabolic hormonal profile compared to females. Studies have shown associations between dehydroepiandrosterone sulfate (DHEA-s) levels in males and testosterone levels in females with sports performance. However, body mass appears to act as a mediator for males (enhancing performance) and an inhibitor for females (limiting performance) [49]. Additionally, Gagnon et al. [50] reported a strong association between testosterone and aerobic capacity in young healthy males, with a weaker relationship to body composition and cardiovascular risk factors [50].

During moderate-intensity endurance training, men and women exhibit different in substrate utilization for energy production. Women demonstrated a lower respiratory rate suggesting a reduced reliance on carbohydrate oxidation compared to men. Additionally, female skeletal muscle utilizes approximately 25 – 50% less glycogen than male skeletal muscle [51]. Consequently, at higher exercise intensities, men's skeletal muscles may exhibit a greater susceptibility to fatigue compared to women. These phenotypic sex differences in various physiological systems likely influence the integrated metabolic threshold during exercise. Interestingly, animal studies have shown sex to be a dominant factor in athletic performance, with females displaying a greater capacity to enhance cardiac muscle hypertrophy in response to exercise compared to males [52].

These findings highlight the need for further research to explore how sex-specific hormonal profiles can be integrated into the development of personalized dietary strategies to optimize athletic performance. Future studies could benefit from incorporating controlled dietary interventions with specific macronutrient ratios, along with standardized physical activity programs. Furthermore, accounting for the specific physiological states of participants, including sex differences, is crucial for drawing generalizable conclusions.

5 Conclusion

The present study observed a high-fat, low carbohydrate dietary pattern among the participants. Despite an overall energy deficit, individual energy intake, appeared sufficient to meet at least basal metabolic rate requirements and maintain normal physiological functions. Most subjects displayed adequate aerobic power. Fat intake showed a negative and significant correlation with aerobic power in females only, while no significant correlations were observed for carbohydrates. Protein intake appeared to play equal role in both sexes, serving as fundamental building block for growth and repair processes.

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