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Does macronutrient consumption affect aerobic capacity?

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Introduction

A decrease in one's health overtime increases their likelihood of developing chronic diseases, such as arthritis, cardiovascular diseases, cancer, diabetes, obesity. The National Health Council reports that more than 40% of people in the United States are affected by one or more chronic disease.[1] Although there are many factors to be considered, poor diet and physical inactivity have been shown to be major causes of chronic diseases.[2] For college students, many contributors play a role in poor diet and physical inactivity. College students are more likely to opt out of physical activity to instead use their cell phones.[3] A study examining the relationships between sleep quality, physical activity, and body mass index in college freshman showed that poorer sleep quality and less amount of hours of sleep was associated with lower performance outcomes.[4] While younger students are more likely to have higher physical activity levels, older students report more time spent on the computer.[5] This means more time is invested in sedentary behavior rather than being active. In another study, 738 college students, ages 18-27, were assessed for being overweight, obese, dietary habits, and physical activity levels. When looking at BMI directly, only 21.6% were classified as overweight and 4.9% were classified as obese. The results shows that most students don't consume the recommended servings of fruits and vegetables and participate in physical activity less than 3 days per week.[6] Many students skip at least one meal a day, with breakfast being the one most decide to eliminate.[7] A major concern is that college students are starting to have higher levels of percent body fat, as well as decreased fitness levels.[8] It seems students are aware that they need to exercise and eat a certain way in order to lose weight, but they are not proactive in doing so. We can see that physical activity levels are decreasing and dietary habits are veering away from USDA recommendations.

Therefore, there is a need to implement healthy lifestyle changes, such as consuming necessary nutrients and participating in physical activity.

Fitness is broken down into five health-related components: (1) cardiorespiratory endurance, (2) muscular endurance, (3) muscular strength, (4) body composition, and (5) flexibility.[9] Each of these components are defined as follows: cardiorespiratory endurance relates to the ability of the circulatory and respiratory systems to supply fuel during sustained physical activity and to eliminate fatigue products after supplying fuel; muscular endurance relates to the ability of the muscle groups to exert external force for many repetitions or successive exertions; muscular strength relates to the amount of external force that a muscle can exert; body composition relates to the relative amounts of muscle, fat, bone, and other vital parts of the body; and flexibility relates to the range of motion available at the joint. There are not many studies that measure the five-health-related components for the college student population, as many focus on physical activity behaviors rather than the fitness levels of college students.[10] One study used Queen's College Step Test to measure cardiorespiratory fitness in 18-24 year-old college students from eight different universities. The majority of the students ranked average to good on their scores, with 46% of men scoring good and 40.8% of women scoring average.[11] Thus, cardiorespiratory fitness is adequate, with some improvement being necessary for a minority of the students.

Depending on the type of exercise being performed, different sources of fuel are broken down and utilized via different energy systems. There are three systems that provide us with energy.

The first system that is used, such as when one stands up or takes a step, provides an immediate energy source for the muscles to use. This is the adenosine triphosphate (ATP) and phosphocreatine (PCr) system. When intense exercise is performed for longer than a few seconds and up to 2 minutes, anaerobic glycolysis becomes the energy-providing system. Types of anaerobic exercises are weight lifting, jumping, and sprinting. Glucose is the source of fuel while performing anaerobic exercises. The third energy system is the long-term energy system, provides us with fuel for aerobic exercise. Aerobic exercise requires oxygen, and includes running, swimming, walking, biking, and kickboxing for longer periods of time.[12]Intensity levels during aerobic activity determines what the fuel source is. At up to 40% of maximum workload fat is primarily utilized. At 55% of maximum workload, there is an increase in carbohydrate oxidation, but no significant decrease in fat oxidation. At 75% of maximum workload, fat oxidation is decreased and carbohydrate utilization is increased, leaving glucose as the primary source of fuel.[13]

In order to get these fuel sources in the body, one must consume food. There are three macronutrients that food is composed of: carbohydrates, fats, and protein. Once digested, carbohydrates are broken down into glucose, which is the fuel source for all three of the energy systems. Fats are broken down into lipids, which are utilized for storage and as an energy source during less intense (up to 40% of maximum workload[13]) aerobic exercise. Rather than being used as a primary fuel source, proteins are broken down into amino acids. Amino acids will either form into urea and be secreted through the urine or feces, or be utilized to produce energy, glucose, ketone bodies, cholesterol, or fatty acids.[14] Protein is essential for muscle building. In order for protein synthesis to occur, all nine essential amino acids are required, which must be obtained through the diet. Leucine is especially important to be consumed for those who participate in resistance training and to increase lean body mass.

Certain nutrients have been shown to be associated with fitness levels. In a study comparing the relationship between physical fitness level and macro-and micronutrient intake, those with higher fitness levels consumed phosphorus, selenium, vitamin B6, C, D, E, niacin, and folate. There was a negative association between high fitness levels and consumption of thiamine and riboflavin.[15] Supplementation of carbohydrates during exercise training showed to have an effect on muscular adaptations, but no significant effects of cardiorespiratory fitness and decreased fat mass compared to not supplementing with carbohydrates.[16] Protein intake has a positive relationship with strength, largely due to the contribution of essential amino acids.[17] A lack of the appropriate amount of macronutrients and micronutrients can play detrimental roles in overall health, as well as performance outcomes. The ketogenic diet, which is a high fat, high protein, low carbohydrate diet has been shown to lower power output.[18] With this, we know that diet has some form of impact on performance outcomes.

Both the diet and exercise play an interconnecting role in the health status of individuals. However, students may fall into "normal" categories of aerobic capacity and BMI, but may or may not be meeting dietary intake recommendations and/or following ACSM's guidelines for exercise. We know that both diet and exercise are important, but there is not much research showing what college students are eating, how much they are exercising, what their maximal aerobic and anaerobic capacities are, and how all of these affect each other. Therefore, the purpose of this study is to compare assessed health status, via fitness assessment, with dietary habits, via 24-hour recall, which will be made in order to determine whether or not those with higher aerobic capacities are consuming closer to their recommended dietary consumption. My hypothesis is that the closer the person comes to meeting estimated energy requirements, along with consistently participating in exercise, the higher their aerobic capacity will be.

Methods

Study design

A convenience sample of 37 participants came into the Exercise Science Research Center at the University of Arkansas. There, they signed a consent form that provided them with information regarding the research procedure. This included anthropometric measurements of height, weight, and body fat; completing a 24-hour dietary recall; answering a questionnaire about their health and exercise habits; completing a fitness assessment; and, participating in a cognitive game on the computer. Subjects had to be a student, faculty, or staff member of the University of Arkansas. Thirty of the 37 participants were signed up as part of Razorwalk, another Exercise is Medicine research project on campus.

24-hour recall

After signing the consent form, the participants were provided with a 24-hour dietary recall. This included all the foods and fluids they consumed from the time they woke up until the time they went to sleep the day prior. After going over a “quick list of food items”, they were asked specific times they consumed the foods and fluids. The occasion, such as breakfast, lunch, snack dinner, etc. was recorded. In order to most accurately collect and analyze this information, the following information was asked: ingredients, how much was consumed (serving size), and where the food was obtained (i.e. home, restaurant, etc.). After the participant reviewed what was recorded, a 24-hour dietary intake questionnaire was provided for them to fill out. The questions included: (1) Was the food you ate yesterday about usual, less than usual, or more than usual? (2) If usual, how could you describe your current dietary habit? (3) If less than usual, what was the main reason the amount you ate yesterday was less than usual? (4) If more than usual, what was the main reason the amount you ate yesterday was more than usual? This information was logged and analyzed in Nutritionist Pro, a food data analysis software system.

Measuring health-related components

After completing the 24-hour dietary recall, the participant's basic vitals were measured. For resting heart rate, the participant sat down with their left or right arm bent, resting on a table with their palms facing the ceiling. Once finding the pulse using the middle and index finger, we counted for 15 seconds and multiplied that number by 4 to calculate their total beats per minute. Next, resting blood pressure was measured using a cuff along the brachial artery. Systolic and diastolic blood pressure measurements were recorded. Then, their height was taken via a stadiometer and weight with a platform scale. Their BMI was calculated using the formula ($BMI= wt (kg)/ [ht (m)]^2$). Muscular strength was measured with a hand-grip test, using the dynamometer. Flexibility was measured with the Canadian Trunk Forward Flexion sit-and-reach test. For this, the participant removed his/her shoes and sat on the floor with their feet flat against the sit-and-reach box with their leg extended. With one hand placed on top of the other, palms down, and fingers extended, the participant slowly reached forward as far as possible, without bending the knees, pushing the metal tab along the measuring line. The number the tab was pushed to was recorded. A push-up test was used to determine muscular endurance. For this, the participant did as many push-ups as possible without rest. For aerobic capacity, a Bruce Protocol was administered. This is a 7-step test to measure the maximal capacity of oxygen the lungs are able to uptake (VO2max). Heart rate, blood pressure, and ratings of perceived exercise exertion were all collected up to stage 4. Speed and grade increased at each stage, until the level at which the participant could not go any longer. Each of these practices follows the American College of Sports Medicine (ACSM) guidelines for exercise testing.

Data analysis

After logging the 24-hour recall information into FoodProcessor, the total carbohydrate, fat, protein, vitamin, and mineral intake was compared to the participants aerobic capacity and BMI. BMI will categorized as “underweight” (<18.5), “normal” (18.5-24.9), “overweight” (25-29.9), and “obese” (>29.9). Estimated energy needs were calculated for each participant based on 30 kcal/kg. The standard calorie range for healthy adults is 25-30 kcal/kg. Since these adults are participating in exercise and their energy needs are being analyzed and compared to aerobic capacity, the higher calorie requirement was selected. Their estimated energy needs were compared to the energy intake measured by the 24-hour recall. This was calculated into the form of a percent by taking total energy consumption divided by total energy recommendations, multiplied by 100. Then, we compared total percentage of recommended macronutrient levels to fitness categories using ANOVA. Based on these percentages, we categorized them into consuming “less than recommendations”, “meeting recommendations”, and “exceeding recommendations”. To be considered “less than recommendations”, they had to consume <70% total recommended energy requirements. To be considered “exceeding recommendations”, they had to consume >130% total recommended energy requirements. Those in the “meeting recommendations” category had a +/- 30% range of DRI consumption.

Results

Table 1: Descriptive, means (SD)

	Female (n=29)	**Male (n=8)**
Age	38.1 (14.0)	43.3 (18.4)
VO2 max (ml/kg/min)	30.2 (9.0)	29.2 (7.4)
Total Kcal (% recommended)	94.6 (60.7)	71.0 (43.8)
Carbohydrates (% recommended)	83.9 (53.3)	65.0 (43.5)
Protein (% recommended)	141.0 (72.8)	113.3 (56.3)

Fat (% recommended)	120.7 (108.1)	90.1 (65.5)

There were a total of 37 participants (n=29 females). The average aerobic capacity of females was 30.2 (SD 9.0). The average aerobic capacity of males was 29.2 (SD 7.4).

Table 2: Linear regression associations between macronutrients and aerobic capacity (adjusted for age and sex), n=37

	Aerobic Capacity	**(ml/kg/min)**
	B (95% Cl)	**p-value**
Total Kcal (% recommended)	-0.02 (-0.05, 0.02)	.361
Carbohydrates (% recommended)	-0.02 (-0.07, 0.02)	.259
Protein (% recommended)	0.003 (-0.03, 0.04)	.854
Fat (% recommended)	-0.007 (-0.03, 0.01)	.529

Aerobic capacity did not differ between those who were at less than recommendations, meeting recommendations, and exceeding recommendations of carbohydrates (β= -0.02, p= .259), protein (β= 0.003, p=.854), and fat (β= -0.007, p= .529).

Discussion

Summary of findings

Prior to analyzing the results, we hypothesized that those who consumed closer to their daily recommended calorie needs would have higher aerobic capacities. In this study, we found that there were no significant differences in VO2 max scores between those who met macronutrient recommendations, those who consumed more than the recommendations, and those who consumed less than the recommendations.

Comparison of findings to other studies

Other studies have shown alternate results. According to a study done in the Human Performance Laboratory at Ball State University, the fast one runs, the quicker they use muscle glycogen stores. Therefore, more carbohydrates are required to be ingested in order to perform at more intense rates.[19] The time and amount of carbohydrates consumed plays a role in the performance outcomes. Studies have shown that the consumption of carbohydrates 30-45 minutes before exercise may cause exertional hypoglycemia.[19] Others have shown that the consumption of carbohydrates after exercise has started may lower the chances of hypoglycemia occurring.[19] The amount of glycogen stores within the muscles prior to exercise heavily influences the work the muscle is able to do.

Explanations to findings

Cardiac output and endurance performance are increased by performing aerobic exercise[20], not solely based on consuming a certain amount of carbohydrates, protein, and fat. This may be a partial explanation to having no significant differences in VO2 max scores based on nutrient intake. However, this should be further studied to see if there is an underlying connection between what one consumes and how it may or may not beneficially affect their performance outcome. Another possible explanation is the possibility that the participants underreported their dietary intake. Eighteen to 54% of participants underreport what they consume, and this can be as high as 70% in some subgroups.[21] Studies have shown that the most commonly there is an underreport of carbohydrates and overreport of protein.[21] If the participants did in fact leave out any food items and they actually ate more than what was reported, the consumption level of carbohydrates, fats, and protein would be inaccurate. This would then alter the outcome of our results. Along with this, most of the sample was composed of older adult females. It is important to keep in mind that older females tend to be more cautious about their dietary habits, so this may be a cause for getting different results than expected due to their caloric restrictions.

Limitations

A limitation of this study was that this was the first time conducting 24-hour dietary recalls and using NutritionistPro for each of the researchers. Therefore, the data collection and analysis is prone to human error due to first-time experience.

As mentioned above, underreporting is a common issue when it comes to doing nutrition research. Due to underreporting, the information was provided to us may not have been fully accurate or representative of actual macronutrient intake. The participants may have consumed more food than what they told us. If this was the case, then our comparison of aerobic capacities among the three different groups (below recommendations, at recommendations, and above recommendations) may have had different results.

With this, each method to collect nutritional data has its own set of pros and cons. We selected to perform 24-hour dietary recalls as they are shown to be a more accurate reflection on one's typical diet, rather than using a food journal. Food journals tend to influence the food choices people make, therefore it is not an accurate depiction of what they would eat on a day-to-day basis. An issue with 24-hour dietary recalls is that one may forget what they ate, how much they ate, when they ate, and may not have been paying attention to the entirety of the ingredients in the foods they consumed. Therefore, macronutrients may have been lost in the reporting process. The sample of participants for this project was mostly female faculty members at the University of Arkansas. So it was not a diverse representative of the population we were targeting.

Conclusion

As far as we know, this was the first study that analyzed the influence of macronutrient consumption on aerobic capacity. This study did show that lower consumption of carbohydrates was associated with a higher VO2max score. Therefore, we know there is some form of an association. Further research should be conducted on the interconnecting role of macronutrient consumption and the body's performance outcome. We know that carbohydrates and fats fuel the body with energy and protein provides the body with the necessary nutrients to build muscle, so research should be done to test and show how eating these nutrients in specific quantities may change the maximum capacity at which the body is able to perform.

To best gather an accurate dietary intake of the participant, a combination of a 24-hour diet recall and in-depth food questionnaire is suggested to be used. Along with this, a larger sample size consisting of more male participants should be included in order to get an accurate representation of the general population. Males and females could then be compared to see if there's a difference between macronutrient consumption influencing fitness based on gender.

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