Case Study on 4 Subjects to Determine the Best Determinant of VO_2max: % Body Fat or Dietary Habits: 2008

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Abstract

The maximal oxygen uptake (VO_2max) is very important because it is used to evaluate cardiorespiratory endurance and aerobic fitness. Without knowledge of their VO_2max value, an obese person may not know how much at risk they are for cardiovascular diseases such as coronary heart disease which buttresses the need 'in such an increasingly obese society, of knowing your VO_2max which can be very beneficial' (Wilmore and Costill, 1999); due to the fact that it provides you with a baseline idea of your cardiovascular health and aerobic fitness level.

The purpose of this study is to determine whether there is a relationship between an individual's percent body fat and their dietary habits in reference to their VO_2max value. To determine if this relationship existed, a mixed method of quantitative and qualitative statistical analysis was carried out on four active individuals ranging from ages 18-30. For the purpose of this study, an R square value of 0.5 or more suggests a relationship between the VO_2max value, and dietary intake value. With an R squared value of 0.89, percent body fat depicts the most significant relationship with VO_2max. % Body fat is very important because the body uses fat for insulation, thermoregulation and, most importantly it is a form of energy storage. The most significant dietary components were carbohydrates ($R^2 = 0.50$), total percentage of caloric intake from fats ($R^2 = 0.75$), fruit ($R^2 = 0.65$), grain ($R^2 = 0.78$), and total fiber ($R^2 = 0.62$). This study was based on only 4 subjects. As a result, data analysis can only be used to suggest relationships and guide future experiments, not to make conclusive statements or to state a level of significance.

Problem Statement

The research literature suggests that runners who ingest a low fat diet ingest fewer total calories, which may reduce their endurance when compared to athletes who ingest a high fat diet that falls within the standard daily caloric intake (Horvath et al., 2000). Maximal oxygen uptake (VO_2max) is very important because it is used to evaluate cardiorespiratory endurance and aerobic fitness. Therefore if high fat diets can increase endurance, then it is possible that an individual's dietary intake could affect an individual's maximal oxygen uptake (VO_2max). % body fat is usually associated with VO_2max, but it is also possible that there might be a relationship between dietary intake and VO_2max in comparison to % body fat. One may also believe that dietary choices may be a determinant of VO_2max because "you are what you eat." The dietary choices we make affect how much sugar, fat, and energy among other things that are available in our body. Hypothetically speaking if an individual's dietary habits were very bad, then that could cause them to have less energy stored, they probably would not be able to achieve a true measurement of their VO_2max.

Purpose of Study

Without knowledge of their VO_2max value, an obese person may not know how much at risk they are for cardiovascular diseases such as coronary heart disease which buttresses the need 'in such an increasingly obese society, of knowing your VO_2max which can be very beneficial' (Wilmore and Costill, 1999); due to the fact that it provides you with a baseline idea of your cardiovascular health and aerobic fitness level. The purpose of this study is to determine whether an individual's % body fat or dietary choice is a better indicator of an individual's VO_2max. To determine this, a mixed method of quantitative and qualitative statistical analysis was evaluated on people ranging from ages 18-35 with no cardiac complications.

Significance of Study

This study is significant in terms of cardiovascular health. Many scientists in the field of cardiovascular health measure and analyze VO_2max. To determine the factors that affect VO_2max, this study investigated the correlation between VO_2max, % body fat, and dietary choices. Although it may be obvious that there is a relationship between the three, the purpose of this study was to determine if the relationship is significant enough to suggest a causative affect, and generate hypotheses for future experimental studies. Results of the study can lead to a better understanding of why people who weigh the same have different VO_2max values, and why people with similar % body fat have different VO_2max values. It is known that though all bodies are structurally similar they may process things differently. However, how much of that difference is significant enough to suggest a relationship with VO_2max. For example: everyone doesn't process sugar the same way, so how does the way they process sugar affect their maximal oxygen uptake?

Theoretical Framework

The methodology of the research is based on the skin fold test, USDA nutritional calculator, and the Fick equation which states that:

VO_2max = Heart rate x Stroke volume (Arterial-venous oxygen difference)

This equation is used to measure the maximum intake of oxygen through the lungs, then the uptake of oxygen through the blood and the consumption/utilization of oxygen in the muscle. There are two methods that can be used to assess

the values for the Fick equation: the manual Douglas Bag method or the automated computer system. Introduced in 1911, the Douglas Bag method remains the "gold standard" for assessing metabolic and cardiorespiratory responses to exercise today. For the purpose of this study we will focus only on the Douglas bag method, though training was received on how to use both systems during summer research experiences.

Summary of Methodology

Based on our overall understanding of VO_2max, we used a treadmill to test our subjects. Our subjects were allowed to pick the face piece; either a mask or mouth piece, they would be most comfortable using for the study. Then we conducted a series of incremental exercise tests on each subject as we monitored their heart rate in hopes of achieving VO_2max. This study was limited by time and the number of subjects who were available and wanted to partake in the study. The dietary logs of our subject were calculated through computer software and Microsoft Excel. The subject's dietary logs were limited by their ability to accurately recall everything they ate in a descriptive manner that was easy to calculate.

Due to the intense nature of this study, all subjects were screened and evaluated before they participated in the study. They were then asked to sign a consent form to show that they fully understood the nature of the study. Typically our ideal subjects were males and females who were between the ages of 18 and 30 and were active. We requested that all subjects fast overnight prior to undergoing our exercise tests.

Literature Review

Maximal oxygen uptake (VO_2max) can be used to determine an individual's fitness level because it measures an individual's maximum ability to intake oxygen to the lungs, transfer it in the blood, and consume it at the muscular level (Mitchell et al., 1957). An individual's VO_2max is based on their absolute ability to efficiently use and carry oxygen throughout the body while performing incremental progressive exercise (Mitchell et al., 1957). To measure VO_2max, an individual exerts a maximal effort during physical exercise that uses large muscle groups in a rhythmic fashion. Typically an individual is exercising on a treadmill or cycle where the work effort incrementally increases, and as they exercise they are connected to a ventilation system that measures the concentration and volume of carbon dioxide and oxygen that they inhale or exhale (Levine, 2008).

Basically the Fick equation tells us that our maximal oxygen uptake is equal to the concentration of the arterial oxygen minus the concentration of the venous oxygen multiplied by the cardiac output (Levine, 2008).

Based on the Fick equation we can expect athletes to have a higher VO_2max than non-athletes because the physical repetitive challenges that they are conditioned to withstand causes them to have a significant difference in their cardiac output due to their increased stroke volume. The reason why their cardiac output would be higher is because of the rigorous activities that they encounter on a daily basis, which trains the heart to increase the size of the cardiac chamber. Clearly, being able to consume oxygen at a high rate during exercise is advantageous because it increases an individual's endurance so they can perform physical activities for a longer period of time (Levine, 2008).

Basset et al. conducted a study and found that the differences between the two systems are minimal. They concluded that the automated system was very accurate and precise (Basset et al, 2001). But based on personal experience in the lab, we chose to conduct the present study using the Douglas bag method.

Procedures

RESEARCH QUESTION:
Based on an individual's dietary habits and % body fat: which is a better determinant of VO_2max?

All subjects were interviewed, evaluated, and signed consent forms before they were allowed to participate in the study. Subjects were then given dietary logs, and asked to complete a detailed description of everything they ate over the course of three days, which had to include a day during the weekend, and two weekdays. A skin fold test was performed on each subject to determine their % body fat. For this study we used the Jackson and Pollock (1978) method of measuring % body fat. The Jackson and Pollock skin fold test is based on measuring subcutaneous skin fold thicknesses at seven anatomical sites: chest, abdomen, thigh, subscapula, triceps, axilla, and suprailium (Adams and Beam, 2008). The seven sites were measured with skin fold calipers to determine the millimeters of subcutaneous fat present at each site. All VO_2 studies were based on the Douglas Bag method, and calculated through formulas for assessing metabolic responses to exercise via indirect calorimetry using an Excel spreadsheet. All environmental conditions were evaluated and recorded prior to the study.

The Douglas Bag method collects air that is expired over a short period of time during aerobic exercise. When using the Douglas bag method a subject was connected to the system though a mouth piece or a mask based on their preference. The mouth piece is connected to a tube that leads to the Douglas bag. The collection of air within the bag was controlled by a valve. These valves allow the test administrator to open and close the passage of air in and out of the bag. As the test administrator synchronizes their clock, the subject walks/runs on the treadmill as they breathe normally through the mouth piece.

As time continues, the intensity of the exercise is gradually increased by raising the treadmill incline, which causes the subject to work harder to maintain their current pace. Expired gases are collected in consecutive one-minute bags throughout the exercise. After the exercise is over and the subject has reached a state of exhaustion, the bag volume and concentrations of O_2 and CO_2 within the bag are measured, calculated, evaluated and used to calculate the subject's VO_2 and

VCO_2 at each stage, with the highest level of VO_2 obtained during the final stage considered the VO_2max (Douglas, 1911, University of Maryland Exercise Physiology Laboratory Manual, 2004).

The subjects' dietary logs were then entered into computer software located on the United States Department of Agriculture (USDA) website under pyramid tracker (http://www.mypyramidtracker.gov/). The program was used to analyze the nutritional content of the individuals' diets. The data were then converted to numerical values and entered into an Excel sheet. Within Excel all the different dietary components were graphically analyzed in relation to VO_2max.

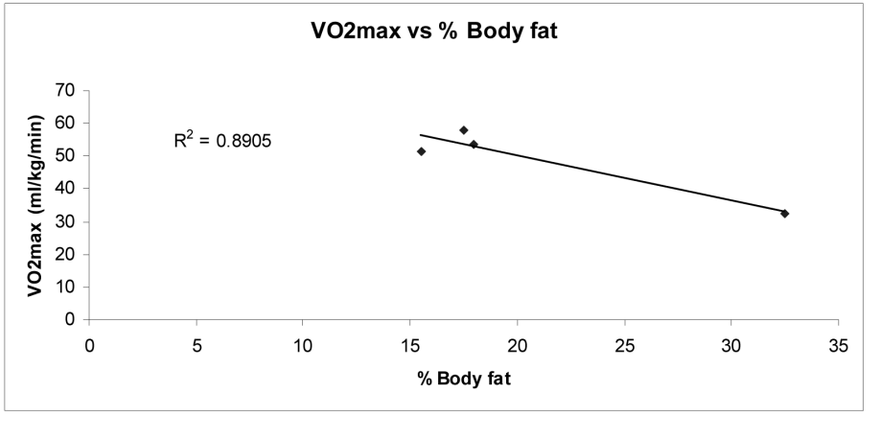
Results

Table 1 VO_2max in comparison to % Body fat

Subjects	Sex	Age	Weight	Height	VO2max	%body fat
1	Female	23	60.7	168.5	57.7	17.5
2	male	25	102.9	184	53.7	17.95
3	male	25	76.3	172	51.4	15.5
4	Female	20	70.9	152	32.2	32.5

This table shows our 4 subjects' VO_2max in comparison to their % Body fat

Figure 1 This graphs shows VO_2max in comparison to % Body Fat



This graph and the strong statistical correlation suggest that there is a relationship between VO_2max and % Body Fat

Based on the slope of the trendline in the graph above, the slope equation is:

$y = -1.3661x + 77.249$

Therefore, if the % body fat value is 40, it is plugged in as the x-value in the equation above, which gives a y-value of 22.605 which shows that the % body fat value is inversely proportional to the VO_2max value.

Table 2 The subject's dietary breakdown of food intake in (mg, cups, oz, %, gm, Kcal)

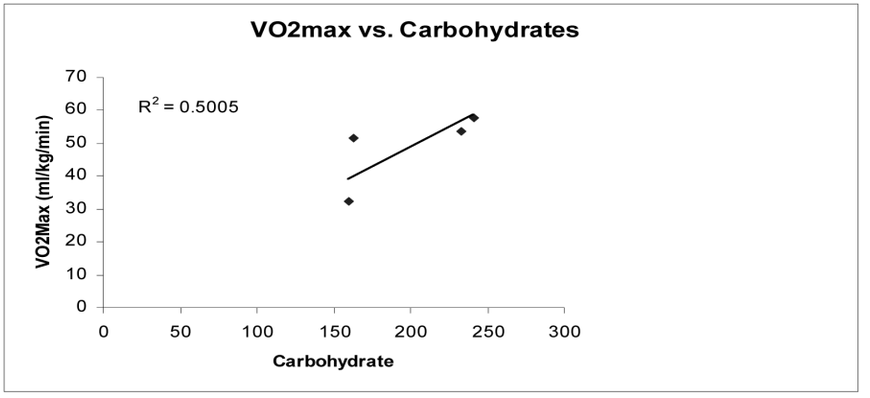
Participants	VO_2max	%body fat	Grain (oz)	Vegetable (cups)
1	57.7	17.5	5.93	7.7
2	53.7	17.9	5.86	2.5
3	51.4	15.5	5.7	0.83
4	32.2	32.5	5.6	0.96
Participants	Saturated Fat%	Saturated Fat%	Cholesterol (mg)	Sodium (mg)
1	4%	4%	9.5	2263
2	12.03%	12.00%	537	4186.33
3	10.33%		255.3	2285
4	13.13%		426.3	3486
Participants	Saturated Fat (gm)	Vitamin A (mcg RAE)	Vitamin C (mg)	Potassium (mg)
1	7.47	639.13	145	2404.66
2	43.4	847.03	98.47	3911
3	12.1	859.8	20	1634.66
4	33.7	591.96	24.3	1560.66

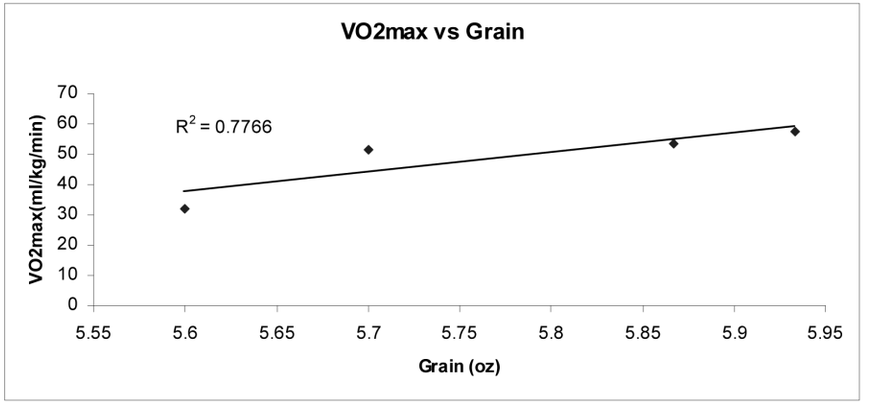
This table shows an average of each subject's dietary habits over the course of three days. The information was derived using the USDA pyramid tracker calculator.

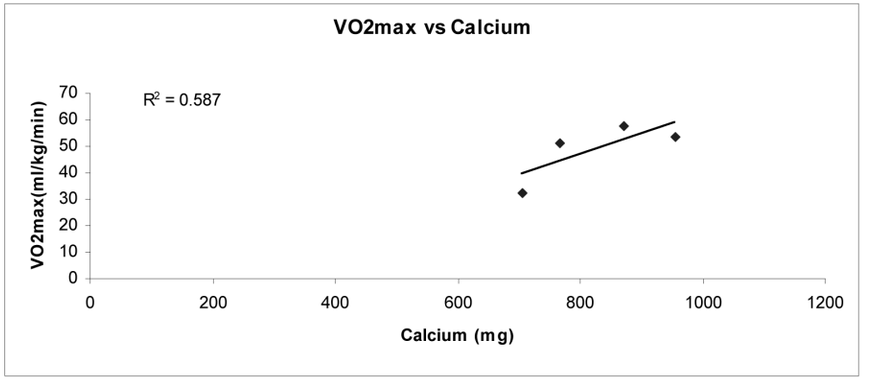
Table 2 *Continued*

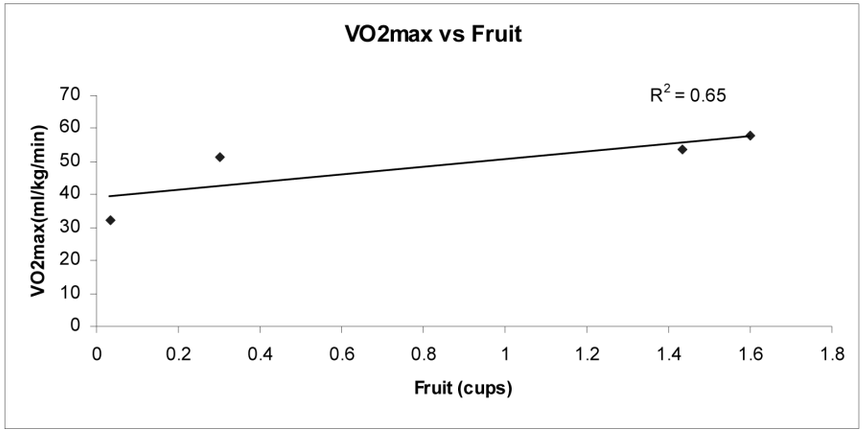
Participants	Fruit (cups)	Milk (cups)	Meat & Beans (oz)	Total Fat %
1	1.6	0.46	5.5	24%
2	1.43	0.53	8.66	31%
3	0.3	1.73	4.23	33%
4	0.03	1.06	7.63	38%
Participants	Food Energy (kcal)	Protein (gm)	Carbohydrate (gm)	Total Fat (gm)
1	1605	75.33	241.33	43
2	3142	113.6	232.66	113.03
3	1298	59.33	163	48.53
4	1766	89.33	160	85.9
Participants	Iron (mg)	Calcium(mg)		
1	19.2	870.87		
2	17.8	955.13		
3	28.3	766.5		
4	13.2	704.67		

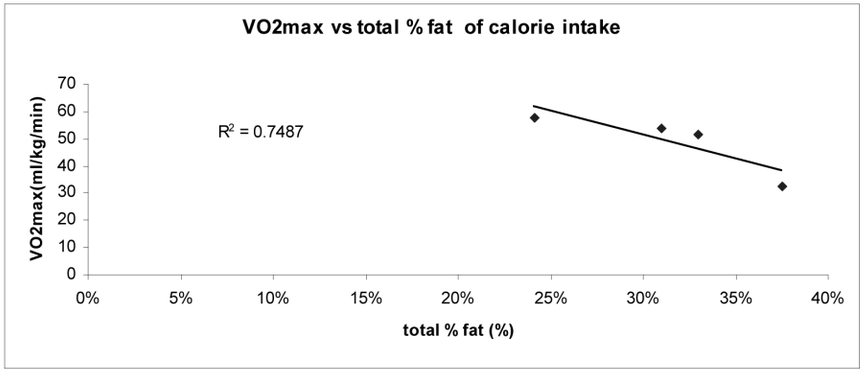
Figure 2 Graphical representation of all the dietary components whose R squared value suggests a significant relationship between VO_2max

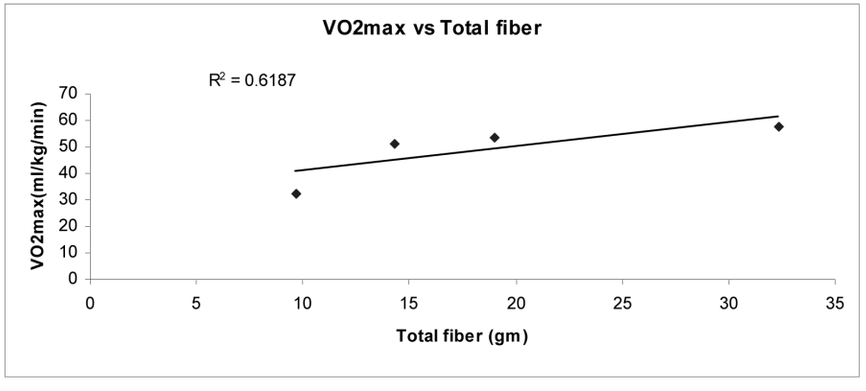












These graphs show the dietary components that had an R square value over 0.5. This was the agreed upon value use to suggest that there maybe a significant relationship between VO_2max and dietary intake. The most significant dietary components were carbohydrates (R square value of 0.50), total percent fat from caloric intake (R square value of 0.75), fruit (R square value of 0.65), grain(R square value of 0.78), and total fiber (R square value of 0.62). So as grain, carbohydrate, fiber, and fruit increase the VO_2max increases, but as total % fat in calories increase VO_2max decrease.

Discussion

Although there is a relationship between VO_2 max and dietary habits, the relationship between % body fat and VO_2max data had the highest R squared value, which suggests that there is a stronger relationship present. Based on all the dietary components shown in table 2, carbohydrates, grain, calcium, fruit, total fiber, and total % fat of calorie intake had significant relationships with VO_2 max as seen in figure 2. Of the significant dietary components grain seemed to be the most relative to VO_2max with an R square value of 0.78. % body fat had the strongest relationship to VO_2max with an R square value of 0.89. The % body fat tells an individual what percentage of their body consists mainly of fat, so if they weigh 150 lbs with 50% body fat; that would mean that their lean body mass is 75lb and their fat is 75 lbs. % Body fat is very important because the body uses fat for insulation, thermoregulation and, most importantly it is a form of energy storage. All components are essential to VO_2max, because you need stored energy to perform the endurance aspect of the test, and insulation and thermoregulation to warm up the muscles so they can be used more efficiently.

Based on our understanding of fiber, it is easy to understand why it may have a relationship with VO_2 max. Dietary fiber contains indigestible carbohydrates that are beneficial. VO_2 max evaluates an individual's cardiovascular health. The introduction of dietary fiber in an individual's diet has the ability to reduce their risk of coronary heart disease and diabetes; it can also help an individual maintain normal blood glucose (USDA, 2005). The maintenance of normal blood glucose levels is important because glucose is a form of energy storage (USDA, 2005).

Carbohydrates are derived from many sources like sugars, starch, and the fiber from fruits, vegetable, milk, and grains. Carbohydrate could have a close relationship with VO_2max because much like fiber, carbohydrates derived the energy source from glucose which comes from the breakdown of sugars and starch. Then, the derived glucose can be used to send energy to the brain, central nervous system, and red blood cells (USDA, 2005).

The relationship between calcium and VO_2 max is not as obvious because calcium is a mineral. It is common knowledge that calcium is used to build strong teeth and bone, thereby playing an overall role in strengthening and maintaining bones. In relationship to VO_2max, calcium is used to initiate muscular contraction, blood clotting, and cell membrane maintenance (USDA, 2005) which are essential components to any aerobic exercise regime.

The rest of the dietary components that showed significant relationships with VO_2 max are sources of the previous breakdowns. Grains are the major sources of energy and fiber. Fruit is a main source of potassium, magnesium, and fiber.

In terms of Vo_2 max, the total fat % of an individual's caloric intake is directly related to cardiovascular health. Fats can be as helpful to an individual's diet as they are harmful. A total fat intake that is less than 20% of calories may actually increase individuals to inadequately absorb vitamin E and other essential fatty acids, which can cause a negative change in their high density lipoprotein cholesterol (USDA, 2005). But total fat intakes that exceed 35% of the calorie intake can cause a person to consume more calories than necessary. This type of reaction can increase an individual's risk of coronary heart disease. Thus, an individual's total % fat of their caloric intake can be good reflection cardiovascular health, which is similar to the purpose of VO_2 max (USDA, 2005).

Conclusion

In conclusion, the result of the experiment was based on only 4 subjects. The data can, therefore, only be used to suggest a relationship, and not make a definitive conclusion. Overall % body fat had the strongest relationship with VO_2max, making % body fat the best predictor of VO_2max. Figure 2 shows that as % body fat increases VO2max decreases, which suggests that as individuals increases in % body fat their cardiovascular fitness may be compromised.

Our results suggest a relationship between dietary choices and VO_2 max, but the small sample size makes it difficult to assess cause and effect. Thus, future studies should use a minimum of 20 subjects to attain a more accurate correlation because it was definitely a limitation in the current study.

Despite the limitation to this study, the basic information can be used as a foundation to guide future experimental studies. A second study could look at both active and sedentary people. All subjects in this study were categorized as active. To eliminate certain factors, like aerobic fitness, we need to determine how the dietary habits of both active and sedentary subjects vary in relationship to % body fat and VO_2 max. For a more in depth understanding of why certain dietary components are significant, we could conduct studies that allow us to experimentally manipulate the amount of caloric intake, fiber, carbohydrate, grain and fruit that is present in an individual's diet. Then we can analyze how variance in these concentrations can affect VO_2max.

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