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Research Proposal

The Effects of Veganism on Endurance Running Performance

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RSCH 202: Introduction to Research Methods

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Abstract

With the growing interest in veganism and its potential health benefits to athletes, it is imperative to consider whether dietary practices could influence athletic performance. The purpose of this research is to find out whether veganism leads to a better performance in endurance runners. We also examine recent studies that attempt to highlight the positive and negative impacts of veganism on athletes' health. This study adopts a similar framework to the Nutritional and Running High Mileage (NURMI) study, which aims to investigate the relationship between different diet types and running performance. 200 volunteers in Singapore will participate in a cross-sectional online survey and undergo an experiment where they will follow a controlled training diet program. Regression analysis will be used to analyze the factors that affect running performance and T-test to determine if there are any statistically significant differences in performance between vegans and omnivores in terms of their 42km marathon timing and VO2 Max. The results from this comparative study aim to help endurance runners to make better decisions when considering adopting a vegan diet and whether it will indeed be beneficial to them.

Keywords: vegan, omnivore, endurance, running, marathon

Introduction

There is an increasing number of the population that is switching to a vegan diet in hopes to get healthier or to have better sports performance. Be it for health or for performance, the media has portrayed that a vegan diet is beneficial for human well-being. There are significantly a lot of marathoners, ultra-marathoners, and athletes in the endurance discipline who are known to be vegans for performance sake. Scott Jurek for example, an ultra-marathon runner, believes that a vegan diet is the reason for his success in the endurance sport (Wirnitzer et al., 2016). But is it really the case?

While many vegan endurance athletes have proven successful while adhering to their diet, there is little research and concrete evidence to prove that a vegan diet is indeed superior to an omnivore diet in terms of endurance. The purpose of this research is to understand the prevalence of a vegan diet amongst endurance runners and to establish whether there is a relationship between a vegan diet and endurance performance. The positive and negative effects of a vegan diet on health will be discussed to identify possible correlations to endurance performance. This research aims to help current and future endurance athletes to make better decisions when deciding whether to follow a vegan diet and whether it will indeed benefit them.

A vegan diet, in general, is one that avoids all animal products including eggs, meat, and dairy (Petre, 2016). An omnivorous diet on the other hand is one that includes both animal and plant products (Schuna, n.d.). For the purpose of this study, the performance of the athletes who follow a vegan diet will be compared against the performance of those who follow an omnivorous diet.

Review of Literature

While there is sufficient evidence to support that endurance athletes can adhere to a vegan diet and still achieve better performance, there is little study done until today that has managed to clearly identify and establish a mutual relationship between a vegan diet and endurance athletes. A vegan diet is especially common in the field of endurance sports such as endurance running. Although scientific data about endurance runners and vegan diets are limited, several researchers have attempted to study the benefits and detrimental effects of a vegan diet on the health status of endurance runners.

Amongst the scarce number of researches, multiple studies have made use of the NURMI study, also known as Nutrition and Running High Mileage study, which is an international interdisciplinary comparative study of running that was designed specifically to compare a large sample in order to investigate the prevalence in marathons and to identify differences in running performance between three subgroups: omnivorous, vegetarian, and vegan endurance runners (Wirnitzer et al., 2016).

Endurance Running Performance

A vegan diet has been proven to reduce body weight and lower **Body Mass Index (BMI)**. An important finding from the NURMI study is that vegetarians and vegans have lower body weight which results in lower BMI (Wirnitzer et al., 2016). BMI is found to be a key factor for running performance. Optimally, the BMI reported for the best performance in above 10km marathon running was found to be between 19–20 kg/m² (Sedeaud et al., 2014). However, BMI should be used carefully as a measure for running performance as it may not directly reflect what it is for active endurance runners. Active endurance runners could have a BMI below the normal range and still perform optimally. A correlation between BMI and maximal race speed was

found and the optimal BMI for men was 19.8 kg/m² for a maximal speed of 5.70 m/s. Equivalents for women were 18.2 kg/m² and 5.19 m/s (Marc et al., 2014).

In another research, participants who adhered to a vegetarian diet four days before completing a graded exercise test on a cycle ergometer were compared to those adhering to a normal (omnivorous) diet. Through this test, it was found that participants on a vegan diet had a higher oxygen consumption at a given workload (Lynch et al., 2018). This contradicts the finding on BMI from the NURMI study as a higher oxygen consumption would mean a reduction in endurance performance. However, it is identified that both pieces of research are limited in observing the nutritional intake of vegan participants compared to omnivore participants. The lack of control of food and nutritional intake may have resulted in the inconsistency of the final results. Hence, further research should be done with precise identification of the variable which is to ensure that food and nutritional intake are controlled factors in both diet groups (vegan and omnivore) before making a comparison between their endurance performance and deducing conclusive results.

Positive Health Effects

The existence of various factual justifications has led to the option of becoming a vegan as the vast majority comprehends and acknowledges the benefits of veganism. The appreciation of the positive outcomes of turning out to be vegan signifies a pivotal part in promoting the practice to anyone.

The major positive outcome of becoming vegan is the promotion of health. According to Lynette Goh, a senior dietician of National Healthcare Group Polyclinics' Clinical Services, vegans reap the benefits of better cardiovascular health (Gan, 2016). The current findings in this study provide a new understanding that an improvement in cardiovascular well-being implies a

lower danger of coronary failure, hypertension, and other related medical problems. Hence, the findings of this study suggest that vegans adapt to the low intake of saturated fat and cholesterol as the elimination of meat products helps to improve blood viscosity. This results in a better flow of oxygen for the muscles and allows improvement in athletic performance. It is evident that changing to veganism is a successful method of remaining solid and preventing medical-related illnesses.

Furthermore, a vegan diet is associated with health benefits as the types of food consumed are relatively high in nutrients. Vegans consume nutrients like fibre, potassium, vitamins A and C, and also phytochemicals which are compounds to assist in preventing unwanted infections. As plant-based foods contain high fibre, vegans tend to be thinner which reduces the chance of heart disease. The current findings add substantially to our understanding that their consumption of food comes from vegetables, fruits, alpha-linolenic acid (ALA), and legumes. Legumes are an alternative to protein sources for vegans. With overall adequate calorie intake, vegans consistently meet the recommended protein intake.

This information can be backed up by Harvard Health Publishing which states that the Recommended Dietary Allowance (RDA) for protein intake is a minimum of 0.8 grams per kilogram of body weight (Pendick, 2019). Besides, ALA are food sources that provide omega 3 fatty acids. Vegans require a high intake of ALA to increase their omega 3 acids. ALA acts as long chains of fatty chains like Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) which are typically absent in vegan diets. These fatty acids play a critical role in cardiovascular health and other body developments (Williams, 2007). This statement was written by both scholars majoring in human nutrition which was mentioned in the Cambridge University article. Interestingly, this correlation is related to sufficient evidence that states the need to provide

stable DHA and EPA levels over many years. Therefore, the findings suggest that in general, there is simplicity in meeting the diet requirements of a vegan diet, as long as the calorie intake is adequate.

In addition, recovery is a way for athletes to restore their body after strenuous exercise. Animal protein is well-known to promote recovery. However, animal protein contains high levels of acids which result in inflammation and ultimately hampering the process of recovery. Inflammation promotes chronic heart diseases, causes heart dysfunction, and increases Low-Density Lipoprotein (LDL). Based on an article published in the US News, a plant-based diet helps to improve recovery times for endurance athletes (Esposito, 2019).

Another research study done by Dr James Loomis, a medical director of the Barnard Medical Center, explained that a vegan diet contains very high antioxidants which help to reduce inflammation and improve the rate of recovery (Esposito, 2019). Whilst comparing long-distance runners, their workout can lead to delayed onset muscle soreness (DOMS) and tight muscles (Zickl, 2019). The second major finding suggests that a plant-based diet helps to speed up recovery alongside preventing cardiovascular diseases. The relevance of the vegan diet to enhance the recovery phase is clearly supported by the current findings. Therefore, these reasons give a logical establishment to expand the utilization of a plant-based eating regimen by endurance competitors.

Negative Health Effects

Veganism has received a lot more attention in recent years, presumably due to the above advantages which are becoming increasingly apparent to athletes. Nevertheless, it is important to understand that what is ideal for one athlete does not automatically make it suitable for everyone. In fact, a vegan diet can have copious negative side effects if entered into blindly. An

examination of the literature suggests that there has been a little directive study about the adverse impacts of a vegan diet on an athlete's performance as many are focused on the benefits it brings.

It is a common understanding from the sources and studies explored that nutrients such as omega-3, iron, calcium, iodine, and vitamin B12 especially are more difficult to obtain from plant-based foods. Dr Tammy Tong, a researcher in the University of Oxford's Nuffield Department of Population Health, explained that vegans are at a higher risk of B12-deficiency since the nutrient can only be acquired from animal foods and an important factor in endurance sports since it affects red blood cells production which transport oxygen to tissues throughout the body. He further added that low B12 levels can be linked to a higher risk of hemorrhagic stroke (Cox, 2019). The study was backed up by Dr David Rogerson, another researcher from the University of Sheffield Hallam, who further explained that athletes with B12 deficiencies may suffer fatigue, poor oxygen transport, and inability to maintain muscle mass (Cox, 2019).

To achieve adequate protein by consuming whole foods, vegans are recommended to eat beans, pulses, lentils, and grains daily—foods that are also carbohydrate-rich (Rogerson, 2017). However, these are also rich sources of fibre, and consuming fibre-rich foods to obtain sufficient protein and carbohydrates might prove to be difficult for some due to digestion and absorption resistance which promote gastric distress (Rogerson, 2017). It is therefore important that athletes seeking to adopt veganism understand the strategies to mitigate the risks of under-consuming nutrients and the health implications it brings if a vegan diet is to optimize health and performance.

It is worth highlighting that the term “vegan” was first coined in 1944 and did not enter the mainstream until much later. Further, scientific studies classified vegans and vegetarians together for a long time (Cox, 2019). While the researches above effectively linked the type of

diet, nutrients consumption, and risk of related diseases, most of the studies reviewed so far are either focused on vegans to the exclusion of vegetarians, or a combination of both, thus allowing no way to discern if the improvement in athlete's endurance performance can be attributed to a plant-based diet per se, or whether relatively similar results could be achieved by a less restrictive and possibly easier to follow a vegetarian diet (Glick-Bauer & Yeh, 2014).

Nevertheless, considering the fact that a "vegan diet" promotes better health and improved recovery process for endurance athletes compared to an animal-based diet as mentioned, it is worth stressing the cons of this diet in an athlete's health. It is important to note, however, that any improvement to endurance performance via a specific diet would likely be minor and difficult to quantify; the findings of the current body of evidence highlight the need for further research in this area.

The Game Changers (Sports Documentary)

To quote Patrik Baboumian, a world-record-holding vegan strongman, "One person asked me, 'how can you get as strong as an ox without eating meat?' And my answer was, 'have you ever seen an ox eating meat?'" The Strongman is a sport that requires superhuman strength. Contrary to popular belief that a diet with a high meat intake is needed in order to consume sufficient protein to get strong, Patrik Baboumian has achieved numerous strength records while on a vegan diet. In the field of endurance sports, Scott Jurek was featured in the documentary setting a new record on the Appalachian trail while on a vegan diet. While these examples may just be mere coincidences between a vegan diet and great achievements, the 2018 documentary film "The Game Changers" tries to convince the public that the vegan diet was the main reason that Patrik Baboumian, Scott Jurek, and many other great vegan athletes achieved their accomplishments.

A common misconception was brought up in the documentary that plant-based diets often lacked essential amino acids (EAAs). It was claimed that all EAAs are found in all plants. However, based on the explored research studies, it is clear that not all plant proteins contain the full range of EAAs. The majority of plants only contain some of the nine EAAs (Lee, 2017). It was also stated that meat adds arterial plaque due to animal fat. This is because meat contains cholesterol and when cholesterol is ingested in our bloodstream, white blood cells trap the cholesterol which causes inflammation, thus muscle cells in the artery multiply and creates plaque on the walls of the artery (Peta, 2019). This leads to a decrease in endothelial function which then impairs endurance performance.

Arnold Schwarzenegger, one of the executive producers of this documentary, owns a vegan supplementation company that sells vegan protein shakes and snacks. In the film, he was presented as a former Mr. Olympia bodybuilder. However, during his bodybuilding days, he was never a vegan. Thus, the documentary may be propagandistic as he may be promoting veganism to the audience as a marketing ploy for his vegan product company (Webber, 2020). False authority was used here as many would consider Arnold to be the face of being fit and muscular, however, he did not achieve his masculine physique through a vegan diet.

Research Methodology

Research Question

As the main objective of this research is to find out whether a specific type of diet has a significant impact on how athletes perform, it is of great importance to specify the type of diet and athletes which will be included in our scope. The research question aims to answer whether athletes following a plant-based diet will have better performance compared to those following a non-plant-based diet. Since there are several types of vegetarian diets namely Lacto vegetarian, ovo vegetarian, lacto-ovo vegetarian, and pescatarian, for simplicity, we have decided to narrow down our topic and focus on vegan and omnivore groups.

As there is little research and a scarce amount of data collected to prove that a vegan diet is indeed superior to an omnivore diet in terms of endurance performance despite the prevalence of a vegan diet amongst endurance athletes, the target group for this study will mainly be endurance runners. Considering all these factors, the research question for this study is: Do vegan endurance runners perform better than omnivore endurance runners?

Hypotheses

The two hypotheses for this study are the testable speculations arising from the variables that affect the performance of endurance runners. The hypotheses consist of a two-tailed test as this study examines the possibility of positive or negative impact on an athlete's performance. Null Hypothesis (H₀): Vegan diet has no significant impact on the performance of endurance runners.

Alternative Hypothesis (H_a): Vegan diet has a significant impact on the performance of endurance runners.

Type of study/data

A panel study will be performed to measure the performance of the endurance runners by measuring the time taken to complete a 42km marathon and VO2 Max of the research subjects. The test will be conducted on the same group two or more times over a period of time. Two types of data will be collected in a form of survey and experiment which uses cross-sectional and panel data respectively.

Data Collection and Analysis

The survey data classified under independent variables for this study will be collected through an online survey which will then be analyzed using regression analysis. The data collected from the experiments will be analyzed using a T-test to identify any significant differences between the results collected from testing the performance of the endurance runners before and after the change in their diet, and whether a vegan diet has a significant impact on their performance.

Population and Sample

For experiment purposes and to account for a large population, a sample size of 200 omnivore runners in Singapore will be selected to participate in this study. Participation will be entirely voluntary to keep the study ethical and to remove the need to force subjects to adhere to a certain diet for an extended period of time. The volunteers must be willing to comply with the conditions given during the controlled training program. Selection criteria for the participants will be of any gender, one with minimally three 42km full marathon completion experiences within the past 3 years. Participants will also have to be medically cleared from any pre-existing health conditions. The volunteers will have to be omnivores to participate in the experiment.

The method of sampling for this study will be volunteer purposive quota sampling. This study requires volunteers to undergo experimentation to determine whether or not the vegan diet affects endurance running performance as compared to the omnivorous diet. Volunteer sampling removes the need to force a diet on the research subjects. Also, purposive sampling will be used as we are only interested in specific groups of samples such as omnivores and marathon runners. Quota sampling will be implemented as well to provide more balanced data based on gender and age group. This would also help to eliminate the limitations of the study by ensuring a less skewed result. For example, the study would implement a gender quota of 50% females and 50% males. Sample collection will continue until the quota is met. However, in the scenario of lack of participants, the gender quota will be allowed a tolerance limit of 10%. For example, the percentages of the groupings can be changed to 60% females and 40% or vice versa.

A sufficiently large sample of volunteers would be needed to address the possibility of biasness in data in the purposive data sampling method. Thus, 200 volunteers would be selected to allow this research experimentation to yield valid and trustworthy results. This would also allow the dataset to represent the population of Singapore as closely as possible. After which, stratified sampling would be applied to the 200 volunteers where they would be divided into two strata. One group will follow an omnivore diet and the other group will follow a vegan diet. Each group will contain 50 females and 50 males respectively (Refer to Figure 1 for the illustration of the sample groupings). The experiment will then be conducted on the two groups where performance-related data such as run timings and VO2 Max will be measured.

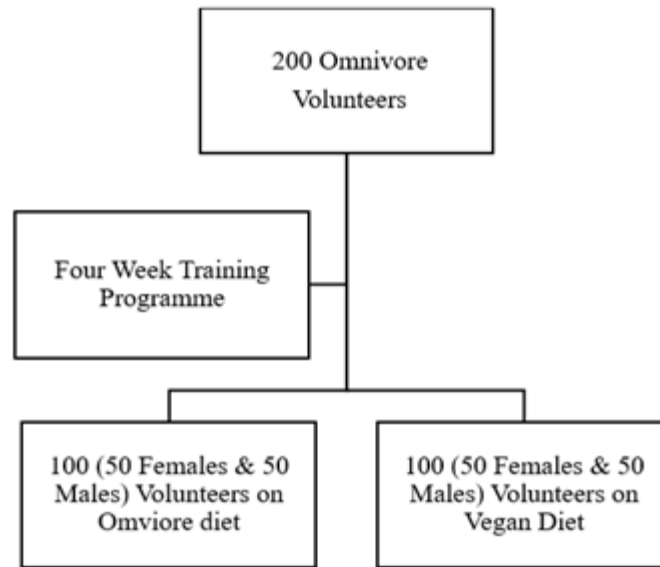


Figure 1: *Sample grouping for the study*

Variables and measure

Key Independent Variable

Based on the discussed literature, there are several important factors and variables that could affect the overall performance of endurance runners following a vegan and omnivorous diet. For the purpose of our study, the key independent variable will be the **type of diet— vegan or omnivorous diet**. Since this study aims to find out whether these two types of diet will significantly impact an athlete's performance, these predetermined variables will therefore be the main cause of improvement (or not) in an athlete's performance.

In this study, the control group will be the omnivore group and the treatment group will be the vegan group. In the experiment, the control group will continue to follow an omnivorous diet whereas the treatment group will change from omnivorous to a vegan diet. Having the control group (omnivore group) will strengthen our ability to draw conclusions from the experiment as its presence will determine whether the treatment under investigation (veganism) indeed has a significant impact on the experimental group (vegan group), so as to reduce the possibility of making an erroneous conclusion.

The type of diet assigned to the athletes, whether vegan or omnivorous, would need to be strictly adhered to when participating in this experiment. A vegan diet is prescribed to the subjects instead of choosing existing vegans since the diet is a key independent variable for this study. For better control of this variable and to ensure a more accurate result, only omnivores will be selected. Prescribing a vegan diet to an omnivore will allow the nutritional intake of all-vegan subjects to be controlled during the course of the study. Since the subjects were not vegan prior to the study, it is also easier to determine if the vegan diet was a cause for an improvement in their endurance performance and not because of their vegan diet prior to the study.

Control Variables

According to Wirnitzer et al. (2016), **BMI** was found to be a key factor for running performance and thus anthropometric variables such as **height and weight** of the runners participating in this study must be taken into account. Furthermore, physical performance can be assessed by muscle strength, bone density, and mobility. Sedeaud et al. (2014) also deduced from a study that higher BMI is associated with reduced levels of physical performance. Demographic control variables are also considered which include **age, gender, and ethnicity**. It is a well-known fact that the aging process is characterized by a gradual decrease in muscle mass and strength, which could ultimately lead to diminished physical performance (Sedeaud et al., 2014).

In addition, the performance of the athletes also depends on the kind of lifestyle they have. As such, other control variables include whether the participants are **smokers and/or alcoholics, their average duration of sleep (in hours), training frequency (number of days per week), and duration of the training (in hours)**. According to Siekaniec et al. (2017), the acute use of alcohol can influence an athlete's motor skills, hydration status, aerobic performance, as well as aspects of the recovery process. Pesta et al. (2013) also mentioned that cigarettes are the most common source of nicotine and that tobacco contains additional harmful constituents and chemicals, which have detrimental effects on the respiratory system. In addition, better sleep may reduce the risk of both injury and illness in athletes, not only optimizing health but also potentially enhancing performance through increased participation in training (Watson, 2017). By looking at the articles above, it shows the importance of the lifestyle of each athlete participating in this research as it contributes to the results on how much they can perform in the final experiment. All these variables will be taken from the response of the participants in the survey and the magnitude of impact on performance will be analyzed.

Lastly, for the purpose of this study, the experiment will be conducted in Singapore where the weather is mostly hot with high humidity levels. Therefore, external factors that could affect the performance are also considered such as **humidity (%) and surrounding temperature (degrees celsius)**. These will be measured using Wet Bulb Globe Temperature which is an accurate national weather service from wbgt.sg website based on location. Running, specifically, in cold weather poses certain risks to athletes such as pulled muscles and shortness of breath, resulting in lower stamina (Jeukendrup, n.d.). In hot weather, athletes need to ensure that they are well hydrated and that they do not overheat as dehydration causes problems that could adversely affect their performance. Heat also, directly and indirectly, influences muscle function, discomfort, effects on pain tolerance, mood, and motivation, all of which can influence performance (Jeukendrup, n.d.).

Dependent Variable

The **performance** of the endurance runners is the dependent variable in this study as this is the variable being tested and measured in the experiment, which is 'dependent' on the independent and control variables mentioned above. The performance will be measured in terms of the **time taken (Hrs & mins)** to complete a full 42km marathon using a stopwatch and the **VO2 Max (ml/kg/min)** of each research subject using a VO2 Max Test (Treadmill).

Data Collection Methods

Cross-sectional data are the result of a data collection, carried out at a single point in time on a statistical unit (Statista, n.d.). With this type of data, the change of data over time is of less importance, and this study is more interested in the current and valid opinion of the participants doing the survey (Statista, n.d.). As such, the first set of data collected will be cross-sectional data from the 200 omnivore volunteers, compiled in the form of an online survey which will account for useful information such as age, gender, lifestyle, etc. to aid at the start of the study to determine whether the respondents are eligible to take part in the experiment. The description of the survey questions is stated below in the appendix section.

The second set of data collected will be panel data in the form of an experiment. Panel data is a collection of data obtained across multiple individuals, in this case, different endurance runners, that are assembled over even intervals in time and ordered chronologically (Erica, 2019). The data from the experiment will be compared between a series of tests and with specific time intervals. Furthermore, panel data models allow for heterogeneity across groups and introduce individual-specific effects (Erica, 2019). This will allow the analysis of the causal relationships between the results from the experiment and the variables. In the experiment, the data will be compiled in a table where the time is taken to complete a 42km marathon and the VO2 Max of each participant will be recorded after conducting each test. The description of the sample data and the table where data will be recorded is shown in the appendix section.

The procedure of each test in the experiment

For the purpose of comparing the performance of vegan endurance runners against omnivore endurance runners, the study will measure endurance performance by the time taken to complete a 42km full marathon. The VO2 Max of participants will also be tested and recorded.

Participants with a shorter 42km completion timing and/or a higher VO₂ max will be deemed as a better endurance performer in this study.

For phase one (Test 1) of the study, all 200 omnivore participants consisting of 100 males and 100 females will be put on a 4 weeks-controlled training program following an omnivorous diet, before their VO₂ Max is tested and their 42km marathon timings are taken. Since the participants will come from different backgrounds, the purpose of the 4 weeks-controlled training program is to ensure that all participants will begin the study at an almost similar level. Thereafter, 100 participants consisting of 50 males and 50 females on a voluntary basis, will be selected to adhere to a vegan diet for 4 weeks for the second phase of the study.

Vegan meals will be provided to all 100 vegan participants. All meals will be prepared according to the average recommended micronutrients and macronutrients profile based on the respective body composition of individual research subjects. Calculation of micro and macro nutrients will be done in collaboration with Food Science and Technology students from the National University of Singapore. Readily prepared meals will be provided to all individuals through a partnership with a meal preparation company, Nutrify Meals. This is to ensure that the dietary intake of both groups is fully controlled during the course of this study.

During the second phase (Test 2) of the study, participants will continue to be put through a controlled training program for the entire duration of 4 weeks following their assigned diet. At the end of the 4 weeks, participants' VO₂ Max will be tested and their 42 km marathon timings will be taken for the second time. All results from phase two of the study will then be compared to the results collected in phase one. Improvements in performance will then be recorded for comparison between the two dietary groups. The dietary group with a significantly larger improvement in performance will be recorded for the purpose of concluding the findings of this

study. If there is no significant difference in performance improvement between the two dietary groups, it will be reasonable to conclude from the study that there is no substantial evidence to support the claims on the benefits of the vegan diet.

Factors to be monitored and noted before and throughout the duration of each test

- 1) Humidity
- 2) Surrounding Temperature

Data to be recorded after each test

- 1) VO₂ Max - the VO₂ Max (ml/kg/min) of each participant
- 2) Timing to record - the time taken (Hours; mins) to complete a 42km full marathon

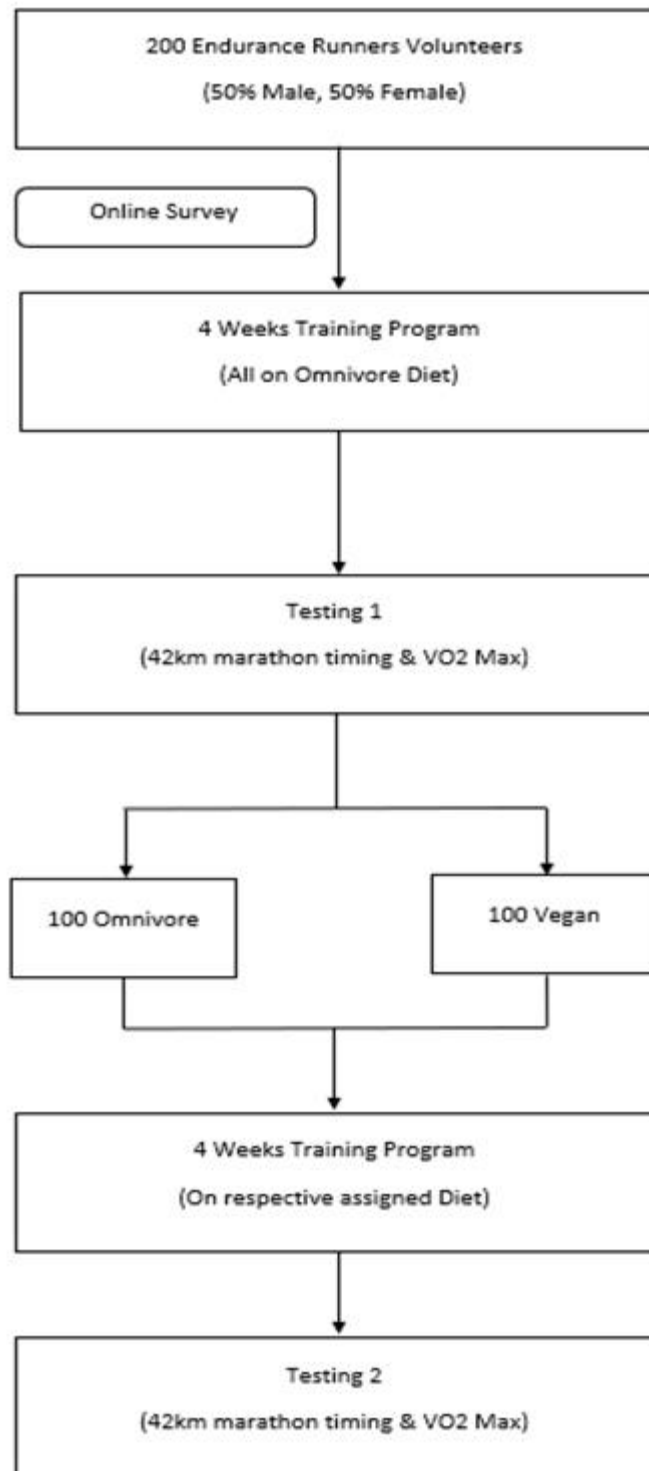


Figure 2: *Flow Chart of the entire data collection process*

Data Analysis Methods

Regression Analysis

Regression analysis is appropriate for the study because it can be used to infer causal relationships between the independent and dependent variables. Furthermore, by using regression analysis, it will be possible to determine which specific variables have a significant impact on the runners' performance, and also whether the impacts are positive or negative, big or small. The magnitude of impacts can be established based on the coefficients.

To establish a relationship between the key independent variable— the type of diet (Omnivore/Vegan) and the dependent variable— endurance running performance (time taken to complete a 42km marathon & VO2 Max), a regression analysis will be carried out to analyze the significance of the impact that a vegan or omnivore diet has on endurance running performance.

Although the main aim of this study is to establish the relationship between key independent variables, the regression analysis will also be used to analyze all other independent variables collected from the research subjects from the survey as they may or may not have a significant impact on performance as well.

We “estimate” two regression equations Y_1 and Y_2 :

$$Y_{1,2} = \alpha + \beta_1 \text{Vegan Diet} + \beta_2 \text{Gender} + \beta_3 \text{Smoking} + \beta_4 \text{Average Sleep Hour} + \beta_5 \text{Age} + \beta_6 \text{Ethnicity} + \beta_7 \text{BMI} + \beta_8 \text{Training Frequency} + \beta_9 \text{Alcohol Consumption} + \beta_{10} \text{Humidity} + \beta_{11} \text{Surrounding Temperature} + \varepsilon_i$$

where Y_2 = Time taken to complete a 42km marathon, Y_3 = VO2 Max, ε is an error term or residual.

A regression analysis will help to determine the independent variables that may have to be considered when concluding the study as they may play a role in affecting the results of the

experiments. This will improve the accuracy of the final findings as improvement in performance may not solely be based on the diet and all other possible factors should be considered. Although any form of relationship and impact identified from the regression analysis may not be scientifically proven, it is still reasonable to account for them.

From the regression analysis results, the adjusted R-square, P-value, and coefficients are analyzed. Since the value of R-square increases naturally as we have many independent variables, we will use the adjusted R-square to determine the goodness-of-fit. This value will determine how well the estimated model explains the data. Next, by looking at the P-value for every variable, we can then assess whether it has a significant impact on the dependent variable. For instance, if the P-value for the independent variable BMI is less than 0.05, it means that the result is statistically significant and this specific variable has a significant impact on the performance of endurance runners. The coefficient determines the size of impact and whether it has a positive or negative effect on the performance.

T-test

The primary objective of our research is to find out whether there is a difference in endurance running performance between vegans and omnivores. Hence, T-test analysis will be used to determine if there is a significant difference between the means of the two groups. The type of T-test to be used is Paired Two Sample for Means because the same group is measured twice for their performance in terms of VO2 Max and marathon timing, before and after the experiment. Comparison of performance will be made between the control group (Omnivore) and treatment group (Vegan) after the experiment as well as the performance results before and after the experiment of the control group (Omnivore) that did not change their diet. The second

comparison is done to check if any difference(s) found in the results from the treatment group is also present in the control group, which may present discrepancies or irregularities.

If the same level of improvements in the vegan group is seen in the omnivore group, it is likely that the vegan diet did not have a significant impact on endurance running performance. However, the results from this study do not 100 percent conclude the lack of correlation between diet and endurance running performance. If no improvements are seen in the vegan and omnivore group, it is likely that diet did not have any significant impact on endurance running performance. However, as the study is limited by its short-term observations, the results may not be accountable for the long-term effects of diet on endurance running performance. A difference in the level of improvements between the vegan and omnivore groups would be ideal in this study, with an improvement from the vegan group supporting the alternative hypothesis, and an improvement from the omnivore group supporting the null hypothesis.

For the purpose of this study, a 5% significance level ($\alpha = 0.05$) is selected. This denotes the probability of committing an error of rejecting the null hypothesis when it is true. Referring back to the null hypothesis, this means that there is a 5% risk of concluding that a vegan diet has no significant impact on the performance of endurance runners when there is a significant impact.

From the T-test results, the P-value will be compared against the significance level to decide whether to reject (or not) the null hypothesis. If the P-value is less than the significance level, we reject the null hypothesis and the result is statistically significant at 5% significance level. Hence, the conclusion would be veganism has a significant impact on the performance of endurance runners. Conversely, if the P-value is more than the significance level, we do not reject the null hypothesis and the result is not statistically significant at 5% significance level.

Therefore, the conclusion would be veganism has no significant impact on the performance of endurance runners.

A second T-test will be carried out to compare whether there is a significant difference in the performance of omnivores before and after the experiment. The results will determine if any improvement or difference is indeed based on the diet practiced during the experiment. If the result is statistically significant, we can deduce that improvement in performance might not be due to the diet but due to other factors such as demographics, social lifestyle, weather, etc. However, if the results and difference in performance are not statistically significant compared with the treatment group (vegan), we can conclude that the improvement is due to the vegan diet accounting for all other independent variables. The diagram below shows the illustration of T-test analysis between different groups.

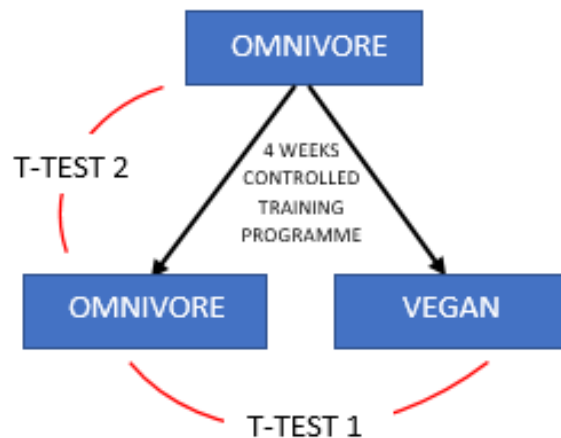


Figure 3. *T-test to be conducted between different groups*

Limitations

One limitation of this research is the lack of data on the long-term effects of a vegan diet on endurance running. If subjects were already vegan prior to the study, the study would be able to measure the long-term effects of their diet on performance. However, the short-term approach was specially chosen due to the prevalence of endurance runners adopting a vegan diet a few weeks prior to running a marathon. Adaptation is also a factor of consideration. If subjects were already vegan prior to the study, their level of adaptation to the diet may vary and this may affect the final result of our study.

Another limitation is that every human body is unique depending on age, ethnicity, and lifestyle, so it may be difficult to pinpoint a specific diet type that is optimal for the entire population. Thus, further detailed study and research on how a vegan diet could affect each specific individual in the population are needed.

Lastly, there is no true measure for endurance performance and the study reflects how the diet would impact endurance performance. Therefore, the speed and time tests were conducted to help determine the acceleration, maximum running speed, and speed endurance. Another factor that can be measured is agility. Agility tests measure an athlete's ability to move quickly and change directions while maintaining control and balance. Good agility requires a combination of speed, balance, power, and coordination. However, the agility test results are not required for the final data thus, this research focuses solely on the speed and timing of the athlete's performance.

Conclusion

In conclusion, the main objective of the research is to determine the effects vegan and omnivore diets have on marathon runners. The data of test subjects will be collected through volunteer purposive quota sampling methods. These data sampling methods will allow the test subjects to willingly take part in the experiments as they have a choice in joining the research study. The experiments will be conducted before and after the runners have changed to the vegan diet. After the experiments are conducted, the results will be shared with dietitians and coaches to reduce the duration of trial and error when finding the best nutrition plan for their athletes. As this study also covers the potential negative effects of a vegan diet on an endurance runner, individuals will be able to understand the pros and cons of adopting a vegan diet from this study and make an educated choice. The findings from this study can also help with future exploration or studies done on this topic.

Appendix

Survey questions for 200 volunteer Omnivore participants.

- 1) Are you an Omnivore? (Yes / No)
- 1) Have you completed at least three 42km marathons in the past 3 years? (Yes / No)
- 2) Please indicate your gender. (Male / Female)
- 3) Are you a smoker? (Yes / No)
- 4) Please indicate your average sleep hours in a day. (Fill in the blanks)
- 5) Please indicate your age. (Fill in the blanks)
- 6) What is your ethnicity? (Chinese, Malay, Indian, Eurasian, Others)
- 7) Please indicate your height in cm. (Fill in the blanks)
- 8) Please indicate your weight in kg. (Fill in the blanks)
- 9) Please state your training frequency in terms of the number of days per week. (Fill in the blanks)
- 10) Do you consume alcohol? (Yes / No)

For the recording of test results

Diet:	Name:					
Data	Test 1	Humidity:	Surrounding temperature:	Test 2	Humidity:	Surrounding temperature:
Time taken (Hrs; mins) for 42km full marathon						
VO2 max (ml/kg/min)						

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