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CHANGES IN BODY COMPOSITION AND PHYSICAL PERFORMANCE IN RESPONSE TO A HIGH PROTEIN DIET

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ABSTRACT

Physical performance and body composition are highly influenced by the diet that individuals consume. The distribution of macronutrient intake an active individual chooses to use as fuel for physical performance, highly depends on the type of exercise. Purpose: To investigate the influence of a high protein diet and a high carbohydrate diet on physical performance, changes in body composition, and psychological status. Subjects (n=24, 21-66 years old) were assigned two diets, each diet lasting three weeks, with a week-long washout between the two diets. The first diet was assigned based off of an assessment of each participant's normal, everyday diet the second diet was the diet that was not consumed the first three weeks. Throughout the diets, subjects were required to attend 5 hours of exercise classes each week, and maintain that same schedule for the entirety of the 7 week study. Results: The protein diet showed an increase in leg strength and push up number and a decrease in diastolic blood pressure as well as highest rating of personal improvement in exercise classes. The high carbohydrate diet had stronger results psychologically with greater rankings in satisfaction with exercise instructor, satisfaction with life, good mental health and pain and stiffness after workouts.

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ACKNOWLEDGEMENTS

I would like to thank the subjects for volunteering and participating in this study and for their great work and incredible cooperation. I want to thank FITOLOGY for the use of their facility for all fitness classes and all measurements. Most importantly I would like to thank Jinger Gottaschall for all of her help with this study and for being a very supporting mentor over the last three years.

Chapter 1

Introduction

According to *Nutrition Today*, only 1 in 5 people in the US population follow the recommendations for fruit and vegetable consumption and only 1 in 4 people meet the daily recommendations for physical activity. It is safe to say that many people in the US population are not properly fueling their bodies for daily living and the issue is one for concern (Bier, 2008).

The general guidelines of macronutrient consumption for active individuals are as follows: 5-7g/kg/d carbohydrates for moderately intense exercise and 7-10g/kg/d carb for highly intense exercise, 1.2-1.4 g/kg/d protein for endurance exercise and 1.6-1.7 g/kg/d for resistance training, and 20-35% fat (20-30% fat for those trying to lose weight). These ranges are the recommended diet for all healthy individuals above the age of two years old.

These guidelines are reassessed and changed from time to time to best fit the needs of the average individual. However, most people within the US population do not come close to meeting the dietary guidelines (Bier, 2008). It is a major breach in nutrition and numerous attempts have been made to improve the national understanding of the guidelines, therefore improving national compliance.

While there is such a large gap between people complying with the recommendations and the actual recommendations, professionals are not surprised by it, when considering all the barriers that food consumers encounter. These barriers include cultural, societal norms, family influences, food availability and commercial advertising influencing behaviors (Dwyer-Lindgren, 2013).

Many issues stem from this problem of nutritional compliance, including the growing obesity problem. The US rate of obesity has rapidly increased over the years, however, recent studies show that this rate of increase is slowly beginning to decline. And while these declined rates are a good sign and an important step for stopping the obesity epidemic, the US is still experiencing growing obesity rates (Dwyer-Lindgren, 2013).

In a study conducted by Eagle in 2012, researchers further defined the association between childhood obesity and household income, community resources and children's behaviors. Throughout this study, over 110,000 children were screened. Ultimately, and not surprisingly, issues observed in this study that were found to be related to obesity are very similar to the barriers causing issues for nutritional compliance.

Low levels of physical activity are known to have a positive correlation with obesity. Within the Eagle obesity study, it was found that three behaviors were highly predictive of obesity. One of those three behaviors identified included low weekly levels of moderate physical activity (Eagle, 2012).

According to the Center for Disease Control and Prevention (CDC), recommended physical activity varies depending on the age group. It is recommended that children and adolescents do 60 minutes of physical activity each day, including vigorous-intensity aerobic activity at least three days a week and muscle strengthening activities at least three days a week. For adults, age 18-65 it is recommended that they do at least 150 minutes of moderate-intensity aerobic activity and muscle-strengthening activities at least two days a week or 75 minutes of vigorous-intensity aerobic activity and muscle-strengthening activities at least two days a week. Older adults, ages 65 and older with no limiting health conditions that are generally fit, are recommended the same amount of physical activity as adults. While the recommended time and amount of activity is much greater for children than adults and older adults differ, there is a general trend of including aerobic activity and muscle building activity, multiple times a week. This demonstrates that all individuals of all ages can benefit from being physically active. Benefits of being physically active include lower body weight and BMI and cardiac benefits including lower blood pressure (CDC, 2011).

Dwyer-Lindgren et al, assessed the prevalence of physical activity across the United States in 2001 and in 2011, to document changes in the amount of physical activity across different populations. It was a surprising find that physical activity trends had not improved over time, even with the increasing awareness of obesity and the benefits of a healthy, active lifestyle. According to this study, the reported physical activity for the male population in 2001 was 22.5% and 22.4% in 2011. For women, it was reported that 28.1% of women participated in regular physical activity in 2001 and only 25.9% in 2011. The female population actually dropped in percentage of individuals participating in regular physical activity in 2011 (Dwyer-Lindgren, 2013).

Ultimately both physical activity and nutritional compliance need to be addressed in improving the health of the average American and decreasing the occurrence of obesity. Over time, many different diets and life styles have been suggested to help people lose weight and live a healthier lifestyle. But the answer is very simple; eat a well-balanced diet that follows the dietary guidelines and get adequate amounts of physical activity. With that simple explanation, it is also important to understand how different diets can affect the obese population. It is beneficial to understand how manipulating dietary intake can be beneficial as well as harmful.

With obesity being such a large issue within the US, it is easy to overlook the active and healthy population. With research and knowledge available about the complications often associated with sedentary, unhealthy lifestyle, many people are trying to combat that with daily exercise regimens and a change in diet. Different diets become popular from time to time. As of recent, there has been a particular interest in a high protein diet promoting weight loss and muscle toning. The diet is often referred to as the "Paleo diet"; it is supposed to mimic the diets of individuals over 10,000 years ago when humans began to cultivate plants. It was a diet high in protein and very low in carbohydrates. The diet consists mainly of fish, grass-fed pasture raised meats, eggs, vegetables, fruit, fungi and nuts with a major emphasis on excluding grains and legumes (Frassetto, 2009).

Fressetto et al (2009) explored the benefits of a Paleo diet. The authors argue that the modern day diet deviates strongly from the Paleolithic diet mainly due to the industrial revolution, making refined grains and processed grains more available, and to the fast food revolution. The authors conducted a study, for 17 days on healthy individuals. Throughout this study, all subjects had paleo meals prepared three times a day for every day of the intervention. The study revealed that there were significant reductions in blood pressure, 24 hour urine sodium, urinary calcium excretions, fasting insulin plasma concentrations, and total cholesterol levels. They also observed improvements in insulin sensitivity. The study, however, did not observe significant changes in weight (Frassetto, 2009).

The science behind the Paleo diet makes sense in that elevated protein intake does in fact increase lean muscle tissue. During glucose deprivation, a low or no carbohydrates diet, triglyceride lipolysis occurs so glucose products can be made and used for fuel. The lipolysis results in more free fatty acids being released into the blood stream which are then used as a substrate in gluconeogenesis. The products of gluconeogenesis are then used to make ATP. Fat stores become the main source of fuel the body, as opposed to glucose, because glucose availability is so limited. The increased use of fat as a fuel source then decreases percent fat tissue and increases the percentage of lean muscle tissue, thus making someone look more muscularly toned and defined (Bergstro, 1996).

With such a drastic increase in protein intake, it is reasonable to question what happens to an individual's anaerobic ability as well as overall physical exertion with daily exercise, since the primary substrate is so low in availability.

However, for active individuals, nutritional intake differs. Protein intake requirements are higher than that of an inactive, sedentary individual. While this topic is often debated, a study conducted by Meredith et al (1989), explored the effects of regular endurance exercise on dietary protein requirements and concluded that there was an increased need for active men of younger and older ages. In the study, it was suggested that there is an increased loss of proteins within a single bout of exercise. This increased loss was due to increased oxidation of leucine and lysine and an increased excretion of urea. This increased loss must be compensated for in order for the active individuals to meet their nutritional needs, the compensation comes from increased overall protein intake. Even with these increased needs, many athletes meet this increased need and even surpass it. However, around 20% of athletes have protein intakes below the recommendation for highly active individuals (Genton, 2010).

Carbohydrates have long been established as the fuel of preference for physical activity, with particular benefits in endurance-based exercises. The research of the effects and benefits of carbohydrate consumption prior to exercise are well supported in a multitude of different studies. An early example is a study conducted by Krogh and Lindhard in 1920, reporting that subjects found exercise easier if a carbohydrate rich diet was consumed, in comparison to a high fat diet. This study also documented that high carbohydrate diets produced a higher respiratory exchange ratio (Krogh, 1920).

Numerous studies have documented the benefits of eating carbohydrates before, during and after exercise, particularly in prolonged exercise, when it comes to carbohydrate consumption during exercise. In a study conducted in 1997 by Kirwan et al, the effects of a moderately glycemic meal 45 minutes before endurance exercise were explored. In this study, subjects performed physically on ergometers to exhaustion. While most measurements throughout the study did not change regardless of what was consumed prior to exercise, those that ate the moderately glycemic food prior to exercise reached the point of exhaustion after all other diet groups, exercise time to exhaustion being 16% longer than all other groups (Kirwan, 1998).

Carbohydrates play an important role in that the body breaks them down easiest for fuel but also that carbohydrates can be stored in the form of glycogen in muscle. Glycogen can be used during exercise when blood glucose levels are low. And carbohydrates must be present in the body in order for glycogen stores to be made for use at a different time. In an article written by Bergstro and Hultman (1966) the resynthesis of glycogen, post-exercise, was explored in subjects that consumed a high-carbohydrate diet. Throughout the study it was observed that bicyclers that pedaled with only one leg had significantly lower glycogen stores in the exercised muscle than non-exercised muscle. However, after one day of rest, the glycogen levels in the exercised leg were higher than that in the non-exercised leg. And those glycogen stores continued to rise dramatically the second day after the exercise. Thus a carbohydrate-rich diet increased muscle-glycogen content considerably above basal values, demonstrating that carbohydrates are necessary not only during exercise but for the recovery process and preparation for upcoming exercise bouts (Bergstro, 1966).

Proteins, on the other hand, have been recognized as having a positive effect on resistance training and muscle anabolism (Brooks, 1997). Muscle hypertrophy can only occur if protein synthesis exceeds muscle protein breakdown; a positive muscle protein balance is necessary. Therefore, muscle anabolism can only occur along with exercise if the proper amount of protein is being consumed. Acute bouts of exercise have shown to have profound effects on muscle protein synthesis. While the exact response it dictated by the type of exercise, it is generally reported that muscle protein synthesis is stimulated with resistance training. However, there must be adequate protein intake and the intensity of the exercise must be high enough. In other words, if the exercise bout is not challenging enough, it will not stimulate enough muscle fibers to promote muscle protein synthesis (Tipton, 2011). However, protein is neither the primary nor the preferred source of fuel throughout exercise, particularly with endurance exercise. This concept is largely supported in that there is not a large increase in urinary nitrogen excretion during or immediately after exercise (Brooks, 1997).

Glucose, as mentioned before, is the preferred fuel for exercise and for metabolism in most tissues of the body. It is particularly important for the brain and red blood cells in any type of physical state. However, it could easily be argued that a low carbohydrate diet does not mean that there is glucose is unavailable in the system, due to the process of gluconeogenesis. Gluconeogenesis produces usable glucose from substrates other than sugar. These substrates include lactate, pyruvate, and alanine (Wallace, 2002). Gluconeogenesis is a backup for when blood glucose levels and glycogen levels are low, and it happens very often in the human body. Conversely, gluconeogenesis is not the preferred source of glucose because the process is energetically costly (Veldhorst, 2009). And when the body is already expending energy through exercise, it would be an inefficient use of energy to expend it producing fuel.

In the past, many studies have been conducted to understand the best fuel type for physical activity. There are numerous studies exploring the difference in performance comparing a high carbohydrate diet to a high fat diet. Among these studies is one conducted by Hargreaves et al (2004); Pre-exercise carbohydrate and fat ingestion: effects on metabolism and performance. In this study, pre-nutritional strategies were manipulated in an attempt to maximize carbohydrate storage to ultimately minimize the effects of carbohydrate depletion throughout exercise. Throughout the study, participants partook in carbohydrate loading days before the exercise, carbohydrate consumption 30-60 minutes prior to exercise and increased fat intake over a 24 hour period. Carbohydrate loading is a diet that consists of high carbohydrate consumption followed by a period of carbohydrate deprivation. This carbohydrate loading strategy supposedly causes an increase in glycogen stores. The consumption of carbohydrates both hours before competition and less than an hour prior to performance increases the immediately available blood glucose levels. The high fat consumption was expected to increase fat availability for lipolysis, therefore reducing carbohydrate use during exercise and delaying carbohydrate depletion (Hargreaves, 2004). Ultimately, this study found that neither the high fat diet nor the carbohydrate consumption within an hours or minutes of exercise altered performance, even though the digestion and fat/glucose availability did occur as predicted. While this study may not have been comparing carbohydrate intake to protein intake, there are some shortcomings of this study much as lacking a long-term diet affecting performance. Short-term changes in diet have short-term changes in performance. The long-term outcomes of these types of diets were not accounted for.

In a study that compared carbohydrate intake to carbohydrate plus protein intake effect on physical performance Genton et al. found that adding more protein to a diet did not affect glycogen synthesis or increase glycogen stores higher than a high carbohydrate diet. Additionally the researchers found that the inclusion of protein did enhance glycogen resynthesis but did not influence or alter overall performance (Genton, 2010). Throughout this study, many things were monitored including muscle strength, body composition, muscle endurance, and VO_2 max. Physical performance was monitored for changes in the different areas mentioned, however, the measurements were only made on the day of the change in fuel source and monitored on a short term basis. The diet changes were made and participants consumed different meals with different macronutrient distributions within hours of the recorded performances. The changes in diet were short-term and therefore the study was only an assessment of immediate changes in blood glucose and glycogen levels. There was no long-term change in dietary consumption nor long-term tracking of changes in performance, so it is difficult to say how the changes in macronutrient distribution affected performance over time.

The current study investigates the long-term effects of a high carbohydrate diet and a high protein diet. Participants consumed a specific diet and partook in weekly exercise classes that involved high intensity fitness, including strength and endurance training. Subjects ate at regular times, whenever they chose to eat, and ate what they desired to eat, as long as they kept their diet within the appropriate ranges for each diet. As opposed to the previous studies mentioned, this study explored how general diet, specifically a high carbohydrate diet and a high protein diet, can affect the physical as well as psychological status of an individual. The focus of the study was not to better understand the best fuel for a highly active individual because the importance of carbohydrates has long been well established as the preferred and least energetically costly fuel. The purpose of the current study was to explore the physical benefits or pitfalls of manipulating the diet in a way that goes against the recommended macronutrient intake and increasing protein intake to a level triple the minimum recommended intake. With an increasing concern in the national obesity rates, it is important to explore all possible avenues that could lead to a decrease in this rate. There was also an interest in seeing how body composition changed with each respective diet as well as the psychological changes. In this study, each participant ate both diets, so that individual changes could be recorded as well group trends. Participants were already highly active individuals so changes in daily physical activity were minimal.

It was originally hypothesized that a high protein diet would have a negative effect on perceived effort and anaerobic exercises but a positive effect on changes in strength. Additionally, it was hypothesized that a high protein diet would show a greater increase in lean muscle tissue percentage than a high carbohydrate diet.

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Chapter 2

Methods

Twenty-four active individuals, ranging from the age of 21 to 60 years old were randomly assigned to one of two diets for three weeks: a high protein diet (45% protein and 25 % carbohydrate intake) or a high carbohydrate diet (55% carbohydrate and 15% protein intake). After a week-long washout, each participant switched diets for the next three weeks; subjects that were previously consuming a high protein diet switched to a low protein diet and subjects preciously consuming a low protein diet switched to a high protein diet. Three weeks was an estimated time that would enable changes in the body to be measured and statistically significant. Diets were monitored by each subject on their own, through the use of “My Fitness Pal”. Investigators of the study had access to all diet diaries. Participants were expected to log an entire day’s diet at least 2 days a week; however they were expected to meet diet requirements every day of the three week diet. Participants were also expected to exercise 5 hours each week. The exercise regimen was high than the recommended levels due to the shortness of the study. The exercise classes available to participants were all offered at a gym, with varying times and instructors. These classes varied in content, some more aerobically focused, others strength development focused and many combing the two components. The weekly exercise regimen was kept the same for the entire 7 weeks, for consistency purposes.

Measurements were taken before each of the three parts of the three diets were started. Each individual underwent BodPod testing to track changes in lean muscle tissue percentages. On testing days, each participant's blood pressure was tested before any other testing was done. Height was measured on the first day but not on subsequent measurement days. Each subject was weighed with their shoes off and fully clothed.

Leg and back strength were measured through the use of an isometric dynamometer. In measuring leg strength, subjects stood upright on the dynamometer platform with feet shoulder-width apart. Palms faced inward, toward the body and the chains were adjusted until the subject's knees bent around 110 degrees. The number of chain links used in the first measurement were recorded and that chain length was used in all other leg strength testing. The subject was then instructed to pull as hard as possible on the chain, without bending their back, in a smooth and steady manner. Back strength was measured similarly however the chain was adjusted to appropriate length. Again, this number was recorded and then used as a standard for the rest of the measurement. Subjects then stood upright and performed the motion of a dead lift. Leg and back strength were both measured 3 times at each stage of measurements, with the dynamometer being reset to zero each time.

A pushup test was also administered. This test was an assessment of chest, shoulder and triceps strength. The ultimate goal was for participants to do as many pushups as they could in a single minute. Men assumed the traditional pushup position whereas females had the option to use the modified pushup position (on knees). Participants were allowed to rest in the upright position (arms extended, body in plank position) if they felt they needed a break in the minute long test. Weights were placed on the ground and the subjects hit their chest against the weights with each pushup, keeping the depth of pushups consistent. The number of weights used and hand position was recorded at the first measurement and then used as a standard for the rest of testing.

Changes in oxygen consumption were also monitored through the use of the Queen's Step Test. Subjects performed the step test at each of the testings. The step test was administered for three minutes and the participants walked up and down the step the entire three minutes to a beat, one step per beat. Males were tested at the rate of 96 beats per minute and females at 88 beats per minute. Subjects wore heart rate monitors for the entirety of the test and heart rate data was collected 20 seconds after the completion of the three minute step test. If the heart rate monitor was not performing correctly, heart rate was measured manually at the wrist.

In measuring lean muscle tissue through the use of the BodPod, subjects were given specific directions to wear tight fitting clothing, with no zippers. All watches and jewelry were also removed. Subjects were instructed not to eat or exercise three hours before the BodPod measurement. All subjects also wore swim caps in the BodPod while testing occurred. Two tests were run at each BodPod measurement and the averages of the two measurements were used as the official number for that day of testing. If there was an issue with any of the test, the BodPod test was performed a third time.

Psychological surveys were also created and expected to be filled out after every completed exercise class. Participants recorded the type of class they attended along with who was the instructor of that class. They then rated how hard they felt they had to exert themselves during the class on the Borg RPE Scale, a scale ranging from 6 to 20 (Borg 1998). Participants also rated satisfaction with the class and instructor, the symptoms and emotions they felt that day, life satisfaction, along with physical and mental health on a scale of 1-7. Attached to this Thesis is a sample of the Psychological survey provided after every workout.

Results were averaged for all 24 participants and then compared through the use of a paired t-test. Statistically significant values were any that were found to have a p value less than .05

Chapter 3

Results

The high protein diet had the most results physically, showing an increase in strength and decreased blood pressure. The high carbohydrate diet made participants feel psychologically healthier.

The general findings from the study were that many areas did not see a significant difference between the two diets. The areas that were found to be statistically different, with a protein diet having greater improvements, included diastolic blood pressure, pushup number, back strength and perceived improved physical ability. The carbohydrate diet showed the greatest differences in the psychological changes associated with each diet. Participants had greater instructor satisfaction, satisfaction with life, mental well-being, and pain and stiffness when they consumed the higher carbohydrate diet.

The areas tested with the largest significant difference in physical measurements were changes in number of pushups (Figure 5) and changes in back strength (Figure 8). The data showed that the protein diet had greater number of pushups (46.2±10.7) than carbohydrate diet (44.9±10.3). (p=0.0030) Changes in back strength were also greater in protein diet (79.1±30.7) than carbohydrate diet (76±29). (p=.0091) The data also showed that diastolic blood pressure also decreased more in protein diet (75.7±8.6) than carbohydrate diet (78.5±9.4). (p=.0258)

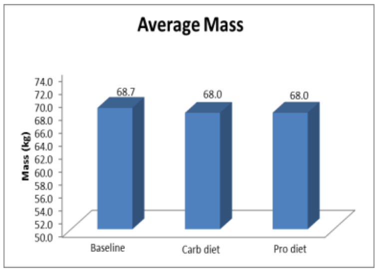
The data showed that there were no statistically different changes in change in weight (Figure 1), systolic blood pressure (Figure 3), VO2 max (Figure 6) and leg strength (Figure 7) with p values all greater the 0.5. ($p>.05$)

There was a trend with changes in percent body fat (Figure 2), with protein being almost statistically significant ($p=.0593$) so it is very possible that with more time or more participants, it would have been statistically significant.

The psychological surveys resulted in significant differences in satisfaction with instructor (Figure 11), improved physical ability (Figure 12), life satisfaction (Figure 14), mental health (Figure 16) and pain and stiffness (Figure 17). Satisfaction with instructor was higher in the carbohydrate diet (6.85±.60) then protein diet (6.49±.78). ($p=.0105$) Improved physical ability was perceived higher with a protein diet (5.28±1.16) than a carbohydrate diet (5.03±1.16). ($p=.0072$) Satisfaction with life was higher with the carbohydrate diet (6.02±.84) than protein diet (5.89±.93). ($p=.0074$) Mental health was perceived better in the carbohydrate diet (5..87±1.05) than protein diet (5.71±1.09). ($p=.0075$) Pain and stiffness were perceived lower in the carbohydrate diet (2.19±1.36) than protein diet (2.46±1.21). ($p=.0002$)

The other psychological data did not indicate a statistically significant difference between diets in satisfaction with class (Figure 10), amount of physical activity (Figure 13) and physical health (Figure 15). ($p>.05$) There were also no statistical differences in feelings of sadness/depression, anxiety, tiredness due to lack of sleep, relax, confidence, motivation and happiness between the two diets. ($p>.05$)

Figure 1.



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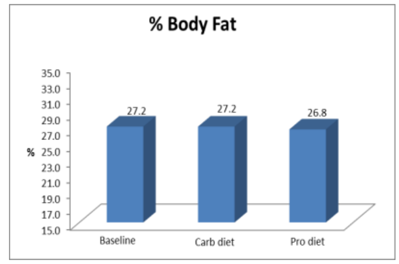

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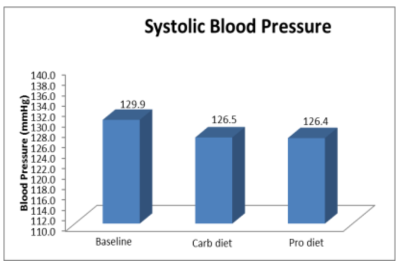

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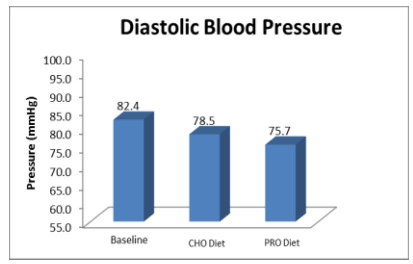

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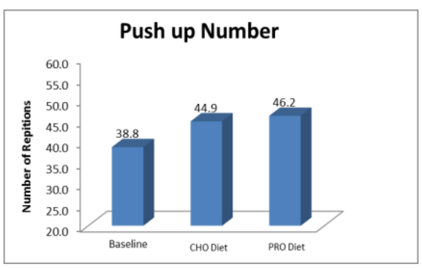

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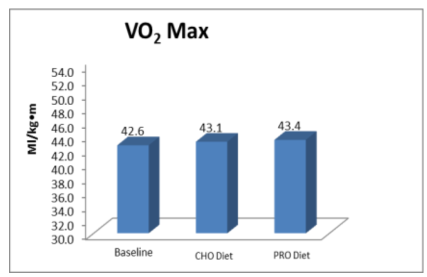

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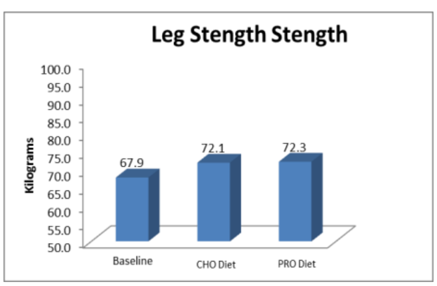

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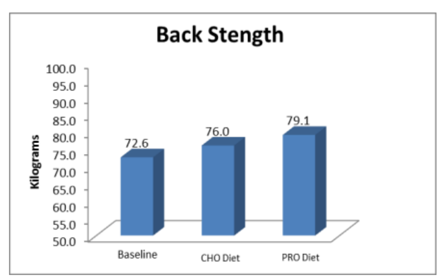

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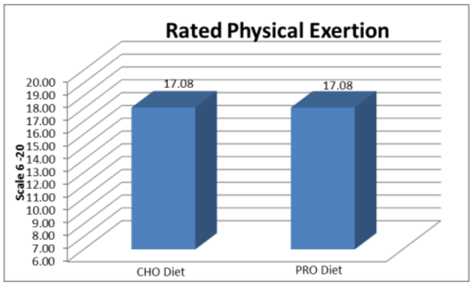

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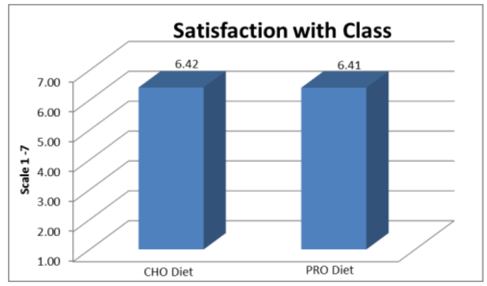

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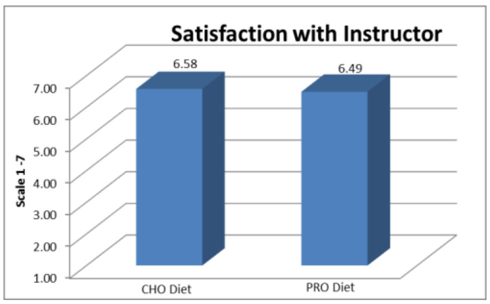

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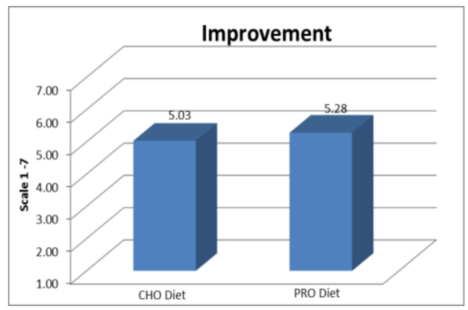

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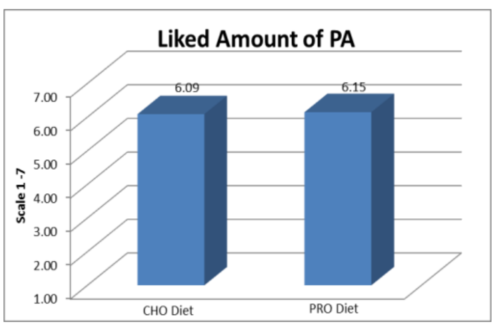

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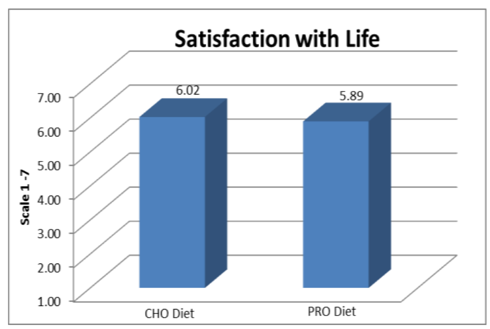

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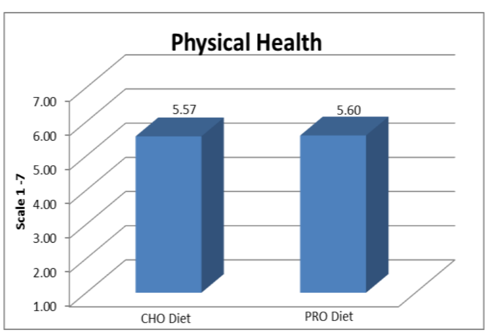

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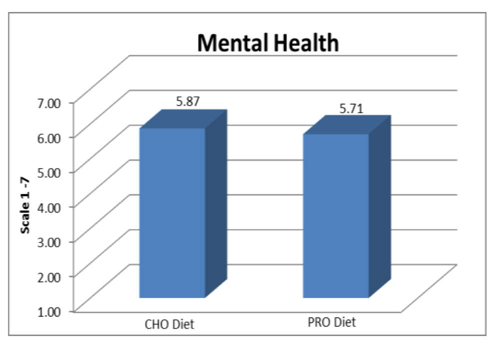

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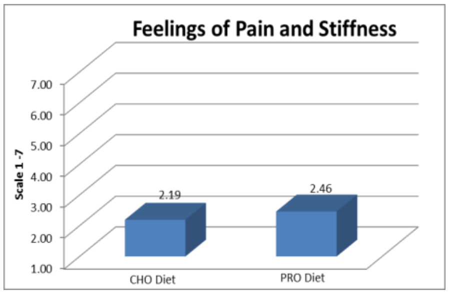

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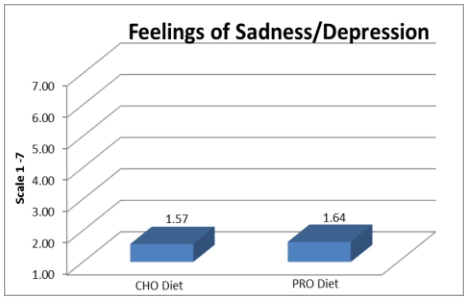

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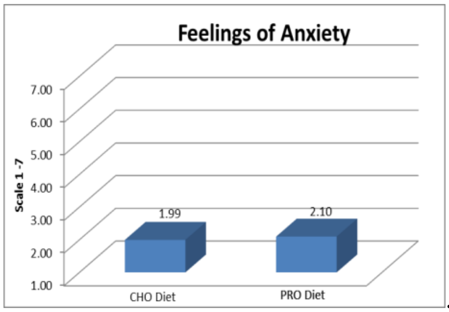


Figure 20

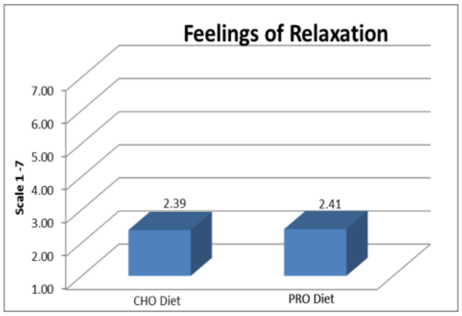


Figure 21.

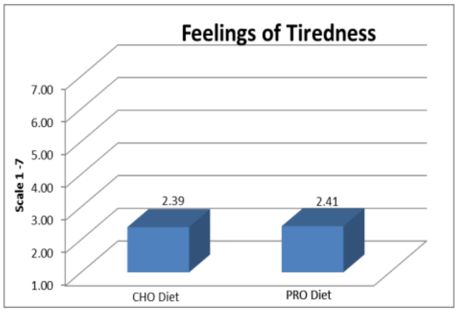


Figure 22.

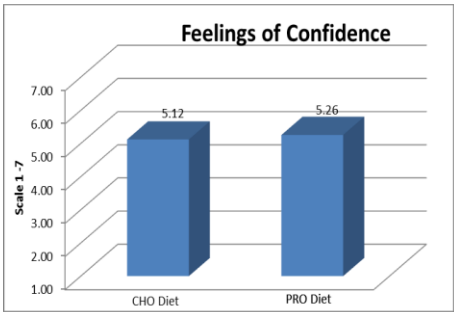
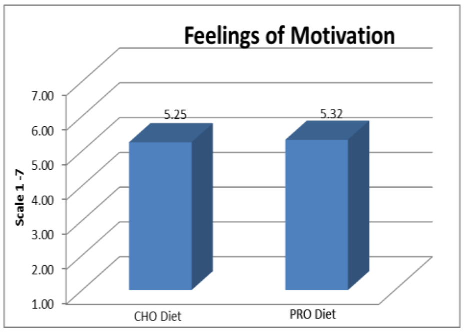


Figure 23.



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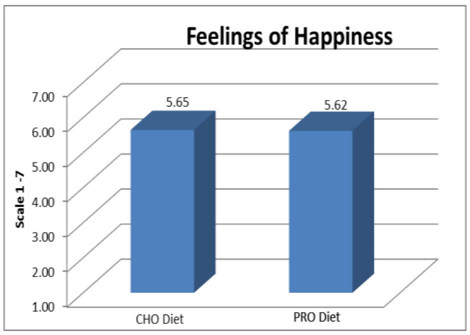

Chapter 4

The data collected in this study provided us with many general conclusions. The protein diet had a greater effect on participants physically. The protein diet showed an increase in back strength as well as an increase in push up number. The protein diet also showed decreases in diastolic blood pressure. Subjects consuming the high protein diet also felt they had greater improvements in physical performance.

The high carbohydrate diet had a much larger effect psychologically. The carbohydrate diet showed greater satisfaction with instructor, satisfaction with life, overall mental health and pain and stiffness.

The protein results pertaining to increased strength are not altogether surprising. Protein is known to be very beneficial with muscles anabolism. The effects of resistance training are greatest when protein is consumed post-exercise because it promotes even greater muscle protein synthesis. The increase in muscle protein synthesis in response to protein consumption is apparent within one hour of the exercise bout, and peaks at three hours post-exercise (Phillips, 2010). While it was not controlled when subjects ate throughout the study, when subjects were on a high protein diet, it is probable that they consumed protein within three hours after a resistance training class.

However, not all strength tests showed improvements in response to a high protein diet. The average of leg strength did not vary between the two diets. While this is not easily explainable, there are some possible explanations. The main plausible explanation would be the inaccuracy that is sometimes associated with the use of a dynamometer to measure back and leg strength. In an article that reviewed the accuracy and reliability of using manual muscle tests. Over 100 studies that used manual muscle testing were reviewed and ultimately it was concluded that the tools can be very useful clinically, but the ultimate scientific validation ad application should be used with further testing methods for better accuracy (Cuthbert, 2007)

We also use our legs more frequently than many other muscles, and on a daily basis, to carry a heavy load, being the upper body. So it is possible that since the back and the arm are used less frequently and with lesser loads that there was more room for improvement in those muscles, resulting in a greater change with the consumption with a high protein diet.

While both diets showed increases in pushup number and back strength, the protein diet showed a greater change than the carbohydrate diet. It is likely that the protein diet would have seen an even larger difference in back strength and push up number, and even possibly leg strength, if the study was longer or the study was duplicated.

The decrease in diastolic blood pressure was an unexpected result. According to Frassetto et al (2009), their study showed that the plaeo diet had a decrease in overall blood pressure, both systolic and diastolic. However, the authors attributed much of this change to the fact that the paleo diet greatly reduces sodium intake, due to the non-processed foods. They also stated that the change in blood pressure was related to a decreased urinary output of calcium (Frassetto, 2009). However, Lindeberg et al (2007) studied the effects of a paleo diet and Mediterranean diet in diabetic subjects and found no reduction of blood pressure in participants that consumed the paleo diet. Frassetto et al claimed that if the paleo diet had been consumed longer it is possible that there would have been an observed decrease in blood pressure.

In another experiment conducted by Dong et al in 2013, the effects of a high protein diet on body weight, glycemic control, blood lipids and blood pressure and were explored in type 2 diabetics. The study found that a high protein diet borderline significantly reduced both systolic and diastolic blood pressure. However, the author notes that the reduction in blood pressure may be attributed to an increased physical activity within subjects. Increased physical activity is known to have a positive effect in reducing overall blood pressure (Dong, 2013).

Overall, it is difficult to conclude that the high protein diet did have causation in the reduction of diastolic blood pressure, since it seems that many other studies have found inconclusive evidence. It is very possible that the high protein diet does have an effect on blood pressure, but it would only be possible to say if another study was run and with urinalysis included as a method of assessment.

Systolic and diastolic blood pressure did decrease in general for both diets. This general trend is most likely attributable to the increase in physical activity and participants monitoring diets more closely. In an article written by Seals and Realing in 1991, it was observed that even regular low-intensity aerobic exercise produced a significant reduction in blood pressure over the course of 24 hours. The subjects that participated in the current study were exercising at high intensity levels multiple times a week, so the decrease in blood pressure was anticipated and not a surprising result.

Also, since the participants were required to monitor their intake so closely and hit a target range for each macronutrient, they were more conscientious of what they ate. Participants even commented on their diet noting that if they were only allowed a certain amount of protein or carbohydrates a day, it would not be wasted on junk food that would not help them stay healthy

The psychological results with the high carbohydrate diet are not unprecedented, but were not an anticipated result. It appears that there is a general trend that people were happier or generally more satisfied when consuming a high carbohydrate diet.

Carbohydrate consumption affecting moods appears to be a mildly controversial research topic. Some researchers agree with the findings of this study, that a high carbohydrate diet can cause more positive psychological effects, while other have found that protein has the greater effect. In an article written by Lemmens et al (2004), stress-related foods were examined as well as the subsequent moods after food consumption. It was anticipated that a high protein meal would better reduce stress levels than a high carbohydrate meal since Lacroix et al (2004) found that consuming a high carbohydrate meal when stressed actually increased stress by increasing cortisol levels. However, the results revealed that neither macronutrient group had a greater effect on stress levels (Lemmens 2011).

The article did make mention of comfort foods being consumed at stressful times. These comfort foods are often high in sugar and/or high in fat content because they are perceived as highly rewarding. This reward factor could arguable demonstrate that carbohydrates do make people feel better or happier because they feel comforting during stressful times.

In another study conducted by Benton (2002), it was found that meals that are almost exclusively carbohydrate increase the availability of tryptophan which then increases the availability of serotonin synthesis in the brain. Serotonin is a neurotransmitter generally associated with feelings of happiness and well-being. Therefore, this article argues that having high blood glucose levels as a result of high carbohydrate intake does make an individual feel more positive feelings and happiness (Benton, 2002).

This article is thorough support for the findings represented in this study. When it was found to be significantly significant, carbohydrates generally accounted for the better feelings of satisfaction with instructor, life and mental health.

Since participants attended the same classes for all seven weeks of the study, the instructors did not change, therefore the satisfaction with instructor could be attributed to overall mood which could be affected by the carbohydrate intake. And while external factors affecting general mood and life satisfaction could not be controlled throughout the seven week study, there was still am overall conclusion that the high carbohydrate diet was content. However, it is possible that there were external influences on mood such as home life, so the results may not be completely a result of dietary intake. This relationship needs to be further explored in a more exclusive study that could eliminate external factors that would influence mood.

The protein diet did show a greater feeling of improvement in classes, which is difficult to explain given the previous article. However, it is possible that there was a mild placebo effect. When subjects were on the high protein diet, many of them discussed feeling more physically able, i.e. able to perform more repetitions with weight lifting, because the protein made them feel stronger. I did not receive this feedback from each participant so this cannot be a general statement, however, it could possibly help explain the unexpected results.

The high carbohydrate diet also reported an increased feeling of pain and stiffness after workouts. This could possibly be explained by the process of glycolysis. With a high carbohydrate diet, it is likely that blood glucose levels were higher, making glucose more available to the muscle during physical activity. With an increased availability in substrate (glucose), it is possible that the anaerobic process of glycolysis was able to produce more acetyl CoA for the Citric Acid Cycle, however, oxygen uptake did not change. Therefore, it is possible that the body could not use the product of glycolysis and it was then converted to lactic acid. This lactic acid built up at faster rates due to the greater availability of substrate. A buildup of lactic acid is known to create muscle stiffness, thus explaining the stiffness associated with the high carbohydrate diet. However, this is not supported by any research findings, and the topic of high carbohydrate intake causing stiffness needs to be further explored to better explain the results of this study.

There is also a general trend in decreased percent body fat with the high protein diet. While the results did not show a statistically significant difference in percent body fat between the two diets it is very likely that with a longer study, the differences would have been statistically significant.

Limitations:

It is important to note that the BodPod used to make measurements was kept consistent throughout the study. However after the first three weeks of the study finished, the BodPod broke and was not available for use until 5 days after the start of the washout portion of the diet. For the purpose of consistency, measurements were taken after the second diet the same amount of days after the diet ended. It is possible that these few days in between the diet and regular consumption made the BodPod measurements less representative of the actual and immediate results of each diet. If this study were to be duplicated, the BodPod measurements would be made within the first day or two after the cessation of a diet

The diets of participants were also self-administered; therefore intake was not tightly regulated. It is very possible that participants underestimated or overestimated the amount of food consumed when entering it into My Fitness Pal Summary: These over or underestimations would then throw off the percent intake, and make the diet less effective and therefore skew the results. Some participants commented on how difficult it was to eat a high protein diet while keeping the fat intake within the specified range. Ultimately, this lack of total control of what foods were consumed with each diet may have skewed results in an inaccurate way. It may be more effective, for future studies, to provide certain meals or provide different recipes for each meal of the day that would ensure participants met the range requirements.

This study was also only a total of seven weeks longs. It is likely that if a longer study were conducted better results would be observed, providing a stronger argument for the findings of the current study. Changes in strength and body composition would most likely be more thoroughly represented.

Summary:

This study supported the concept that a high protein diet does promote muscle anabolism, as observed through the increase in overall strength. The study also supports the previous findings that a high carbohydrate diet can increase happiness, possibly due to the effect of increased serotonin levels

This study did not find conclusive evidence that high protein intake will change body composition, decreasing BMI and increasing lean muscle tissue. It is likely that, had the study occurred over a longer period of time, the results would be more conclusive and the evidence would be thoroughly supported.

Overall, from this study, there is a better understanding of the benefits of an increased protein intake for increased strength and muscle development and anabolism. This study provided a better understanding of the psychological benefits of a high carbohydrate diet.

The study did leave some questions unanswered questions due to the results. The decreased diastolic pressure is an unexpected outcome that appears to have no previous exploration. It would likely be beneficial to better understand this relationship, if one between high protein intake and blood pressure does exist. It would also be beneficial to look into the occurrence of increased soreness with high carbohydrate intake, since most physically active individuals do consume a high carbohydrate diet.

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ACADEMIC VITA

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Education

The Pennsylvania State University — University Park, PA
Schreyer Honors College — Anticipated Graduation: May 2014

- Kinesiology Major
- Nutrition Minor

Experience

Penn State Women's Health Research Lab
Undergraduate Student Research Assistant (January 2013-Present)

- Enter numerical data obtained from participants into database
- Prepare lab materials
- Prepare blood and urine samples
- Evaluate blood and urine samples
- Analyze Thermic Effect of Food (TEF) tests
- Examine Bone Mineral Density (BMD) tests

Penn State Biomechanics Research Lab
Undergraduate Student Research Assistant (Summer 2012)

- Measure participants weight, height, strength
- Draw blood samples
- Analyze data obtained in studies
- Enter data obtained from participants into database
- Co-Author of publication

Mount Nittany Medical Center
Physical Therapist Aide (Summer 2011-Present)

- Transport patients to and from patient rooms and physical therapy department
- Provide customer service to hospital patients and patient family members
- Interact with patients, doctors, nurses, nurses assistants and physical therapists
- Enter billing information into the hospital Electronic Health Record (EHR)
- Wipe down and sanitize walkers and exercise devices/materials

Activities

- **THON 2014 Special Events Captain** (September 2013-Present)
  - *Choose and lead THON community volunteers for Special Events Committee*
  - *Organize different THON related activities and events including THON 5K and Family Carnival*
- **Global Medical Brigades, Penn State Chapter** (Spring 2012-Present)
  - *Traveled to Nicaragua over Spring break 2013 as a student volunteer to help build sustainability in underserved areas and assist with the provision of medical care and advice*
  - *Work year round to raise funds for medical supplies*
  - *Procure supplies from health care providers*
- **Lion Scout, Tour Guide** (Fall 2012-Present)

    - *Give campus tours to prospective Penn State Students and their families*
- **JumpStart Leader** (2011-Present)
    - *Help first year, Penn State students adjust to college life by addressing potential problems that can arise in college and offering advice*
- **Camp Horizon Counselor** (Summer 2011-Present)
    - *Volunteer as counselor at a week-long stay away camp for children from all over the United States with rare skin diseases*
- **Penn State Dance Marathon Volunteer** (Fall 2010-Present)
    - *Raise funds and awareness for pediatric cancer and the Four Diamonds Fund at Hershey Medical Center.*
    - *Work with dancers participating in 46 hour dance marathon*
    - *Provide monetary and emotional support for every Four Diamonds family*