

2010

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## Recommended Citation

Pharr, Jennifer R. (2010) "Carbohydrate Consumption and Fatigue: A Review," *Nevada Journal of Public Health*: Vol. 7 : Iss. 1 , Article 6.

Available at: <https://digitalscholarship.unlv.edu/njph/vol7/iss1/6>

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## Carbohydrate Consumption and Fatigue: A Review

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### *Abstract*

Fatigue is a condition that negatively impacts quality of life and occurs in about twenty four percent of adults worldwide. Many factors may contribute to fatigue. One factor is the macronutrient composition of a person's diet, particularly, the amount of simple carbohydrates. This paper is a review of the current literature and examines the relationship of carbohydrate consumption and fatigue to determine if a diet low in simple carbohydrates results in an improvement in fatigue ratings. Results of studies regarding carbohydrate consumption and fatigue vary, the preponderance demonstrate a positive relationship between simple carbohydrate consumption and fatigue. Additionally, diets low in simple carbohydrates may improve cognition, mood and help reduce type 2 diabetes. To date, no study has been conducted to examine the long term effect of a diet low in simple carbohydrates therefore further research is needed in this area.

### *Introduction*

Fatigue is a growing concern. Recently the National Institute on Aging conducted a conference to identify causes of fatigue and fatigability in the elderly (2007). Fatigue has a strong negative association with health and quality of life (O'Connor & Puetz, 2005). A better understanding of the causes of fatigue can contribute to improvements in "work productivity, quality of life and the diagnosis and treatment of a myriad of fatigue-related health problems" (O'Connor & Puetz, 2005). The purpose of this paper is to review current material that examines carbohydrate consumption and fatigue and to determine if a diet low in simple carbohydrates results in an improvement in fatigue.

### *Fatigue*

Fatigue can be defined as a subjective feeling of a physical or mental lack of energy that results in an individual's inability to complete usual or desired activity (O'Connor, 2004; 2005). Fatigability has been defined as the degree of fatigue that an individual experiences in relation to activity

and can be measured objectively by using physical or mental tests (National Institute on Aging, 2008). The prevalence of fatigue in adult populations varies with the population being studied. In general, twenty percent of adults worldwide report persistent fatigue (Wessely, Hotopf, Sharp, 1998). In the United States, twenty-four percent of the population report feelings of fatigue with a 1.5 times greater risk for women than men (Chen, 1986; Kroenke & Price, 1993). In groups of individuals with diseases such as HIV, Parkinson's, or cancer, the prevalence of fatigue is higher. In various studies, fatigue has been reported in five to fifty percent of subjects depending on the study population (Unexplained Fatigue in the Elderly, 2007). Fatigue is a major problem for the elderly and has a strong association with the loss of independence (National Institute on Aging, 2008). This is of particular concern for public health professionals in Nevada. Based on estimates from the state demographer's office, the number of people in Nevada who are sixty-five years or older in 2010 will be 355,440, which represents 11.5% of the total population. The number of people sixty-five years or older is projected to increase to 627,134 by 2026, comprising 14.4% of the total population (Nevada State Demographer's Office, 2006). Based on these projections, there will be a seventy-four percent increase in the number of residents in Nevada who are 65 years old or older. There are multiple factors thought to contribute to fatigue and fatigability in the elderly such as: depression and sleep disorders, neurological disorders, chronic disease, changes in skeletal muscle, dehydration and electrolyte disturbances, and inflammatory mediators (Unexplained Fatigue in the Elderly, 2007). An additional factor is the consumption of macronutrients, particularly carbohydrates.

### *Macronutrients*

The macronutrients that make up the human diet are fats, proteins and carbohydrates. Although the human body is able to convert excess protein and carbohydrates to fat for storage, fats are also an essential macronutrient. The human body is not able to synthesize essential fatty acids in an amount sufficient to meet the bodily needs (Hamilton, Whitney, Sizer, 1988). Essential fatty acids must be consumed as part of the diet and include: omega 3, omega 6, and omega 9 fatty acids. Foods that are sources of omega fatty acids are fish, olives, olive oil, nuts and flax seed. Protein is composed of carbon, hydrogen, oxygen and nitrogen which are arranged as strands of amino acids. Essential amino acids, like essential fatty acids, cannot be synthesized by the

body in a quantity great enough to meet the body's physiological need or cannot be synthesized at all (Hamilton, Whitney, Sizer, 1988). Foods that are rich in essential amino acids come from animal products and include chicken, turkey, beef, pork, eggs and dairy products. Plant sources also provide essential amino acids, but are usually lacking at least one of the essential amino acids. Plant sources must be consumed in combination to provide all of the essential amino acids such as beans and rice. Carbohydrates are foods that are composed of carbon, hydrogen and oxygen and are the by-product of photosynthesis. Carbohydrates are classified as simple or complex. Simple carbohydrates are single or double sugars while complex carbohydrates are long chains of sugar arranged as starch or fiber (Hamilton, Whitney, Sizer, 1988). Carbohydrates are broken down into glucose which is the source of energy for human metabolism. Excess glucose is stored as fat. Of the three macronutrients, only carbohydrates cause an increase in the glucose levels in the blood when digested (Brand-Miller, 2009). Because of this, carbohydrate consumption and fatigue will be the focus of this review.

#### *Physiological Response to Carbohydrates.*

Foods that are high in simple carbohydrates cause a rapid rise in blood glucose levels and a corresponding rapid rise in blood insulin levels. Insulin helps the muscle cells extract glucose from the blood, which causes a sudden drop in blood glucose levels (Hamilton, Whitney & Sizer, 1988). The glycemic index of a food is a measure of how much that food increased the blood glucose level when compared to a standard carbohydrate – usually glucose (Jenkins, Wolever & Taylor, 1981). The glycemic load of a food is determined by multiplying the glycemic index of a food by the amount of carbohydrate contained in the food and dividing by 100 (Foster-Powell, Holt & Brand-Miller, 2002). Foods that are high in simple carbohydrates have a high glycemic index, meaning a high rate of absorption of glucose in the stomach with resulting high blood glucose levels. Foods that are high in simple carbohydrates also have a high glycemic load - amount of glucose that enters the blood and the corresponding load of insulin released from the pancreas (Foster-Powell, Holt & Brand-Miller, 2002). Complex carbohydrates are digested much more slowly than simple carbohydrates and do not cause a rapid rise in blood sugar (Hamilton, Whitney, & Sizer, 1988). Complex carbohydrates have a low glycemic index and a low glycemic load. When examining the impact of nutrition on fatigue,

carbohydrates in the diet need to be classified as simple (high glycemic index/high glycemic load) or complex (low glycemic index/low glycemic load) due to their differing result in blood sugar level and insulin release.

#### *American Diet*

The earliest information about the human diet dates back to the Stone Age or the Paleolithic Period beginning more than two million years ago. At that time, humans were hunter/gathers and consumed food that they could catch or pick. The diet of the Paleolithic Period consisted of wild animal sources - lean meats, internal organs, bone marrow and uncultivated plant sources - fruits, non-grain vegetables and nuts (Frassetto, Schloetter, Mietus-Synder, Morris & Sebastian, 2009). The Paleolithic people are thought to have consumed 1.5 times more calories than people do today; however, they were never obese (Hamilton, Whitney, & Sizer, 1988). As humans evolved they began using agriculture as a way to secure sources of food. The industrial revolution expanded the use of agriculture for food production, which is the primary source of food for humans today. In the 1970's, Americans became convinced that fat was the primary evil in their diet (Taubes, 2007) and the American Medical Association advised people to eat carbohydrates and to avoid fat. An assessment by the United States Department of Agriculture (USDA) shows that between 1970 and 2005, consumption of added sugar and sweetener increased by 19 percent while corn sweetener consumption increased by over 387 percent (Wells & Buzby, 2008). A snapshot of the American diet by the Harvard School of Public Health shows that the average American eats thirty teaspoons of added sugars and sweeteners per day compared to the recommended eight teaspoons or less (Harvard Heart Letter, 2009). Additionally, an average American eats 7.2 ounces of refined grains (simple carbohydrates) per day compared to the recommended three ounces of refined grains.

#### *Carbohydrate Consumption and Fatigue*

Nutrition studies have examined both acute and chronic effects of high carbohydrate (glycemic) diets on the feeling of fatigue and fatigability. The results of these studies has been mixed, with some studies demonstrating an increase in fatigue with an increase in simple carbohydrates and other studies reporting no difference in fatigue based on macronutrient consumption. Cunliffe, Obeid and Powell-Tuck (1997) looked at the acute relationship

of a pure simple carbohydrate diet on central fatigue (fatigue) and peripheral fatigue (fatigability) compared to a mixed diet and a pure fat diet in sixteen male/female subjects with an average age of 29.7 years. Compared to the mixed diet (control) group and the pure fat diet (fat) groups, those who consumed pure carbohydrates (CHO) had a higher level of the subjective feeling of fatigue two to four hours after the meal. The feeling of fatigue in the CHO group increased more than 100% two to four hours after the meal, while the control group and FAT group's feeling of fatigue remained relatively constant. This difference in the feeling of fatigue was not statistically significant, however, the CHO group also had a slower reaction time as compared to the control group.

Maridakis, O'Connor and Tomporowski (2009) analyzed the affect of 200 mg of caffeine with and without the addition of 50 g of simple carbohydrates on the feeling of fatigue and cognitive performance in eighteen men with an average age of 23.4 years. They found that the combination of caffeine and carbohydrate increased the subjects' feeling of energy, decreased the feeling of fatigue and improved reaction time; however, when compared to the caffeine only subjects, these increases were not significantly different. Limitations of this study were that only a small amount of carbohydrate was administered and that blood glucose levels were not measured.

Pasman, Blokdijk, Bertina, Hopman and Hendriks (2003) examined the effect of two breakfasts with different carbohydrate composition on fatigue in twenty-six healthy male subjects ages 25- 45. They found that the perception of fatigue was significantly lower in subjects who consumed a complex carbohydrate breakfast as compared to those who consumed a simple carbohydrate breakfast.

Nabb and Benton (2006) analyzed the interaction between breakfasts of varying carbohydrate and fiber content on mood and cognition in one hundred and sixty eight undergraduate students with a mean age of 20.4. They found that the greater the amount of carbohydrate consumed, the greater the rating of being tired rather than energetic was reported at twenty, fifty and eighty minutes post meal. They also found that those subjects with poor glucose tolerance reported a poorer overall mood.

Smith, Bazzoni, Beale, Elliott-Smith, and Tiley (2001) studied the impact of a high fiber

breakfast on fatigue. One hundred and forty four subjects with an average age of 52 were randomly assigned to one of three breakfast cereal intake groups. Two groups consumed a breakfast cereal that was high in fiber (low simple carbohydrate diet) while one group consumed a breakfast cereal that was low in fiber (high simple carbohydrate diet). After fourteen days, subjects who consumed the high fiber breakfast cereal reported significantly less fatigue than subjects who ate the low fiber breakfast cereal.

A study by Cheatham, Roberts, Das, Gilhooly, Golden, Hyatt, Lerner, Saltzman and Lieberman (2009) examined the effect of a low glycemic calorie restricted diet versus a high glycemic calorie restricted diet on fatigue, mood and cognition over a twelve month period in forty-six healthy, overweight subjects ages 20-42. The study revealed no difference in cognition, and fatigue between the high glycemic and low glycemic group, but subjects who consumed a high glycemic diet had a negative change in their depression score. Their conclusion being that a low glycemic diet could have psychological benefits, but further research is needed in the area.

Chen (1986) evaluated data collected for the HANES1 Augmentation Survey of Adults 25 – 74 years of age collected by the National Center for Health Statistics during 1974 – 1975. In examining their 24 hour dietary recall, he found no significant difference in protein, fat or carbohydrate intake between fatigued and non-fatigued men and women.

White, Johnston, Swan, Tjonn and Sears (2007) examined the impact of a low carbohydrate diet (40% carbohydrate, 30% fat and 30% protein) compared to a very low – ketogenic diet (5% carbohydrate, 65% fat, 30% protein). They found that subjects who consumed a very low – ketogenic diet for two weeks had a higher rating of fatigue and total mood disturbance while exercising than those who consumed the low carbohydrate diet. They concluded that a very low carbohydrate diet may adversely impact a person's ability and desire to exercise and that a low carbohydrate diet should include 35-40% of energy from vegetables, fruits and whole grains.

### *Discussion*

Though the findings of the studies reviewed vary, the preponderance demonstrated a positive relationship between simple carbohydrate

consumption and fatigue with measures of fatigue being lower in those subjects who ate fewer or no simple carbohydrates. Diets higher in fiber (complex carbohydrates), protein and fat tended to be protective of fatigue. Table 1 is a comparison of the studies reviewed and reports the study design, sample size, and average age of subjects and reveals that: 1) those studies with the stronger study design showed a positive relationship between simple carbohydrate consumption and fatigue, and 2) of the studies with a stronger study design, those that had larger sample sizes and an older average age of participants showed a significantly positive relationship between simple carbohydrate consumption and fatigue. A randomized control trial (RCT) is considered to be a

stronger study design than a cross sectional study because an RCT provides information about temporality or cause and effect. A cross sectional study can provide information about associations but temporality cannot be established and it is more difficult to rule out the effects of confounders. The two studies that demonstrated a significant positive relationship between simple carbohydrate consumption and fatigue were cross-over randomized control trials. Additionally, a ketogenic (very low carbohydrate) diet tended to increase the feeling of fatigue and a calorie restricted diet tended to decrease fatigue with no difference between high and low glycemic diets.

**Table 1 Studies of Carbohydrate Consumption and Fatigue**

Study (year)	Study Design	Sample Size	Subject Age, Gender	Macronutrient Comparison	Fatigue Measure	Main Findings
Cunliffe et al 1997	Randomized control trial (RCT)	16	M/F, $\bar{x}$ age 29.7	Pure fat & mixed meal compared to pure simple carbohydrate (CHO)	Visual Analogue Scale (VAS)	↓ fatigue w/ mixed, pure fat meal compared to pure simple CHO
Maridakis et al 2009	Double-blind, RCT	18	M, $\bar{x}$ age 23.4	200 mg of caffeine without 50 g of simple CHO compare to 200 mg of caffeine with 50 g simple CHO	Profile of Mood State (POMS) -Brief	↓ fatigue 200 mg caffeine without 50g CHO
Pasman et al 2003	Open, Cross-over, RCT	26	M, $\bar{x}$ age 34	Complex CHO breakfast compared to simple CHO breakfast	POMS	↓* fatigue with complex CHO breakfast
Nabb et al 2006	RCT	168	F, $\bar{x}$ age 20.41	High CHO breakfast compared to low CHO breakfast	POMS	↓ tired, ↑energy with low CHO breakfast
Smith et al 2001	Cross-over, RCT	148	M/F, $\bar{x}$ age 52	Complex CHO breakfast compared to simple CHO breakfast	Questionnaire not specified	↓* fatigue with complex CHO breakfast
Cheatham et al 2009	RCT	42	M/F, $\bar{x}$ age 35	High glycemic load / calorie restricted diet compared to low glycemic load calorie restricted diet	POMS	↓ fatigue in both groups w/ no significant difference between groups. ↑ depression with high glycemic diet
Chen 1986	Cross sectional	6913	M/F age range 25-74	24 hour intake recall comparing fat, protein and CHO	Questionnaire not specified	↔ fatigue with macronutrient consumption variation
White et al 2007	RCT	20	M/F, $\bar{x}$ age 37.2, 38.4	Ketogenic (very low CHO) diet compared to non ketogenic diet	POMS, RPE	↑* fatigue with ketogenic diet

\* = significant finding

To date, there have been no long term studies to determine the impact of simple carbohydrate consumption compared to complex carbohydrate consumption on fatigue and more research is needed in this area. However, for public health professionals, particularly those who work in health promotion for elderly populations, these findings demonstrate the benefit of including nutrition education regarding delineation of simple and complex carbohydrates. Older adults seek to improve their diet, but are often frustrated with the insufficient nutrition consultation provided by their health care provider (Shatenstein, 2008). The majority of people do not know the difference between simple and complex carbohydrates. The new 2005 United States Department of Agriculture food pyramid emphasizes the consumption of grain, with that area of the pyramid being proportionally larger than vegetables, fruit, milk, meat and beans, and oil. Based on a 2,000/day calorie diet, the USDA recommends the consumption of 6 oz of grains from bread, cereals, pasta and cooked rice. If the bread, cereals, pasta and rice that are consumed following this recommendation are highly processed, this would result in a diet high in simple carbohydrates. Based on the studies reviewed above and findings in related studies that demonstrate improvements in cognition / mood with a low glycemic index and low glycemic load diet (Pasman et al, 2006; Nabb et al, 2003; Benton, Slater, Donohoe, 2001; Cheatham et al, 2009; Lloyd, Green, Rogers, 1994; Lloyd, Rogers, Hedderly, Walker, 1996; Markus, Panhuysen, Tuiten, Kipperschaar, Fekkes, Peters, 2003 ) and a reduced risk of type 2 diabetes with a low glycemic diet (Halton, Liu, Manson and Hu, 2008), there is evidence that greater emphasis needs to be placed on the type of carbohydrate consumed (Willet, 1998).

Nevada continues to attract numbers of the sixty-five plus age group due to a mild climate, no state income, inheritance or capital gains taxes. This age group is expected to increase by seventy-four percent in the next sixteen years (Nevada State Demographer's Office, 2006). These findings are important for public health professionals, dietitians and healthcare providers who work with the elderly population in Nevada. Nutrition education regarding the distinction between simple and complex carbohydrates could be shared with the elderly in Nevada through the Nevada Aging and Disability Services Division, Nevada Care Connect or through seminars and workshops sponsored by retirement communities. As Smith et al suggests, simply educating the elderly about the importance of consuming a high fiber instead of a simple

carbohydrate breakfast "may be one simple method of reducing fatigue" (2001) in our community.

The contemporary American diet is a consequence of agriculture, the industrial revolution and the fast food revolution (Frassetto et al, 2009). Paleolithic foods have been replaced by refined cereal grains, and energy-dense nutrient poor food such as refined carbohydrates and hydrogenated fat (Frassetto et al, 2009). Additionally, Americans consume 3.75 times more sugar and sweetener than recommended and 2.4 times the recommended amount of refined grains (Harvard News Letter, 2009). A diet which is high in fiber and vegetable sources of protein and fat may be beneficial in the reduction of fatigue.

### Conclusion

Although the majority of the studies reviewed demonstrate an improvement in fatigue with a diet low in simple carbohydrates, there is relatively little research specifically focused on the impact of carbohydrate consumption on fatigue. The studies reviewed with the strongest study designs, largest sample sizes and older mean ages showed a significant relationship between simple carbohydrate consumption and fatigue; however, further research is needed to establish causality. Additionally, research is needed to understand the long-term effects of a diet low in simple carbohydrates.

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