1999

The Pre-Absorptive, Instantaneous Effects of Natural and Refined Sugar on Quadriceps Peak Torque

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THE PRE-ABSORPTIVE, INSTANTANEOUS EFFECTS OF NATURAL AND REFINED SUGAR ON QUADRICEPS PEAK TORQUE

By

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THESIS

Submitted to the Physical Therapy Program at Grand Valley State University
Allendale, Michigan
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN PHYSICAL THERAPY

1999
THE PRE-ABSORPTIVE, INSTANTANEOUS EFFECTS OF NATURAL AND REFINED SUGAR ON QUADRICEPS PEAK TORQUE

ABSTRACT

The purpose of this study was to compare the effect of natural and refined sugar at an instantaneous, pre-absorptive level on quadriceps peak torque and to measure any prolonged effect on normal, healthy subjects. The experimental group (n=40) was randomly assigned to sugar testing order, with refined sugar testing occurring on one day and natural sugar testing occurring on the opposite day. The control group (n=10) followed the same protocol but held distilled water in their mouth. Isokinetic peak torque was recorded for each subject at three intervals, pretest, post-test I (~1 min.), and post-test II (~15 min.). Results showed that neither the sugars nor the placebo had a significant effect on peak torque in under one minute. However, both sugars produced a significant decrease ($p<0.05$) in peak torque at the fifteen-minute interval, while the placebo did not. The authors concluded that both natural and refined sugar had a negative effect on peak torque approximately fifteen minutes after its administration.
ACKNOWLEDGMENTS

We would like to extend a special thank you to our committee chairperson, Arthur E. Schwarcz, Ph.D., P.T., A.T.C., M.N.S.M.T., for his commitment and expertise in the organization and presentation of this research study. Our research group would also like to thank Jim Scott, B.S., M.A., P.E.S., for his knowledge in isokinetic testing and exercise physiology, use of the human performance lab and helping in the recruitment of subjects. We would also like to thank Daniel Vaughn, P.T., M.O.M.T., for his help in subject recruitment and commitment to the organization of this research study. We also appreciate Paul Stephenson, Ph.D. for his statistical and organizational skills. Specifically, we would like to recognize Brett Mazarka, our statistical student, for his willingness and patience to provide us with every statistical test and comparison we asked for and then some.

We would personally like to thank Mr. and Mrs. Dennis Adams for their hospitality and lodging during this busy and time-consuming experience. Finally, we would like to thank Rebecca, Kathy and Jennie for their understanding and support during our prolonged absence from home.
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CHAPTER 1
INTRODUCTION

Context and Background of the Problem

Multiple studies have been performed focusing on carbohydrate (CHO) ingestion and its utilization before, during and after exercise (Marmy-Conus, Fabris, Proietto, and Hargreaves, 1996; Murray, Paul, Seifert, Eddy, and Halaby 1989; Walther, 1988). These studies were all based on the idea that the CHO must first be absorbed into the bloodstream before it elicited an effect on the subject. However, Walther (1988) proposed that the effects of refined sugar consumed by hypoglycemic patients before absorption into the bloodstream (pre-absorptive) produced an instantaneous decrease in muscular strength. In a study by Nicolaidis, the author examined this pre-absorptive effect of sugar in the diabetic population. He noted that only 20 seconds after placing sugar in the hypoglycemic subject’s mouth, there was a significant decrease in their hypoglycemic symptoms (Walther, 1988). However, data was not collected on how long this effect lasted or if this effect could be extrapolated to a non-diabetic population.

Rybeck and Swenson (1980) conducted a study that focused on the effects of oral administration of refined sugar on muscle strength in a nondiabetic population. They utilized the latissimus dorsi as the target muscle group and tested it via isometric strength testing both mechanically and manually. Their results showed no statistically significant difference in muscle strength as tested by mechanical means, but manual muscle testing revealed a statistically significant decrease in muscle strength.
Walther's (1988) theory, coupled with and Rybeck and Swenson's (1980) study, have implications for high powered anaerobic athletic performance and for rehabilitation of musculoskeletal injuries because each author implies that different sugar substances can have an instantaneous effect on a muscle group's force output. Athletes, coaches, athletic trainers, physical therapists and patients all need to be aware of how this element could enhance or inhibit their optimum performance during anaerobic athletic activities and rehabilitation exercise sessions.

Problem Statement

The human body responds systemically to oral absorption of sugars at an instantaneous, pre-absorptive level via gustatory receptors (Walther, 1988; Rybeck and Swenson, 1980). This response, an immediate and full body insulin release which results in metabolic changes, is dependent on the type of sugar, fructose (monosaccharide) or sucrose (disaccharide), and the form (natural or refined) of sugar consumed, respectively (Grill, Berridge, and Ganster, 1984). Oral absorption of refined and natural sugar has been reported to affect the degree of muscle power output and peak torque immediately (< 1 minute) after ingestion (placed on the tongue). This could have either a positive (increased strength) or negative (decreased strength) effect on the performance of anaerobic exercise and rehabilitation exercises that are performed. How long these effects last, however, has not yet been established.
**Purpose/Aims**

The purpose of this study was to compare the effect of natural sugar and refined sugar at an instantaneous, pre-absorptive level (< 1 minute) on quadriceps muscle’s peak torque in normal, healthy subjects. This study also attempted to measure the prolonged effects (~15 minutes) of these two different types of sugars.

**Significance of the Problem to Physical Therapy**

Many of today’s foods, drinks, candy, gum and sport supplements currently contain refined sugars. Consuming any of these products immediately prior to and during the performance of anaerobic exercise and/or rehabilitative activities could actually decrease performance and/or increase the possibility of injury. Patients consuming refined sugars immediately prior to rehabilitation treatment could present in a weakened state. This could negatively affect all aspects of exercise, including total work, power output, and peak torque, which could affect restoration of functional tasks. On the other hand, the consumption of natural sugars may have a positive effect on the performance of anaerobic exercise and/or rehabilitative exercises immediately after consumption.

**Hypothesis/Research Questions**

This study will attempt to support the following hypothesis: 1) the pre-absorptive consumption of natural sugars in a randomly selected, non-diabetic population will elicit an immediate state of significantly increased quadriceps muscle peak torque, as measured by isokinetic testing, and 2) the pre-absorptive consumption of refined sugars, in a randomly selected non-diabetic population, will elicit an immediate state of significantly decreased quadriceps peak torque, as measured by isokinetic testing. From the data that
was collected, the following questions will be addressed: 1) does oral absorption of refined or natural sugar affect the peak torque of the quadricep muscle group and 2) will this effect last for 15 minutes?
CHAPTER 2
REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

The pre-absorptive effects of glucose and sucrose on peak torque can be better understood through the breakdown and analysis of each integral part of the research hypothesis. This chapter will review pertinent information and research related to 1) types of carbohydrates, their chemical make-up, and how each affects the body, 2) carbohydrates and their relation to the body's systems (neuroendocrine), and 3) the testing equipment employed in this study (reliability, validity, quantification of data).

Carbohydrate Chemistry

Carbohydrates are a major source of energy for the body, allowing it to perform and maintain a variety of activities. The four main components of carbohydrate utilization by the body include: ingestion, the initial intake of carbohydrates orally; digestion, the breakdown of carbohydrates by the gastrointestinal tract; absorption, the transportation of the carbohydrate's components across the intestinal wall; and metabolism, using the components to form the body's energy source (ATP). Most studies focus on digestion, absorption, and metabolism of carbohydrates, while the ingestion phase of carbohydrate utilization has typically been overlooked. Carbohydrates can be classified into three main categories: monosaccharides, disaccharides and polysaccharides.
Monosaccharides

Monosaccharides (natural sugars) are simple sugars, consisting of a single molecule. They have a carbon ring formation which can have three carbons (triose sugars), five carbons (pentose sugars), or six carbons (hexose sugars). Fructose is a pentose sugar and glucose is a hexose sugar. The three-dimensional shape of these sugars is also very important. Like most molecules, sugars can have the same empirical formula but have different physical structures and possibly different functions. All of these sugars can be readily absorbed through the small intestine and transported throughout the body.

Disaccharides

Disaccharides (refined sugars) are sugars consisting of two monosaccharides joined together, usually by a bond called a glycosidic linkage. Sucrose is an example of a disaccharide. It is made up of a single glucose and a single fructose molecule. Disaccharides are too large to be absorbed by the body. They must be split into their monosaccharide components in the digestive tract before they can be utilized.

Polysaccharides

Polysaccharides are complex carbohydrates that are insoluble in water and have a bitter taste, unlike their monosaccharide and disaccharide counterparts. They are composed of multiple monosaccharides linked by glycosidic bonds. Before the body can utilize polysaccharides, they too must be broken down into individual monosaccharides by disrupting the glycosidic bonds.

Metabolism of Carbohydrates

Southgate, in his 1995 review article, described different aspects of sugar digestion and metabolism. The human diet contains a number of different types of
carbohydrates, and the food consumed in the diet provides a wide variety of physical properties and chemical compositions, each having a specific role in digestion. Southgate discussed the importance of the specific forms of carbohydrate consumed. Sugar is commonly found dissolved in liquid products like carbonated drinks, teas and coffee. The solubility of sugars varies with the complexity of the sugar. The crystalline form of sugar, most commonly seen as table sugar, is also used in many foods. These factors, physical and chemical, can influence the rate of gastric emptying and affect the rate of transport across the membrane of the small intestine. The food’s composition is less important after absorption because the sugar components can eventually be transformed to glucose, which is readily used by the body.

Riby et al. (1993) examined the digestion and absorption of fructose. Fructose is found in most diets as a component of sucrose. Free fructose is found only in honey and fruits such as dates, figs, apples, grapes, and most berries. Therefore, free fructose doesn’t contribute significantly to the intake of dietary carbohydrate. However, it is often ingested as a sucrose component. The absorption of fructose may depend on its form and on the presence of glucose to enhance transport. The conclusions of Riby et al.’s study showed that there is a specific carrier for fructose located in the brush-border membrane, which facilitates diffusion across the membrane of the small intestine. Fructose absorption after the digestion of sucrose, or in the presence of free glucose, appears to be more efficient than absorption of (free) fructose alone. This study provides insight on fructose absorption, but raises questions about the interaction of fructose and other sugars at all physiological levels, including ingestion.
Carbohydrates and Exercise

Marmy-Conus et al. (1996) looked at the ingestion of glucose before exercise and its effects on liver glucose output and muscle glucose uptake. The order of the trials was counterbalanced and conducted double blind. Subjects ingested glucose or a sweet placebo 30 minutes before a 60-minute exercise bout. A tracer chemical monitored the appearance and disappearance of glucose. The subjects rode a stationary bike for one hour at a work level of 70\% of peak VO$_2$. Expired gases and blood draws were analyzed. The researchers concluded that pre-exercise glucose ingestion results in increased muscle glucose uptake and reduced liver glucose output during exercise. This study suggests that the timing of ingested glucose (pre-exercise) intake has an effect on glucose kinetics. Also, liver glucose output in the placebo group increased, whereas the glucose group had decreased liver glucose output during the first ten minutes. “This could imply that hyperglycemia and hyperinsulinemia before exercise blunts the normal feed-forward activation of glucose production observed at the onset of exercise” (Marmy-Conus et al., 1996).

Koivisto et al. (1981) examined the effects of pre-exercise ingestion of glucose, fructose and sweet placebo ingestion on the performance of a 30-minute cycle ergometer exercise bout. Nine trained males ingested one of the above solutions 45 minutes before riding a cycle ergometer at 75\% of VO$_2$ max. The results of the three trials showed that glucose ingestion before exercise resulted in hypoglycemia during exercise. Hyperinsulinemia followed glucose ingestion resulting in increased transportation of glucose from the blood into the tissues (muscle), resulting in a decrease in blood glucose (hypoglycemia). Fructose ingestion did not produce hypoglycemia due to mild increases
in plasma insulin levels. Blood glucose levels in the sweet placebo group were used as a baseline measure.

Thomas et al. (1991) studied the results of pre-exercise meals, consisting of either a low or high glycemic index (GI), and their effect on exercise. “The glycemic index of a food is defined as the degree to which it raises the plasma glucose concentration relative to glucose, which has been assigned the arbitrary number of 100,” (Thomas, 1991). The study took place over a four-week period, with each of four foods randomly assigned to each cyclist. After ingesting one of the four randomly assigned foods, the cyclist pedaled to exhaustion (65-70% of VO\(_2\) max). The trials were repeated, approximately one per week, for each of the four randomly assigned foods. They found that endurance times averaged 20 minutes longer following ingestion of low GI foods than with high GI foods. They concluded that a low GI pre-exercise meal might increase endurance and performance during strenuous exercise by minimizing the occurrence of hyperglycemia followed by hyperinsulinemia.

**Sugar Refinement**

The most common source of sugar is from the naturally grown sugar cane. Sugar beets are the next most common source of sugar. The procedure used to refine raw sugar material consists of crushing sugar (cane) and extracting the juice. This juice is then clarified, crystallized and centrifuged. Although the refining process produces the purest form of sugar, it strips the vitamins, minerals and fiber from the sugar. Ingesting large amounts of refined sugars places a higher demand on the body, requiring it to supply the nutrients (B vitamins) needed to convert sugars into glucose. (Buscher, 1997)
The majority of refined sugar products are extra-fine granulated, white, brown, powdered, liquid and co-crystallized forms. Extra-fine granulated is the most common form of refined sugar, composed of 99% sucrose. Brown sugar is typically used for cooking and consists of white sugar mixed with molasses. Pulverizing white sugar into various amounts of fineness makes powdered sugar. Liquid sugar is made by melting white sugar or decolorizing syrups and is used in soft drinks and ice cream. Co-crystallized sugar has a high molasses content and requires extensive processing (http://www.floridaeystals.com).

Refined sugars have also been found to have an impact on brain function through their effect on the neurotransmitter serotonin, increasing their levels in the blood, which can cause drowsiness and other systemic problems. Natural sugars, however, because of their high fructose composition, have been shown to have less of an impact on serotonin levels and brain function (Buscher, 1997).

**Insulin Release**

Grill et al. (1984) tested seven sugars (glucose, sucrose, fructose, maltose, galactose, mannose, lactose) and two sugar alcohols (glycerol, sorbitol) for their overall insulin response-eliciting effects upon oral administration in rats. Glucose elicited a statistically significant elevation of insulin levels, independent of the rise in blood glucose, compared to the other eight. This immediate (pre-absorptive) insulin response persisted for approximately 8-10 minutes after its administration. They also found that this pre-absorptive insulin response could more than double the insulin base-line levels. Their findings were supported by six other studies (Berthoud, Bereiter, Trimble, Siegel, and Jeanrenaud, 1981; Fischer, Hommel, Ziegler, and Michael, 1972; Hommel, Fischer,
Researchers noted this finding was a surprise, since glucose is neither the most intense (electrophysiologically) nor the most palatable (behavioral preference) sugar as found in taste tests. This article suggested the existence of a gustatory and/or gastrointestinal chemoreceptor that are/is highly responsive to glucose. These receptors can elicit a major response in systemic insulin levels. Grill et al. sited Goldfine et al. (1969) who showed that glucose flavored cola elicited a rapid elevation of insulin levels in humans, while neither saccharin-flavored cola nor water elicited any significant response.

Barnard et al. (1992) performed a study of sugars at the biochemical level. The entry of glucose into muscle cells is achieved primarily via a carrier-mediated system consisting of protein transport molecules. GLUT-4 transporter is normally found in the sarcolemmal (SL) membrane and is involved in glucose transport during basal levels. Insulin accelerates this system by “translocating” GLUT-4 out of an intracellular pool and into the T-tubules and SL membranes. The researchers noted that most studies showed no change in the intracellular pool of GLUT-4 translocating to the SL. This implies the presence of an “insulin resistance”, which was attributed to the typical American diet of high-fat and refined sugar foods (when compared with a low-fat, complex-carbohydrate diet). They also noted that individuals who exercised had an increase in insulin sensitivity. The relevance of the article by Barnard et al. was their attempt to explain how a systemic insulin response to a gustatory stimulation (via refined/natural sugars) could possibly affect muscle performance. This is a topic that needs further research.
Gustatory Nerve Stimulation

Spector et al. (1996) studied the desire for sugar in rats, measured quantitatively by counting total-lick responses. What they found was a pronounced decrease in sugar responsiveness after gustatory nerve transection. The response to maltose decreased after transection of the chorda tympani, and the response to sucrose decreased after transection of the glossopharyngeal nerve. This study demonstrated the linkage between a neuronal component to taste-recognition and desire for different sugars in rats. Further correlations have been specifically drawn between the glossopharyngeal, the chorda tympani, and the greater superficial petrosal nerves for sucrose taste.

Ramirez et al. (1994) conducted a similar study to that of Spector et al. (1996), except they compared the effects of sucrose and fructose on gustatory nerve response. Quantitatively, sucrose appeared to be 2-4 times sweeter than fructose. The rats could determine the difference between the two solutions, even when the sweetness difference was equalized. The significance of these findings is the apparent preference between the two sugars. The gustatory receptors respond in different ways to different forms of sugar, which could ultimately affect the release of insulin and other components of muscular contractions.

Rybeck and Swenson (1980) performed one of the more comprehensive and objective studies that investigated the effects of refined sugar on muscle strength. They tested muscle strength mechanically and manually with a refined sugar cube in the subject’s mouth. They found a significant decrease in strength as measured by a manual muscle test (Wilcox Rank Sum Test, p=. 0062) approximately 90 seconds following sugar administration. This study demonstrated the effects of refined sugar on muscle
performance. However, there are questions concerning the reliability and validity of manual muscle testing versus a mechanically administered test.

Goldman et al. (1986) studied the behavioral effects, in children, of juice sweetened with sucrose when compared to the ingestion of juice sweetened with an artificial sweetener. The children were observed for 90 minutes after the consumption of the juice. The results clearly demonstrated a decrease in performance in structured testing situations, coupled with inappropriate behavior during these activities for those children that consumed sucrose sweetened juice when compared to artificial sweetened juice consumption. The effect was most pronounced 45–60 minutes after sucrose juice ingestion. This study identified a behavioral effect of sucrose on humans.

Neuroendocrine Reflex

Nicolaidis (1969) analyzed the difference between feeding on sucrose to feeding on saccharine, and their effect on a rat’s respiratory quotient (RQ = VCO₂/VO₂), blood glucose level, and electrophysiological aspects of feeding. What he found was that upon feeding, the RQ of a food deprived (hypoglycemic) rat spiked immediately within the first minute, and slowly rose from there in the remaining 50 minutes. The initial spike was attributed to pre-absorptive effects of the sugar-gustatory-endocrine response, while the slow rise was due to the influx of sugar into the circulatory system. The initial blood glucose spike occurred less than one minute after oral stimulation in both trials. The main difference was apparent at the 10-minute mark, when blood sugar levels in the saccharine-subjects quickly dropped while they steadily rose in the sucrose-subjects. This study shows how both the RQ and blood glucose levels can be effected by sucrose, while the apparent time frame in which this commences and concludes can vary by solution.
In a more recent study by Nicolaidis (1977), he performed a thorough investigation on the physiological effects of oral stimulation with a 30% sucrose solution. This time, Nicolaidis accounted for hyper- and hypoglycemic subjects (rats). The results showed that a reflex-elicited response releases both insulin and glucagon. The first response started approximately one minute after oral stimulation, with a duration of ten minutes (for initial spike), followed by a second, more prolonged increase. These findings supported his earlier work (1969). This initial hormone release-phase was attributed to the oropancreatic hypoglycemic reflex, while the second was attributed to gastrointestinal and systemic reactions/reflexes. The rationale for the initial flux was to help the organism adapt to the “stress” of sudden nutritional influx by preparing for digestion ahead of time. It was also postulated that with these responses came a complementary mechanism, consisting of adrenaline secretion “during food ingestion, from the intrahepatic chromaffin cells, recently located in the portal spaces of liver parenchyma” (Nicolaidis, 1977).

Isokinetic Testing

In a study conducted by Moffroid et al., isokinetic devices and exercise were examined to determine their reliability and validity in measuring torque, work, range of motion, and power (1969). The study also analyzed the ability and effectiveness of isokinetic exercise to increase muscular strength. Research done by Moffroid et al. supported isokinetic exercise to be both reliable and valid in assessing torque, work, and power output of the specific muscle group being tested. Other pertinent findings of their study include: 1) torque curves of these muscles at slower speeds matched those found for isometric forces at concurrent specific angles; 2) with increasing speeds of
contraction, the torque decreases; and 3) with increasing speeds of contraction, the peak torque occurs later in the range of motion of the tested movement (Moffroid, Whipple, Hofkosh, Lowman, and Thistle, 1969).

Pincivero et al. (1997) stated that some of the advantages of isokinetic testing included: permitting isolation of specific muscle groups, providing balanced amounts of resistance throughout the entire range of movement, and presenting quantifiable data for peak torque, work and power. The disadvantage was a lack of specificity in functional tasks due to open chain movement and testing velocities that are held constant throughout the ROM and are not relevant to functional activities. Previous studies found the Cybex® II (Cybex, Ronkonkoma, NY) produced low-test retest reliability at angular velocities of 180 and 240 degrees/second. The purpose of Pincivero et al.’s study was to examine the test retest reliability of the isokinetic apparatus in determining concentric quadriceps strength. They concluded that the measurement of concentric quadriceps peak torque, work and power had high test retest reliability at 60 and 180 degrees/second on the Biodex® Dynamometer and any other isokinetic instrument with the same testing protocol (e.g. Cybex® II).

In a similar study done by Tredinnick (1988), isokinetic testing was analyzed for reliability of measurement of both concentric and eccentric loading. Three different trials were performed on three different days. The first session was designed to familiarize the subjects with the testing equipment and control for the learning effect. Two days later, the first real test session was completed, followed a week later by the second test session. To ensure consistent activity levels and accurate data, subjects were tested on the same day of the week at approximately the same time of day. Intraclass correlation coefficients
(ICCs) were calculated to determine the level of accuracy and agreement between the two
test trials. For concentric measurements, there were high ICC values found at 60°/sec and
120°/sec, indicating high test-retest reliability of concentric peak torque measurements at
lower velocities. These values were lower for the 180°/sec testing velocity.

Lord et al. (1992) stated that isokinetic testing is a highly reproducible technique
for dynamic strength testing. In isokinetic testing, increased force of muscle contraction
does not change the velocity of the contraction but does produce increased torque.
Results also included an inversely proportional relationship between angular velocity and
peak torque.

Fleshman and Keppler (1992) stated that the Cybex II® is an established
apparatus for isokinetic testing, and it provides the best quantitative measure of dynamic
muscle activity. Most research assessing muscle strength has been done with this specific
apparatus, which has been found to be both reliable and valid in measuring muscle
strength.

A general protocol for isokinetic testing often requires multiple trials performed
over multiple days, thus the reliability of measurement has been questioned. A study by
Johnson and Siegel (1978) addressed this issue by analyzing the reliability of an
isokinetic knee extension movement over a given number of trials and days. They found
that the two sources of error variance in their study, days and trials were of minimal
importance at 5.10% and 2.05%, respectively. Their study also concluded that “a protocol
which provides for three submaximal trials followed by three maximal warm-up efforts is
essential before stable measures are manifested,” (Johnson and Siegel, 1978).
Common factors influencing subject performance in isokinetic testing include pain, fatigue and level of motivation and cooperation. Pain can be regulated through inclusion/exclusion criteria, eliminating subjects with chronic problems or injury. Fatigue can be controlled through limiting subject activity prior to the study, and/or limiting the number of repetitions and effort during the study. However, motivation and cooperation can be difficult to control due to many intrinsic and extrinsic factors affecting the subject. In a study by Dillitto et al. (1991), peak torque, flexion/extension ratio, and average work were measured in trunk musculature, including an attempt to quantify motivation. They found that the average points of variance (APV), which identified consistency of effort, was not a reproducible factor. Therefore, subject motivation cannot be controlled and continues to be a limiting variable in research.

"Isokinetic equipment is used to measure the maximum torque-generating capability of a muscle (in ft-lbs.), which has been shown in biomechanical investigations to be directly related to the muscular effort, and thus to the strength of the muscle(s) being tested," (Fleshman and Keppler, 1992). The Cybex® II relies on Newton’s third law, which states that for every action, there is an equal and opposite reaction. Resistance provided by the isokinetic apparatus is the reaction force and is equal to muscular force acting against the machine’s lever arm. Power for the Cybex® II is generated by an electrical motor, with force input measured by an internal load cell. This load cell acts as a feedback mechanism controlling the angular velocity of the dynamometer such that a constant velocity is maintained.
To quantify the neuroendocrine response related to pre-absorptive sugar consumption, isokinetic testing of the quadriceps muscle group was selected due to its high reliability and validity in measuring peak torque.

**Summary and Implications for the Study**

The literature supported carbohydrates to be an important source of energy in humans. More specifically, much was found about the effects of carbohydrates after digestion/absorption and how they were utilized to provide increased energy to the body upon demand. Minimal research was found supporting the pre-absorptive effects of these molecules. However, limited studies revealed support for the idea of oral ingestion of carbohydrates (natural and refined sugars) that stimulate gustatory nerve receptors, leading to a neuroendocrine reflex. This reflex involved the release of varying amounts of insulin and metabolic hormones (depending on sugar form) that may have had an effect on muscle power output.

This study is important from the fact that the American diet is saturated with refined sugars. From a physical therapy perspective, it may be possible that patients ingesting these sugars prior to rehabilitation could present in a weakened state, with a negative affect on their rehabilitation performance. In addition, this negative effect could also decrease performance in the high level athlete who consumes carbohydrates immediately prior to his/her sport, where minimal changes in the body’s equilibrium could mean the difference between success and failure in competition.
CHAPTER 3
METHODOLOGY

Design of the Study

Working within the experimental framework, this study contained characteristics of the multigroup-pretest-posttest control group design. This design allowed the researchers to explain differences between two or more treatment groups and a control group. The number of subjects enlisted in the study totaled 58, however, eight subjects were not included in the data set. Two of the subjects did not follow the testing protocol while the remaining six were excluded due to illness or inexplicable absence. Ten subjects made up the control group, (mean age 24 years old), which was implemented to reduce the effects of extraneous variables such as fatigue and learning on muscle performance, thus attributing any change in the experimental groups’ peak torque to be a result of the sugars. The subjects were randomly assigned to one of two treatment groups. All subjects within the treatment groups were exposed to the independent variable and performance was compared across treatment conditions within each subject and with the control group (Portney & Watkins, 1993).

Upon completion of the treatment, each subject went through a posttest measure. The individual’s data was compared to their own pretest data and to the control group’s data, which provided an illustration of a possible cause-and-effect relationship.

Advantages of this quantitative design included: objectivity, eliminated biases and values of the tester, results shown in a cause-and-effect relationship, and proven reliability and validity. By using this experimental method, the study provided maximal
control for extraneous variables through random assignment. The utilization of the multigroup-pretest-posttest control group design was beneficial in that history, maturation, and instrumentation affected all groups equally and allowed the study to be conducted in the most efficient and effective manner possible.

**Population and Sample**

Twenty-five male, (age ranged from 19-32 years old with a mean of 24 years old), and twenty-five female, (age ranged from 19-26 years old with a mean of 22 years old), voluntary subjects were solicited by word-of-mouth and flyers from the student population on the campus of Grand Valley State University, in addition to surrounding communities and neighborhoods. This conveniently randomized sample consisted primarily of students between the age of 19 and 32 years old. Inclusion/exclusion criteria were assessed via a questionnaire (Appendix A). Prior to scheduling, subjects who did not meet the specific criteria were excluded. This included subjects with any recent ankle, hip or knee injuries that required the consultation of a physician or medical specialist within the last six months. All subjects less than 18 years old on the date of testing or those having been clinically diagnosed with any of the following: hypoglycemia, hyperglycemia, or diabetes (Adult Onset Diabetes Mellitus (AODM), Juvenile Onset Diabetes Mellitus (JODM)), were also excluded. Due to the utilization of resistive exercise, subjects clinically diagnosed with low back problems within the last year, including exacerbations of reoccurring problems/symptoms and subjects currently pregnant or less than 6 months post delivery, were excluded from the study. Also, any subject clinically diagnosed with a cerebral vascular accident (CVA), myocardial infarction (MI), hypertension (HTN), or having had abdominal surgery or herniations was
also excluded from the study. All subjects were free of inflammation or pain in their low back, hip, knee, and ankle, and had not suffered from osteoarthritis or rheumatoid arthritis.

**Site**

All testing was conducted in the Human Performance Lab, located in the Fieldhouse on the Allendale campus, Allendale, MI. The Human Performance Lab was a large, open lab with tile floors. It was well lit and contained multiple units of physiologic testing equipment, which included a Cybex® Isokinetic testing apparatus.

**Apparatus / Materials**

The subject’s peak torque was tested using a Cybex® II Isokinetic testing apparatus located in the human performance laboratory at Grand Valley State University. The Cybex II® has shown to be a widely accepted system for isolated joint testing and rehabilitation. The standard system consisted of two upright tables, a low flat treatment table, a dynamometer, various stabilizing straps and extremity attachments, (see figure 1). The peak torque was calculated by a designated researcher from the paper graphs generated by the Cybex II®. These torques were transcribed into the data collection sheets by the same researcher who was blinded to the order of sugar administration.

The sugar substances used consisted of two separate sugar sources, refined and natural sugar, which were in a readily available form for ease of preparation and practical application. For the refined sugar source, a 1 cm x 1 cm C&H Pure Cane® sugar cube was placed on the tongue and held in the subject’s mouth during testing. The producer of this product, C&H Sugar, confirmed the components of the cubes to be 99.9% refined sucrose. For the natural sugar source, a Macintosh apple was peeled and cut into 1 cm x
1cm squares, placed on the tongue and held in the subject’s mouth during testing.

Absopure® purified drinking water was used as the control substance during the pre-test protocol and to rinse out the subject’s mouth between trials. Using Absopure® purified drinking water eliminated the chance of foreign particles or substances that are commonly found in tap water that may influence the study.

**Procedures**

Each subject was contacted by phone prior to testing in order to complete the pre-test questionnaire (Appendix A) and determine if they were eligible for the study. Eligible subjects were then scheduled for testing. They were informed that they should abstain from eating or drinking anything other than water two hours prior to their arrival for testing to decrease the potential for any sugar being in their mouth before and during testing. The subject arrived at the testing site 15 minutes prior to testing. The purpose and procedure of the research study was explained to each subject. The subject was allowed to make inquiries to clarify any questions he/she had about the study or procedure. Finally, the subject received in-depth instructions on the testing procedure, with time to ask any final questions that he/she had. They were then asked to sign the pretest questionnaire and informed consent form (Appendix B) to indicate voluntary participation.

A non-randomly selected control group (n=10) was tested initially to establish a baseline measure without the independent variable. This was done to verify whether the independent variables were responsible for the increase or decrease in muscle peak torque as compared to an extraneous variable.
A second group of treatment subjects (n=40) was then assigned to either treatment group A or B according to a randomly determined list which indicated the order of sugar substance administration. The randomized list was generated by drawing 26 slips of paper which were divided into 13 A’s and B’s to determine the female order and then drawn again to determine the male order of testing. The extra numbers were allowed for additional subjects on an as-needed basis. Two researchers knew the order of sugar administration, and they administered the sugars. The researcher who conducted the testing and analyzed the results was blinded to the sequence of sugar administration.

Immediately after all questions had been answered, the subject warmed up for 10 minutes on a stationary bike, and performed two uniform stretching exercises to the quadriceps and hamstring muscle groups of his/her right leg (Appendix C).

The subject sat in the Cybex® seat. The testing procedure began by adjusting the seat to produce 90° of hip flexion and then aligning the axis of rotation of the Cybex® lever arm to the subject’s lateral epicondyle of their right femur. Distally, the ankle cuff was aligned to one inch above the malleoli. The subject was stabilized with three straps, one crossing each shoulder and extending down to the contralateral hip and a third across the pelvis. A fourth and fifth strap were placed across their distal right thigh and tightened to his/her comfort. Subjects folded their arms across their chest, to reduce excessive movements. The position of the seat, lever arm, and ankle cuff was recorded for use on day two of testing.

It was established prior to testing that each subject would complete a consistent range of motion at the knee ranging from 90° of flexion to 30° flexion, which allowed for 60° of movement. Each subject was asked to fully extend his/her knee, and this point became
the baseline (0°) measurement from which range of motion was extrapolated. From this point, stoppers were placed at 30° and 90° of knee flexion, as measured by the goniometer located on the dynamometer. This measurement was then cross-checked with the positional marker on the recording unit for accuracy.

The subject was then instructed to perform three sub-maximal contractions and three maximal contractions at 60°/sec to become familiar with the Cybex® II. Following a 30-second rest and rinsing his/her mouth out with purified water, the subject was asked to perform the pre-test, consisting of five maximal contractions at 60°/sec, to establish a baseline measure. The subject then rested for one minute, at which time they received instructions for the remainder of the test. At the completion of the one minute rest, the subject was given either a sucrose or fructose substance, based on their random group assignment. The subject was then instructed to retain the substance in their mouth without swallowing. One minute after the subject had placed the substance in their mouth, they commenced with five maximal concentric contractions at 60°/sec. This data served as their posttest-I measurement.

Upon completion of the posttest-I measurement, the subject was instructed to rinse the sugar from their mouth using purified water. He/she remained seated in the Cybex® II for 15 minutes, restraints in place, with the apparatus set for freedom of movement of the tested limb. Subjects were offered reading material if they so chose, but they were required to remain seated. No food or beverages were allowed to be consumed during this time. After the 15 minutes had elapsed, the subject again performed five maximal contractions at 60°/sec, which served as their posttest-II data. This measurement provided information on the temporal effects of the sugar treatment. Upon completion of
the test, the subject was encouraged to perform the pretest stretching routine previously
stated before leaving, to minimize the effects of delayed onset muscle soreness.

On the next day at approximately the same time of day, the test procedure
described above was then repeated using the second sugar substance. The previous
format for set-up and testing was exactly duplicated.

The researcher who was blinded to the type of sugar was assigned to the
following groups of tasks. These tasks included Cybex® calibration, subject positioning,
data collection, and calculation of the torque graphs (Appendix E). The non-blinded
researcher was responsible for providing subject paperwork, answering questions,
verbatim instructional reading (Appendix D), and treatment/substance distribution.

This study possessed possible subject hazards. Possible problems and how they
were safeguarded against included muscle strains and delayed onset muscle soreness,
which were minimized through proper warm up and stretching. Compensatory
movements to increase peak torque were limited by arm placement and restraints at key
points of control (i.e. thigh, ankle, and trunk). Educating the subject on limiting valsalva
usage/compensation prevented cardiovascular problems.

Data Collection

The Cybex® Isokinetic apparatus monitored and recorded peak torque
(PEAK₁₅) for each of the five contractions while maintaining a constant angular velocity
(60°/sec) for every contraction in each trial. The peak torque for each contraction
(PEAK₁₅) was entered into the data collection sheet (Appendix E). The average peak
torque (PEAKₐ) was determined by averaging the greatest three values from (PEAK₁₅)
in each trial. This was the data utilized for the *repeated measure analysis of variance* statistical analysis, incorporating the *Greenhouse-Geisser Correction*. 
CHAPTER 4
RESULTS/DATA ANALYSIS

Techniques of Data Analysis

This study used a repeated factors to evaluate the performance of each subject under several experimental conditions. "The repeated measures design is applied to study variables where practice or carryover effects are minimal and where differences in an individual’s performance across treatment levels are of interest (Pourtney and Watkins, 1993)." The data was broken down into several different factors to perform the analysis (see Table 4.1).

<table>
<thead>
<tr>
<th>Table 4.1</th>
<th>Factors used to Perform Repeated Measures Analysis of Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factors</strong></td>
<td><strong>Statistical designation</strong></td>
</tr>
<tr>
<td>Day (2 levels)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Time (3 levels)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Sugar (2 levels)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Gender (2 levels)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Because the assumption of sphericity was violated, the analysis was more susceptible to a type I error, therefore, the Greenhouse-Geisser correction was used to improve the reliability of the results. The significance was determined by a $p$-value less than 0.05 ($p<0.05$). SPSS 8.0® statistical software was utilized to perform the analysis.
Hypothesis/Research Questions

This study attempted to support the following hypothesis: 1) the pre-absorptive consumption of natural sugars in a randomly selected, non-diabetic population will elicit an immediate state of significantly increased quadriceps muscle peak torque, as measured by isokinetic testing, and 2) the pre-absorptive consumption of refined sugars, in a randomly selected non-diabetic population, will elicit an immediate state of significantly decreased quadriceps muscle peak torque, as measured by isokinetic testing.

The statistical analysis for this study compared the mean peak torque values of the experimental groups by examining their differences in relation to time, sugar type and gender. The mean peak torque values of the control group were analyzed using the factors of day and time only. The examination of all of these factors attempted to establish significant relationships ($p<0.05$), which would then support the hypotheses.

Results

The mean peak torque values and their standard deviations (values in parenthesis) for the control group were: pretest one (first day) 135.6 (50.6) ft-lbs.; pretest two (second day), 130.4 (47.0) ft-lbs.; post-test I (first day), 133.0 (48.8) ft-lbs.; post-test Ia (second day), 132.8 (47.7) ft-lbs.; post-test II (first day), 131.9 (49.0) ft-lbs.; and post-test IIa (second day), 134.4 (48.2) ft-lbs. The mean values are listed in Table 4.3 and graphed in Figure 4.1.

The repeated measures analysis of the control group revealed that there was insufficient evidence to conclude that a significant difference existed in the mean peak torque values for the different days and the different times. The significance level for each source was day, $p=0.834$ and time, $p=0.845$, see Table 4.2.
Table 4.2  Repeated Measures Analysis Results for the Control Group

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>F statistic</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>1</td>
<td>0.047</td>
<td>0.834</td>
</tr>
<tr>
<td>Time</td>
<td>2</td>
<td>0.141</td>
<td>0.845</td>
</tr>
</tbody>
</table>

*notes significant findings (p<0.05).

The results of this analysis showed no significant change in peak torque values between day one and day two of testing or across the three tested time intervals [pretest (time zero), post-test I (1 minute), post-test II (15 minutes)]. In addition, this data suggested that extraneous variables such as fatigue and learning effect did not influence mean peak torque values of the control population according to this specific experimental procedure. Therefore, any change in the mean peak torque of the experimental population could be hypothesized to be the result of the natural or refined sugars.

Table 4.3  Mean Peak Torque Values in Ft-lbs.

<table>
<thead>
<tr>
<th></th>
<th>CONTROL</th>
<th></th>
<th>NATURAL</th>
<th></th>
<th>REFINED</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
<td>Mean</td>
<td>Standard deviation</td>
<td>Mean</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>Pretest I</td>
<td>135.6</td>
<td>50.6</td>
<td>129.0</td>
<td>37.0</td>
<td>132.0</td>
<td>40.8</td>
</tr>
<tr>
<td>2</td>
<td>130.4</td>
<td>47.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-test I</td>
<td>133.0</td>
<td>48.8</td>
<td>128.4</td>
<td>36.5</td>
<td>133.0</td>
<td>39.9</td>
</tr>
<tr>
<td>Ia</td>
<td>132.8</td>
<td>47.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-test II</td>
<td>131.9</td>
<td>49.0</td>
<td>125.4</td>
<td>34.6</td>
<td>128.1</td>
<td>37.9</td>
</tr>
<tr>
<td>IIa</td>
<td>134.4</td>
<td>48.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The mean values for natural sugar, sugar A, were: pretest, 129.0 (37.0) ft-lbs.; post-test I, 128.4 (36.5) ft-lbs.; and post-test II, 125.4 (34.6) ft-lbs. The mean values for refined sugar, sugar B, were: pretest, 132.0 (40.8) ft-lbs.; post-test I, 133.0 (39.9) ft-lbs.; and post-test II, 128.1 (37.9) ft-lbs. The mean values are listed in Table 4.3 and graphed in Figure 4.1.

The repeated measures analysis of the experimental group found that there was sufficient evidence to conclude that a significant difference existed in the mean peak torque values across time. The significance level for time, $p = 0.000$, see Table 4.4.

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>$F$ statistic</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>2</td>
<td>12.655</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Although time in general was found to be a significant factor in relation to peak torque, time needed to be broken down and analyzed at each specific level [pretest (time zero), post-test I (1 minute), post-test II (15 minutes)] to address the hypotheses and research questions. In analyzing the time interval data, the results show no significant change in the mean peak torque between the pretest and post-test I ($p = 0.562$). However, there was sufficient evidence to support a significant difference in the mean peak torque values between the post-test I and post-test II intervals ($p = 0.000$) for both types of sugars (see Table 4.5). Although these statistical values cannot determine the direction of change (increase or decrease), these significant changes appear to be decreases in the peak torque values. The mean values for both sugars are shown in Figure 4.1. Therefore,
the data does not support the hypothesis that sugar A, natural sugar, would produce a significant increase in peak torque; or sugar B, refined sugar, would produce a significant decrease in peak torque at an instantaneous, pre-absorptive level. Both types of sugar appeared to produce a significant decrease in peak quadricep torque after a period of just over fifteen minutes.

<table>
<thead>
<tr>
<th>Source</th>
<th>Time Intervals</th>
<th>Degrees of freedom</th>
<th>F statistic</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>pretest vs. post-test I</td>
<td>1</td>
<td>0.343</td>
<td>0.562</td>
</tr>
<tr>
<td></td>
<td>post-test I vs. post-test II</td>
<td>1</td>
<td>21.083</td>
<td>0.000*</td>
</tr>
</tbody>
</table>

*notes significant findings ($p<0.05$).
Other Findings

In spite of the fact that the hypothesis/research questions were not proven to be significant, there were some other findings from our data analysis that were quite intriguing. First, although natural sugar did not produce an increase in peak torque at an instantaneous level and refined sugar did not produce a decrease in peak torque at an instantaneous level, both decreased peak torque approximately 15 minutes post sugar administration.

Although beyond the scope of this study, the analysis revealed sufficient evidence to conclude that a difference exists in peak torque for the different sugars and genders. Randomization of sugar administration to subjects attempted to negate differences in peak torque at a pretest level. However, at the conclusion of the study, the data revealed that a significant difference was found not only at the pretest level but remained significant across all testing intervals. This does not suggest that the sugars affected the peak torque values differently between each subject, only that the values differed between sugar A, natural sugar, and sugar B, refined sugar, groups. In addition, mean peak torque values significantly differed between genders. This was postulated to be due to the strength differences between males and females.

Finally, results of this study suggested a possible interaction between sugar type and gender. A \( p \)-value of 0.063 was found, indicating a strong but insignificant change in peak torque hypothesized by the researchers to be due to varying sugar types and their different effects on gender. For example, natural sugar may affect male populations’ peak torque values differently than the female populations’, either in direction (increase or decrease) or magnitude of direction.
CHAPTER 5
DISCUSSION AND IMPLICATIONS

Discussion of findings

The purpose of this study was to determine the effect of natural sugar and refined sugar at an instantaneous, pre-absorptive level (< 1 minute) on quadricep muscles’ peak torque in normal, healthy subjects. This study also attempted to measure the prolonged effects (~15 minutes) of these two different types of sugars.

The findings of this study displayed no significant difference in the effects of natural or refined sugar on peak torque at an instantaneous level. However, the study did show a significant decrease in peak torque produced by both sugars following an approximate 15-minute delay. The control group did not display the same significant change after an approximate 15-minute delay; therefore, the intervention, not fatigue or learning effects, influenced the decrease in peak torque.

In answering the research question, does oral absorption of refined or natural sugar affect the peak torque of the quadriceps, the data revealed that there was no instantaneous effect by either natural or refined sugar on peak torque of the quadriceps muscle group. Nicolaidis stated that oral administration of a sweet substance in the hypoglycemic population may cause a neurological reflex which "stimulates the central nervous system to respond with a neuroendocrine secretion" (Walther, 1988). Although this secretion is unidentified in Nicolaidis' study, Walther (1988) hypothesized that this was the link between oral absorption and muscle function.
The current study tried to analyze how two types of oral sugar administration and the subsequent neurological reflex affected strength output in a normal population, which was not compromised by abnormal blood sugar levels. The data concluded that the administration of sucrose or fructose does not affect muscle peak torque of normal subjects at an instantaneous level (~ 1 min) following sugar placement on the tongue. Because of the limited research in the understanding of the physiologic links between gustatory nerve stimulation (neurological reflex) and muscle function, the researchers in this study were unsure why the results contradicted those of previous studies. However, it was possible that while the body was in blood sugar homeostasis, there was recognition of adequate endogenous glucose; therefore, the body's response to this oral administration was minimal, with less emphasis on sensitivity to the gustatory nerve receptors.

In answering the research question, will the preabsorptive effects of sugar last for 15 minutes; this research study was unable to prove a duration effect since there was no initial significant response to either sugar. No other studies found in the literature tested for a lasting effect of this gustatory nerve response, but many of these previous studies had identified an insulin spike that occurred both immediately and at least 10 minutes post sugar administration. However, these spikes did not show any increases or decreases in muscle strength over a ten minute time period. This study did not find instantaneous effects of oral administration of sugar, so it was impossible to measure the duration of these effects. However, in differentiating between the control groups and the experimental groups, there was a significant decrease in peak torque approximately 15 minutes post sugar administration in both the natural and refined sugar experimental groups. The control group, though, did not exhibit this same decrease in muscle strength;
therefore, the decrease in strength was due to the ingestion of sugars, both natural and refined, and not fatigue.

Because there was not an instantaneous effect related to sugar and gustatory nerve response as supported by previous research, the researchers postulated that the decrease in muscle strength was due to the difference in subject population (hypoglycemic vs. normal). Normal subjects may have a slower physiologic response or an absent/non-effective gustatory nerve response. The speed of the physiologic response could be affected at all levels, including the neurological reflex, neuroendocrine secretion, and muscular function. Not only could it affect each level, but the interaction and timing of their interrelated systemic response could be altered as well. In addition, it is possible that the sugar substance was actually absorbed into the system (bloodsystem), thus bypassing gustatory nerve stimulation, which has the ability to change function without oral absorption.

The results of this study challenges theories and results of two other related studies (Nicolaidis in Walther, 1988 and Rybeck and Swenson, 1980) that were found in the literature. These results also bring into question the clinical significance of correlating nutrition and muscle testing theorized by those using Applied Kinesiology (Walther, 1988). The methods employed in the current study were based on a combination of the methods used in the Rybeck and Swenson (1980) study, as well as the clinical theory of Applied Kinesiology (Walther, 1988).

Nicolaidis (Walther, 1988) examined individuals who were diagnosed with hypoglycemia, concluding that sugar produced an instantaneous decrease in hypoglycemic effects. Walther (1988) states that oral stimulation by refined sugar
produced an instantaneous decrease in muscle strength in the diabetic population. The results from this current study are hypothesized to differ from Nicolaidis and Walther's findings in that the population was not hypoglycemic. Nicolaidis's findings, although interesting and significant, cannot be extrapolated to the general population. This study expanded the population base to college-aged students, ages 19-32, with no history of major medical problems/conditions. Although this sample is not representative of the population as a whole, it more closely resembles a normal cross-section of the general population.

The purpose of Rybeck and Swenson's study "was to compare the results of mechanical and manual evaluations of muscle strength in testing the commonly presented hypothesis of Applied Kinesiology that refined sugar placed in a subject's mouth will often markedly weaken a previously strong muscle" (Rybek and Swenson, 1980). Their results showed that manual muscle testing revealed a statistically significant decrease in muscle strength 90 seconds after oral administration of refined sugar. Although manual muscle testing is commonly used in the clinic to measure muscle strength, it is not as objective as isokinetic measurement in determining muscle strength. Possible limitations in their study included insufficient sensitivity of their mechanical device, the HPR-100; insufficient information to reproduce their procedure, and the inherent differences found in what mechanical and manual muscle testing actually evaluate. Therefore, the current study used mechanical muscle testing, specifically isokinetic equipment, because it has consistently been proven in and by the literature as being reliable and valid in assessing muscle strength.
Application to Practice/Administration/Education

The evidence provided by this study could have notable effects on high level athletes, but its clinical importance is questionable. Natural (fructose) and refined (sucrose) sugars are present in many of today’s foods, drinks, candy, gum and sport supplements. Athletes and/or patients consuming natural or refined sugars 15 minutes before rehabilitation interventions could present in a weakened state. This could negatively affect all aspects of exercise, including total work, power output, and peak torque, which could affect restoration of functional tasks.

Although this study found statistical significance for a decrease in muscle peak torque at approximately 15 minutes post sugar administration for both natural and refined sugars, a distinction must be made between statistical and clinical significance. Clinical significance implies being able to apply experimental findings to the rehabilitation setting. In this research, a statistically significant decrease in strength was found with the use of both natural and refined sugar following a 15-minute time interval. However, to make the data more applicable for clinical use, the percent change for the mean peak torque values was calculated for the two significant testing scenarios using the two formulas listed below:

\[
\left(\frac{|\text{pretest} - \text{post-test I}|}{\text{pretest}}\right) \times 100 = \text{Percent Change}
\]

\[
\left(\frac{|\text{post-test I} - \text{post-test II}|}{\text{post-test I}}\right) \times 100 = \text{Percent Change}
\]

These numbers are summarized in Table 5.1.
Table 3.1 Mean Peak Torque Values and Percent Decrease for the Experimental Groups

<table>
<thead>
<tr>
<th></th>
<th>MEAN PEAK TORQUE (ft-lbs.)</th>
<th>PERCENT DECREASE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NATURAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest vs. Post-test II</td>
<td>129.0 (37.0) vs. 125.4 (34.6)</td>
<td>2.8</td>
</tr>
<tr>
<td>Post-test I vs. Post-test II</td>
<td>128.4 (36.5) vs. 125.4 (34.6)</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>REFINED</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest vs. Post-test II</td>
<td>132.0 (40.8) vs. 128.1 (37.9)</td>
<td>3.0</td>
</tr>
<tr>
<td>Post-test I vs. Post-test II</td>
<td>133.0 (39.9) vs. 128.1 (37.9)</td>
<td>3.7</td>
</tr>
</tbody>
</table>

() notes standard deviation from mean peak torque.

The percent decrease in peak torque for the natural sugar group between pretest and post-test II comparison measurements was 2.8 %, while the percent decrease between post-test I and post-test II measurements was 2.3 %. The percent decrease in peak torque for the refined sugar group between pretest and post-test II comparison measurement was 3.0 %, while the percent decrease between post-test I and post-test II measurements was 3.7 %.

Percent decrease in peak torque for both natural sugar and refined sugar groups was minimal. In a rehabilitation setting, this change may be difficult to assess and document. In addition, this modest difference will have a minimal affect on patient performance in the clinic. However, this small percent change could have a large effect on the highly trained athlete. A minimal disruption in these athletes' physiological equilibrium could mean the difference between winning and losing in short anaerobic events.
Limitations

As stated above, one of the largest limitations to the study is its relevance to the rehabilitation population. Small changes (2-4 %) in muscle strength may not significantly correlate with altered performance in the clinic. Second, the neurophysiologic mechanisms involved in the gustatory-sugar/insulin cycle are not fully understood. These interactions may also vary between subjects due to each individual's sensitivity to insulin, as is dictated by activity level. Third, although group assignment was randomized, most of the sample was taken from the university campus and surrounding areas. Thus, the results are representative of university students between the ages of 19 to 32 only. Fourth, the study was a short-term manipulation of the subject's diet. It did not take into account the dietary habits of the subjects, nor their eating schedule. However, instructing subjects to abstain from eating and drinking anything (except for water) two hours before testing attempted to control for this effect. Next, the repeated measures design for statistical analysis is biased towards a Type I error, or an incorrect decision to reject the null hypothesis, concluding that a relationship exists when in fact it does not. This is due to the test's sensitivity to differences in variance. However, this was corrected for by using the Greenhouse-Geisser correction. In addition, the subject's motivational level could not be controlled, and they may not have provided maximal effort on both days. However, the exact same instruction was given on both days to each subject, the treatment order was randomized, and each subject was then tested around the same time each day. Finally, the treatment substance, although primarily containing sugar, may have had other ingredients, which could have affected the performance of the subject.
Suggestions for Further Research/Modifications

Further research is needed to examine the different aspects of carbohydrate physiology and its relation to muscle strength, including the gustatory nerve reflex, the central nervous system neuroendocrine response, insulin-glucose interaction relating to instantaneous response, and neuromuscular components of this system. This study has examined the effects of natural and refined sugars at an instantaneous level and then approximately 15 minutes following sugar ingestion. However, the study did not find any instantaneous effects on quadriceps muscle peak torque to oral sugar administration, so it was impossible to measure duration of effects that did not exist. A more detailed examination of time may determine the critical moment when strength is affected, through either absorption or gustatory nerve stimulation, and provide a time table in which the muscle function has significantly changed. Isokinetic testing provides detailed objective measures; however, it does not carry over into functional activities. A functional testing device or activity could provide a better link to the affects of sugar during every day function. This study also attempted to explore gender differences through data analysis. A similar study that examines only males or females could provide more detailed evidence of the effects of preabsorptive sugar on the body by specific genders. Finally, the current study looked at a limited age range (19-32) and population sample, consisting only of university students. A broader range of subjects would allow the results to be applicable to a more diverse population.

Conclusion/Summary

This study attempted to determine if both natural and refined sugar had an instantaneous, preabsorptive effect on peak torque of the quadriceps muscle group. The
researchers were unable to find a significant increase in peak torque with natural sugar and a significant decrease in peak torque with refined sugar at an instantaneous level as was reported in two previous studies. However, the research study did show both natural and refined sugar had a negative effect on peak torque approximately 15 minutes after oral administration. It is unknown as to what underlying physiologic mechanisms occur during this process. Either a gustatory reflex or absorption could have accounted for the change in muscle function. Although these findings were statistically significant, they lack significance for the rehabilitation setting. However the results from this study may have significant implications for the high level athletic population, where minimal changes in the body's homeostasis may disrupt optimal performance in anaerobic type activity requiring maximal, or near maximal, strength output.
REFERENCES


APPENDIX A

Medical/Health Questionnaire
MEDICAL/HEALTH QUESTIONNAIRE

I. Personal Data
Name: ___________________________ (First) ___________________________ (Mf)
Gender: M F Date of Birth: ___________________________ Age: ___________________________
Address: ___________________________ City: ___________________________
State: ___________________________ Zip Code: ___________________________
Phone: Home ( ) ___________________________ Work ( ) ___________________________
Emergency Contact: ___________________________ Phone: ( ) ___________________________
Height: ___________________________ Weight: ___________________________

II. Health History
Orthopedic
1. Have you had any ankle, knee or hip injuries that required a consultation with a
physician or medical specialist within the last six months? no yes
If yes, please explain: ___________________________

2. Are you currently suffering from any ankle, knee, hip or low back pain or
inflammation? no yes
If yes, please explain: ___________________________

3. Have you been clinically diagnosed with any lower back problems within the
last year, including any return of previous problems? no yes
If yes, please explain: ___________________________

General Medical
4. Have you ever been clinically diagnosed with any of the following?
   Low Blood Sugar no yes
   High Blood Sugar no yes
   Diabetes no yes
   High Blood Pressure no yes
   Heart Problems no yes
   Stroke no yes
   Hernia no yes
   Arthritis no yes
If you answered yes to any of the above conditions, please explain: ___________________________

5. Are you currently pregnant or have you had a child within the last six months? no yes
6. Are you currently taking any prescribed medications? no yes
   If yes, please list and explain reason for prescription:

   ________________________________________________________________
   ________________________________________________________________

7. Please list all major surgeries:

   ________________________________________________________________

8. Have you ever been advised by a physician not to participate in an exercise program? no yes
   If yes, please explain:

   ________________________________________________________________

I, ________________________________, understand that the information contained in this form will be kept strictly confidential by the researchers of this study. I also understand that this information will be used by the researchers to determine my eligibility for participation in this study only. If any illness or previous injury could have a potentially negative effect on my health during this study, my involvement in this study will be terminated immediately.

By signing this form, I agree that all the information on this form is true to the best of my knowledge. By signing this form I am also waiving any liability on the part of the researchers and Grand Valley State University, unless it is determined that the researchers were negligent.

_____________________________  ______________________________
Signature of Participant         Date

_____________________________  ______________________________
Signature of Researcher/Witness  Date
APPENDIX B

Informed Consent Form
INFORMED CONSENT FORM

I, ______________________________, understand that I am participating in a research study which will examine the effects of two different types of sugars on their ability to affect my right quadriceps muscle group function by just placing the sugar in my mouth, not eating it, and that the results of this study will be used by various health care professionals to better understand how the short term effects of nutrition impact rehabilitation and client performance. I also acknowledge the following to be true:

1. that my participation in this particular study will involve maximal strength testing on a Cybex II dynamometer, at least fifteen repetitions on two separate but consecutive days. The first five repetitions will allow me to become familiar with the machine and the research protocol. The second five repetitions will be done with a sugar substance in my mouth, measuring its effects. Finally, the last five repetitions will be done 15 to 20 minutes later to examine the lasting effects of the sugar substance on my body.

2. that I have been chosen to participate in the study because the researchers do not anticipate any threat to my health, safety, or general well-being during the procedure based on the information which has been gathered from the separate medical/health questionnaire. I am also aware that maximal strength testing may bring about delayed onset muscle soreness (muscle tenderness and/or temporary stiffness due to vigorous, unaccustomed exercise or any form of muscular overexertion) one to two days after the study and which may last five to seven days. I understand this condition to be temporary, but in the unlikely event of an injury, the researchers can arrange for medical assistance for me. I acknowledge that there is no financial compensation for this study, and that all financial arrangements for treatment must be set up and met by me.

3. that my participation in this study will require me to be at the Human Performance Lab for two separate testing sessions on two consecutive days for approximately 45 minutes per session. An interval of approximately twenty-four hours will separate each test session.

4. that all the information collected from this study will be kept strictly confidential. I understand that the researchers may release this information for scientific literature publication, but that in no way will I be named or identified.

5. that all of my questions and inquiries were answered prior to my participation in the study. However, I am allowed to continue to ask questions at any time during and/or after the study by contacting researchers Brian Adams (616) 676-2480, Kevin Valdes (616) 782-8355, or Scott VanZanten (616) 388-8739; committee members Arthur Schwarcz or Daniel Vaughn (616) 895-3356; or chair of the Human Research Committee, Paul Huizenga (616) 895-2472.
6. that if at any time I become uncomfortable with the research or testing procedure, I may drop out of the study, no questions asked and without penalty, by contacting the researchers.

7. that I have been given adequate warm-up exercises and stretches to minimize injury during the testing procedure. Also, I have received cool-down exercises and stretches, with education on their usage, as post-treatment measures to alleviate any possible muscle soreness. I will not hold the researchers responsible for discomfort following testing, as I have been informed of the possible effects this study will have on my body, and I have been educated on how to treat those effects.

I acknowledge that I have read and understand the above information, and based upon this information, I am voluntarily agreeing to participate in, and assume the risks of engaging in this study.

_________________________  ___________________
Participant’s Signature       Date

_________________________  ___________________
Researcher’s Signature        Date

_____ I am interested in receiving a summary of the study results and will fill out a self-addressed envelope at the testing site, receiving the results in late April 1999.
APPENDIX C

Stretching Exercises
**Hamstring Stretch**

1. Elevate leg to a comfortable height
2. Keep both legs straight, hips square, and upper back straight
3. Bend forward at the waist, lowering trunk towards raised leg, feeling stretch behind your leg
4. Hold stretch for 30 seconds
5. Repeat twice for a total of one minute per leg

**Quad Stretch**

1. Stand upright using free hand for balance
2. Flex leg, raising foot to buttocks
3. Grab raised foot with one hand, pull towards buttocks
4. Hold stretch for 30 seconds
5. Repeat twice for a total of one minute per leg
APPENDIX D

Instructions and Explanations to Subjects
INSTRUCTIONS AND EXPLANATIONS TO SUBJECTS

Intro:

Introduction to the research project

1) Brief tour of facility, answering pertinent questions and making sure that the subject feels comfortable.

2) Initial information packet distributed, containing the following forms:
   ♦ Medical Health Questionnaire- which was completed via phone interview.
   ♦ Informed Consent

Explain: "these forms will tell you all that you will need to know about the purpose of the study and the general procedure, within reason. We will need for you to sign each form after all of your questions have been answered to your satisfaction."

3) Subject will be instructed to warm up on a stationary bike for 10 minutes, with moderate resistance (Borg Scale of Perceived Exertion: 12/20, fairly light to somewhat hard). This will be followed by two sets of stretching, one for the right quadriceps (subject standing, reaching back with one hand to pull the foot of leg towards his/her buttocks) and one for the hamstrings (placing foot up on chair, knee straight, lean body towards knee while maintaining a straight back). These stretches will be held for 30 seconds each, repeated twice for a total of one minute.

Setup:

Initial setup prior to testing

1) Subject setup for isokinetic testing, explaining that:

   "This machine will allow us to measure how much force you can produce against this arm (pointing to lever arm), as well as how quickly you can make it move. The Velcro
straps are here to help keep you stable during the test, since you will be pushing with all your might. Let's get you set up, and I will explain more in a minute”

♦ Instruct subject to get into the isokinetic chair, placing right leg into the lever arm.
♦ The Cybex® seat should allow for 90° of hip flexion, while aligning the axis of rotation of the lever arm to that of the lateral epicondyle of the right femur.
♦ The ankle cuff should be aligned to one inch above the lateral malleoli.
♦ Help them fasten the Velcro straps across their trunk, hip and thigh as tight as the subject can comfortably tolerate.

Testing:

Testing and data accumulation

1) Data accumulation will consist of the subject performing five sub-maximal repetitions to become familiar with the Cybex®. Instruct the subject:

"We want you to do five submaximal repetitions, starting with your foot all the way back. Extend your knee until it is straight, then pull it back until it comes all the way back. This is not being recorded, it is only to introduce you to the machine and the movements that you will be required to perform".

2) This will be followed by a 30 second rest. Instruct the subject:

"Now you have 30 seconds to rest after which time you will do five more reps, as hard as you possibly can, and as fast as you can. These will be recorded, so make them count. I will tell you when to go, and when to stop after five. Do you have any questions?"

♦ Questions pertaining to the instructions will be answered within reason.
3) Then five maximal contractions will be performed to establish a baseline measure, serving as the subject's control data. The tester will instruct the subject on when to start, and when to stop, and congratulate them on their efforts with a "Good job". No encouragement or motivation will be given during the testing.

4) The subject will then rest for one minute, at the end of which they will receive the appropriate sugar substance to hold in their mouth, based on random group assignment. The sugar source will be prepared the other tester, so that neither the subject nor the administering tester knows what type of sugar is being given. Instruct the subject:

"Hold this sugar substance in your mouth, without swallowing it. In ten seconds you will be told to perform another five repetitions with the sugar substance in your mouth. You will be instructed on when to start, and when to stop. At the end of the five reps, you will spit the sugar into the cup (on desk along side the Cybex®), and you will be given some water to rinse out your mouth. Any questions?"

5) The subject will remain strapped in the Cybex® for 15 minutes, with the restraints in place, and with the resistance arm set for freedom of movement of the tested limb, after which the subject will again perform five maximal reps, following the same instructions as before.

Post-testing warm down:

1) Upon completion of the testing, the subject will be encouraged to warm down on the stationary bicycle and repeat the stretches done as warm ups, to decrease the chances of muscle tightening and soreness.
APPENDIX E

Data Collection Sheet
DATA COLLECTION SHEET

Patient's Name/Number: ________________________________
Sex: Male  Female
Trial 1 date: _____________ Sugar Code: ______

Seat Position: _____________
Lever arm: vertical: ______ horizontal: ______
Ankle cuff length: _____________

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Comments ________________________________
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Trial 2 date: _____________ Sugar Code: ______

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Comments ________________________________
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*PEAK_{A1} & PEAK_{A2}: Average of three highest torque values.