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Glucose Recovery in Collegiate Female Distance Swimmers: A Case Study on Exploring How Glucose Delivered Orally Affects Collegiate Distance Swimmers After Exercise

Elizabeth McNutt
Bowling Green State University

GLUCOSE RECOVERY IN COLLEGIATE FEMALE DISTANCE SWIMMERS

A case study on exploring how glucose delivered orally affects collegiate distance swimmers after exercise

Elizabeth McNutt

A Research Project

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Committee:

Matthew Kutz, Advisor

Mary Jon Ludy

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Introduction

Energy is the most important substance a human requires for the body to function. It grants the body the ability to do everything from movement to maintenance of basic living conditions, such as the creation and destruction of cells. The energy needed for the body to perform these tasks comes from glucose, a basic building block that can be chained together with both macro and micronutrients and fiber to form carbohydrates (Greene, Louis, Korostynska, & Mason, 2017). Carbohydrates primarily come from fruits, vegetables, and grains, allowing for variety in the diet based on the preferences of each individual, such as beans, leafy greens, and berries for those who do not desire to eat wheat products (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). While simple carbohydrates like apples and oranges contain shorter chains of molecules, more complex carbohydrates like wheat contain longer chains of the same molecules, bound together chemically, that can be broken down to the simple components of glucose, fructose, galactose, fiber, vitamins, and minerals (Olsson, 2017). Each source is comprised of differing lengths of chains with varying amounts of their root components (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). Fructose and galactose are converted to glucose to be used by the body for energy, allowing for increased performance both at rest and during exercise (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). When activity levels are increased in athletes, the body requires increased amounts of glucose to continue, often receiving it from sources such as fruits and electrolyte drinks (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). This compensation will prolong time to fatigue and reduce exhaustion in the individual, allowing them to maintain their performance levels for longer (Greene, Louis, Korostynska, & Mason, 2017).

One way to prolong time to exhaustion is through a healthy, balanced diet that ensures proper quantities of all macronutrients (i.e., protein, carbohydrates, and fats) are met (Lee, et al., 2017).

The usage of food outside of exercise allows for maximum intake and storage of glucose as glycogen, allowing for it to be ready to be used when needed, giving athletes the ability to perform at peak skill levels for longer periods of time (Gonzalez, Fuchs, Betts, & van Loon, 2017). Without the forethought and education of consuming proper foods between bouts of exercise, athletes can be left feeling fatigued and unwell, creating a situation of subpar performance and poor technique during exercise. This puts them at a disadvantage because their opponents can outperform them by preparing and pre-planning more adequately. Planning out what to eat at specific times allows for proper ingestion of the maximum amount of nutrients, allowing for the best athletic performance possible.

Even though evidence shows that proper caloric and nutrient intake is necessary for optimal performance, many athletes do not adhere to proposed nutrition standards, or receive incorrect information from less than knowledgeable sources (Olsson, 2017). There is evidence that some athletes, more prevalently females, will restrict caloric intake to prevent weight gain or to lose weight they feel is unnecessary due to unrealistic self-image expectations placed on them by themselves, their peers, and their coaches (Carrigan, Petrie, & Anderson, 2015). The percentage of athletes with unrealistic body standards is increasing in both males and females as society places greater emphasis on what is considered an ideal physique (Olsson, 2017). Research shows that 35% of female athletes and 10% of male athletes were at risk for anorexia nervosa, and 58% of female athletes and 38% of male athletes were at risk of bulimia nervosa (Disorders, 2018). This caloric restriction reduces carbohydrate intakes more so than fats or proteins in the diet, as carbohydrates are incorrectly seen more as food that causes weight gain rather than food that provides energy for all body functions, including optimal sport performance such as competitions on a national level (Olsson, 2017). Evidence shows that consuming carbohydrates that contain glucose or fructose directly after exercise increases insulin release by the pancreas, allowing for better intake of glucose in the cells and creation of glycogen in the muscles, decreasing recovery times for the athlete (Gonzalez, Fuchs, Betts, & van Loon, 2017). This release and reception is aided by the cells, needing energy to recover, being more accepting of insulin and glucose than they normally are in a resting state (Gonzalez, Fuchs, Betts, & van Loon, 2017).

It is important to ensure that along with glucose ingestion, fiber is also taken in during times of rest or recovery to reduce rapid blood glucose fluctuations (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). Insoluble fiber is an indigestible part of carbohydrates, increasing digestion times when in the body, allowing for the maximum intake and conversion of glucose to glycogen, and absorption of nutrients needed in the body through the small intestine (Olsson, 2017). This reduces a rapid influx of excess glucose into the bloodstream, increasing the time between occurrences of extreme elevations in blood glucose (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). In turn, this reduces the likelihood of a sudden and large amount of insulin being released that can go on to create a blood glucose crash that tends occur when glucose is ingested with little to no fiber content (Olsson, 2017). Conversely, insoluble fiber helps slow digestion and binds to nutrients in the body, allowing for them to be transported to the small intestine and be taken into the body, allowing for better regulation of blood glucose (Sass, 2016). The relationship between fiber and glucose is important to understand because the more stable blood glucose levels can be throughout the course of a day, the more digestion and use of glucose is possible, giving way to adequate glycogen storage and reduced adipose tissue creation in the body (Gonzalez, Fuchs, Betts, & van Loon, 2017).

Research Limitations

While there has been some research conducted into recovery after exhaustion with glucose and fructose ingestion on athletes, specifically cyclists, and other elite athletes such as runners (Stumvoll, et al., 2000; Bergman, et al., 2010; Lee, et al., 2017; Castillo, Kern, Lee, & Bolter, 2016), most of the current research conducted on insulin sensitivity has been either on subjects with diabetes or on older populations (Connolly, et al., 2016; Tuomilehto, et al., 2001; Olsson, 2017). This information, while useful for the medical field and helping with management and prevention of disease and the prolonging of increased quality of life as populations age, is impossible to apply to healthy athletes and others that do not live within these disease states. More research needs to be conducted on how glucose affects both exercise and recovery in athletes to better understand the best ways to improve on ways to keep up on the health and recovery of an athletic population and continue the reduction of disease states as the athletic populations age. The data collected can be used, not only by the medical field, but by trainers and dietitians as well to more accurately assess how to better serve their clients and improve upon performance and recovery, increasing competitive skill.

The limited data on healthy, young, athletic individuals impacts athletes and generally active college-aged populations (Olsson, 2017; Lee, et al., 2017). This is because without knowing how to properly manage their healthy bodies to maintain their current health statuses, athletes put themselves at increased risk of disease states later in life (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018; Gonzalez, Fuchs, Betts, & van Loon, 2017). Providing more information to these populations will be helpful in preventing diseases as they age, decreasing healthcare costs for the entire population. The more information gathered for various populations, the better the availability of conclusions and individualized advice that can be given, increasing accuracy and practicality of results obtained, and allowing for an increased number of knowledgeable professionals to understand and assist with the upkeep of diet plans created by dietitians for more healthy athletes.

Given this limitation, my research was meant to help fill in this gap, figuring out what foods will assist in the recovery of athletes pushed close to exhaustion the quickest, and what foods will help maintain blood glucose levels and reduce spiking and subsequent crashing after near-exhaustion is met. The study helped set up groundwork to continue deciding what is the best option for recovery for collegiate female swimmers after energy depleting exercise with a mile swim by testing their blood glucose levels at timed points before and after swimming and ingestion of specific foods that promote recovery. It helped to begin to answer questions of the best fruit to help with recovery between bananas and oranges, and if fruit is better than Gatorade Chews for recovery, or if the pre-packaged Gatorade Chews that are meant to aid in recovery are the best option available. Because of the high fiber content and lower glucose content, oranges were be tested to see if they are the best for maintaining blood glucose levels over time while bananas and Gatorade Chews will be tested to see if they will be better at improving glucose in the short term and spiking blood glucose levels.

Literature Review

At any given time, the human body uses simple sugar molecules to create energy for activities ranging from breathing during times of inactivity to supplying the muscles and organs with nutrients while running a marathon (Gropper & Smith, 2013). Simple sugar molecules, glucose, fructose, and galactose, form the basis of every carbohydrate consumed, ranging from table sugar to complex carbohydrates in whole-wheat pasta (Gonzalez, Fuchs, Betts, & van Loon, 2017).

Simple sugars help with exercise and sport by providing glucose to the muscles to be converted to adenosine tri-phosphate (ATP) when oxygen is present through glycolysis and the citric acid cycles, allowing for continued movement for longer periods of time (Gropper & Smith, 2013).

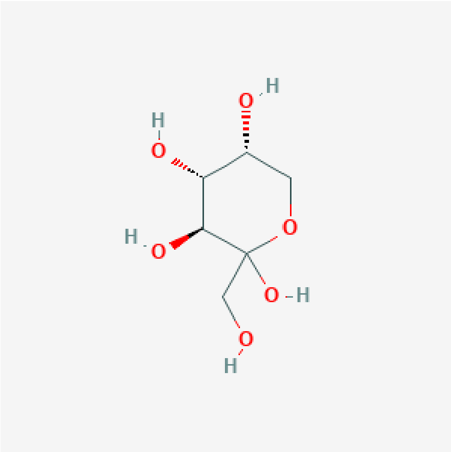


Figure 1: A Fructose Molecule. Chemical compound: $C_6H_{12}O_6$. It is a monosaccharide in a cyclic hemiketal structure *(Medicine, 2019)*.

The body readily utilizes glucose but can also use fructose due to its similar structure to glucose, allowing fructose to be quickly converted to glucose for ease of use, and to account for its availability in fruits and vegetables (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). While fructose (Figure 1) is readily available in natural foods and easily converted to be used by the body, galactose (Figure 2) is only found in dairy products and has a different structure than glucose, giving the body more difficulty converting it to glucose for use, making it harder to use (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). Glucose (Figure 3) is stored in the body to be used during intense exercise by the muscles as glycogen (Gonzalez, Fuchs, Betts, & van Loon, 2017). Because of the body's limited ability to store glucose as glycogen, much of the glucose the body takes in that is not used immediately is turned into adipose tissue for better storage (Gonzalez, Fuchs, Betts, & van Loon, 2017). If there is left-over glucose not processed into adipose tissue or changed into glycogen for storage, it is removed from the body as waste (Gonzalez, Fuchs, Betts, & van Loon, 2017). When stored as glycogen,

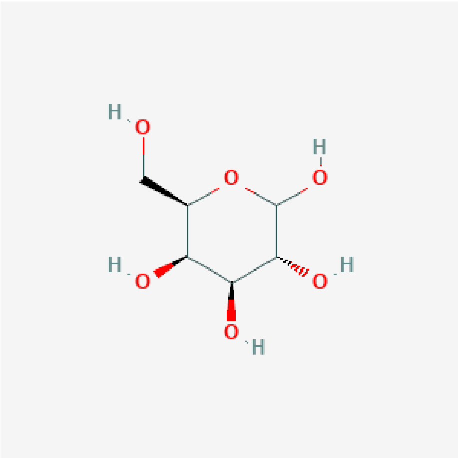


Figure 2: A Galactose Molecule. Chemical compound: $C_6H_{12}O_6$. It is a monosaccharide in an aldohexose configuration *(Medicine, 2019)*.

glucose molecules are more compact than when they are freely flowing, allowing for more units to be held in a smaller space (Greene, Louis, Korostynska, & Mason, 2017).

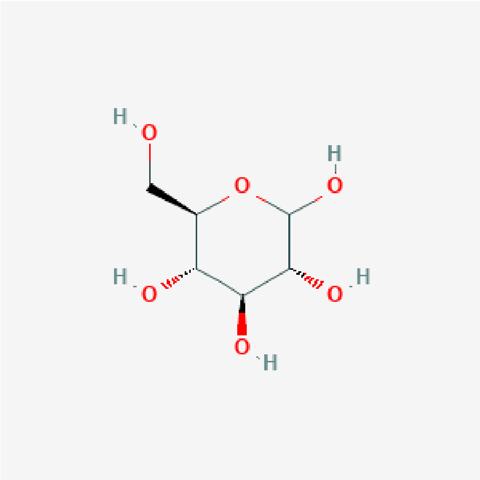


Figure 3: A Glucose Molecule. Chemical compound: $C_6H_{12}O_6$. It is a monosaccharide in an aldohexose configuration. *(Medicine, 2019)*

Glycogen is stored in the muscles for immediate use at the start of intense exercise, the tissue surrounding the muscles, or in the liver for use during prolonged intense exercise after muscle glycogen is depleted (Alghannam, Gonzalez, & Betts, 2018). As depletion occurs, glycogen cannot be replenished until after exercise is complete and recovery has started, creating a fatigue state in the body that must be compensated for through ingestion of glucose to be used in place of glycogen during exercise, or carbohydrates to breakdown into glucose and restore glycogen stores during recovery (Alghannam, Gonzalez, & Betts, 2018). Replenishment of glucose during and after exercise is important to maintain performance and recover quickly to allow exercise to be resumed sooner (Alghannam, Gonzalez, & Betts, 2018). This is usually done through consumption of foods containing high amounts of fructose and glucose, such as fruits or electrolyte-filled drinks like Gatorade and Powerade to allow the body to convert the nutrients it receives into energy to replenish stores used by the body during intense exercise (Alghannam, Gonzalez, & Betts, 2018).

VO_2max and glucose usage in the body

Researchers have discovered that during exercise at or greater than 70% of VO_2max based on the person's usual VO_2max, the main fuel source used by the body is glucose (Coyle, Coggan, Hemmert, & Ivy, 1986). The higher VO_2 training intensity means that carbohydrates are utilized more than fats to maintain the energy balance in the body to allow for continued performance. This occurs because the glucose from carbohydrate-filled foods is carried in the bloodstream on free fatty acids that are released by the adipose tissue in the body when the pancreas releases insulin to aid in the transport of glucose in the blood (Costill, et al., 1977). Research also shows that this effect can be recognized up to four hours post carbohydrate-rich meal, allowing for athletes to consume meals ahead of time and prolong exercise without having excess food in their stomachs to make them feel weighed down (Coyle, Coggan, Hemmert, Lowe, & Walters, 1985).

Glycogen is depleted out of muscles at differing rates depending on the athlete, the muscle mass, and the muscle usage while exercising (Gejl, et al., 2017). The more muscle mass an athlete has, the more glycogen can be stored in and around the muscle fibers, allowing for increased amounts of work to be performed before exhaustion is reached (Gejl, et al., 2017). Type one, or endurance muscle fibers, also deplete glycogen more than type two, or sprint muscle fibers (Gejl, et al., 2017). This is because glycogen depletion occurs over time, helping to increase endurance for athletes ranging from runners, to cyclists, to swimmers (Alghannam, Gonzalez, & Betts, 2018). Type two muscles are more often used for anaerobic environments, meaning glycogen cannot be used as easily for energy and the muscles fatigue more quickly due to the lack of oxygen rather than the lack of glucose availability (Alghannam, Gonzalez, & Betts, 2018). While athletes in varying sports use muscles differently, when the muscles they are using deplete glycogen stores and do not have enough glucose entering in from the bloodstream to maintain performance, the same thing occurs for each of them: fatigue (Gejl, et al., 2017). To delay fatigue, it is recommended to consume foods containing glucose during prolonged exercise, replenishing the glucose in the blood that can be used after glycogen depletes (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018).

While glucose is necessary to continue performing at peak levels during athletic activity, it causes gastrointestinal distress when ingested as the sole source of carbohydrate replenishment in elite athletes. This makes it less ideal as a sole replenishment after exercise compared to fructose or mixtures of glucose and fructose, such as fruits and vegetables (Fuchs, et al., 2016). For these cases, studies have shown that sucrose (Figure 4), or a molecule of fructose joined to a molecule of glucose, reduces or eliminates gastrointestinal distress, allowing for maintained performance (Fuchs, et al., 2016; Gropper & Smith, 2013). Because the body has an easy time changing fructose to glucose to utilize it for energy production, this substitution is adequate to maintain performance during exercise (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018).

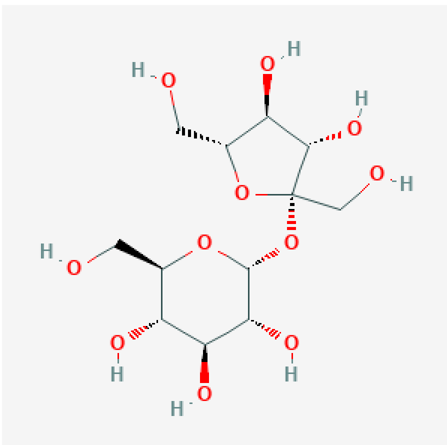


Figure 4: A Sucrose Molecule. Chemical compound: $C_{12}H_{22}O_{11}$. It is a disaccharide consisting of 1 glucose and 1 fructose molecule *(Medicine, 2019)*.

Galactose is an option for replenishment for athletes as well, however, with the increased incidence of lactose intolerance diminishing the ability of some to break down lactose to galactose and glucose, and the difficulty in converting galactose to glucose for use in the body, it is not a recommended energy replenishment option for athletes with these intolerances during or after sporting events (Alghannam, Gonzalez, & Betts, 2018; Gropper & Smith, 2013). It is estimated 30 to 50 million Americans have a lactose intolerance ranging from being born with a lactose intolerance, to developing one in adulthood (National Institute of Child Health and Deveopment, 2006).

When combined with fiber, glucose is less available to be absorbed into the blood stream by the small intestine, reducing the need for excess insulin to be released and allowing for fewer fluctuations of blood glucose levels (Olsson, 2017; Alghannam, Gonzalez, & Betts, 2018). Because glucose can only enter a cell in the body if it is accompanied by insulin, the release of insulin is important to maintain not only the flow of glucose into the cell for energy creation, but the amount of glucose left in the blood (Lee, et al., 2017). Fiber slows down digestion mainly due to its inability to be digested, allowing for insulin to maintain more control over blood glucose without the pancreas creating and releasing more quickly (Lee, et al., 2017). This reduces a glucose crash in the body, created when the blood is rushed by glucose and the pancreas reacts too harshly by releasing excess amounts of insulin to help drive the glucose into the cells for conversion into energy, glycogen, or adipose tissue to be stored for later (Stumvoll, et al., 2000). The steadiness of glucose entering the cells continuously allows for the cells to maintain a constant, steady flow of energy while reducing the amount of adipose tissue made due to the lack of excess glucose being forced in, allowing for more efficiency in the cell and, in turn, the body (Stumvoll, et al., 2000). The risk of diabetes is important for understanding glucose tolerance levels in any subject because heightened blood glucose levels without the ability to bring them down through insulin generated by the body reduces the ability for the body to perform work, creating athletes who are unable to perform at the peak level that is expected of them.

As compared to liquid or gel glucose, fruit has more fiber in relation to glucose and fructose, allowing for slower breakdowns and a more steady release of glucose over time, allowing the body to compensate for the glucose that is introduced into the bloodstream easier without sending the endocrine system into overdrive, reducing insulin release (Naderi, Rezaei, Moussa, Levers, & Earnest, 2018). This helps reduce the risk of type 2 diabetes mellitus as the cell is more responsive to the insulin released and not overrun with glucose, causing a reduction in insulin effectiveness over time (Connolly, et al., 2016). Exercise helps to play a role in this cycle because a cell is more receptive to insulin and glucose after exercise due to its lower amounts of energy stored and higher needs of energy for recovery (Connolly, et al., 2016). This insulin receptiveness helps to lower blood glucose and reduce the risk of diabetes mellitus as glucose is removed from the blood to create energy for cells to function (Connolly, et al., 2016). Without the fiber to reduce the amount of glucose released at any given time, glucose would flood the small intestine, creating a glucose spike and triggering a mass insulin release by the pancreas, resulting in a glucose crash (Castillo, Kern, Lee, & Bolter, 2016).

Athletes and Type 2 Diabetes

It is important to ensure athletes do not have impaired glucose tolerance or full type 2 diabetes mellitus to maintain a healthy life without the need for medication due to a preventable disease (Sellami, Abderrahman, Kebsi, De Sousa, & Zouhal, 2017). This is because diabetes and glucose intolerances can affect the way the body can intake and use glucose through the reduced effectiveness of insulin made by the body, sometimes being so severe it requires insulin to be injected into the body to assist in the movement of glucose into the cells (Stumvoll, et al., 2000). It has been established that type 2 diabetes mellitus occurs when fasting blood glucose levels rise over 140mg/dL after a ten hour fast, or over 200mg/dL two hours after eating food containing a standard amount of carbohydrate (30 grams), such as 1 serving of fruits or vegetables (Tuomilehto, et al., 2001; Mayo Clinic, 2017). While it is not typical for athletes to have such high glucose numbers, it is important to keep the prevalence of diabetes in older populations known to the public as a reminder for athletes and non-athletes alike to retain a healthy and active lifestyle to prevent this disease from occurring in their lives. Research shows that the risk of diabetes can be reduced by losing at least 5% of body weight if overweight or obese, and exercising a minimum of four hours per week (Tuomilehto, et al., 2001).

For swimmers specifically, the varying amounts of glucose entering the body can be detrimental, especially on rest days or practice times where the amounts of exertion vary. Due to the nature of swimming, there will be days of hard practices and large amounts of exertion followed by days of very little effort being required, based on specific events and the abilities of each swimmer (Shaw, Boyd, Burke, & Koivisto, 2014). These changes in practice schedules from day to day, and even practice to practice in the same day, change the nutrient needs of the athlete, not allowing for set diets to be energetically adequate during periods of high exertion, or over-nourishing during periods of rest and recovery (Shaw, Boyd, Burke, & Koivisto, 2014). For practices such as these, it is important to plan ahead for any changes needed in the diet and to utilize nutrition and carbohydrates as needed after practice for recovery rather than guessing what will be needed for practice beforehand and risking making incorrect choices (Olsson, 2017). Better understanding of what foods are important and why they are is needed to understand what replenishment and recovery methods work best at certain times for each sport and the athletes that compete in them.

Muscle and fat mass are important factors in glucose tolerance in the body itself. Fat mass helps to retain glucose in the blood by attracting it to free fatty acids in the bloodstream, reducing the amount insulin is able to carry into the cell (Bergman, et al., 2010). This helps maintain glucose levels in subjects with higher fat percentages by reducing the blood glucose that is removed from the blood when there is excess, restricting glucose crashes (Bergman, et al., 2010). While this can be beneficial for athletes and untrained subjects alike, excess fat in the body can increase the likelihood of type 2 diabetes mellitus as free fatty acids in the blood retain too much glucose, not allowing insulin to transport it into the cell when it is needed (Bergman, et al., 2010; Connolly, et al., 2016). With swimmers specifically, fat mass can vary between sprinters and long distance due to the varying needs of each event. Sprinters have higher muscle masses, allowing for greater power output in shorter amounts of time (Sellami, Abderrahman, Kebsi, De Sousa, & Zouhal, 2017). This high muscle mass is a large mix of both type one and type two muscle fibers, requiring varying amounts of glycogen and glucose as the swimmer changes between long-distance warm up and recovery periods and short-distance, anaerobic environments during race times, altering how energy is used in the muscle fibers themselves (Sellami, Abderrahman, Kebsi, De Sousa, & Zouhal, 2017; Gropper & Smith, 2013). Comparatively, long distance swimmers have lower muscle masses and higher fat masses, allowing for more endurance over time at slower speeds (Sellami, Abderrahman, Kebsi, De Sousa, & Zouhal, 2017). The muscle fibers they possess also contain more type one fibers over type two, requiring more glucose utilization through glycogen and free blood glucose during both practices and race events, allowing for better utilization of glucose for energy (Gropper & Smith, 2013; Sellami, Abderrahman, Kebsi, De Sousa, & Zouhal, 2017). While this difference in muscle and fat masses may seem as if it results in differing glucose tolerances, research shows that, especially with younger populations, activity level is a larger predictor of glucose tolerance than fat mass in the body (Bergman, et al., 2010). This is because the activity levels, being high and frequent, utilize as much available glucose in the blood as possible during and after exercise, reducing overall blood glucose in the body regardless of fat mass (Lee, et al., 2017).

Accompanying fat mass, muscle mass also plays an important role in glucose management in the body. While muscles use glucose to create energy for exercise, they also require carbohydrate to reduce the incidence of muscle breakdown after resistance training (Glynn, et al., 2010). Research shows that ingesting carbohydrate after resistance training slows down the breakdown of muscle, allowing for rebuilding and recovery to occur quicker, giving the athlete the ability to exercise or compete sooner than those that do not consume carbohydrates after resistance training (Glynn, et al., 2010). This combined with the utilization of glucose by muscle that can be increased based on muscle mass means the muscle mass in the body is exceptionally important for glucose intake and maintenance in the body for everyone, not just athletes (Greene, Louis, Korostynska, & Mason, 2017).

Glucose tolerance testing is the best measure of glucose impairment levels in the body while remaining minimally invasive. The testing allows for researchers and doctors alike to know the amount of glucose that is freely in the blood on demand, making patient care easier to individualize. Testing for glucose tolerance levels is important to conduct at intervals to measure the amounts of glucose entering the body and being used by the cells over time (Stumvoll, et al., 2000). Researchers learned that glucose levels increase 45-120 minutes after ingesting carbohydrates, with longer time frames for foods higher in fiber, which slows down digestion rates for glucose (Stumvoll, et al., 2000). With this understanding it is important to test glucose tolerance levels in research moving forward at appropriate intervals to allow for the digestion of carbohydrates and release of glucose into the bloodstream to be utilized by the cells for energy creation and recovery.

Energy is important for the body to function throughout everyday life, whether exercising intensely or sleeping through the night. Without the proper fuel, the body will fail to maintain peak performance, overexerting itself during times of stress. Attention to proper nutrition and correct intakes of carbohydrates, fats, and proteins will ensure the body is fueled with adequate glucose while maintaining slow digestion speeds to reduce insulin dumping from the pancreas that would result in a mass uptick of glucose entering the cells, resulting in a plummet of blood glucose levels (Lee, et al., 2017). While there has been research conducted into the methods of transportation into the body glucose takes, there is a need for more research into how glucose affects the body of healthy athletes when compared to the fiber content in the food. The aim of this project was to help bridge the gap and gain understanding of this missing piece to learn more about what foods adequately recover athletes while reducing blood glucose spiking and dropping. The question this project asked is what types of carbohydrates help recover female swimmers the best between clementine oranges, bananas, or Gatorade chews as compared to a water only baseline.

Methods

The study consisted of testing collegiate female swimmers blood glucose before and after swimming and ingesting of food to track the changes over time. After a meeting with the Bowling Green State University Women's Swimming Team (N=4) and explaining in detail the study, the reasons for the study, and answering any questions potential subjects had, eight initially agreed to the study and filled out written consent forms. Four decided not to continue with the study, resulting in four swimmers being tested. The swimmers were all between the ages of 20 and 21 and were all mid to long distance swimmers. Each subject was randomly assigned a food: 1 banana, 3 clementine oranges, 1 sleeve of Gatorade Chews, or 1 bottle of water as control (Table 1).

	Banana	Clementine Oranges	Gatorade Chews	Water
Number Eaten	1	3	1 sleeve (5)	20 oz
Calories	100	100	100	0
Carbohydrates	27g	27g	24g	0g

Table 1. Nutrition information for variable foods (USDA, 2019)

The swimmers came in at 6 am on different days, not having eaten prior to the study to ensure other food did not skew the results. They were instructed to only have water for at least 4 hours before the test to ensure glucose was not added to the diet, causing the results to be skewed. They all stretched and had their blood glucose levels measured using a Care Touch glucometer and McKesson 28G lancet before climbing in and swimming 1 mile. After swimming (approximately 20 minutes), each swimmer again had their blood glucose levels measured, then were given their assigned food source and were tested every 15 minutes after consuming their food until their blood glucose levels went back to their starting levels and remained there for 15 minutes. After their blood glucose levels returned to previous levels or were similar over time, they were released from the study. The only exception to this rule was the swimmer with clementine oranges had to leave earlier than complete recovery to go to class.

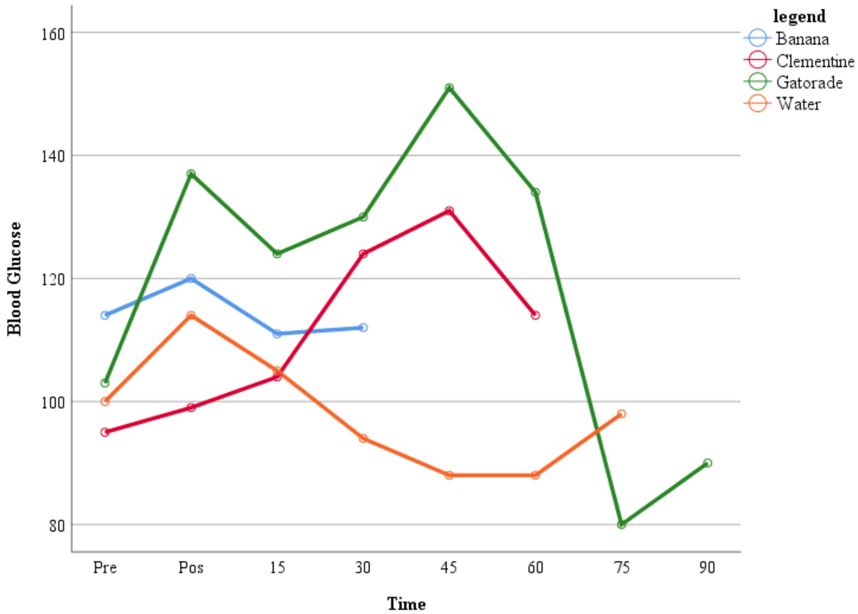
Results

The recovery times for each food source is as follows:

Glucose Recovery Tests				
	Water	Banana	Clementine	Gatorade Chews
Pre-Test	100	114	95	103
Post-Swim	114	120	99	137
15 min post food	105	111	104	124
30 min post food	94	112	124	130

45 min post food	88	121	131	151
60 min post food	88		114	134
75 min post food	98			80
90 min post food				90

Table 2. Glucose recovery for each subject over time



Graph 1: Glucose recovery for each subject over time

The statistical analysis is as follows:

Descriptive Statistics						
	# Blood Glucose Tests	Minimum	Maximum	Range	Mean	Std. Deviation
Banana	4	111	120	9	114.3	4.0
Clementine	6	95	131	36	111.2	14.3
Gatorade	8	80	151	71	118.6	24.9
Water	7	88	114	26	98.1	9.4

Table 3. Descriptive statistics for each of the variable foods

Discussion

The data showed that for this study, bananas recovered a swimmer faster than any other source and the control in terms of length of time. While Gatorade chews did recover blood glucose quickly, they caused the subject's blood glucose to increase rapidly, then drop below pre-test levels, causing the opposite effect as what was intended in the study for the subject. This was of concern as the goal of the study was to find initial results for the best food to recover a swimmer after exercise and recovering glucose before creating a crash does not create the intended effect. It is important to note that these results are meant for initial results and further testing must be conducted to come to conclusions on the best foods for swimmers as there were only 4 subjects.

The study also showed that Gatorade had the largest change from the minimum to the maximum glucose numbers of 71 points where bananas had the smallest change at 9 points. This is important to reduce blood glucose from changing too drastically when recovering to allow maximum usage of available glucose over a longer period of time for recovery. In terms of normal ranges for blood glucose, it is recommended to have fasting (no intake of anything but water for 8+ hours) blood glucose between 70 and 99 mg/dL, and non-fasting levels less than 140 mg/dL (Virginia Mason, 2019).

As a separate recovery product, Gatorade chews could potentially be used when paired with a high-fiber food that could reduce the insulin release, allowing for slower intake and more complete recovery of all systems. Foods such as vegetables would be ideal to helping with this recovery as they have lower sugar contents than fruits do.

While the study yielded excellent initial results and shows the potential for bananas to be the recovery food of choice for elite athletes between swimming events, more research must be done before this can be concluded, especially with each subject repeating the test with each variable to allow for them to be their own controls, larger sample sizes for more evidence of each food choice, and different types of swimmers (sprints, long-distance, middle distance swimmers, etc.). Future studies can bring more data to help understand how collegiate female swimmers recover after racing and can prepare for further races more efficiently, allowing for better awareness in the future.

Conclusion

In this case study, bananas were the best source tested for recovery after swimming longer distances. It must be noted that all four swimmers that performed this test were distance swimmers, meaning they had similar muscle and fat mass structures as each other. This allowed for a more accurate test grouping as it has been documented that muscle and fat mass change glucose intake and use in the body.

These food choices were picked for a variety of reasons. All of the options are relatively easy and inexpensive for college students to access, allowing for them to be easier choices for the subjects outside of the study. These choices are also lower in risk of allergy or adverse reactions, with exception to Gatorade Chews containing wheat products that would affect anyone with celiac disease or wheat intolerances. Finally, these were chosen as options because many swim teams already provide them as recovery choices for their swimmers, but do not understand why.

This study was a case study into the better choices for recovery in collegiate female swimmers. Future studies will be needed to make a definitive answer however they must include more subjects and longer test times. A 1-mile swim for a collegiate swimmer will not push them to exhaustion, meaning this data collected can be used as recovery after a race or a short practice, allowing for better performance in competition, but not be used to help determine better options for recovery from exhaustion. There is also limited data in terms of subjects. To help reduce variability between swimmers for each food group, each swimmer should do the study with each food chosen and the control. To increase certainty of better options for recovery there must be more subjects in each group. This will allow for outliers in the study to be noticed easier and account for them, giving more accurate data.

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