THE USE OF BANANAS IN PREVENTING EXERCISE ASSOCIATED MUSCLE CRAMPS

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The Use of Bananas in Preventing Exercise Associated Muscle Cramps

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ABSTRACT

Bananas have been consumed by athletes in the belief that they prevent muscle cramping. However, there are no studies in the literature that test plasma potassium concentration as a prevention technique for exercise associated muscle cramps. The purpose of this study was to determine if potassium in bananas increased threshold frequency (TF) of an electrically induced muscle cramp (EIMC) in young adults who have a history of muscle cramps. On the day of testing, subjects had a baseline blood sample and baseline EIMC, then ate 2 servings (300g) of bananas. After 60 minutes of rest, a final blood sample was drawn and a final EIMC was induced. Plasma potassium concentration did significantly increase, whereas cramp TF did not. Potassium in bananas does not affect cramp TF one hour after ingestion.

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DEDICATION

I dedicate this thesis to my lovely supportive family that has stood there by my side during this process. Thank you for letting me go half-way across the country to further my education and go on this amazing journey and thank you for answering your phone in the middle of the night when things got hard. I look forward to discovering my next journey knowing that you will always be there for me. Thank you.

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CHAPTER 1. INTRODUCTION

Exercise-associated muscle cramps (EAMCs) are an involuntary contraction of skeletal muscle that are believed to occur during or after physical activity.[1-3] Exercise associated muscle cramps occur at the end of competitions, and affect muscles which cross multiple joints (e.g. quadriceps, hamstrings, and gastrocnemii).[8,9]

There are many purported contributors to EAMC development. Some authors suggest ammonia[10] or nitric oxide[5] accumulation in the muscle contributes to EAMC development. Others suggest muscle cramping has a genetic component.[11-14] Variations in collagen genes[11] and type II muscle fibers[12] have also been reported. Moreover, cramping is thought to be a autosomal dominant trait, only needed to be passed down from one parent.[13,14] However, two prevailing beliefs are dehydration and electrolyte imbalance[6,16,17] (sodium and potassium) or alterations in the neuromuscular control as a result of fatigue.[2,6,7] The majority of clinicians believe EAMCs are caused by dehydration.[9,15]

Researchers have used electrically-induced muscle cramping (EIMC) techniques in a laboratory setting because it is the most popular and reliable method to study muscle cramping.[17-20] Cramp threshold frequency (TF) is the frequency (Hz) of stimulations it takes for a cramp to occur and is thought to be an indicator of cramp risk. A lower TF means a greater risk for EAMCs and a higher TF means a lower risk.[19] Studies used EIMC to look into causes[17,18] of cramping, but minimal prevention techniques have been studied using that method.

Several anecdotal strategies have been advocated to prevent EAMC. Forty-four percent of athletic trainers believe that nutrition is a key prevention technique for EAMCs.[9] Eating bananas is a popular myth for preventing EAMC possibly because EAMCs are thought to occur because of potassium losses and fatigue. [21,23] However, it has been observed in a study that

$[glucose]_p$ also increased as well as $[K^+]_p$ at 60-minutes post ingestion of two servings of banana.[21] One-serving of cut-up bananas contains 594 mg of potassium and is 74% water.[22] Bananas have also been observed to increase plasma glucose concentration ($[glucose]_p$).[21,23,24] Experimental research on the effectiveness of eating bananas and the prevention of cramping was not found in an exhausted search.

Purpose of Study

The purpose of this study was to determine if cramp TF and $[K^+]_p$ increased following two-servings of bananas. This information could be helpful to determine if bananas could be used in the clinical setting to prevent EAMCs.

Research Questions

1. Did ingesting two servings (300g) of bananas increase cramp TF when compared to baseline (0-servings)?
2. Did $[K^+]_p$ increase following 60 minutes of rest following banana ingestion?

Definition of Terms

Bananas-A yellow cylinder fruit that contains potassium, carbohydrates, water, glucose and other nutrients.[22]

Dehydration- The loss of water in the body.[2]

Electrically Induced Muscle Cramp (EIMC)- Muscle cramps that induced by electrical stimulation.[17-20]

Electrolyte- Can conduct an electrical impulse in the body. The most common ones are sodium, potassium, chloride and magnesium. Important in muscle contractions.[6]

Electromyography (EMG)- Measures the electrical impulses of skeletal muscle.[18-20]

Exercise-associated muscle cramp (EAMC)- Muscle cramps that occur during or after exercise which is a result from exercising.[3,17-20]

Fatigue- When exercises can no longer be performed completely or with proper form.[6]

Flexor Hallicus Brevis Located on the posterior lower leg attaching at the big toe assisting in flexion.[20]

Muscle contraction- the ability for a muscle to perform an action[18-20]

Potassium- A positive ion found inside cells that is needed to allow normal function of the heart and nervous system. A normal potassium level in blood is 3.5-5 mmol/l.[21]

Limitations

1. There was only one dosage of bananas (2-servings) given to the subjects.
2. Intracellular K^+ was not measured because the equipment was not available to perform in the laboratory.

Delimitations

1. Subjects avoided high potassium foods 24 hours prior to testing day.
2. Twelve hours prior to testing, subjects fasted and only maintained hydration with water.
3. Subjects did not exercise during the 60 minutes between pre and post testing.
4. Subjects were between the ages of 18-30 years.

Significance of Study

The significance of this study was to help determine if the potassium in bananas helps prevent muscle cramping. There have been multiple methods in the treatment of muscle cramps, but limited experimental studies on the prevention of muscle cramping in athletes. This study will help bring more scientific evidence to the prevention of muscle cramps.

CHAPTER 2. REVIEW OF LITERATURE

The purpose of this literature review was to discuss previous research on exercise-associated muscle cramps in the athletic population and to help determine if the potassium in two-servings of bananas helps prevent muscle cramping by increasing the threshold frequency. The purpose of this study was to determine if cramp TF and $[K^+]_p$ increased following two-servings of bananas. This information could be helpful to determine if bananas could be used in the clinical setting to prevent EAMCs. The research questions that were investigated were 1) Did ingesting two servings (300g) of bananas increase cramp TF when compared to baseline (0-servings)? and 2) Did $[K^+]_p$ increase following 60 minutes of rest following banana ingestion? The review of literature is organized into the following areas exercise associated muscle cramp/electrically induced muscle cramp, prevalence of cramping, theories of cramping, why bananas, prevention of cramping, and a summary.

Exercise Associated Muscle Cramp/ Electrically Induced Muscle Cramp

Muscle cramps are generally painful, involuntary contractions of a muscle or muscle group.[25, 26] There are multiple types of muscle cramps that affect people of all ages, but a type of cramp that effects athletes is an exercise associated muscle cramp (EAMC). Exercise associated muscle cramps are skeletal muscle cramps that occur during or after exercise and are involuntary, spasmodic and painful contractions[1-3] that result from exercise and are one of the most common conditions to require medical attention.[3]

In previous studies, researchers had tried to determine multiple treatment ideas in a laboratory and were able to do so because of the ability to induce a cramp using an electrically induced muscle cramp (EIMC) method.[17, 19, 20] An electrical stimulation has been used to elicit a cramp to test threshold frequency in studies that used subjects who cramp and those who do not cramp,[19] healthy individuals,[17] and a study with those who are self-reported crampers.[20] Threshold frequency (TF) is defined as a minimal stimulation frequency at which a cramp can be elicited.[20] Miller et al.[19] found that those with a history of cramping had a significantly lower cramp TF (14.9± 1.3 Hz) than those who did not have a history of cramping (25.5 ±1.6 Hz). Participants were separated into two groups based on their history of cramping that was identified during a meeting with the investigator.[19] Nineteen healthy college-aged students with a history of self-reported muscle cramps and 12 students who did not have a history of muscle cramping completed the study. An EIMC was performed on two days with one week rest in between testing days. Participants were asked where they experienced a muscle cramp and it was reported that feet and/or toes were the most common sites of a muscle cramp (13/19, 68%), followed by the calf (12/19, 63%), and then the hamstrings (6/19, 32%).[19] Between the two groups, the history of cramping group had a higher family history of cramping than the non cramping group (16/18, 89% > 3/11, 27%).[19] Miller et al. suggested that those who are prone to muscle cramping would have a decreased cramp TF than when compared to those who do not have a history with EAMC.[19] This study showed that those who were prone to EAMCs did have a lower TF when compared to those with no history of cramping.

In another study, Miller and Knight, wanted to determine if TF would be similar depending on if they started the stimulation at 4 Hz or 14 Hz because it has been observed that TF is much higher than 14 Hz.[20] Participants were tested on two days, and told to keep their normal diet, drink water consistently and to avoid exercise for 24 hours prior to each day. Thirteen males (age = 20.6±2.9 years, height = 184.4 ± 5.7 cm, mass 76.3± 7.1 kg) and seven females (age = 20.4± 3.5 years, height 166.6± 6.0, mass = 62.4±10.0 kg) participated in this study.[20] The participants first performed maximal voluntary isometric contractions of the flexor hallicus brevis by flexing their great toe as hard as they could. After 30 minutes of rest, they were induced with an electrical stimulation either starting at 4 Hz or 14 Hz, increasing by 2 Hz until a cramp was induced.[20] It was determined that cramp TF was not affected by the initial stimulation frequency (4 Hz = 16.2± 3.8 Hz, 14 Hz = 17.1±5.0 Hz; t_{19} = 1.2, P = .24).[20]

Threshold frequency was also examined when Stone et al.[17] tested seven males and nine females (age= 25.1± 4.8 years, height 1.74± .009m, mass 73.3± 13.9kg) using a fatiguing protocol to determine if TF would change from baseline to post-fatigue.[17] Five subjects were excluded from statistical analysis because they could not achieve the proper fatigue criteria. Of the remaining 11 participants, post-fatigue TF was 12.9 Hz greater than pre-fatigue.[17] Since TF increased, it could imply that fatigue decreases the possibility of developing EAMCs during activity, however more studies with larger sample sizes are needed to come to this conclusion.

Another study that was done with EIMCs wanted to determine what kind of fluids help alleviate muscle cramping. The ten subjects included in statistical analysis were hypo-hydrated to approximately 97% of their body weight and then given 30 minutes of rest before being induced with an electrical stimulation to cramp the flexor hallicus brevis.[18] Muscle cramps had to last more than 90 seconds and at approximately 50% of the muscular voluntary isometric contraction. Each subject drank distilled water or pickle juice on one of the two testing days. Pre ingestion of both fluids had similar cramp duration following an induced EIMC, pickle juice was slightly higher (153.2±23.7 seconds) than deionized water (151.9±12.9). The subjects were then induced with another EIMC followed by the consumption of either of the beverages. Cramp duration was shorter following pickle juice ingestion (84.6±18.5s) than post deionized water (133.7±15.9s).[18] Cramp duration was significantly shorter (difference of (49.1±14.6) following pickle juice ingestion than after deionized water ingestion.

Prevalence of Cramping

Exercise associated muscle cramps have been reported in multiple sports, but occur more frequently in endurance sports.[23,28] A study in 2006 and 2007 on tri-athletes from the Port Elizabeth, South Africa area reported that 155 out of 202 (76%) participants reported having an EAMC within the last 12 months during or immediately after exercise.[8] In another study, triathlon athletes had a lifetime prevalence of EAMCs of 67-68%.[28] Rugby players were reported at 52% prevalence, cycling 60%, and marathon runners in 42.2 km race had a reported 39% EAMC prevalence.[8]

Theories of Cramping

There are many theories about the causes of EAMC. The most common theories are dehydration, abnormal electrolyte concentrations, and environmental stress.[16] New theories are being presented more frequently as researchers are investigating the cause. The most recent theory that is being discussed is that collagen genes are found more commonly in athletes with a history of EAMCs.[11] However, the most common theories are dehydration and electrolyte imbalance, dating back to miners in hot humid conditions.[30] It has also been observed that those who are prone to EAMCs, have a family history of cramping suggesting that genetics may play a role.[8] The following theories will be discussed: Dehydration, Neuromuscular Control, Environmental, Fatigue, and Electrolyte Imbalance.

<u>Dehydration Theory</u>

Dehydration occurs most commonly because of two reasons: (1) sweat loss during physical activity can be large, and (2) ingesting fluids may not keep up with the sweat rate.[15] Dehydration was also perceived by athletic trainers as the most common cause (71%) of EAMCs.[9] In a study that tested a hydrated and a hypo-hydrated group with exercise, the onset of an EAMC resulted in both groups. The 13 subjects were put through a cramping protocol that was 56% successful in causing EAMCs in their laboratory. The protocol included calf raises, treadmill walking, jumping rope, depth jumps, recumbent cycling and kick turns.[16] The hypo-hydration group performed all exercises but did not consume any fluids. The hydration group drank a standard sports drink from powder and added half a teaspoon of table salt for each liter.[16] The hypo-hydration group experienced cramping at a much quicker rate (14.6 ± 5.0 Hz) than hydration group (36.8±17.3 Hz); however, more subjects cramped during the hydration protocol (9/13) than compared to hypo-hydration (7/13).[16] A limitation to this study was that the hypo-hydration group only reached approximately 1% body loss. It is suggested that after 2% body loss, cramping and other heat illness could start to negatively affect an athlete's physical performance.[1, 15]

It has also been reported that dehydration does not affect TF of skeletal muscles.[34] Braulick et al.[34] investigated the TF of nine hypo-hydrated subjects who self-reported leg cramps in the past 12 months. Subjects performed maximal voluntary isometric contractions of the flexor hallicus brevis and then a baseline EIMC was taken. Following the baseline test, subjects exercised in a heat chamber to help assist with achieving 5% hypo-hydration. Then, three maximal voluntary isometric contractions were performed for 2-s each followed by a 15-minute rest. Cramp TF was then reevaluated using EIMC methods.[34] Significant or serious hypo-hydration of 5% body weight did not alter TF of the flexor hallicus brevis ($F_{1,9}$= 3.0, p= .12, 95% CI of mean differences= -.4.6 to 0.61 Hz).[34] These findings support the findings of Katzberg et al.[25] They studied 72 distance runners and determined the hydration status was not related to EAMCs. They measured blood volume, plasma volume, and red cell volume in addition to weight pre and post race. They found that there was no significant difference between pre and post race hydration levels in people who cramped and those who did not cramp.[25]

Neuromuscular Control Theory

Another theory as to the cause of EAMCs is the altered neuromuscular control hypothesis. The altered neuromuscular control hypothesis implicates four primary factors in the development of EAMCs: 1) increase in exercise intensity or duration, 2) muscle fatigue, 3) contraction of the muscle in a shortened position, or 4) possible tissue damage.[11] When a muscle is unable to relax, adenosine tri-phosphate (ATP) is used to assist in the relaxation and needed for two main components.[2] Adenosine tri-phosphate is first used to detach the myosin head off of the actin molecule, as well as for pumping the Ca^{2+} from the cytoplasm into the longitudinal portion of the sarcoplasmic reticulum.[3] When calcium ion concentrations in the sarcoplasmic reticulum are decreased, the actin-myosin can't disconnect and will therefore cause a persistent contraction in the skeletal muscle.[2] Those sarcoplasmic calcium ion concentrations are maintained by an ATP-dependent calcium pump.[2]

Neuromuscular factors that have been observed to cause muscle contractions are also related to acetylcholine and alpha motor neuron activity. Acetylcholine is neurotransmitter that acts as an excitatory neurotransmitter at the neuromuscular junction in skeletal muscle. When the degradation of acetylcholine is reduced or stimulated through pharmacological means, a muscle spasm could occur.[2] For a muscle to relax, the extrapyramidal and muscle spindles must decrease to relax. If none of these happen, then the muscle cannot relax; causing a muscular contraction.[2] Another belief of the neuromuscular control theory that is being researched is genetics. O'Connell et al.[11] hypothesized that variants within the collagen genes that code for components of the musculoskeletal system (COL5A1, COL3A1, COL6A1, and COL12A1) may modulate the risk of developing EAMCs. They thought that the polymorphism of collagen genes have been associated with soft tissue injuries, endurance running performance and range of motion.[11] They collected blood samples and genotyped for COL5A1, COL3A1, COL6A1, COL12A1 from participants of the South African Ironman triathlon and the Two Oceans ultra-marathon because of a high prevalence of EAMCs in participants. Only COL5A1 genotype frequency was significantly associated with EAMCs. This was underrepresented when compared to those who did not report cramping (11.1% to 21.8%) .[11] This study shows that a structural component of the extracellular matrix of musculoskeletal soft tissue could be associated with a history of EAMCs.[11]

Environmental Theory

The environmental theory is related to cramps that occur during hot days where the athlete sweats considerably more verses losing more water and electrolytes. These cramps may be more wide spread through out the body in comparison to EAMCs from fatigue.[2, 16] In one of the only epidemiological studies, 'heat cramps' were experienced more often with a heat index between high (23-28°C) and extreme (>28°C) when compared to those during low (<18°C) or moderate (18-23°C) temperatures and humidity recorded on a wet bulb globe thermometer.[4] Four collegiate universities from the southeastern region of the United States completed the study. Athletic Trainers at each school were asked to record Wet Bulb Globe Temperature data for each practice and the number of exertional heat illnesses and athlete-exposures.[4] The total number of illnesses reported were 139 of 33,196 total athlete exposures. August had the highest (122/139, 88%) reports of heat exhaustion illnesses with a decline to 12% (17/130) in September and none in October.[4] Of those 122 heat exhaustion illnesses, 70% (86/122) were heat cramps.[4] These results coincided with preseason and two-a-day practices that occur in August, and support that a hot, humid environment could be a cause of EAMCs.

However, a study on ultra-distance road racers reported they experienced cramping when the temperature was between 14° and 23.8°C (57.2-74.84°F).[32] This study refutes the environmental theory as a main cause of EAMCs, but could be a contributing factor to other theories. Heat could increase sweating that would increase fluid and electrolyte loss, which would support other theories such as the electrolyte depletion and the dehydration theories.

Fatigue Theory

The fatigue theory suggests that muscle fatigue can prompt an excitatory increase in the activity of the muscle spindles and a decrease in the inhibition of the Golgi tendon organs.[2] The Golgi tendon organs are used to detect muscle tension and cause a reflexive relaxation and thus are disrupted during the inhibition because of an abnormal increase in the firing of type Ia and II of the muscle spindles.[2, 6, 7] While the Golgi tendon organs are depressed because of Type Ib afferent activity,[2, 7] muscle spindles are receiving excitatory activity which causes the involuntary muscle contractions that could not be prevented because the Golgi tendon organs are being disrupted.[6]

It is reported that EAMCs resulting from fatigue tend to be more specific to one muscle instead of wide spread as in those related to heat.[2, 6, 16] A majority of runners who have developed EAMCs state that they had experienced feeling muscle fatigue prior to the onset of the cramping.[7] A different study, that focused on hydration and electrolyte supplementation found that participants experienced cramping in both trials of hypo-hydration and carbohydrate-electrolyte replenishment. Fluid loss was only 1% of body weight and the cramps were described as localized which suggests that the EAMCs were primarily a result of fatigue.[16]

Furthermore, all ultra distance road racer study participants reported experiencing a cramp in the second half of the race. Sixty-seven percent of their cramps occurred right after the race, 48% were reported in the hamstrings and 38% in the quadriceps. [32] One study assessed 16 healthy participants who performed a fatigue protocol for the flexor hallicus brevis. An electrically induced muscle cramp (EIMC) was recorded for a baseline TF followed by the fatiguing protocol then another EIMC.[17] The researchers hypothesized that a fatigued muscle would have a decreased TF and cause people to be more susceptible to EAMCs. However, this was the first study to report the opposite effects.[17] Each subject had gone through a fatigue protocol of their flexor hallicus hallicus longus and had EMG recorded. The mean EMG recordings were 24.8 Hz lower after the fatigue protocol than before. This means that their muscles had reached fatigue, however, the cramp TF following the fatigue protocol had increased 12.9 Hz from baseline test.

Electrolyte Imbalance Theory

The electrolyte imbalance theory is the second most common theory (20.4%) of EAMCs seen and treated by athletic trainers.[9] Prevention of EAMCs with electrolyte replacement was the third most often (70.3%)[9] technique used by those athletic trainers with their athletes. There were some researchers who did not believe that electrolyte imbalance was a primary cause to EAMCs. Jung et al.[16] determined that hydration or electrolyte supplementation had no influence in the incidence of EAMCs. Nine of the 13 subjects who consumed an electrolyte beverage (69%) experienced a cramp and 7 of the 13 (54%) experienced a cramp when no fluid was ingested.[16] Those with a higher sweat rate were more likely to experience EAMCs, but it was undetermined if the EAMCs were caused by dehydration or electrolyte imbalance because neither were assessed.[16] A different type of muscle cramp, often referred to as heat cramps, suggests that treatment should include hydration and an increase in the electrolytes sodium, potassium, magnesium, and calcium.

Sodium and EAMCs: Sodium has been thought to have a large role in EAMCs and has been tested more frequently than the other electrolytes. Miller, Mack and Knight looked into the effects of pickle juice, carbohydrate-electrolyte drink and water to see if there would be any changes in plasma volumes and plasma concentrations of potassium, sodium, magnesium and calcium.[9] The researchers also wanted to see if the changes would happen in less than one minute because a prior study had suggested pickle juice relieved EAMCs in 30-35 seconds after consumption.[31] Plasma volume had not changed among the drinks over time, and neither did plasma osmolality. Plasma sodium concentration was higher in pickle juice than water at 15 and 25 minutes and carbohydrate-electrolyte at 25 and 30 minutes.[31] When compared to baseline, none of the plasma sodium concentrations were different from the drinks at the end of 60 minutes. These findings are important because it suggests that fluid ingestion of pickle juice, carbohydrate-electrolyte drink, or water did not alleviate EAMCs since there was no change in plasma volume or plasma sodium. It was originally suggested that plasma volume or sodium would decrease in an athlete causing EAMCs during exercise.[31]

In another study, pickle juice and hypo-hydrated participants (3%) showed that the pickle juice alleviated muscle cramps approximately 85 seconds post ingestion.[18] An electrically induced muscle cramp in the flexor hallicus longus that was induced prior to the ingestion as a baseline, lasted almost twice as long (pre 153.2 ± 23.7; post 84.6±18.5)[18] when pickle juice was in the body. As in the study before, it was noted that the approximately 85 seconds to relieve a muscle cramp, is not enough time for the pickle juice to be absorbed by the body.[18] Therefore the author suggested the pickle juice causes a reflexive response. However, Other studies have shown drinking a salt mixture to be effective.[6] Ingesting a large salt bolus beverage (0.5L of carbohydrate-electrolyte drink with 3.0 grams of salt) to relieve EAMCs and to prevent muscle twitches from becoming an EAMC.[6] After an ultra road race, post-race serum sodium levels were lower in the cramping group (139.8mmol/l) than in the non cramping group (142.3 mmol/l).[32] There was no significant difference between pre and post-race serum potassium, calcium concentrations, or plasma glucose levels.

Potassium and EAMCs: There is limited research regarding plasma potassium and one researcher doesn't believe potassium plays a role in EAMCs.[6] In ultra distance road racers, there was no difference between potassium serum concentrations from pre and post racers with those who experienced cramping.[32] However, Miller et al.[21] hypothesized that K^+ may impact EAMCs if eaten before cramps occur. Plasma potassium concentration increased significantly after ingesting two-servings of bananas in exercised males.[21] The nine males that were involved in the study were given either 0, 1, or 2-servings of bananas on three days of testing. The participants were instructed to consume the pre-cut bananas containing 594mg of potassium per serving within three minutes.[21] At 15 and 30 minutes, plasma potassium volume was significantly higher than at 60 minutes. Plasma potassium concentration was greater at 60 minutes with 2-servings of bananas and was significantly higher than zero and one-serving groups.[21] Because plasma potassium concentration does not significantly increase until 60 minutes with two-servings of bananas, it is assumed bananas do not play a role in relieving EAMCs, but have not been observed in the prevention of EAMCs with the consumption of bananas. It is also thought that because bananas are high in potassium increasing the extracellular potassium concentration in the body, it could contribute to early muscle fatigue and increase the risk of EAMCs.[33]

Why Bananas

Bananas have been consumed for multiple reasons such as high carbohydrate content, easy to obtain and they are easy to hold during long endurance events.[24] Miller's study showed that there was no significant change in $[K^+]_p$ until 60 minutes post ingestion[21], meaning that if the potassium in bananas were to prevent EAMCs it would have to be ingested at least 60 minutes before physical activity. Another inference from Miller's study could be that if EAMCs are prevented at 15 minutes post ingestion it could be because of the glucose that the bananas provide and not the potassium since there was no plasma potassium concentration change at that time.[21] It is also observed that 1-serving of bananas does not show a difference between 0-servings most of the time[21] so if future studies were to be performed, 2-servings of bananas (300g) should be used instead of 1-serving (150g).

Although there are no reported studies with bananas and the prevention of muscle cramping, studies have used bananas to determine carbohydrate changes[23] and plasma potassium concentration.[21] Gaby[26] suggested that hypokalemia, a severe potassium deficiency, can cause muscle cramps. In a case study of a 76 year old man who had persistent calf cramps was advised to take a potassium magnesium aspartate daily. It was reported that the patients' leg cramps disappeared within 36 hours and stayed away for over a 5-month period. Gaby's research also suggested that potassium deficiencies are common in the western hemispheres because of the low consumption of fruits and vegetables and are a contributing factor in muscle cramping.[26]

The best way in preventing muscle cramps is to stay hydrated,[9] but a close second recommendation is good nutrition for electrolyte maintenance (43.8%)[9] for the athletes. Most prevention techniques utilize sodium replacement, but potassium is over looked in most studies because it is not lost in as great of quantity as sodium. Bananas provide a sufficient source of potassium, as reported above, and has been chosen by athletes because of their taste, semi-solid state, ease to eat, and is a good source of carbohydrates.[21,24]

Previous studies have used bananas as a variable. Mitchell et al.[23] determined how different carbohydrate sources influenced glycemic response. They used 54 grams of bananas as one of the carbohydrate sources to add a semi-solid pre-exercise option. They also tested subjects while consuming Powerade, Gatorade and water. They observed that the blood glucose in the banana participants showed no significant difference between the water placebo until 30 minutes of exercise. There was no significant difference between insulin measurements pre-exercise and 60 minutes post ingestion.[23] So, if EAMCs were to be prevented at and following the 60 minute mark, glucose would not be a reason.

Another researcher studied plasma potassium concentration changes in exercised males after eating a banana. Miller[21] looked into the plasma potassium concentration ($[K^+]_p$), potassium content changes from baseline, plasma glucose and plasma volume changes after eating 0, 1 or 2 servings of bananas. The only significant difference between the groups in $[K^+]_p$ results were at 60 minutes and showed that 2-servings of banana were greater than 1 and 0-servings of bananas.[21] Plasma glucose showed an increase in both the 1-serving and 2-serving groups at 15, 30 and 60 minutes with the 2-serving group having a high significant difference.[21] Plasma volume showed no difference between time and serving size. Plasma potassium levels were significantly higher in the 2-serving group at 30 and 60-minutes, where there was no difference between the 0-serving and 1-serving groups throughout the time periods.[21] A problem with ingesting multiple bananas is the high potassium levels in bananas and the risk of hyperkalemia in the athlete. Hyperkalemia is defined as a $[K^+]_p$ level greater than 7.0 mmol/L.[21] Miller's results showed that the marginal increase of plasma potassium concentration stayed well within the normal clinical limits.[21]

However, there is no reported research to determine the effect of potassium in bananas in preventing EAMCs from occurring in an athlete. A study examined the consumption of three medium sized bananas as a carbohydrate source. The study, done in 1993, compared the effects of eating solid (three whole bananas), slurried (blended mixture of three bananas an 4.4oz of water) or a placebo (16oz of artificially sweetened, flavored and colored drink) forms of carbohydrates between two prolonged bouts of exercise.[24] The results showed there was no significant difference between the solid and slurried group in plasma glucose concentration. The two treatments were statistically higher than the placebo.[24] These results are not very surprising because bananas have a very high water content (74%[22]) which allows them to be metabolized easily.

Prevention of Cramping

Multiple studies have been done to formulate the best practice treatment method when an EAMC is occurring in an athlete. No reported method that has been tested as a prevention for EAMCs, nevertheless maintaining hydration and adequate electrolytes have been good strategies.[1,9,27] Hydration and electrolytes may aid in the prevention of EAMCs up to a specific threshold frequency or muscular fatigue.[16] Another suggestion in preventing EAMCs is exercising the target muscle spindles and GTO receptors to delay the neuromuscular fatigue onset, which would delay the EAMC.[27] Nine hundred ninety-seven athletic trainers completed a survey about the causes and best treatments of preventing EAMCs. Athletic trainers identified hydration as the primary method of prevention of EAMCs. The second best method in preventing EAMC's was nutrition with 43.8%.[9] Seventy-three percent felt that consuming the recommended nutrition was very successful with 25% saying it was somewhat successful as a prevention just below hydration for EAMCs.[9]

There have been studies using other methods for prevention. A report on nocturnal cramps suggests that stretching the affected area three times a day could decrease the occurrence of cramps.[25] However, there was insufficient data that related stretching to a decrease in nocturnal cramps.[25] There have also been reports on the use of quinine to treat cramps. The study showed that quinine derivatives were effective in reducing the frequency, but the benefit was minimal.[25] It is suggested that if quinine is used in the prevention of cramping or to reduce the occurrence of cramps, that it should be avoided for a routine treatment since there are serious side effects such as blindness, blurred or double vision, fainting, and rapid or irregular heartbeat.[25]

Summary

EAMCs are defined as painful, spasmodic, involuntary contractions of a muscle that occur during or after physical activity.[1-3,7,25,26] The most common type of cramp that affects athletes are EAMCs and occur mostly in endurance athletes.[8,11,28] There are multiple different theories explaining why EAMCs exist, consisting of dehydration, electrolyte imbalance, fatigue, environmental and neuromuscular abnormalities.[9] Electrolyte imbalances, including sodium and potassium, are a popular explanation of the cause of EAMCs. Electrolytes have been studied in the treatment of muscle cramps, but very little research has been done with electrolytes and the prevention of muscle cramping, specifically potassium. Bananas are a good source of potassium and have been studied recently to determine how many bananas and how much time it would take to increase $[K^+]_p$.[21] Bananas are widely consumed by athletes because they are inexpensive as well as easily digested.[21,222,24] There is minimal research with the use of bananas, and research to support bananas as a source of prevention of EAMCs.

CHAPTER 3. METHODS

The purpose of this study was to determine if cramp TF and $[K^+]_p$ increased following two-servings of bananas. This information could be helpful to determine if bananas could be used in the clinical setting to prevent EAMCs. The following questions were investigated: 1) Did ingesting two servings (300g) of bananas increase cramp TF when compared to baseline (0-servings)? and 2) Did $[K^+]_p$ increase following 60 minutes of rest following banana ingestion? This chapter focuses on the experimental design, subjects, instrumentation, procedures, and statistical analysis.

Experimental Design

A 1x2 factorial design with two paired T-tests was used to analyze plasma potassium concentration levels and cramp threshold frequency. The independent variable was time, pre and post banana consumption. The dependent variable for the first question was cramp TF. Plasma potassium concentration was the dependent variable for the second question.

Subjects

Twelve healthy male and female young adults (18-30 years) who had a history of muscle cramping in the lower extremity were recruited. Participants were excluded if (1) they had a food allergy to bananas or any swallowing problems; (2) had surgery or an injury to their dominant leg within the past six months; (3) had a vascular disorder, inability to clot blood, diabetes, or a nervous system disorder; (4) or if a muscle cramp could not be induced. The subjects' dominant leg was used and defined as the leg they would use to kick a soccer ball. Each subject signed an informed consent form and completed an inclusion criteria questionnaire prior to the testing day (Appendix A). They were informed of the procedures during that time.

Instrumentation

A Grass S88 stimulator and SIU5 Stimulus Isolation Unit (Astro-Med, Inc, West Warwick, RI) with an 8mm Ag/AgCl- shielded active electrode (EL258S; Biopac Systems) and an 8cm square dispersive electrode was used to deliver the electrical stimuli from the Digitimer to induce the cramp. The stimulus intensity was set at 80 V because this intensity had shown to induce muscle cramps in healthy subjects.[34] Electromyography (EMG) recorded muscle potential using the MP150 analog-digital data acquisition system with Acq*knowledge* software (version 3.7.3; Biopac Systems, Inc).

Procedures

Subjects were recruited by word of mouth and email to the Fargo-Moorhead area. This study was approved by the University's Institutional Review Board. Recruitment materials included procedures of the study as well as directions to the laboratory. At least one day before testing, the co-investigator explained the study procedures to the subjects who then signed the informed consent form, as well as completed an inclusion criteria questionnaire to determine that they qualified for the study. Subjects were instructed to avoid exercise for 24 hours and foods that were high in potassium such as bananas and potatoes (Appendix B). They were instructed to fast and maintain adequate hydration with water and to avoid drinks that had caffeine and electrolytes such as sports drinks twelve hours prior to the testing time. On the testing day, subjects reported to Bentson Bunker Fieldhouse room 14.

Prior to participants arriving, the co-investigator cut and weighed 300 grams of bananas (approximately 2 large bananas). Upon arrival, participants were asked to lay supine on the table with their foot hanging over the edge of the table. The flexor hallicus brevis area was shaved, debrided with small grain sandpaper, and was cleaned with alcohol. To find the motor point, a dispersive ground electrode was placed on the lateral ankle and a stimulating electrode with gel on the end was placed over the posterior tibial nerve. The stimulating electrode delivered a single wave shock and was moved after each impulse to locate the best site for the nerve to be stimulated. When the location of the stimulating electrode was found, electrodes were wrapped on with elastic wrap to keep them in place. The EMG was recorded to determine when the muscle cramped, as well as subject confirmation of a cramp. There was three EMG pads used. The first location of the EMG pads was found by measuring the length of the first metatarsal, and dividing by two. That spot was marked with a permanent black marker on the plantar aspect of the foot. The big toe was then extended to feel for the flexor hallicus longus tendon and matched up with the previous mark. This was the location that the first two EMG pads were placed, 1mm away from each other. The third one was placed on the tibial tuberosity of the same leg.

Next, the participant's right arm was prepared for a blood draw. The superficial vein of the cubital fossa was used to take blood samples. The arm was cleaned with isopropyl alcohol in a circular motion starting at the center and moving outwards. A 20-guage catheter was inserted into the subjects' superficial forearm and connected to a 3-way stopcock. A 3-mL "garbage" sample was taken first, to draw out the saline that would have altered the sample, then a 5-mL blood sample was collected as a baseline test. Saline was pushed back into the stopcock to prevent clotting. After the baseline blood sample was taken, the cramping procedure began with a 10 Hz stimulation using the Grass S88 Stimulator. If a cramp could not be induced, the subject rested one minute and the stimulation was increased by 2 Hz until a cramp occurred. The EMG recorded muscle activity during the stimulus and after to determine if the muscle was still contracting after the stimulus ended. After the first cramp was induced, the subjects ate two-servings (300g) of bananas in 5-minutes then remained in the supine position and rested for 60 minutes. At the end of the 60 minutes, another 3-mL "garbage" blood draw was collected to remove the saline, and then the final blood sample was collected. The catheter was removed, the subjects' arm was cleaned and a bandaid was put on over the insertion site. The final EIMC was induced; following the same procedures as previously stated starting at 10 Hz. After the final cramp was induced, the co-investigator removed the electrodes on the subjects' leg. The subject was informed of signs and symptoms of an infection concerning their arm following a blood draw. Signs and symptoms of infection included redness around the injection site, warm to the touch, puss around the site, as well as pain. Subjects were advised to ice and stretch the bottom of their foot for the remainder of the day to prevent prolonged discomfort they may have experienced. Subjects received compensation of their time of $30 cash.

Statistical Analysis

Two separate T-tests were used to 1) determine if there was a significant difference between pre and post cramp TF, and 2) Did $[K^+]_p$ increase following 60 minutes of rest following banana ingestion? The independent variables were time, pre-banana and post-banana. The dependent variable for the first questions was cramp TF, and for the second question $[K^+]_p$. Mini-Tabs was used to analyze the data. Frequencies were determined from demographic information of the subjects.

CHAPTER 4. MANUSCRIPT

The use of bananas in preventing exercise associated muscle cramps

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Abstract

Context: Exercise associated muscle cramps (EAMCs) are an involuntary skeletal muscle contraction. It has been suggested that those prone to EAMCs should eat bananas prior to events because of their high concentration in potassium. We wanted to investigate the relationship of plasma potassium concentration and cramp threshold frequency. **Objective:** To determine if 1) ingesting two servings (300g) of bananas would increase cramp TF when compared to baseline (0-servings)? and 2) would $[K^+]_p$ increase following 60 minutes of rest following banana ingestion? **Design:** A 1x2 factorial design with two paired T-tests guided this study. Independent variables were time (pre and post). The dependent variables were cramp threshold frequency and plasma potassium concentration. **Setting:** Laboratory **Patients or Other Participants:** Twelve females (age=19.917± 1.73 yrs, ht= 163.398± 5.41 cm, wt= 67.208 ± 6.46kg) with a history of EAMCs in their lower extremities participated. **Intervention(s):** Each participant completed a baseline blood sample and baseline electrically induced muscle cramp (EIMC). Then, they ingested 300g of bananas and rested for 60 minutes. A final blood sample was taken and EIMC was administered. **Main Outcome Measure(s)**: The plasma potassium concentration ($[K^+]_p$) and threshold frequency changes from pre to post ingestion of bananas. **Results:** The mean for cramp threshold frequency increased over time (pre= 29.67± 3.60, post= 31.50± 4.36), however the increase was not significantly different (t_{11}=2.11, p=.059). Plasma potassium concentration increased significantly (t_{11}= 3.44, p= .006) over time. **Conclusions:** There was a significant increase in $[K^+]_p$, however cramp threshold frequency did not increase from pre ingestion to 60 minutes post. Different rest times and the different amounts of bananas need to be investigated further. **Key Words:** Exercise associated muscle cramps, plasma potassium concentration, cramp threshold frequency.

Introduction

Exercise-associated muscle cramps (EAMCs) are an involuntary contraction of skeletal muscle and are believed to occur during or after physical activity. [1-3] There are multiple theories defining how muscle cramps occur, but the two prevailing beliefs are dehydration and electrolyte imbalance.[4,5] The dehydration theory is characterized as when the body becomes less than two percent dehydrated. At this point, dehydration could start affecting the body negatively such as causing EAMCs.[1,6] Other theories include alterations in neuromuscular control[7], fatigue from exercise[2] and electrolyte imbalance.[5,8-10] Electrolyte imbalance occurs when there is loss of electrolytes such as sodium, potassium, magnesium and calcium, resulting in an EAMC.[8-11] Dehydration is the most common cause of EAMCs perceived among athletic trainers in the clinical setting. Electrolyte imbalance is the second most common cause of EAMCs. Electrolyte consumption is the third best technique suggested by those athletic trainers, followed by fluid consumption and proper nutrition.[12]

Several anecdotal strategies advocate prevention of EAMCs. Forty-four percent of athletic trainers believe that nutrition is a key prevention technique for EAMCs.[12] Since potassium is lost during exercise as a result of sweating, eating bananas is a popular myth in treating and preventing EAMCs.[13] Researchers have been testing methods for the treatment of EAMCs using electrically induced muscle cramps (EIMCs) to help determine if threshold frequency (TF) is altered in any way. Those with a history of cramping had a significantly lower cramp TF (14.9± 1.3 Hz) than those who did not have a history of cramping (25.5. ±1.6 Hz).[14] Experimental research on the effectiveness of eating bananas and the prevention of cramping using EIMCs and TF was not found in an exhausted search. Therefore, the purpose of this study was to determine if cramp TF and $[K^+]_p$ increased following two-servings of bananas. This information could be helpful to determine if bananas could be used in the clinical setting to prevent EAMCs. The following questions were investigated: 1) Did ingesting two servings (300g) of bananas increase cramp TF when compared to baseline (0-servings)? and 2) Did $[K^+]_p$ increase following 60 minutes of rest following banana ingestion?

Methods

Participants

The sample size was based on previous research that utilized the same protocol to determine cramp TF, as well as ingesting bananas.[8-10,12] This research protocol was approved by the University's Institutional Review Board. Twelve males and females ages 18-30 with the following inclusion criteria were recruited: a self-reporting history of cramping, no allergies to bananas, no difficulty swallowing, no surgery to their dominant leg in the past six months, and no vascular disorders, inabilities to clot blood, diabetes or nervous system disorders. Only females (age=19.917 ± 1.730 yrs, ht= 163.398± 5.410 cm, wt= 67.208±6.46 kg) volunteered to take part in this study. At least 24 hours prior to testing, subjects met with us to discuss the procedures, sign the informed consent form, and complete an inclusion criteria questionnaire (Appendix A) to determine if they were qualified. If qualified, subjects were instructed to avoid exercise and foods that were high in potassium (Appendix B) 24 hours prior to their testing time. Subjects were also instructed to fast twelve hours prior to testing, but could maintain adequate hydration with water only.

Experimental Design

A 1x2 factorial design with two T-tests guided data collection for cramp threshold frequency (TF) and plasma potassium concentration ($[K^+]_p$). The independent variables were time, pre and post banana ingestion. The dependent variable for the first research question was cramp TF and for the second research question was $[K^+]_p$ level. Height, weight, gender, and dominant foot were all documented as well.

Testing Procedures

On the testing day, subjects reported to the laboratory wearing shorts and were asked to lay supine on the table with their ankles hanging slightly off the table. Electromyography pads were placed on the subjects' plantar aspect of their foot over the flexor hallicus tendon, as well as a ground pad on their ipsilateral tibial tuberosity. A stimulating electrode was placed inferior to the medial malleolus just over the tibial nerve. The tibial nerve was stimulated using the Grass Stimulator and SIU5 Stimulus Unit (Astro-Med, Inc, West Warwick, RI) approximately 3-5 times, varying between subjects. A 1-ms stimulus at 80V using an 8mm Ag/AgCl-shielded active electrode (EL258S; Biopac Systems) to find a site that caused the greatest flexion of the hallux. A dispersive pad was placed over the lateral mallelous and both pads were strapped on with elastic wrap. After the foot was prepared, the subjects superficial vein of their arm was cleaned and prepared for blood samples. A single use 20 gauge venous catheter connected to a 3-way stopcock via an extension tube was used. A "garbage" blood sample was drawn to eliminate contamination prior to a baseline 5-mL blood sample.

After the baseline blood sample was taken, the cramping protocol for the flexor hallicus longus was followed starting at 10Hz and increased by 2Hz every minute until a cramp was recorded. A cramp was established if visually the great toe stayed flexed following the stimulus for 5 seconds, the subject expressed feeling a cramp in their great toe, and/or EMG activity remained after the stimulus ended for 5 seconds. Following the baseline cramp, subjects ate two servings (300g) of cut bananas. Subjects were then instructed to remain supine for the next 60 minutes. Following the 60 minutes, another "garbage" sample was drawn and than a final 5-mL blood sample was taken, as well as a final EIMC following the same procedures as previously stated.

Blood Analysis Procedures

Blood for plasma analysis was drawn into heparinized tube and centrifuged (model IEC Micro-MB; International Equipment CO, Needham Heights, MA) at 3000 rpm for 15 minutes. Plasma was distracted from the blood sample and placed into a freezer that was utilized for biohazard materials. After all samplers were collected from all subjects, a carrier from a local hospital came and picked up the samples. The hospital laboratory ran each blood sample for plasma potassium concentration.

Statistical Analysis

Two separate related sample T-tests were used to 1) determine if there was a significant difference between pre and post cramp TF, and 2) Did $[K^+]_p$ increase following 60 minutes of rest following banana ingestion? Descriptive statistics were used to determine demographic information of the subjects.

Results

Descriptive statistics were used for subject demographics. The mean age=19.917 ± 1.730 years, height= 163.398 ± 5.410cm, weight= 67.208 ±6.46kg (Table 1). Related sample T-tests were used because the same people were tested under different conditions. Over the 60 minutes of rest, cramp TF did not significantly increase (t_{11}= 2.11, p=.059) from pre to post EIMC. The means had increased over time from baseline (29.67±3.60Hz) to 60 minutes after banana ingestion (31.50±4.36Hz)(Table 2). It was approaching statistical significance p=.059 which could indicate a need for a larger sample size or a longer rest time to test K^+ metabolism. However, eating two servings of bananas (300g) did increase $[K^+]_p$ over the 60 minutes. The means increased from pre= 3.617±.393mmol/l to post= 3.850±.361mmol/l and showed that it significantly increased as well (t_{11}=2.11, p=.006) (Table 2).

Discussion

To date, there are no reported prevention techniques in the literature for EAMCs There have been anecdotal suggestions based on experience from athletic trainers[9]. A survey of 997 athletic trainers about the causes, treatment and prevention methods of EAMCs revealed that nutrition (43.8%) and electrolyte replacement (12.2%) were among the top perceived methods of preventing EAMCs[12]. A follow-up question of how successful those methods were showed that these athletic trainers believed proper nutrition was 72.8% successful and electrolyte consumption was 70.3% successful as methods in preventing EAMCs.[12] Miller[10] reported athletes consumed bananas because of the source of K^+ they contain (594mg/serving). They are also a great source of carbohydrates and sugars, easy to obtain and to hold and eat during long endurance events.[15]

We found out that following 60 minutes post ingestion of 2 servings of bananas significantly increased $[K^+]_p$ from pre (0 mins) to post (60 mins), this agreed with Millers' findings of increased $[K^+]_p$. He first reported that 2 servings of bananas significantly increased $[K^+]_p$ 60 minutes post ingestion which is why we had decided to use two-servings of bananas. However, differences between the two studies were that had his subjects exercised during that time in an environmental chamber to help the metabolism of the bananas. We decided to not exercise our subjects for the reason that we wanted to look at the sole effect of $[K^+]_p$ on muscle EAMCs without adding any other factors that could cause an EAMC to occur, such as fatigue or the loss of other electrolytes with exercise.[1-3,16] Exercise has also been shown to increase $[K^+]_p$ consumption[17] and we wanted to see if the K^+ from bananas had an effect on EIMCs. With our subjects not exercising, it shows that bananas could be used prior to the start of activity and still have an increase in $[K^+]_p$. However, Schwellnus et al.[11] believed that K^+ did not play a role in the development of EAMCs. His main finding was that there was no significant changes in $[K^+]_p$ from before the ultra-distance race to after the race in those racers who developed EAMCs either during or immediately after the race.[11] It was also discovered that those who consumed electrolyte beverages during a race, experienced more cramps (9 of 13, 69%) whereas less subjects cramped when they did not have the carbohydrate beverage (7 or 13, 54%).[5] They reported that although dehydration and electrolyte imbalance are not the sole cause of EAMCs, hydration and electrolytes aid in the prevention of EAMCs.[5]

With $[K^+]_p$ increasing, we wanted to see if cramp TF would increase as well to show that bananas could be used as a technique to prevent EAMCs. However, we found that cramp TF did not significantly increase over the 60 minutes. The mean of cramp TF did increase over time and was approaching significance. With the results approaching significance, however more time may be needed to allow for more of the K^+ to be absorbed. Miller and Knight had discovered that EIMCs correlate well with EAMCs. They found that those who had a self-reported history of muscle cramping had a significantly lower cramp TF than those who did not have a history of cramps.[14] With the history of EAMCs correlating with EIMCs, it would indicate that prevention techniques that increase cramp TF could prevent the occurrence of an EAMC. The cramp TF of our study did not significantly increase, however it was approaching significance which could mean that it may prevent an EAMC with some athletes, but a larger sample pool would be needed to come to this conclusion.

The results found in our study can be used as a building block to more additional research. We had only used one specific serving size (2 servings, 300g) of bananas because of previous research findings. In addition, our timeframe of 60 minutes was based off of Millers' study.[10] Since we did not have a significant increase in $[K^+]_p$ at 60 minutes, a longer time of approximately 90 minutes or greater needs to be investigated. The greater time difference would allow for more absorption of the banana since our subjects did not exercise. Extra time would aid in the increase of K^+metabolism.[10] We only tested females because those volunteers responded to our recruitment first and fit the criteria. The previous banana study only used males, so it would be interesting to have a subject pool of both male and females to determine if there are any differences between the two genders. Future research should also have a larger sample size.

Finally, a limitation to our study was that we were only able to test extracellular $[K^+]_p$ because of the equipment we had. Extracellular K^+ is found in the blood capillaries and is easily tested with a blood sample, where as intracellular K^+ is stored within the muscle fibers and not as easily available to test.[17] Extracellular $[K^+]$ is stored clinically around 3.8-5mmol/l and can reach values between 6.5 and 8.5 mmol/l whereas the levels of intracellular $[K^+]$ are stored at approximately 165mmol/l.[20] Knowing the effects of how intracellular $[K^+]$ were affected could explain why there was not a statistically significant increase in cramp TF. The K^+ may not have had the time to be absorbed in the muscle fibers and result in a greater increase of cramp TF.

Conclusion

The primary conclusions to this study were that two servings of bananas significantly increased $[K^+]_p$ over 60 minutes, and cramp TF approached statistical significance. Our goal was to see that cramp TF had also increased significantly along with $[K^+]_p$ increase to show that bananas could be used as a tool in preventing EAMCs. Although there was no significant increase, it was approaching statistical significance, which could suggest that at 60 minutes, two-servings of bananas could prevent EAMCs. Athletic trainers could suggest to their athletes to consume two-servings of bananas at a time greater than 60 minutes when they would consume their pregame meal or a snack on the bus on the way to a game. Bananas are inexpensive, easy to consume and are a good source of K^+. There needs to be more research into prevention strategies with larger sample sizes, both genders, and more clinically tested.

Table 1: Subject Demographic Means and Standard Deviation

Demographics	Mean	SD
Age (yrs)	19.92	1.73
Height (cm)	163.40	5.41
Weight (kg)	67.21	6.46

Table 2: Cramp Threshold Frequency and Plasma Potassium Concentration Means

	Mean	SD
Pre Cramp TF (Hz)	29.67	3.60
Post Cramp TF (Hz)	31.50	4.36
Pre $[K^+]_p$ (mmol/L)	3.62	.39
Post $[K^+]_p$ (mmol/L)	3.85	.36

References

1. Binkley HM, Beckett J, Casa DJ, Kleiner M, Plummer PE. National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses. *J Athl Train.* 2002;37(3):329-343.
2. Schwellnus MP, Derman EW, Noakes TD. Aetiology of skeletal muscle 'cramps' during exercise: a novel hypothesis. *J Sports Sci.* 1997;15:277-285.
3. Schwellnus MP. Cause of exercise associated muscle cramps (EAMC)- altered neuromuscular control, dehydration or electrolyte depletion? *Br J Sports Med.* 2009;43:401-408.
4. Bergeron, MF. Muscle cramps during exercise: Is it fatigue or electrolyte deficit. *Curr Spor Med Report*. 2008;7(4):S50-S55.
5. Jung AP, Bishop PA, Al-Nawwast A, Dale RB. Influence of hydration and electrolyte supplementation on incidence and time to onset of exercise-associated muscle cramps. *J Athl Train.* 2005;40(2):71-75.
6. Murray B. Hydration and physical performance. *J Am Coll Nutr.* 2007; 26(5):542S-548S.
7. O'Connell K, Posthumus M, Schwellnus MP, Collins M. Collagen genes and exercise-associated muscle cramping. *Clin J Sport Med.* Published online: August 14, 2012 (DOI:10.1097/JSM.0b013e3182686aa7).
8. Miller KC, Mack G, Knight KL. Electroylyte and plasma changes after ingestion of pickle juice, water, and a common carbohydrate-electrolyte solution. *J Athl Train.* 2009;44(5):454-461.
9. Miller KC, Mack GW, Knight KL, et al. Reflex inhibition of electrically induced muscle cramps in hypohydrated humans. *Med Sci Sports Exerc.* 2012;42:953-961.

10. Miller KC. Plasma potassium concentration and content changes after banana ingestion in exercised men. *J Athel Train*. 2012;47(6):648-654.

11. Schwellnus MP, Nicol J, Leubscher R, Noakes TD. Serum electrolyte concentrations and hydration status are not associated with exercise associated muscle cramping (EAMC) in distance runners. *Br J Sports Med*. 2004;38:488-492.

12. Stone MB, Edwards JE, Stemmans CL, Ingersoll CD, Palmieri RM, Krause BA. Certified athletic trainers' perceptions of exercise-associated muscle cramps. *J Sport Rehab.* 2003;12:333-342.

13. Sizer FSS, Whitney EN. Appendix A: table of food composition. In: *Nutrition: Concepts and Controversies*. 9th ed. Belmont, Ca: Thomson Learning Inc; 2003: A1-A87.

14. Miller KC, Knight KL. Electrical stimulation cramp threshold frequency correlates well with the occurrence of skeletal muscle cramps. *Muscle Nerve.* 2009;39:364-368.

15. Murdoch SD, Bazzarre TL, Snider IP, Goldfarb AH. Differences in the effects of carbohydrate food form on endurance performance to exhaustion. *Int J Sport Nutr.* 1993;3(1):41-54.

16. Shang G, Collins M, Schwellnus M. Factors associated with a self-reported history of exercis-associated muscle cramps in ironman triathletes: a case-control study. *Clin J Sport Med*. 2001;21(3):204-210.

17. Nielson OB, de Paoli FV. Regulation of Na^+-K^+ homeostastis and excitability in contracting muscles: implications for fatigue. *Appl Physiol Nut Metab.* 2007;32:974-984.

18. Miller KC, Knight KL. Initial electrical stimulation frequency and cramp threshold frequency and force. *J Athl Train.* 2012;47(5):643-647.

19. Miller KC, Stone MS, Huxel KC, Edwards JE. Exercise-associated muscle cramps: causes, treatment, and prevention. *Sports Health* 2010;2(4): 279-283.

20. Kristensen M, Juel C. Potassium-transporting proteins in skeletal muscle: cellular location and fiber-type differences. *Acta Physiol*. 2010;198:105-123.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to determine if cramp TF and $[K^+]_p$ increased following two-servings of bananas. This information could be helpful to determine if bananas could be used in the clinical setting to prevent EAMCs. The following questions were investigated: 1) Did ingesting two servings (300g) of bananas increase cramp TF when compared to baseline (0-servings)? and 2) Did $[K^+]_p$ increase following 60 minutes of rest following banana ingestion? There are multiple theories as to why EAMCs occur. Theories include dehydration, neuromuscular control abnormalities, fatigue, and electrolyte imbalance. The electrolyte imbalance theory suggests that EAMCs occur because of the loss of electrolytes, primarily sodium, potassium, magnesium, and calcium, that are lost during sweat. We had focused primarily on the loss of potassium because of the lack of research associated with EAMCs and because bananas are widely used by athletes and contain a high concentration of potassium.

Subjects reported to the lab for one testing day. They were instructed to avoid high potassium foods 24 hours prior to testing and to fast from all foods 12 hours prior to testing. On testing day, subjects had a baseline 5-mL blood sample and EIMC then ingested two-servings of bananas (300g). After they finished eating, subjects rested for 60 minutes before a final 5-mL blood sample was drawn, and an EIMC. Over the 60 minutes, $[K^+]_p$ significantly increased from pre to post ingestion. Cramp TF, however, did not significantly increase over time but the means started to increase over time approaching significance. This suggests that either a larger sample size is needed and or a longer time to metabolize the K^+.

To date, there are no reported prevention techniques in the literature for EAMCs, but there have been anecdotal suggestions based on experience from athletic trainers.[9] A survey of 997 athletic trainers was performed about the perceptions of EAMCs and how those athletic trainers believed how they were caused, treated and prevented in the clinical setting. When asked what they believed to be the most common cause of EAMC, 20.4% believed that electrolyte imbalance was a primary cause, only behind dehydration.[9] Electrolyte replacement was reported as the 5th method in how athletic trainers would treat EAMCs, and was only 36.8% "very successful" in the treatment of those EAMCs that were seen clinically. When asked about the best method for preventing EAMCs, athletic trainers believed the electrolyte replacement was the 5th best technique, but when asked how successful electrolyte consumption was in preventing EAMCs, they reported it to be 72.8% successful.[9] This shows that electrolyte consumption is being suggested to athletes from athletic trainers as a prevention to EAMCs. This is why more studies need to be done in the prevention of EAMCs by consuming electrolytes that are lost during physical activity.

Most of the research that has been done on electrolyte imbalances have looked at sodium and have focused on replacement of electrolytes as a treatment to EAMCs. One study had looked at the effects of pickle juice vs. deionized water and how long it would take an EIMC to be relieved. A baseline EIMC of the flexor hallicus longus was taken to see how long it would take the body to relieve an EIMC without the aid of a beverage.[18] On the next testing day, another EIMC was induced into the flexor hallicus longus again. After a muscle cramp was induced, subjects drank either pickle juice or the deionized water. The pickle juice alleviated the EIMC significantly quicker than when subjects drank the deionized water.[18] This was beneficial to understand how to treat EIMCs, because it acted within a minute and a half, it is not beneficial to use this strategy as a prevention technique.

Another study that looked at electrolytes, focused on how long it would take K^+ from bananas to increase in the blood system to possibly alleviate EAMCs. Their subjects had been tested on three separate days, testing three different servings of bananas (0, 1, and 2). When the subjects arrived, they had a blood sample drawn and ate one of the three samples. After ingesting the bananas, they were instructed to ride the bike and had blood samples drawn throughout the study. The only serving size and time after banana ingestion to significantly increase was with two-servings and 60-minutes post ingestion.[21] Miller had investigated this to see if the K^+ from bananas could alleviate EAMCs, however with the delayed increase in $[K^+]_p$ it would not be the best treatment method.

The findings from Miller[21] had led to investigation of bananas as a prevention strategy because of the time it took for the body to ingest and absorb K^+ into the body. This study examined if cramp TF would increase at 60 minutes following ingestion of two servings of bananas, as well as if $[K^+]_p$ also increased. Plasma potassium concentration significantly increased over the 60 minutes, but cramp TF did not increase significantly. The similarities to these studies were the choice of two-servings of bananas because it did increase the $[K^+]_p$ over 60 minutes time. The main differences were that Miller had only tested males, whereas this study had only tested females. This could lead to different amount of potassium absorbed into the body as both male and females have different metabolism rates. Another similarity was that only extracellular K^+ was used because it was easier to obtain through a blood sample rather than extracting intracellular K^+ that is stored within the muscle fibers. Both studies had subjects $[K^+]_p$ that remained within the normal clinical level of 3.8-5mmol/L and well below any values that are believed to cause cardiac abnormalities or hyperkalemia ($[K^+]_p$ <7mmol/L). A difference between the two studies was that Miller had his subjects exercise for 60 minutes and in an environmental chamber. In this study, the subjects did not exercise to determine the effect of $[K^+]_p$ increase from banana ingestion on EIMCs. Exercising has been shown to increase $[K^+]_p$,[17] so it was removed from this study to eliminate other factors that could cause an EAMC to occur, such as fatigue or the loss of other electrolytes with exercise.[1-3,16]

Plasma potassium concentration levels were also tested before and after an ultra-distance road race on runners who had both a history of EAMCs and those who did not. Blood samples were taken both prior to the start of the race and immediately following the end of the race to test plasma electrolyte concentrations. The only significant difference that was found from pre to post race was that plasma sodium concentration was lower following the race in those who experienced an EAMC.[32] Schwellnus et al.[32] also uncovered that those runners who consumed carbohydrate-electrolyte beverages during a race experienced more EAMCs (9 of 13, 69%), whereas not as many subjects cramped when they did not consume the electrolyte-carbohydrate beverage (7 of 13, 54%). With both groups experiencing EAMCs, especially with a greater chance of developing an EAMC while consuming carbohydrate-electrolyte beverage, it could suggest that electrolytes do not have an effect on EAMCs. The results of this study could suggest the same as well, since cramp TF did not significantly increase 60 minutes after banana consumption and $[K^+]_p$ did significantly increase. With both studies having small sample sizes, a larger sample size in the future would need to be used to come to this conclusion.

Cramp threshold frequency has been studied frequently. It has been studied to correlate an EIMC to EAMCs by testing subjects who had a history of EAMCs and those who did not. It was found that those who did not have a history of EAMCs had a significantly higher cramp TF than those who had a history of EAMCs.[19] This was used as the rationale to recruit subjects with a history of EAMCs for this study because it could be correlated with the results of EIMCs. Because the cramp threshold frequency did not significantly increase over time and since EIMCs have been found to correlate with EAMCs, it could suggest that the K^+ from bananas would not prevent EAMCs in athletes. However, because cramp threshold frequency was approaching significance, the time between banana consumption and EIMC may need to be extended or a larger sample size would need to used in the future to come to this conclusion.

Electrically induced muscle cramps have been used frequently in the laboratory setting; however, it has been used to study treatment methods rather than prevention methods. It has been used to test the fatigue theory as a main cause to EAMC. Stone et al.[17] had subjects have a baseline EIMC then perform a fatigue protocol for the flexor hallicus longus. Then another EIMC was induced, and they reported that the post EIMC was significantly higher than the EIMC tested as the baseline. With EIMC being greater after fatigue, it disagrees with the theory stating that EAMCs occur because of muscle fatigue during and after exercise.[17] Another study that investigated the electrolyte imbalance theory was already previously discussed. Miller had tested the use of pickle juice and deionized water to test how quickly EIMCs could be alleviated with the consumption of either beverage. Pickle juice alleviated the EIMC much quicker than deoinized water when compared to baseline tests.[18] There are no studies that use EIMCs in the prevention of EAMCs which is why this study was performed to begin the discussion of prevention techniques that could be used in the clinical setting.

Exercise associated muscle cramps have been reported in the clinical setting in multiple athletes.[4,23,28] Athletes who are involved in endurance sports such as triathlons,[28] rugby players,[8] and football players during preseason[4] have all experienced EAMCs. Seventy-six percent of tri-athletes participating in a South African triatholan exercienced a cramp during the past year of training,[8] and 67-68% reported having a lifetime prevalence.[28] Rugby players reported a 52% prevalence, cycling reported 60%, and marathon runners reported 39% prevalence.[8] Football athletes experienced more EAMCs during the month of August than compared to any other month during the season.[4] There have been techniques to treat EAMCs after they occur; however, there have not been any studies that looked into preventing EAMCs. This is the first study that looks into a prevention strategy that could be used easily with athletes both at home and on the road. Although at 60 minutes cramp TF did not significantly increase, it was approaching significance, which with a larger subject pool could help come to a stronger conclusion. However, with these results, it could be suggested that athletes would need to consume two-servings of bananas before an hour of activity. These findings could help start preventing EAMCs before they occur and cause difficulties with athletes during their activities. This study has started the research of prevention techniques in those individuals who have a history of EAMCs; however, more research is needed. To continue this research of prevention, there needs to be different testing times greater than 60 minutes should be used to determine when $[K^+]_p$ is greatest and to see how long prior to activity bananas should be consumed. A larger sample pool also needs to be investigated that involves both male and females since most previous research have focused on males. This is the first of a study that needs to be researched much more that could have a great effect on athletes that could keep them in the game longer without a risk of an EAMC.

REFERENCES

1. Binkley HM, Beckett J, Casa DJ, Kleiner M, Plummer PE. National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses. *J Athl Train.* 2002;37(3):329-343.
2. Schwellnus MP, Derman EW, Noakes TD. Aetiology of skeletal muscle 'cramps' during exercise: a novel hypothesis. *J Sports Sci.* 1997;15:277-285.
3. Schwellnus MP. Cause of exercise associated muscle cramps (EAMC)- altered neuromuscular control, dehydration or electrolyte depletion? *Br J Sports Med.* 2009;43:401-408.
4. Cooper ER, Ferrara MS, Broglio SP. Exertional heat illness and environmental conditions during a single football season in the southeast. *J Athl Train.* 2006;41(3):332-336.
5. Maddali S, Rodeo SA, Barnes R, Warren RF, Murrell GAC. Postexercise increase in nitric oxide in football players in muscle cramps. *Am J Sport Med.* 1998;26(6):820-824.
6. Bergeron, MF. Muscle cramps during exercise: Is it fatigue or electrolyte deficit. *Curr Spor Med Report*. 2008;7(4):S50-S55.
7. Schwellnus MP. Muscle cramping in the marathon: Aetiology and risk factors. *Sports Med.* 2007;37(4-5):364-367.
8. Shang G, Collins M, Schwellnus M. Factors associated with a self-reported history of exercis-associated muscle cramps in ironman triathletes: A case-control study. *Clin J Sport Med*. 2001;21(3):204-210.
9. Stone MB, Edwards JE, Stemmans CL, Ingersoll CD, Palmieri RM, Krause BA. Certified athletic trainers' perceptions of exercise-associated muscle cramps. *J Sport Rehab.* 2003;12:333-342.

10. Brouns F, Beckers E, Wagenmakers AJM, Saris WHM. Ammonia accumulation during highly intensive long-lasting cycling: individual observations. *Int. J Sports Med.* 1990;11:S78-S84.

11. O'Connell K, Posthumus M, Schwellnus MP, Collins M. Collagen genes and exercise-associated muscle cramping. *Clin J Sport Med.* Published online: August 14, 2012 (DOI:10.1097/JSM.0b013e3182686aa7).

12. Telerman-toppet N, Bac M, Khoubesserian P, Coers C. Type 2 fiber predominance in muscle cramp and exertional myalgia. *Muscle Nerve*.1985;8:563-567.

13. Van den Bergh P, Bulcke JA, Dom R. Familial muscle cramps with autosomal dominant transmission. *Eur Neurol*. 1980;19:207-212.

14. Lazaro RP, Rollinson RD, Fenichel GM. Familial cramps and muscle pain. *Arch Neurol*. 1981;38:22-24.

15. Murray B. Hydration and physical performance. *J Am Coll Nutr.* 2007; 26(5):542S-548S.

16. Jung AP, Bishop PA, Al-Nawwast A, Dale RB. Influence of hydration and electrolyte supplementation on incidence and time to onset of exercise-associated muscle cramps. *J Athl Train.* 2005;40(2):71-75.

17. Stone MB, Edwards JE, Hexel KC, Cordova ML, Ingersoll CD, Babington JP. Threshold frequency of an electrically induced cramp increases following a repeated, localizing fatiguing exercise. *J Sports Sci.* 2010; 28(4): 399-405.

18. Miller KC, Mack GW, Knight KL, et al. Reflex inhibition of electrically induced muscle cramps in hypohydrated humans. *Med Sci Sports Exerc.* 2012;42:953-961.

19. Miller KC, Knight KL. Electrical stimulation cramp threshold frequency correlates well with the occurrence of skeletal muscle cramps. *Muscle Nerve.* 2009;39:364-368.

20. Miller KC, Knight KL. Initial electrical stimulation frequency and cramp threshold frequency and force. *J Athl Train.* 2012;47(5):643-647.

21. Miller KC. Plasma potassium concentration and content changes after banana ingestion in exercised men. *J Athel Train*. 2012;47(6):648-654.

22. Sizer FSS, Whitney EN. Appendix A: table of food composition. In: *Nutrition: Concepts and Controversies*. 9th ed. Belmont, Ca: Thomson Learning Inc; 2003: A1-A87.

23. Mitchell JB, Braun WA, Pizza FX, Forrest M. Pre-exercise carbohydrate and fluid ingestion: influence of glycemic response on 10-km treadmill running performance in the heat. *J Sports Med Phys Fitness*. 2000;40:41-50.

24. Murdoch SD, Bazzarre TL, Snider IP, Goldfarb AH. Differences in the effects of carbohydrate food form on endurance performance to exhaustion. *Int J Sport Nutr.* 1993;3(1):41-54.

25. Katzberg HD, Khan AH, So YT. Assessment: Symptomatic treatment for muscle cramps (an evidence-based review) *Neurology* 2010;74:691-696.

26. Gaby, AR. Nutritional interventions for muscle cramps. *Medical* R_x. 2007;6(6):20-23.

27. Miller KC, Stone MS, Huxel KC, Edwards JE. Exercise-associated muscle cramps: causes, treatment, and prevention. *Sports Health* 2010;2(4): 279-283.

28. Schwellnus MP, Drew N, Collins M. Muscle cramping in athletes-risk factors, clinical assessment, and management. *Clin Sports Med*. 2008;27:183-194.

29. Lane HW, Cerda JJ. Potassium requirements and exercise. *J Am Diet Assoc.* 1978;26(3):65-70.

30. Edsall DL. New disorder from heat: a disorder due to exposure to intense heat. *JAMA* 1908;11:1969-71

31. Miller KC, Mack G, Knight KL. Electroylyte and plasma changes after ingestion of pickle juice, water, and a common carbohydrate-electrolyte solution. *J Athl Train.* 2009;44(5):454-461.

32. Schwellnus MP, Nicol J, Leubscher R, Noakes TD. Serum electrolyte concentrations and hydration status are not associated with exercise associated muscle cramping (EAMC) in distance runners. *Br J Sports Med*. 2004;38:488-492.

33. McKenna MJ, Bangsbo J, Renaud JM. Muscle K^+, Na^+, and Cl^- disturbances and Na^+-K^+ pump inactivation: impications for fatigue. *J Appl Physiol* 2008;104:288-295.

34. Braulick KW, Miller KC, Albrecht JM, Tucker JM, Deal JE. Significant and serious dehydration does not affect skeletal muscle cramp threshold frequency. *Br J Sports Med* 2012; doi: 10.1136.

35. Nielson OB, de Paoli FV. Regulation of Na^+-K^+ homeostastis and excitability in contracting muscles implications for fatigue. *Appl Physiol Nut Metab.* 2007;32:974-984.

36. Kristensen M, Juel C. Potassium-transporting proteins in skeletal muscle: cellular location and fiber-type differences. *Acta Physiol*. 2010;198:105-123.

APPENDIX A. INCLUSION CRITERIA QUESTIONNAIRE

Subject Number:_________.

Initials:_______________ Age:_______________ Dominant Leg:________________

Height:_____________________inches Weight:________________lbs.

Please answer the following questions as accurately as possible:

1. Do you have a history of cramping?		Yes	No
If yes:	a) When was the last time you had cramped?	≤ 6 months	> 6 months
	b) What area of the body did you cramp?	Foot	Calf
		Quads	Hamstrings
	c) What side of the body did you cramp on?	Right	Left
2. Do you have an allergy to bananas?		Yes	No
3. Do you have any difficulties with swallowing?		Yes	No
4. Have you had surgery or injury to your dominant leg within the last six months?		Yes	No
5. Do you have a vascular disorder?		Yes	No
6. Do you have an inability to clot blood?		Yes	No
7. Do you have diabetes?		Yes	No
8. Do you have a nervous system disorder?		Yes	No

Answering no to the first question and answering yes to any of the questions 2-8 will eliminate you from this study for safety concerns.

APPENDIX B. HIGH POTASSIUM FOODS LIST

List of Foods High in Potassium To Avoid <u>24 Hours Prior</u> to Test Day

Test Date and Time:____

24 Hour high potassium fast (date and time):_________________________

12 hour all food fast (date and time): ______________________________

Vegetables

Artichokes
Avocado
Bamboo shoots
Beans (pinto, white, black)
Beans (wax, yellow, frozen)
Beet Greens
Beets
Black-Eyed Peas
Chinese cabbage
Corn on the Cob
Cucumber
Mushrooms
Okra
Parsnips
Peas
Plantains
Potatoes
Spinach
Squash
Swiss Chard
Tomatoes

Fruits

Bananas
Cantaloupe
Guava
Kiwi
Mangos
Nectarines
Papaya
Peaches
Pomegranate
Raisins

Beverages

Milk
Orange juice
Soy milk

If you have any questions of concerns regarding foods or beverages that may contain potassium, feel free to contact the co-investigator Hannah Hallissey at (860) 917-8693 or at hannah.hallissey@my.ndsu.edu.

This list of foods is provided by: The End Stage Renal Network of Texas. More information at esrdnetwork.org

APPENDIX C. INFORMED CONSENT FORM

NDSU North Dakota State University
Dept. of Health, Nutrition, and Exercise Science
PO BOX 6050
Fargo, ND 58108-6050
701-231-5686

Title of Research Study: The Use of Bananas in Preventing Exercise Associated Muscle Camps

This study is being conducted by: Dr. Pamela Hansen EdD, ATC; Hannah Hallissey ATC

Why am I being asked to take part in this research study? You are being asked to volunteer in the study because you are a healthy male or female between the ages of 18-30 and have a history of muscle cramping in the lower extremity within the last 6 months. A muscle cramp is defined as a painful, spasmodic involuntary muscle contraction. You can not participate if you have an allergy to bananas or a problem with swallowing; have had surgery in your dominant leg within the past six months; have a vascular disorder, inability to clot blood, diabetes, or a nervous system disorder; or a muscle cramp cannot be induced.

What is the reason for doing the study? The purpose of this study is to determine if the potassium in two-servings of bananas prevents muscle cramps. By performing this study, we hope to indentify a prevention technique for physically active individuals who are at-risk for muscle cramping.

What will I be asked to do? One day before testing you will meet with the co-investigator to fill out and sign the informed consent as well as the inclusion criteria questionnaire. At this time you will be instructed to avoid exercise and foods high in potassium (a list will be given to you) for 24 hours prior to the testing time. Twelve hours before testing you will be instructed to fast and avoid drink that have caffeine and drinks with added electrolytes, such as Gatorade or PowerAde.

On testing day, you will come to the Bentson Bunker Fieldhouse Laboratory (room 14). Upon arrival you will be instructed to remove your shoes, roll up your pant leg or asked to put shorts on, and lay on your back with your foot off the end of table. The co-investigator will clean the base of the big toe and lateral ankle. The base of the big toe will be shaved if necessary and lightly rubbed with fine sandpaper than wiped with alcohol. This helps prevent interference of the muscle activity that will be recorded. The co-invesitgator will first find a point on your medical foot right by your ankle that has the strongest sensation, when that spot is found the electrode will be wrapped on to you using elastic wrap to prevent it from moving. This electrode will provide the electrical stimulation to the muscle of the big toe. Muscle activity will also be measured and three pads will be placed around your foot. Two of them will be on the base of the big toe, and one will be placed just below your knee.

After the co-investigator has set up your big toe for the cramp, the co-investigator will clean and prepare your arm for two blood samples. The first blood sample will be taken at this time and 5mL (approximately 1tsp) will be drawn as a baseline. Universal precautions will be used when preparing your arm and taking the blood sample. The second blood sample will be taken at 60 minutes after eating bananas.

Once the first blood sample is drawn, the first cramping protocol will begin. You will be advised of the types of sensations you may feel before the electrical stimulation is administered. Sensations include tapping or pins and needles. If you do not cramp after the bout of stimulation, you will rest one minute. This process will continue until a cramp can be stimulated. This will be your baseline cramp. It will take approximately 3-7 minutes to induce a muscle cramp, only have about 5 seconds of stimulus and than one minute rests between each stimulus. An unsuccessful cramp and therefore removal from the study would be considered after 30mHz of stimulus.

After the cramp is induced, you will sit up and be instructed to eat two servings of bananas, approximately two whole bananas, within five minutes. After the bananas are completely ingested you will lie back down and rest for 60 minutes. At the end of the 60 minutes, we will take the second and final 8mL blood sample (approximately 1.5 tsp). Once the blood sample is drawn, we will repeat the cramping protocol.

Where is the study going to take place, and how long will it take? At least one day prior to testing day, you will meet with the co-investigator at a convenient location to discuss, fill out and sign the informed consent and inclusion criteria questionnaire. On testing day you will report to the Bentson Bunker Fieldhouse Room 14 for testing day. The meeting session will last approximately 30 minutes and testing day will last 1.5 to 2 hours for a total of 2-2.5 hours of your time.

What are the risks and discomforts? The risks to you are slightly more than you would experience in daily life. There is potential to develop an infection at the site of the blood draw. Universal precautions will be used for handling blood. You may feel some discomfort with the electrical stimulation, but will be monitored. You may develop an upset stomach with the ingestion of bananas. Also, with fasting for twelve hours you may feel light headed. If you are known to have a sensitivity to any food or food ingredient, or have had violent allergic reactions to drugs, chemicals, or food ingredients, you should not take part in this study.

What are the benefits to me? You are not expected to get any benefit from being in this research study.

What are the benefits to other people? Athletes and physically active individuals suffer from muscle cramps and have very limited research on prevention techniques. Although it is not proven, it is thought that the potassium in bananas prevents the loss of potassium where it is necessary for muscle contraction. Thus, this research can potentially help athletes and those who are physically active who have a history of cramping prevent them during exercise.

Do I have to take part in the study? Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

What will it cost me to participate? There is no monetary cost to you.

What are the alternatives to being in this research study? There are no other alternatives to this study.

Who will see the information that I give? We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study, we will write about the combined information that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key. If you withdraw before the research is over, your information will be (retained in the research record) OR (removed at your request), and we will not collect additional information about you.

Can my taking part in the study end early? If you fail up to show for testing day or do not follow pre-testing instructions you may be removed from the study and not receive your monetary compensation.

Will I receive any compensation for taking part in this study? The study will consist of a 30 minute meeting session at least 24 hours prior to testing day, as well as a 1.5-2 hour testing day. If you complete the entire study you will receive $30 for your time. However, you decide to terminate your time while completing the study, or a cramp cannot be stimulated, you will be compensated $10 for your time. In order to receive the 10$ you must at least complete the baseline blood sample and cramp.

What happens if I am injured because of this research? If you receive an injury in the course of taking part in the research, you should contact Dr. Pamela Hansen at the following phone number (701) 231-8093 or Pamela.J.Hansen@ndsu.edu of the co-investigator, Hannah Hallissey at (860) 917-8693 or at Hannah.hallissey@my.ndsu.edu. Treatment for the injury will be available including first aid, emergency treatment and follow-up care as needed. Payment for this treatment must be provided by you and your third party payer (such as health insurance or Medicare). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of your participation in this research.

What if I have questions?
Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the chief investigator, Dr. Pamela Hansen at the following phone number (701) 231-8093 or Pamela.J.Hansen@ndsu.edu of the co-investigator, Hannah Hallissey at (860) 917-8693 or at Hannah.hallissey@my.ndsu.edu.

What are my rights as a research participant?
You have rights as a participant in research. If you have questions about your rights, or complaints about this research [may add, "or to report a research-related injury" if applicable], you may talk to the researcher or contact the NDSU Human Research Protection Program by:

- Telephone: 701.231.8908 or toll-free 1-855-800-6717
- Email: ndsu.irb@ndsu.edu
- Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/irb .

Documentation of Informed Consent:
You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.

You may request a copy of this informed consent if you wish to have one for your records.

______________________________________ _______________
Your signature Date

____
Your printed name

______________________________________ _______________
Signature of researcher explaining study Date

____
Printed name of researcher explaining study

APPENDIX D. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

December 20, 2013

Pamela Hansen
Department of Health, Nutrition & Exercise Sciences
BBFH

IRB Approval of Protocol **#HE14109**, **"The Use of Bananas in Preventing Exercise Associated Muscle Cramps"**
Co-investigator(s) and research team: **Hannah Hallissey**

Approval period: 12/20/2013 to 12/19/2014 **Continuing Review Report Due: 11/1/14**

Research site(s): **NDSU** Funding agency: **n/a**
Review Type: Full Board, meeting date – 12/13/2013
Risk Level: A minor increase over minimal risk
IRB approval is based on original submission, with revised: protocol, recruitment script and consent (received 12/16/2013).

Additional approval is required:

- prior to implementation of any proposed changes to the protocol (*Protocol Amendment Request Form*).
- for continuation of the project beyond the approval period (*Continuing Review/Completion Report Form).* A reminder is typically sent two months prior to the expiration date; timely submission of the report is your responsibility. To avoid a lapse in approval, suspension of recruitment, and/or data collection, a report must be received, and the protocol reviewed and approved prior to the expiration date.

A report is required for:

- any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence (*Report of Unanticipated Problem or Serious Adverse Event Form*).
- any significant new findings that may affect risks to participants.
- closure of the project (*Continuing Review/Completion Report Form*).

Research records are subject to random or directed audits at any time to verify compliance with IRB regulations and NDSU policies.

Thank you for cooperating with NDSU IRB procedures, and best wishes for a successful study.

Sincerely,

Kristy Shirley

Kristy Shirley, CIP
Research Compliance Administrator

INSTITUTIONAL REVIEW BOARD
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | ndsu.edu/irb
Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo, ND 58102

APPENDIX E. IRB AMENDMENT CHANGE APPROVAL

RECEIVED
Date Received
FEB 04 2014
INSTITUTIONAL REVIEW BOARD

IRB Protocol #: HE14109

NDSU NORTH DAKOTA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
office: Research 1, 1735 NDSU Research Park Drive, Fargo, ND 58102
mail: NDSU Dept. #4000, PO Box 6050, Fargo, ND 58108-6050
p: 701.231.8995 **f:** 701.231.8098 **e:** ndsu.irb@ndsu.edu **w:** www.ndsu.edu/irb

Protocol Amendment Request Form

Changes to approved research may not be initiated without prior IRB review and approval, except where necessary to eliminate apparent immediate hazards to participants. Reference: SOP 7.5 Protocol Amendments.

Examples of changes requiring IRB review include, but are not limited to changes in: investigators or research team members, purpose/scope of research, recruitment procedures, compensation strategy, participant population, research setting, interventions involving participants, data collection procedures, or surveys, measures or other data forms.

Protocol Information:

Protocol #: **HE 14109** Title: **The Use of Bananas In Preventing Exercise Associated Muscle Cramps**

Review category: ☐ Exempt ☐ Expedited ☒ Full board

Principal investigator: **Dr. Pamela Hansen** Email address:
Dept: **HNES**

Co-investigator: **Hannah Hallissey** Email address: **hannah.hallissey@my.ndsu.edu**
Dept: **HNES**

Principal investigator signature, Date: Pamela Hansen (email) 2/4/14

In lieu of a written signature, submission via the Principal Investigator's NDSU email constitutes an acceptable electronic signature.

Description of proposed changes:

1. Date of proposed implementation of change(s)*:
   ** Cannot be implemented prior to IRB approval unless the IRB Chair has determined that the change is necessary to eliminate apparent immediate hazards to participants.*

2. Describe proposed change(s), including justification:

Page 1 of 4

APPENDIX F. IBC APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

NOTICE OF IBC APPROVAL Dec. ~~18~~ 27, 2013

Pamela Hansen, Dept. of Health, Nutrition and Exercise Science
Co-investigator(s) and research team: **Hannah Hallissey**

#B14005– **"The Use of Bananas in Preventing Exercise Associated Muscle Cramps"**

Approval Date: Dec. ~~18~~ 27, 2013

Dr.Hansen:

The NDSU Institutional Biosafety Committee has reviewed and approved the above referenced protocol under the category '***Human Blood and Tissue***'. A copy of the approved protocol is enclosed for your records.

Approved Biosafety Level: BL 2

Research location(s): **BBF 14**

Applicable guidance: *NDSU Bloodborne Pathogen/Exposure Control Plan*
Occupational Exposure to Bloodborne Pathogens, OSHA
Biosafety in Microbiological and Biomedical Laboratories, CDC

Additional reporting to the NDSU IBC is required for this project:

- when making changes in personnel and/or any approved procedures, locations or agent(s). Submit the *IBC Request for Change Form* prior to implementation of the change(s). Please note that changes may require re-evaluation of the risk assessment and biosafety level for appropriate containment.
- in the event of significant problems concerning exposure or containment of the agent(s) involved. Submit the *IBC Adverse Event Reporting Form* within 24 hours of awareness of the event.
- Annually (via the *IBC Annual Update/Completion Report Form*) to inform the committee on status of the project. You should receive a reminder approximately one month prior to the report date.

NOTE Report all exposure incidents (e.g., via skin puncture, mucous membrane, non-intact skin, or other means) immediately to the Safety Office at 701-231-7759 for evaluation and follow up. Also notify the IBC of the incident within 24 hours.

Thank you for complying with NDSU IBC procedures, and best wishes for success with your project.

Institutional Biosafety Committee

INSTITUTIONAL BIOSAFETY COMMITTEE
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