Potential nutrition contributions to exercise associated muscle cramping – a case study approach

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B.A., Metropolitan State University of Denver, 2006
B.S., Metropolitan State University of Denver, 2013

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Food, Nutrition, Dietetics and Health
College of Human Ecology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2019

Approved by:

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Abstract

Beliefs regarding the role of electrolytes and hydration in exercise associated muscle cramping (EAMC) may be hindering meaningful nutrition-based improvements and prevention strategies. There is a need to explore the role of carbohydrate, energy availability, exertion level, electrolyte status, and hydration status in combination with the emerging nervous system fatigue research to assess the role of these possible predictors of EAMC. However, these factors vary dramatically between individual athletes, and prior to assessing the role of possible predictors of EAMC, the nutrition and hydration practices, the individual responses to competition, and the history of EAMC in endurance athletes must first be better characterized. To achieve this, a case study approach was used to capture pre-race and on course food and beverage intake, pre and post-race body weight, relative perceived effort, and history of EAMC for four recreational runners.

Carbohydrate, energy availability, and hydration status varied across cases with one occurrence of EAMC. Reported pre-race CHO intake for all but one participant fell below 5 g/kg/day. Two of the four runners reported a history of EAMC, one of which experienced EAMC during the race. The two participants with a prior history of EAMC, also reported the lowest energy and CHO intakes. The one participant who experienced an EAMC reported a history of prior EAMC, experienced the greatest body mass loss, experienced the greatest estimated sodium loss, and reported suboptimal energy and CHO intakes. While this observed case of EAMC does not appear to be inconsistent with the traditional dehydration/ electrolyte loss theory, it also generates questions regarding the potential contribution of suboptimal energy and CHO intakes.

Overall, this study presents an in-depth perspective for four recreational runners. An improved understanding of the nutrition and hydration practices of endurance athletes along with an enhanced appreciation of the unique nature of each athlete's responses can benefit professionals who work with athletes and can serve to generate vital research questions related to the role nutrition and hydration play in the occurrence of EAMC.

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Acknowledgements

A grateful and sincere thank you to my advisor/committee chair Dr. Jennifer Hanson as well as committee members Dr. Mark Haub and Dr. Ryan Thiele at Kansas State University for supporting my decision to complete a research thesis as a distance student. Without their direction, mentorship, and approval this professional development experience would not have been possible.

Chapter 1 - Introduction

Exercise-associated muscle cramping (EAMC), a specific classification of debilitating skeletal muscle spasms occurring during or after exercise, are common among all sports, genders, age groups, and environments.[1] The cause of EAMC remains unknown, but new research is challenging decades of interventions that historically have been rooted in anecdotal evidence or limited research to support their use.[2–6] Emerging science suggests altered neuromuscular control and the peripheral nervous system (PNS) are key components in the etiology of EAMC; challenging the electrolyte or dehydration theories that currently drive EAMC intervention strategies.[1,7–10]

Historically, dehydration along with electrolyte loss from sweating has been viewed as the primary cause of EAMC. Despite being based on observational or anecdotal evidence, this widely accepted belief has formed the foundation for EAMC interventions. A brief snapshot of the ubiquitous nature of the dehydration/electrolyte loss theory-based interventions is provided in Table 1.1. Although the dehydration/electrolyte loss theory-based interventions are widely recommended, recent research into the cause of EAMC has been unable to demonstrate a connection between dehydration and electrolyte loss.

Table 1.1 Electrolyte and Fluid Recommendations

SOURCE	DATE	AUTHOR/ENTITY	RECOMMENDATION
Heat Illness: A Handbook for Medical Officers [11]	1991	U.S. Army Institute of Environmental Medicine	0.1 % table salt solution
The Importance of Salt in the Athlete's Diet [12]	2007	Verle Valentine, MD	16 fl oz sports drink with 2.5 mg of additional salt with onset of muscle twitching
National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes [13]	2000	Casa, D et. al.	0.3-0.7 g table salt/L solution
Muscle Cramping in the Heat [14]	retrieved 3/22/2019	University of Washington - The Sports Institute	consume extra salt in diet 1/4 tsp table salt per 16 oz water, salt tablets
Heat Cramps: Fluid and Electrolyte Challenges during Tennis in the Heat [15]	2003	M F Bergeron	At the first signs of muscle twitching, consume an appropriate salt solution - for example, 3 g (0.5 tsp.) of salt dissolved in 16-20 ounces of Gatorade ®.
Muscle Cramps: The Right Ways for the Dog Days; Gatorade Sports Science Institute [16]	3/1/2003	Randy Eichner, MD	1/4 tsp table salt per 16-20 oz water
Curbing Muscle Cramps: More than Oranges and Bananas; Gatorade Sports Science Institute [17]	7/25/2003	Randy Eichner, MD	"The prevention - and the cure - of heat cramping is salt and fluids. The solution is saline. "
49ers Fitness Corner: Nutrition [18]	9/28/2005	San Francisco 49ers NFL	"add extra electrolytes to their Gatorade and have them drink 20 oz of salted Gatorade® before games and practices; and drink Gatorade® during the game"
Workout Tips for Exercise in the Heat [19]	3/15/2005	University of Colorado Sports Medicine	1/4 - 1/2 tsp table salt per liter of fluid

In a 2009 review, Schwellnus identified that the foundational literature regarding EAMC, originating in 1904 by Edsall and in 1933 by Talbott, could be considered incomplete and observational in nature.[1,20] Edsall's paper was based upon the observations of approximately seven hospital patients admitted during hot weather. No blood work or clinical data was obtained.[21] Talbott's work provided bloodwork assessments of seven patients experiencing "heat cramps" and heat exhaustion but no control groups were established.[20]

Recent controlled research studies assessing hydration and electrolytes status using plasma volume, blood volume, and body weight differences failed to find an association between dehydration or electrolyte loss and cramping. A review of these studies follows.

In 2013, 10 men with a history of EAMC within the prior 12 months underwent an intensity-controlled muscle threshold frequency protocol using electrical impulses to stimulate cramping while inducing significant (3-5%) or serious (>5%) levels of dehydration through exercise in a temperature-controlled environment. Electrical threshold frequency was established in all subjects prior to dehydration with a progressive increase in electrical stimulus until a cramp was achieved. Analysis of sweat patch collections showed a mean 4.7% body mass loss paired with a 4-g loss of sodium did not induce muscle cramping among the participants. The range of dehydration was 4.6-5.1% among participants. Hydration status did not change electrical threshold frequency of cramping. Dietary intake was not controlled for in this study.[4]

A study conducted in 2010 reported that among a sample of triathletes participating in an Ironman triathlon, 43 reported EAMC, whereas 166 were unaffected. The cramping group lost an average of 2.4 kg while the non-cramping group lost an average of 2.2 kg. This difference in weight loss between crampers and non-crampers was non-significant.[6]

Jung et al conducted a cross-over controlled hydration and electrolyte study among adult men with a history of EAMCs in 2005. Participants were exposed to heat, calf-fatiguing exercise protocols and either hypohydration or euhydration with a CHO/electrolyte beverage. The alternating calf fatiguing protocol involved five different movements separated by modified calf-raises. During the hypohydration trial 7 of the 13 participants (54%) reported an EAMC with a mean body mass loss of 1% .[2] At face value this appears to support dehydration as a precursor to cramping. However, in the follow-up trial at least 48 hours later, the participants were exposed to the same physical and environmental conditions while provided a carbohydrate-electrolyte beverage; 9 of 13 participants (69%) still reported an EAMC despite euhydration, CHO, and electrolyte supplementation. Study subjects did cramp earlier in the hypohydration trial and this supports the role of proper hydration in delaying the onset of fatigue and acting as a possible predictor of EAMC as well as being part of intervention protocols for prevention of EAMC.

Studies evaluating the loss of electrolytes and electrolyte serum levels in a variety of participants including football, marathon, and triathlon, have not made a connection between electrolyte levels or electrolyte loss and the occurrence of EAMC.

Maughan (1986) found no significant differences in pre or post-race serum electrolyte levels or plasma volume losses between those developing a cramp (n =15, 18%) and those without EAMC among 82 male marathon runners.[22] Blood samples were obtained from the runners before the start of the race and immediately after. Pre and post-race weights were recorded wearing shorts only. Additionally, all subjects were provided a controlled 200 ml of either water or glucose-electrolyte product.

In 2005, Ironman participants (N = 20) were evaluated immediately post-race for serum electrolyte concentrations and electromyographic assessment (EMG). Statistically significant differences were not found between those experiencing EAMC (n=11) and those that did not cramp (n= 9).[5] Post-race blood samples were taken immediately after completion of race and evaluated for serum Na, K, Cl, and Mg. Additionally, pre and postrace body weights were taken to assess body mass loss. No significant difference in body mass loss between the EAMC group (3.4%) and non-EAMC group (3.9%) was reported. Participants that experienced EAMC where tested using surface EMG immediately post-race. EMG electrodes were placed on participants non-cramping muscle, which served as control, and on the most severe cramping muscle. An increase in muscle activity was demonstrated in the EAMC muscle. Dietary intake was not recorded for this study.

Schwellnus (in 2011) showed pre- and post-race serum sodium and chloride levels did not differ between 210 Ironman participants reporting (n=43) or not reporting (n=166) EAMCs.[6] Body weight and blood samples were taken 60 minutes before start of race and immediately post-race. Among both groups pre-race serum Na was reported as 139.8 mmol. Post-race serum Na for the EAMC group was 140.2 mmol and 139.6 mmol for the non-EAMC. The EAMC group showed an absolute weight change post-race of 2.4 kg as compared to 2.2 kg for the non-EAMC group. Dietary intake was not recorded for this study.

These findings related to electrolyte status are not to be confused with the known effect of severe ironized serum electrolyte imbalances, specifically the depletion of calcium (Ca) and magnesium (Mg), on the development of muscle spasms. These muscle spasms are associated with medical conditions or pharmacological side-effects.[23]

One emerging variable for EAMC is the effect fatigued muscles have on neuromuscular control at the alpha motor neurons of the cramping muscle. This fatigue response is associated with the build-up of metabolic biproducts in working muscles (increased CO^2, decreased O^2, and elevated H^+ ions) during repetitive activity and results in the reduction of energy derived from ATPase for free energy which is used for maintenance of the Na-K gradient in the cell membranes as well as down-regulated Ca^{2+} ATPase activity required to maintain excitation and contraction processes. This hindrance of muscle function results in membrane excitability and possible sustained tetany.[24] One example of this, as detailed earlier, was Suzler's (2005) observation of increased surface EMG activity in cramping muscles of marathon runners.[5] Additionally, CHO availability may play an increased role in muscle contractile processes through (CHO) signaling pathways during prolonged activities where the duty cycle of the muscle begins to rely heavily on glycolysis to maintain ATP availability.[24–26] CHO serves as both a precursor to ATP availability and as a cell signaling pathways for muscle contractile processes through muscle cell Ca2+ release. [26] Low glycogen stores impair muscle cell release of Ca2+ impeding muscle cell activation. [27]

Muscle fatigue (MF) is defined as "any exercise-induced reduction in the ability to exert muscle force or power, regardless of whether or not the task can be sustained". [28] Gandevia (2001) continues to explain that MF is not a delayed side effect of workload that appears suddenly but begins at the onset of activity. Additionally, MF is not isolated to the muscle fibers themselves. Feedback from fatigued muscles affects the nervous system altering functions such as postural control and proprioception. It is possible that increases in acidity levels resulting from bouts of moderate to high-intensity muscular contractions, may lead to stimulation of group III & IV chemoreceptor afferent neurons which have inhibitory effects on the alpha-motor neurons innervating the fatigued muscle. Taken together, the aforementioned fatigue-related physiological alterations may be contributing factors to the inability to sustain optimal muscular performance or avoid an EAMC.

As evidence mounts against old theories behind EAMC there is also a need to reassess nutritionally modifiable causes, specifically CHO, because it is well-known that glycogen depletion results in muscle fatigue.[24] Additionally, the importance of CHO on EAMC may be attributed to more than energy availability as research uncovers CHO metabolism as an integral component of cell signaling associated with muscle contraction.[24,25]

Nutrition and hydration practices vary dramatically between individual athletes.[26] Bergeron demonstrated that individual responses to athletic competition (i.e., sweat rate, sweat sodium concentration) vary dramatically as well.[27] In addition, the risk of EAMC is known to be related to a prior history of cramping. As such, prior to assessing the role of possible predictors of EAMC, the nutrition and hydration practices, individual responses, and history of EAMC in endurance athletes must first be better characterized. The purpose of this study is to gain an in-depth understanding of the nutrition-related practices and outcomes of half-marathon racers with an emphasis on possible predictors of EAMC.

Chapter 2 - Methods

Study Design

A case study approach was used to capture pre and on-course race food and beverage intake, pre and post-race body weight, perceived effort, history of EAMC, and occurrence of EAMC for four half-marathon runners competing within recreational categories.

All adult runners with a minimum age of 18 years old registered to participate in a designated half-marathon scheduled to take place in the fall of 2018 in Colorado were queried electronically at race registration for participation in this study. This study was approved by the Institutional Review Boards at Kansas State University (Appendix A) and conformed to the ethical principles set forth in the Declaration of Helsinki. Runners who volunteered to participate provided written informed consent for the collection of data (Appendix B).

Inclusion in the study was based upon the ability and willingness to:

- complete a food log using the MyFitnessPal application for a minimum of (3) days
- allow researchers to measure their height and weight pre and post-race.
- answer both a pre and post-race questionnaire
- provide researches access to their MyFitnessPal data

Data Collection

A pre-race questionnaire and contact information form was used to gather participant information and demographics including age, height, weight, race/ethnicity, history of cramping, location of cramping, personal record for distance, estimated completion time, and altitude of residence prior to the race. The pre-race questionnaire and contact form was provided to the participants electronically after registration through email and was completed 7-14 days prior to race day.

All participants self-reported dietary intake using the MyFitnessPal application. Intake of food, beverages, and supplements was collected for three consecutive days leading up to the race, as well as any pre-race meals. Instructions on how to maintain the food log were provided through email. Video chat and email support were available by researcher on an as needed basis. Participant's dietary data was extracted and reviewed remotely from the digital food log utilizing participant login information generated specifically for each participant and stored offline. Based on the dietary intake recorded, the application provided researchers with reports detailing the total daily energy, fat, protein, carbohydrate, and sodium intake for each participant from food and beverage intakes.

The post-race questionnaire was administered by researchers immediately after each participant completed the race. This questionnaire was used to document the consumption of any on course nutrition, measure relative perceived effort, record the occurrence of EAMC during the race, and identify the location of cramp if EAMC occurred.

A Withings Nokia Body+ Body Composition Scale was used to obtain participants pre and post-race body weights. Body weights were obtained with runners in race clothing with shoes removed. Height was self-reported. BMI's were calculated using the recorded heights and pre-race measured weights in the standard mathematical formula: weight (kg) / [height (m)] 2.[28]

Estimated energy and macro nutrient needs were created using 5-8 g/kg CHO, 1.2 g/kg PRO and 1 g/kg fat.[29,30] These macro nutrient ranges assume that the athlete is completing less than 3 hours of training per day.

In this study, electrolyte concentrations from sweat losses were not measured. Instead, estimated electrolyte loss tables were created for each participant based upon body weight changes using Shirreff & Maughan's average sweat concentration.[31] Estimated body stores of

Na and K combined with electrolyte intake at aid stations where compared to the estimated electrolyte losses for all participants. Estimations for whole body Na and K were approximated using 52-60mmol/kg Na for males, 48-55mmol/kg Na for females and 1759mg/kg K for both genders.[32]

Fluid intake was reported by participants on post-race questionnaire and then adjusted for spill and fill at aid stations post-race by researcher. One ounce was subtracted from every reported cup of fluid intake.

Chapter 3 - Results

The designated half-marathon took place as scheduled at 7:50am MST. Start time temperature and weather conditions were: 52° F, 70% humidity, 42° F dew point, sunny, with no cloud cover. Six runners initially enrolled in the study; however, only four provided all of the necessary information. Of these four, two were male and two were female. A case presentation of each of the four participants who provided all the necessary information follows.

Participant B2 Case Presentation

Participant B2 was a 31-year-old male recreational runner, having four or more years of running experience, with a history of completing at least one half or full marathon prior to participating in the study race. This participant's half marathon personal best time was 1' hour 47" minutes. B2 resides at 6200 feet elevation with no history of EAMC within the 12 months preceding the study.

Pre-Race Data Collection – Anthropometrics

Participant B2 self-reported body weight was 165 lbs (75 kg) and his self-reported height was 68". His pre-race weight, as measured by researchers 30-60 minutes prior to the start of the race was 170.4 lbs. (77.5 kg). Pre-race BMI was 25.1 kg/m^2.

Pre-Race Data Collection – Nutrition

For the three days leading up the race, the food log revealed an average energy intake of 4353 kcals. CHO provided 63.1% of total energy intake, 22.8% was obtained from fat (FAT), and 14.1% was obtained from protein (PRO). Macronutrient intake data is summarized in Table 3.1. Mean dietary sodium (Na) intake from food and beverage sources was 3589 mg per day; provided in Table 3.2.

Table 3.1 Daily Macronutrient and Energy Intake Three Consecutive Days Before Race B2

Day	**PRO** (g)	**CHO** (g)	**FAT** (g)	**PRO** (kcal)	**CHO** (kcal)	**FAT** (kcal)	**Total Energy** (kcal)
1	149	669	103	596 (14.2%)	2676 (63.7%)	927 (22.1%)	4199 (100.0%)
2	160	680	96	640 (15.2%)	2720 (64.4%)	864 (20.4%)	4224 (100.0%)
3	149	711	133	596 (12.9%)	2844 (61.3%)	1197 (25.8%)	4637 (100.0%)
Average	153	687	111	(14.1%)	(63.1%)	(22.8%)	4353

Protein (PRO) ; Carbohydrate (CHO)

Table 3.2 Daily Sodium Intake B2

Three Consecutive Days Before Race

Day	**Na** (mg)
1	2207
2	4130
3	4429
Average	3589

Participant B2 consumed a breakfast meal prior to race. Total energy intake for this meal was 1148 kcal comprised of 49.4% CHO, 15.3% FAT, and 49.4% PRO. Dietary Na at this meal was 832 mg. Macronutrient and Na intake for pre-race breakfast meal is summarized in Table 3.3.

Table 3.3 Macronutrient and Energy Intake – Breakfast Race Day B2

Day	**PRO** (g)	**CHO** (g)	**FAT** (g)	**PRO** (kcal)	**CHO** (kcal)	**FAT** (kcal)	**Total Energy** (kcal)
1	44	142	45	176 (49.4%)	568 (35.3%)	405 (15.3%)	1149 (100.0%)
Total	153	687	111	(49.4%)	(35.3%)	(15.3%)	

Protein (PRO) ; Carbohydrate (CHO)

Post-Race Anthropometric Data Collection

Body weight post-race was 163.8 lbs. Total body weight lost during the race was 8.35 lbs., which includes food and fluid consumed during race and accounts for 4.9% of total body mass.

Post-Race Cramping and RPE Data Collection

No EAMC was experienced during the race with a reported relative perceived effort (RPE) of eight on a scale from 1-10.

Post-Race Environmental and Race Data Collection

Participant B2 had a finish time of 1':39":54''' with an average pace per mile for this effort of 7':37'''. Total race time for B2 was 29% faster than the mean race time of 2:21:36''' (47/49 finishers). Temperature range start to finish for participant B2 was an unseasonably warm 52°-66° degrees F respectively.

Post-Race Nutrition Data Collection – On-Course Intake

Participant B2 consumed no solid or semi-solid products during the race; this includes gels, cubes, or electrolyte tablets. Adjusted fluid intake was estimated at 28 oz of which 16 oz of hydration formula provided 199.6 kcals as CHO in the form of glucose, fructose and dextrose as well as 948 mg Na, 111 mg Ca, 97 mg of both K and Mg. Summary of energy and electrolytes provided in Table 3.4.

Table 3.4 Energy and Electrolyte Intake During Race B2

Fluid	SKRATCH					
	Energy (kcal)	CHO (g)	Na (mg)	Ca (mg)	K (mg)	Mg (mg)
	200	52	948	111	97	97
Total	200	52	948	111	97	97

Nutrition and Electrolyte Estimations Participant B2

Estimated energy and macro nutrient needs for B2 are displayed in Table 3.5.

Table 3.5 Estimated Energy and Macronutrient Guidelines B2

WT (kg)	75						
MACRO	g/kg/bdwt	g/day	kcal/day	**Energy Needs Range**			
PRO	1.2	90	360	PRO+FAT+CHO	**% Daily Estimation**		
FAT	1	75	675	(kcal)	FAT	PRO	CHO
CHO	5	375	1500	2535	26.6%	14.2%	59.2%
CHO	6	450	1800	2835	23.8%	12.7%	63.5%
CHO	8	600	2400	3435	19.7%	10.5%	69.9%

PRO intake for B2 was 2.0 g/kg on average leading up to race day. Fat intake was 1.48 g/kg. Three-day CHO intake was 9 g/kg/d. Comparison of reported macronutrients and energy intake to estimated provided in Table 3.6.

Table 3.6 Comparison of Three-Day Energy and Macronutrient Intake to Estimated Three Day Needs B2

3 Day Average Intake		Estimated Daily Needs 5;6;8 (g) CHO					
PRO (g)	153	PRO (g)	90	PRO (g)	90	PRO (g)	90
FAT (g)	111	FAT (g)	75	FAT (g)	75	FAT (g)	75
CHO (g)	687	CHO (5g)	375	CHO (6g)	450	CHO (8g)	600
PRO (kcal)	14.1%	PRO (kcal)	14.2%	PRO (kcal)	12.7%	PRO (kcal)	10.5%
FAT (kcal)	22.8%	FAT (kcal)	26.6%	FAT (kcal)	23.8%	FAT (kcal)	19.7%
CHO (kcal)	63.1%	CHO (kcal)	59.2%	CHO (kcal)	63.5%	CHO (kcal)	69.9%
Total Energy (kcal)	4353	Total Energy	2535	Total Energy	2835	Total Energy	3435

Fluid balance for participant B2 represented in Table 3.7 indicates a 4.9% loss of body mass within the race time of 1h':39m'.

Table 3.7 Body Mass Pre and Post Race B2

PRERACE WT (lbs)	POST RACE WT (lbs)	WEIGHT LOST (lbs)	OUNCES LOST (oz)	FLUID INTAKE (adjusted oz)	TOTAL WT LOST (lbs)	BDWT LOST (%)
170.4	163.8	6.6	105.6	28	8.78	4.90%

Estimated electrolyte losses and gains for B2 are provided in Table 3.8. A comparison of B2's predicted Na and K body stores combined with the electrolyte intake at aid stations to predicted losses is provided in Table 3.9.

Table 3.8 Estimated Electrolyte Losses B2

Mineral	Loss Range (mg)	
Na	967	6713
K	569	1235
Mg	(+97)	523
Ca	(+110)	389

adjusted for electrolytes consumed during race

Table 3.9 Predicted Electrolyte Body Stores and Losses During Race B2

Mineral	Body Stores (mg)	Predicated Range of Stores Lost %	
Na	68970	(1.4%)	(9.7%)
K	131925	(0.4%)	(0.9%)

Participant M4 Case Presentation

Participant M4 was a 25-year-old female, recreational runner, with two to three years of running experience and a history of completing at least one half or full marathon prior to participating in the study race. Half marathon personal best time was 2' hour 30" minutes. M4 resides at approximately 5280 feet elevation with a history of EAMC within 12 months preceding study. Location of EAMC was reported as "calf".

Pre-Race Data Collection – Anthropometrics

Participant M4 self-reported a body weight of 136 lbs. (61.8 kg) her self-reported high was 65". Pre-race weight, as measured by researchers 30-60 minutes prior to the start of the race was 134.4 lbs. (61 kg). Her pre-race BMI was 22.7 kg/m^2.

Pre-Race Data Collection – Nutrition

For the three days leading up the race, the food log revealed an average energy intake of 1207 kcals of which 43.3% was obtained from CHO, 33.2% was obtained from FAT, and 22.2% was obtained from PRO. Macronutrient intake data is summarized in Table 3.10. Mean dietary Na intake from food and beverages was 2676 mg per day (Table 3.11). Participant M4 did not consume a breakfast meal prior to race. Total energy intake reported before the race was 0 kcal.

Table 3.10 Daily Macronutrient and Energy Intake Three Consecutive Days Before Race M4

Day	PRO (g)	CHO (g)	FAT (g)	PRO (kcal)	CHO (kcal)	FAT (kcal)	Total Energy (kcal)
1	67	126	28	268 (26.2%)	504 (49.2%)	252 (24.6%)	1024 (100.0%)
2	72	131	54	288 (22.2%)	524 (40.4%)	486 (37.4%)	1298 (100.0%)
3	72	131	54	288 (22.2%)	524 (40.4%)	486 (37.4%)	1298 (100.0%)
Average	70	129	45	(23.5%)	(43.3%)	(33.2%)	1207

Protein (PRO); Carbohydrate (CHO)

Table 3.11 Daily Sodium Intake M4

Three Consecutive Days Before Race

Day	Na (mg)
1	3052
2	2488
3	2488
Average	2676

Post-Race Anthropometric Data Collection

Body weight post-race was 130.6 lbs. Total body weight lost during the race was 3.8 lbs. which includes food and fluid consumed during race and accounts for 4.3% of total body mass.

Post-Race Cramping and RPE Data Collection

No EAMC was experienced during the race with a RPE of eight on a scale from 1-10. M4 did report an abdominal cramp or side stitch. This type of cramping is known as exercise-related transient abdominal pain (ETAP) and is not considered a form of EAMC. [33]

Post-Race Environmental and Race Data Collection

Participant M4 had a finish time of 2':31":00''' with an average pace per mile for this effort of 11':37'''. Total race time for M4 was 6% slower than the mean race time of 2:21:36 (47/49 finishers). Temperature range start to finish, for participant M4 was an unseasonably warm 52°-66° degrees F respectively.

Post-Race Nutrition Data Collection – Intake During Race

Participant M4 reported consuming a "handle full of Skittles" estimated by participant to be about 10-12 in quantity. Ten candies were used to calculate nutritional value. Adjusted fluid intake was estimated at 32 oz. Of this, 5 oz of hydration formula provided 49.9 kcals as CHO in the form of glucose, fructose and dextrose as well as 237.12 mg Na, 27.6 mg Ca, 24.3 mg of both K and Mg. A summary of energy and electrolyte intake during the race is provided in Table 3.12.

Table 3.12 Energy and Electrolyte Intake During Race M4

Fluid	SKRATCH						
	Energy (kcal)	CHO (g)	Na (mg)	Ca (mg)	K (mg)	Mg (mg)	
	50	13	237	28	24	24	
Solid	SKITTLES						
	Energy (kcal)	CHO (g)	Na (mg)	Ca (mg)	K (mg)	Mg (mg)	Fat (g)
	40	9.25	2.5	0	0	0	
Total	90	22	240	28	24	24	

Nutrition and Electrolyte Estimations for Participant M4

Estimated energy and macro nutrient needs for B2 are displayed in Table 3.13.

Table 3.13 Estimated Energy and Macronutrient Guidelines M4

WT (kg)	61.8						
MACRO	g/kg/bdwt	g/day	kcal/day	**Energy Needs Range**			
PRO	1.2	74	297	PRO+FAT+CHO	**% Daily Estimation**		
FAT	1	62	556	(kcal)	FAT	PRO	CHO
CHO	5	309	1236	2089	26.6%	14.2%	59.2%
CHO	6	371	1483	2336	23.8%	12.7%	63.5%
CHO	8	494	1978	2830	19.7%	10.5%	69.9%

PRO intake for M4 was 1.13 g/kg on average leading up to race day. FAT intake was 0.73 g/kg and not within the range of 0.8-2.0 g/kg/d recommendation. [30] Three-day CHO intake was 2.1 g/kg/d. Comparison of reported macronutrients and energy intake to estimated is provided in Table 3.14.

Table 3.14 Comparison of Three-Day Energy and Macronutrient Intake to Estimated Three Day Needs M4

3 Day Average		**Estimated Daily Needs 5;6;8 (g) CHO**					
PRO (g)	70	**PRO (g)**	74	**PRO (g)**	74	**PRO (g)**	74
FAT (g)	45	**FAT (g)**	62	**FAT (g)**	62	**FAT (g)**	62
CHO (g)	129	**CHO (5g)**	309	**CHO (6g)**	371	**CHO (8g)**	494
PRO (kcal)	23.5%	**PRO (kcal)**	14.2%	**PRO (kcal)**	12.7%	**PRO (kcal)**	10.5%
FAT (kcal)	33.2%	**FAT (kcal)**	26.6%	**FAT (kcal)**	23.8%	**FAT (kcal)**	19.7%
CHO (kcal)	43.3%	**CHO (kcal)**	59.2%	**CHO (kcal)**	63.5%	**CHO (kcal)**	69.9%
Total Energy (kcal)	1207	**Total Energy**	2089	**Total Energy**	2336	**Total Energy**	2830

Fluid balance for Participant M4 represented in Table 3.15 indicates a 4.3% loss of body mass within the race time of 2h':31m".

Table 3.15 Body Mass Pre and Post Race M4

PRERACE WT (lbs)	**POST RACE WT** (lbs)	**WEIGHT LOST** (lbs)	**OUNCES LOST** (oz)	**FLUID INTAKE** (adjusted oz)	**TOTAL WT LOST** (lbs)	**BDWT LOST** (%)
134.4	130.6	3.8	60.8	32	6.3	4.3%

Estimated electrolyte losses and gains for M4 are provided in Table 3.16. A comparison of M4's predicted Na and K body stores combined with the electrolyte intake at aid stations to predicted losses is provided in Table 3.17.

Table 3.16 Estimated Electrolyte Losses M4

Mineral	**Loss Range** (mg)	
Na	1134	5248
K	453	930
Mg	(+97)	84
Ca	(+111)	328

adjusted for electrolytes consumed during race

Table 3.17 Predicted Electrolyte Body Stores and Losses During Race M4

Mineral	Body Stores (mg)	Predicated Range of Stores Lost %	
Na	52569	(2.2%)	(10.0%)
K	108706	(0.4%)	(0.9%)

Participant R5 Case Presentation

Participant R5 was a 26-year-old male, recreational runner, with two to three years of running experience and a history of completing at least one half or full marathon prior to participating in the study race. His half marathon personal best time was 2’ hour 07” minutes. R5 resides at 7720 feet elevation with no history of EAMC within 12 months preceding study.

Pre-Race Data Collection – Anthropometrics

Participant R5 self-reported body weight was 184.5 lbs. (83.8 kg) and his self-reported height was 75.5”. His pre-race weight, as measured by researchers 30-60 minutes prior to the start of the race was 181.4 lbs. (82.5 kg). His pre-race BMI was 22.8 kg/m^2.

Pre-Race Data Collection – Nutrition

For the three days leading up the race, the food log revealed an average energy intake of 2541 kcals. CHO contributed 48.2% of total energy intake, 31.6% was obtained from FAT and 20.2% was obtained from PRO. Macronutrient intake data is summarized in Table 3.18. Mean dietary Na intake from food and beverage sources was 3636 mg per day (Table 3.19). Participant M4 did not consume a breakfast meal prior to race. Total energy intake reported before the race was 0 kcal.

Table 3.18 Daily Macronutrient and Energy Intake Three Consecutive Days Before Race R5

Day	PRO (g)	CHO (g)	FAT (g)	PRO (kcal)	CHO (kcal)	FAT (kcal)	Total Energy (kcal)
1	134	297	98	536 (20.6%)	1188 (45.6%)	882 (33.8%)	2606 (100.0%)
2	111	328	84	444 (17.7%)	1312 (52.2%)	756 (30.1%)	2512 (100.0%)
3	140	293	86	560 (22.4%)	1172 (46.8%)	774 (30.8%)	2506 (100.0%)
Average	128	306	89	(20.2%)	(48.2%)	(31.6%)	2541

Protein (PRO) ; Carbohydrate (CHO)

Table 3.19 Daily Sodium Intake R5

Three Consecutive Days Before Race

Day	Na (mg)
1	4704
2	4432
3	1771
Average	3636

Post-Race Anthropometric Data Collection

Body weight post-race was 178.4 lbs. Total body weight lost during the race was 6.7 lbs., which includes food and fluid consumed during race and accounts for 3.6% of total body mass.

Post-Race Cramping and RPE Data Collection

No EAMC was experienced during the race with a reported relative perceived effort (RPE) of between seven and eight on a scale from 1-10.

Post-Race Environmental and Race Data Collection

Participant R5 had a finish time of 2’06”:44’’’ with an average pace per mile for this effort of 9’:40’’’. Total race time for R5 was 10% faster than the mean race time of 2:21:36 (47/49 finishers). Temperature range start to finish, for participant R5 was an unseasonably warm 52°-66° degrees F respectively.

Post-Race Nutrition Data Collection – Intake During Race

Participant R5 consumed no solid or semi-solid products during the race; this includes gels, cubes, or electrolyte tablets. Adjusted fluid intake was estimated at 58.7 oz. with 8 oz of hydration formula providing 99.84 kcals as CHO in the form of glucose, fructose and dextrose as well as 474 mg Na, 55.3 mg Ca, 48.7 mg of both K and Mg. Summary of energy and electrolytes provided in Table 3.20.

Table 3.20 Energy and Electrolyte Intake During Race R5

Fluid	SKRATCH					
	Energy (kcal)	CHO (g)	Na (mg)	Ca (mg)	K (mg)	Mg (mg)
	50	13	237	28	24	24
Total	50	13	237	28	24	24

Nutrition and Electrolyte Estimations Participant R5

Estimated energy and macro nutrient needs for R5 are displayed in Table 3.21.

Table 3.21 Estimated Energy and Macronutrient Guidelines R5

WT (kg)	83.8						
MACRO	g/kg/bdwt	g/day	kcal/day	**Energy Needs Range**			
PRO	1.2	101	402	PRO+FAT+CHO	**% Daily Estimation**		
FAT	1	84	754	(kcal)	FAT	PRO	CHO
CHO	5	419	1676	2832	26.6%	14.2%	59.2%
CHO	6	503	2011	3168	23.8%	12.7%	63.5%
CHO	8	670	2682	3838	19.7%	10.5%	69.9%

PRO intake for R5 was 1.5 g/kg on average leading up to race day. Fat intake was 1.06 g/kg. Three-day CHO intake was 3.65 g/kg/d. Comparison of reported macronutrients and energy intake to estimated provided in Table 3.22.

Table 3.22 Comparison of Three-Day Energy and Macronutrient Intake to Estimated Three Day Needs R5

3 Day Average		**Estimated Daily Needs 5;6;8 (g) CHO**					
PRO (g)	128	**PRO (g)**	100.5	**PRO (g)**	100.5	**PRO (g)**	100.5
FAT (g)	89	**FAT (g)**	84	**FAT (g)**	84	**FAT (g)**	84
CHO (g)	306	**CHO (5g)**	419	**CHO (6g)**	503	**CHO (8g)**	670
PRO (kcal)	20.2%	**PRO (kcal)**	14.2%	**PRO (kcal)**	12.7%	**PRO (kcal)**	10.5%
FAT (kcal)	31.6%	**FAT (kcal)**	26.6%	**FAT (kcal)**	23.8%	**FAT (kcal)**	19.7%
CHO (kcal)	48.2%	**CHO (kcal)**	59.2%	**CHO (kcal)**	63.5%	**CHO (kcal)**	69.9%
Total Energy (kcal)	2541	**Total Energy**	2382	**Total Energy**	3167	**Total Energy**	3838

Fluid balance for Participant R5 represented in Table 3.23 indicates a 3.68% loss of body mass within the race time of 2’:06’:44’’’.

Table 3.23 Body Mass Pre and Post Race R5

PRERACE WT (lbs)	POST RACE WT (lbs)	WEIGHT LOST (lbs)	OUNCES LOST (oz)	FLUID INTAKE (adjusted oz)	TOTAL WT LOST (lbs)	BDWT LOST (%)
181.4	178.4	3	48	58.7	6.7	3.68%

Estimated electrolyte losses and gains for R5 are provided in Table 3.24. A comparison of R5's predicted Na and K body stores combined with the electrolyte intake at aid stations to predicted losses is provided in Table 3.25.

Table 3.24 Estimated Electrolyte Losses R5

Mineral	Loss Range (mg)	
Na	984	5359
K	459	966
Mg	(+97)	65
Ca	(+111)	325

adjusted for electrolytes consumed during race

Table 3.25 Predicted Electrolyte Body Stores and Losses During Race R5

Mineral	Body Stores (mg)	Predicated Range of Stores Lost %	
Na	77062	(1.3%)	(7.0%)
K	147404	(0.3%)	(0.7%)

Participant S6 Case Presentation

Participant S6 was a 49-year-old female, recreational runner, with less than one year of running experience and no history of completing a half or full marathon event distance prior to participating in the study race. S6 resides at 5280 feet elevation and identifies with a history of EAMC within 12 months preceding study. Location of EAMC was reported as "calf".

Pre-Race Data Collection – Anthropometrics

Participant S6 self-reported body weight was 136 lbs. (61.8 kg) and self-reported height was 67”. Pre-race weight, as measured by researchers 30-60 minutes prior to the start of the race, was 138.8 (63.1). Her pre-race BMI was 22.4 kg/m^2.

Pre-Race Data Collection – Nutrition

For the three days leading up the race, the food log revealed an average energy intake of 1664 kcals. CHO contributed 42% of total energy intake, 39% was obtained from fat (FAT), and 19% was obtained from protein (PRO). Macronutrient intake data is summarized in Table 3.26. Mean dietary Na intake from food and beverage sources was 2819 mg per day; provided in Table 3.27. Participant S6 reported eating a breakfast meal prior to race. Details of this meal are presented in Table 3.28. Total energy intake reported before the race was 342 kcal.

Table 3.26 Daily Macronutrient and Energy Intake Three Consecutive Days Before Race S6

Day	PRO (g)	CHO (g)	FAT (g)	PRO (kcal)	CHO (kcal)	FAT (kcal)	Total Energy (kcal)
1	84	136	64	336	544	576	1456
				(23.0%)	(37.4%)	(39.6%)	(100.0%)
2	91	184	99	364	736	891	1991
				(18.2%)	(37.0%)	(44.8%)	(100.0%)
3	56	168	72	224	672	648	1544
				(14.5%)	(43.5%)	(42.0%)	(100.0%)
Average	77	163	78	(19.0%)	(39.0%)	(42.0%)	1664

Protein (PRO) ; Carbohydrate (CHO)

Table 3.27 Daily Sodium Intake

Three Consecutive Days Before Race S6	
Day	**Na** (mg)
1	1952
2	2845
3	3660
Average	2819

Table 3.28 Macronutrient and Energy Intake – Breakfast Race Day S6

Day	**PRO** (g)	**CHO** (g)	**FAT** (g)	**PRO** (kcal)	**CHO** (kcal)	**FAT** (kcal)	**Total Energy** (kcal)
1	13	32	18	52 (15.2%)	128 (37.4%)	162 (47.4%)	342 (100.0%)
Total	13	32	18	(15.2%)	(37.4%)	(47.4%)	

Protein (PRO) ; Carbohydrate (CHO)

Post-Race Anthropometric Data Collection

Body weight post-race was 134.6 lbs. Total body weight lost during the race was 7.6 lbs., which includes food and fluid consumed during race and accounts for 5.1% of total body mass.

Post-Race Cramping and RPE Data Collection

Participant S6 reported experiencing an EAMC during the race with a relative perceived effort (RPE) of four to six on a scale from 1-10.

Post-Race Environmental and Race Data Collection

Participant S6 had a finish time of 2’39”:17’’’ with an average pace per mile for this effort of 12’:10’’’. Total race time for S6 was 10% slower than the mean race time of 2:21:36 (47/49 finishers). Temperature range start to finish, for participant S6 was an unseasonably warm 52°-66° degrees F respectively.

Post-Race Nutrition Data Collection – Intake During Race

Participant S6 consumed no solid or semi-solid products during the race; this includes gels, cubes, or electrolyte tablets. Adjusted fluid intake was estimated at 44 ounces with 8 oz of hydration formula provided 150 kcals as CHO in the form of glucose, fructose and dextrose as well as 711 mg Na, 83 mg Ca, 150 mg of both K and Mg. Summary of energy and electrolytes provided in Table 3.29.

Table 3.29 Energy and Electrolyte Intake During Race S6

Fluid	SKRATCH						
	Energy (kcal)	CHO (g)	Na (mg)	Ca (mg)	K (mg)	Mg (mg)	
	150	39	711	83	150	150	
Fluid	COKE						
	Energy (kcal)	CHO (g)	Na (mg)	Ca (mg)	K (mg)	Mg (mg)	Fat (g)
	47	13	15	0	0	0	0
Total	197	52	726	83	150	150	0

Nutrition and Electrolyte Estimations Participant S6

Estimated energy and macro nutrient needs for S6 are displayed in Table 3.30.

Table 3.30 Estimated Energy and Macronutrient Guidelines S6

WT (kg)	61.8						
				Energy Needs			
MACRO	g/kg/bdwt	g/day	kcal/day	**Range**			
PRO	1.2	74	296.64	PRO+FAT+CHO		**% Daily Estimation**	
FAT	1	62	556	(kcal)	FAT	PRO	CHO
CHO	5	309	1236	2089	26.6%	14.2%	59.2%
CHO	6	371	1483	2336	23.8%	12.7%	63.5%
CHO	8	494	1978	2830	19.7%	10.5%	69.9%

PRO intake for S6 was 1.25 g/kg on average leading up to race day. Fat intake was 1.26 g/kg. Three-day CHO intake was 2.63 g/kg/d. Comparison of reported macronutrients and energy intake to estimated provided in Table 3.31

Table 3.31 Comparison of Three-Day Energy and Macronutrient Intake to Estimated Three Day Needs S6

3 Day Average		**Estimated Daily Needs 5;6;8 (g) CHO**					
PRO (g)	77	**PRO (g)**	74	**PRO (g)**	74	**PRO (g)**	74
FAT (g)	78	**FAT (g)**	62	**FAT (g)**	62	**FAT (g)**	62
CHO (g)	163	**CHO (5g)**	309	**CHO (6g)**	371	**CHO (8g)**	494
PRO (kcal)	18.6%	**PRO (kcal)**	14.2%	**PRO (kcal)**	12.7%	**PRO (kcal)**	10.5%
FAT (kcal)	42.0%	**FAT (kcal)**	26.6%	**FAT (kcal)**	23.8%	**FAT (kcal)**	19.7%
CHO (kcal)	39.3%	**CHO (kcal)**	59.2%	**CHO (kcal)**	63.5%	**CHO (kcal)**	69.9%
Total Energy (kcal)	1664	**Total Energy**	2089	**Total Energy**	2336	**Total Energy**	2830

Fluid balance for Participant S6 represented in Table 3.32 indicates a 5% loss of body mass within the race time of 2':39':17'''.

Table 3.32 Body Mass Pre and Post Race

PRERACE WT (lbs)	**POST RACE WT** (lbs)	**WEIGHT LOST** (lbs)	**OUNCES LOST** (oz)	**FLUID INTAKE** (adjusted oz)	**TOTAL WT LOST** (lbs)	**BDWT LOST** (%)
138.8	134.6	4.2	67.2	44	7.6	5.00%

Estimated electrolyte losses and gains for S6 are provided in Table 3.33. A comparison of B2's predicted Na and K body stores combined with the electrolyte intake at aid stations to predicted losses is provided in Table 3.34.

Table 3.33 Estimated Electrolyte Losses S6

Mineral	Loss Range (mg)	
Na	1180	6143
K	527	1102
Mg	(+97)	81
Ca	(+111)	376

adjusted for electrolytes consumed during race

Table 3.34 Predicted Electrolyte Body Stores and Losses During Race S6

Mineral	Body Stores (mg)	Predicated Range of Stores Lost %	
Na	52568	(2.2%)	(11.7%)
K	108706	(0.5%)	(1.0%)

Summary of Exploratory EAMC Data

A summary of the exploratory EAMC predictors in all subjects is provided in Table 3.35.

Table 3.35 Summary of Possible EAMC Predictors

Subject ID	**EAMC** History	**Mean 3 Day CHO** g/kg/d	**Race Time** h:m	**RPE** 1-10	**Body Mass Lost** %	**EAMC** Race day
B2	no	9.1	1h:39m	8	4.9	no
M4	yes	2.1	2h:31m	7-8	4.3	no
R5	no	3.7	2h:06m	7	3.6	no
S6	yes	2.6	2h:39m	4-6	5	yes

Chapter 4 - Potential Nutrition Contributions to Exercise Associated Muscle Cramping – a case study approach

Abstract

A case study approach was used to gain an in-depth understanding of the nutrition-related practices and outcomes of half-marathon racers with a particular emphasis on possible predictors of exercise associated muscle cramping (EAMC). Pre-race and on course food and beverage intake, pre and post-race body weight, relative perceived effort, history of EAMC, and occurrence EAMC were recorded for four recreational runners. Each participant had a different approach to nutrition and hydration before and during the race. Carbohydrate (CHO), energy availability, and hydration status varied across cases. Reported pre-race CHO intake for all but one participant fell below 5 g/kg/day. Weight loss during the race was between 3.6-5.0%. Two of the four runners reported a history of EAMC, one of which experienced EAMC during the race. The two participants with a prior history of EAMC, also reported the lowest energy and CHO intakes. These findings highlight variability in nutrition practices among athletes and the need to understand their nutritional habits when reviewing EAMC occurrence. Future research is needed to assess the occurrence of EAMC and the presence of chronic sup-optimal nutrition and to identify where nutritional and physiological predictors converge and how their confluence exerts pressure on the central nervous system leading to muscle fatigue and ultimately EAMC.

Key Words: endurance, electrolyte, EAMC, nutrition, cramping

Exercise-associated muscle cramping (EAMC), a specific classification of debilitating skeletal muscle spasms occurring during or after exercise, are common among all sports, genders, age groups, and environments (Schwellnus, 2009). The cause of EAMC remains unknown, but new research is challenging decades of interventions that historically have been rooted in anecdotal evidence or limited research to support their use (Braulick, Miller, Albrecht, Tucker, & Deal, 2013; Jung, Bishop, Al-Nawwas, & Dale, 2005; Murray, Miller, & Edwards, 2016; Schwellnus, Drew, & Collins, 2011; Sulzer, Schwellnus, & Noakes, 2005). Emerging science suggests altered neuromuscular control and the central nervous system are key components in the etiology of EAMC's; challenging the electrolyte or dehydration theories that currently drive EAMC intervention strategies (Miller, 2015; Miller, Stone, Huxel, & Edwards, 2010; Schwellnus, 2009; Stone et al., 2003; Summers, Snodgrass, & Callister, 2014).

Historically, dehydration along with electrolyte loss from sweating has been viewed as the primary cause of EAMC. Despite being based on observational or anecdotal evidence, this widely accepted belief has formed the foundation for EAMC interventions. A brief snapshot of the ubiquitous nature of the dehydration/electrolyte loss theory-based interventions is provided in Table 1. Although the dehydration/electrolyte loss theory-based interventions are widely recommended, recent research into the cause of EAMC has been unable to demonstrate a connection between dehydration and electrolyte loss.

Table 4. Electrolyte and Fluid Recommendations

SOURCE	DATE	AUTHOR/ENTITY	RECOMMENDATION
Heat Illness: A Handbook for Medical Officers (Handbook, 1991)	1991	U.S. Army Institute of Environmental Medicine	salt supplementation
The Importance of Salt in the Athlete's Diet (Valentine, 2007)	2007	Verle Valentine, MD	16fl oz sports drink with 2.5 ml of additional salt with onset of muscle twitching
National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes (Casa et al., 2000)	2000	Casa, D et. al.	0.3-0.7 g/L salt
Muscle Cramping in the Heat ("Muscle Cramping In the Heat," n.d.)	retrieved 3/22/2019	University of Washington - The Sports Institute	consume extra salt in diet, 1/4 tsp table salt per 16oz, salt tablets
Muscle Cramps: The Right Ways for the Dog Days; Gatorade Sports Science Institute (Randy Eichner, 2003b)	3/1/2003	Randy Eichner, MD	1/4 tsp table salt per 16-20oz
Curbing Muscle Cramps: More than Oranges and Bananas; Gatorade Sports Science Institute (Randy Eichner, 2003a)	7/25/2003	Randy Eichner, MD	"The prevention - and the cure - of heat cramping is salt and fluids. The solution is saline. "
49ers Fitness Corner: Nutrition ("49ers Fitness Corner: Nutrition," 2005)	9/28/2005	San Francisco 49ers NFL	"add extra electrolytes (GatorLytes) to their Gatorade and have them drink 20 oz of salted Gatorade before games and practices; and drink Gatorade during the game, at the half, and after the competition."
Workout Tips for Exercise in the Heat ("Workout Tips for Exercise in the Heat," 2005)	3/15/2005	University of Colorado Sports Medicine	1/4 - 1/2 tsp table salt per liter of fluid

Recent controlled research studies assessing dehydration using plasma volume, blood volume, and body weight differences of participants reporting EAMC to those that do not reflect a strong disassociation between dehydration or electrolyte loss and cramping (Braulick et al., 2013; Jung et al., 2005; Schwellnus et al., 2011; Sulzer et al., 2005).

Studies evaluating the loss of electrolytes and electrolyte serum levels in a variety of participants including football, marathon, and triathlon, have not made a connection between electrolyte levels or electrolyte loss and the occurrence of EAMCs (Jung et al., 2005; Maughan, 1986; Schwellnus et al., 2011; Sulzer et al., 2005).

One emerging variable for EAMC is the effect fatigued muscles have on neuromuscular control through hypothesized mechanisms of hyperexcitability related to increased neuron activity, exercise induced fatigue of muscle control elements (golgi tendon organ and muscle spindles), as well as muscle contractile processes associated with carbohydrate (CHO) signaling (Bentley, 1996; Hearris, Hammond, Fell, & Morton, 2018).

As evidence mounts against old theories behind EAMC there is also a need to reassess nutritionally modifiable causes; specifically CHO, because it is well-known that glycogen depletion results in muscle fatigue (Hearris et al., 2018). Additionally, the importance of CHO on EAMC may be attributed to more than energy availability as research uncovers CHO metabolism as an integral component of cell signaling associated with muscle contraction (Hearris et al., 2018; Ørtenblad, Westerblad, & Nielsen, 2013).

Nutrition and hydration practices vary dramatically between individual athletes (Baranauskas et al., 2015). Bergeron demonstrated that individual responses to athletic competition (i.e., sweat rate, sweat sodium concentration) vary dramatically as well (Bergeron, 2014). In addition, the risk of EAMC is known to be related to past history of cramping. As such, prior to assessing the role of possible predictors of EAMC, the nutrition and hydration practices, individual responses, and history of EAMC in endurance athletes must first be better characterized. The purpose of this study is to gain an in-depth understanding of the nutrition-related practices and outcomes of half-marathon racers with a particular emphasis on possible predictors of EAMC.

Method

A case study approach was used to capture pre-race and on course food and beverage intake, pre and post-race body weight, perceived effort, history of EAMC, and occurrence of EAMC for four recreational half-marathon runners competing within age-group categories. All adult runners with a minimum age of 18 years old registered to participate in a designated half-marathon scheduled to take place in the fall of 2018 in Colorado were queried for participation in this study. This study was approved by the Institutional Review Boards at the university where the study was housed and conformed to the ethical principles set forth in the Declaration of Helsinki. Runners who volunteered to participate provided written informed consent.

A pre-race questionnaire was used to gather participant information and demographics including age, race/ethnicity, history of cramping, location of cramping, personal record for distance, estimated completion time, and altitude of residence prior to the race. The pre-race questionnaire was provided to the participants electronically after registration through email and was completed 7-14 days prior to race day.

All participants self-reported dietary intake using the MyFitnessPal application. Intake of food, beverages, and supplements was collected for three consecutive days leading up to the race, as well as race day breakfast. Instructions on how to maintain the food log were provided through email. Video chat and email support were available by researcher on an as needed basis. Participant's dietary data was extracted and reviewed remotely from the digital food log utilizing participant login information generated specifically for each participant and stored offline. Based on the dietary intake recorded, the application provided researchers with reports detailing the total daily energy, fat, protein, carbohydrate, and sodium intake for each participant. A post-race questionnaire was administered by researchers immediately after each participant completed the race. This questionnaire was used to document the consumption of any on course (peri-race) nutrition record the occurrence of EAMC during the race, and identify the location of cramp if EAMC occurred.

A Withings Nokia Body+ Body Composition Scale was used to obtain participants pre and post-race body weights. Body weights were obtained with runners in race clothing with shoes removed. Height was self-reported. BMI's were calculated using the self-reported heights and pre-race measured weights in the standard mathematical formula: weight (kg) / [height (m)] 2 ("Centers for Disease Control and Prevention. About adult BMI, healthy weight.," n.d.).

Energy Need Estimations

Estimated energy and macronutrient needs were created using a standardized g/kg chart widely used in sports dietetics (Burke, Hawley, Wong, & Jeukendrup, 2011). The chart which provides a range of CHO intakes is based on the assumption that the athletes is engaged in less than 3 hours of training per day. Estimated electrolyte losses were calculated based on changes in body weight using Shirreff & Maughan's average sweat concentration (Shirreffs & Maughan, 1997). Estimated body stores of Na and K where combined with electrolyte intake and compared to estimated electrolyte losses. Estimations for whole body Na and K were approximated using 52-

60 mmol/kg Na for males, 48-55mmol/kg Na for females and 1759mg/kg K for both genders (Alpers D; Stenson W; Taylor B; Beir D, 2008).

Fluid intake was reported by participants on post-race questionnaire and then adjusted for spill and fill at aid stations post-race by researcher. One ounce was subtracted from every reported cup of fluid intake.

Observations

Start time temperature and weather conditions were: 52° F, 70% humidity, 42° F dew point, sunny, with no cloud cover. Six runners initially enrolled in the study; however, only four provided all of the necessary information. Of these four, two were male and two were female. Additional participant characteristics are listed in Table M1.

Participant B2 was a 31-year old male having four or more years of running experience with a history of completing at least one half or one full marathon prior to participating in the study race. No reported history of EAMC within the 12 months preceding study. For the three days prior to the race, mean energy and sodium intakes were 4353 kcal and 3589 mg, respectively. CHO intake averaged 9 g/kg /day and accounted for 63.1%, of total energy, PRO intake averaged 2.0 g/kg/day and accounted for 14.1% of total energy, while fat intake averaged 1.48 g/kg/ day and accounted for 22.8% of total energy. Prior to the race, participant B2 consumed a breakfast providing 1148 kcal,142 g CHO and 832 mg sodium.

Participant M4 was a 25-year-old female with two to three years of running experience and a history of completing at least one half or full marathon prior to participating in the study race. She had a history of EAMC within the 12 months preceding the study. Location of EAMC was reported as "calf". For the three days prior to the race, mean energy and sodium intakes were 1207 kcal and 2676 mg, respectively. CHO intake averaged 2 g/kg /day and accounted for

43.3%, of total energy, PRO intake averaged 1.1 g/kg/day and accounted for 22.2% of total energy, while fat intake averaged 0.73 g/kg/ day and accounted for 33.2% of total energy. Participant M4 did not consume a breakfast meal prior to race. Total energy intake reported before the race was 0 kcal.

Participant R5 was a 26-year-old male with two to three years of running experience and a history of completing at least one half or full marathon prior to participating in the study race. No reported history of EAMC within the 12 months preceding study. For the three days prior to the race, mean energy and sodium intakes were 2541 kcal and 3636 mg, respectively. CHO intake averaged 3.7 g/kg /day and accounted for 48.2% of total energy, PRO intake averaged 1.5 g/kg/day and accounted for 20.2% of total energy, while fat intake averaged 1.1 g/kg/ day and accounted for 31.6% of total energy. Participant R5 did not consume a breakfast meal prior to race. Total energy intake reported before the race was 0 kcal.

Participant S6 was a 49-year-old female with less than one year of running experience and no history of completing a half or full marathon event distance prior to participating in the study race. Identifies with a history of EAMC within 12 months preceding study. Location of EAMC was reported as "calf". For the three days prior to the race, mean energy and sodium intakes were 1664 kcal and 2819 mg, respectively. CHO intake averaged 2.6 g/kg /day and accounted for 39.3%, of total energy, PRO intake averaged 1.2 g/kg/day and accounted for 19% of total energy, while fat intake averaged 1.3 g/kg/ day and accounted for 42% of total energy. Participant S6 did report eating a breakfast meal prior to. Total energy intake reported before the race was 342 kcal.

Summary of Exploratory EAMC Data

Two of the four participants reported a prior history of EAMC while one participant reported a race occurrence of EAMC. All of the participants lost weight during the course of the race. Weight loss ranged from 6.3 lbs. to 8.8 lbs.. K losses at the estimated maximum was 1% or less for all subjects and varied little from the extremes. Na loss estimations varied greatly between the extremes ranging from 1% up to 12%. A summary of the exploratory EAMC predictors for all subjects is provided in Table M2.

Table M1 Summary of Participant Characteristics

	Participant			
Characteristic	**B2**	**M4**	**R5**	**S6**
Sex/Gender	Male	Female	Male	Female
Age	31	25	26	49
Height	68"	65"	75.5"	67"
Weight	165#	136#	184.5#	136#
BMI	25.1	22.7	22.8	21.3
Altitude of Residence	6200 ft	5280 ft	7220 ft	5280 ft
Running Experience	4+ years	2-3 years	2-3 years	0-1 year

Table M2 Summary of Incidence of EAMC and Possible Predictors

		Participant			
Variable		**B2**	**M4**	**R5**	**S6**
EAMC	History	no	yes	no	yes
EAMC	race day	no	no	no	yes
Mean 3 Day CHO	g/kg/d	9.1	2.1	3.7	2.6
Est. Energy Needs	kcals	2535-3435	2089-2830	2382-3838	2089-2830
Mean 3 Day Energy Intake	% of Est.	127-172	43-58	66-107	59-80
Race Time	h:m	1h:39m	2h:31m	2h:06m	2h:39m
RPE	1-10	8	7-8	7	4-6
Body Mass Lost	%	4.9	4.3	3.6	5
On-course CHO	g	52	22	26	52
On-course Fluid	*fl oz	28	32	59	44
Na Predicted Stores	grams	69	53	77	52
Na Predicted Losses	%	1.4 - 9.7	2.2 - 10	1.3 -7	2.2 - 11.7
K Predicted Stores	grams	131.9	108.7	147.4	108.7
K Predicted Losses	%	0.4 - 0.9	0.4 - 0.9	0.3 - 0.7	0.5 - 1

*adjusted fluid intake. **estimated (Est.)

Discussion

Each participant had different approaches to nutrition and hydration before and during the race. This highlights variability in nutrition practices among athletes and the need to understand their nutritional habits when reviewing EAMC occurrence. Many athletes, especially female athletes, do not meet nutritional guidelines for optimal performance(Baker, Heaton, Nuccio, & Stein, 2014; Masson & Lamarche, 2016). This study founds similar results. For example, when compared to best-practices one subject greatly exceeded total energy intake at 128%-172% of needs. The remaining three subjects reflected suboptimal to poor energy intake ranging from 40%-80% of needs. Fat and PRO were less variable between participants and fell within or just outside of recommended intakes. CHO intake for all but one participant fell below the 5-8 g/kg recommendation associated with endurance sports lasting less than three hours per day during race season (Burke et al., 2011).

Hydration status was well below the goal of limiting body mass loss to less than 2% of total loss and ranged from 3.6-5%. Estimated Na loss reinforced the need for individual assessment and replacement strategies, because the ranges were too vast to base any practical recommendations upon. Na loss estimations varied greatly between the extremes; ranging from 1% up to 12%. K estimations were far below the researcher's expectations; reflecting 1% or less of total body K loss.

Intensity combined with duration proved to be a confounding variable. This is likely to due to the variance in the participant's level of fitness which was not queried as well as unseasonably warm weather conditions. Unexpectedly, EAMC occurred in the participant with the lowest reported RPE.

Limitations of this study included the inability to obtain nude post-race weights to control for soaked clothing resulting in weight and body mass loss calculations assuming an error factor of up to 10%. The inability to control aid station fluid intake for participants prevents accuracy in electrolyte and body mass loss data. Self-reported height reduces the precision of calculations. Lastly, volume and intensity of training was not documented. This would have provided insight into whether energy intakes for the participants were adequate, as well as providing a means of comparison for RPE on race day.

It is beyond the scope of this case study approach to prove or disprove the validity of any single proposed predictor of EAMC. It lacks statistical strength due to low participation (n=4) and prevents hypothesis testing. However, a case study approach such as this one balances the aggregate data of all recent and relevant research on EAMC within the context real-world outcomes and its impact on decision-making in practice. The mixture of qualitive research and quantitative data collection highlights the exploratory nature of a case study approaches which helps to generate questions and identify specific questions for future hypothesis testing. For example, from this study one possible avenue for future research could be to assess the occurrence of EAMC and the presence of chronic sup-optimal nutrition. Another would be to determine where nutritional and physiological predictors converge and how their confluence exerts pressure on the central nervous system leading to muscle fatigue and ultimately EAMC.

49ers Fitness Corner: Nutrition. (2005). Retrieved March 22, 2019, from https://www.49ers.com/news/49ers-fitness-corner-nutrition-549320

Alpers D; Stenson W; Taylor B; Beir D. (2008). *Manual of Nutritional Therapeutics*. Philadelphia: Wolters Kluwer - Lippincott Williams & Wilkins.

Baker, L. B., Heaton, L. E., Nuccio, R. P., & Stein, K. W. (2014). Dietitian-observed macronutrient intakes of young skill and team-sport athletes: adequacy of pre, during, and postexercise nutrition. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(2), 166–176. https://doi.org/10.1123/ijsnem.2013-0132

Baranauskas, M., Stukas, R., Tubelis, L., Žagminas, K., Šurkienė, G., Švedas, E., … Abaravičius, J. A. (2015). Nutritional habits among high-performance endurance athletes. *Medicina (Kaunas, Lithuania)*, *51*(6), 351–362. https://doi.org/10.1016/j.medici.2015.11.004

Bentley, S. (1996). Exercise-induced muscle cramp. Proposed mechanisms and management. *Sports Medicine (Auckland, N.Z.)*, *21*(6), 409–420. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8784961

Bergeron, M. F. (2014). Hydration and thermal strain during tennis in the heat. *British Journal of Sports Medicine*, *48*(SUPPL. 1), 1–7. https://doi.org/10.1136/bjsports-2013-093256

Braulick, K. W., Miller, K. C., Albrecht, J. M., Tucker, J. M., & Deal, J. E. (2013). Significant and serious dehydration does not affect skeletal muscle cramp threshold frequency. *British Journal of Sports Medicine*, *47*(11), 710–714. https://doi.org/10.1136/bjsports-2012-091501

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences*, *29*(SUPPL. 1). https://doi.org/10.1080/02640414.2011.585473

Casa, D. J., Lawrence, A. E., Susan, H. K., Scott, M. J., Ralph, R. V, Brent, R. S. E., … Jennifer, S. A. (2000). National Athletic Trainers’ Association Position Statement: Fludi Replacement for Athletes. *Journal of Athletic Training*, *35*(2), 212–224.

Centers for Disease Control and Prevention. About adult BMI, healthy weight. (n.d.). Retrieved December 27, 2017, from https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

Handbook, A. (1991). *Heat Illness: A Handbook for Medical Officers*.

Hearris, M. A., Hammond, K. M., Fell, J. M., & Morton, J. P. (2018). Regulation of muscle glycogen metabolism during exercise: Implications for endurance performance and training adaptations. *Nutrients*. https://doi.org/10.3390/nu10030298

Jung, A. P., Bishop, P. A., Al-Nawwas, A., & Dale, R. B. (2005). Influence of hydration and electrolyte supplementation on incidence and time to onset of exercise-associated muscle cramps. *Journal of Athletic Training*, *40*(2), 71–75.

Masson, G., & Lamarche, B. (2016). Many non-elite multisport endurance athletes do not meet sports nutrition recommendations for carbohydrates. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition et Metabolisme*, *41*(7), 728–734. https://doi.org/10.1139/apnm-2015-0599

Maughan, R. J. (1986). Exercise-induced muscle cramp: a prospective biochemical study in marathon runners. *Journal of Sports Sciences*, *4*(1), 31–34. https://doi.org/10.1080/02640418608732095

Miller, K. C. (2015). Rethinking the Cause of Exercise-Associated Muscle Cramping: Moving beyond Dehydration and Electrolyte Losses. *Current Sports Medicine Reports*, *14*(5), 353–354. https://doi.org/10.1249/JSR.0000000000000183

Miller, K. C., Stone, M. S., Huxel, K. C., & Edwards, J. E. (2010). Exercise-Associated Muscle Cramps: Causes, Treatment, and Prevention. *Sports Health*, *2*(4), 279–283. https://doi.org/10.1177/1941738109357299

Murray, D., Miller, K. C., & Edwards, J. E. (2016). Does a Reduction in Serum Sodium Concentration or Serum Potassium Concentration Increase the Prevalence of Exercise-Associated Muscle Cramps? *Journal of Sport Rehabilitation*, *25*(3), 301–304. https://doi.org/10.1123/jsr.2014-0293

Muscle Cramping In the Heat. (n.d.). Retrieved March 22, 2019, from https://depts.washington.edu/shsi/article/muscle-cramping-in-the-heat-2/

Ørtenblad, N., Westerblad, H., & Nielsen, J. (2013). Muscle glycogen stores and fatigue. *Journal of Physiology*, *591*(18), 4405–4413. https://doi.org/10.1113/jphysiol.2013.251629

Randy Eichner, M. D. (2003a). Curbing Muscle Cramps : More than Oranges and Bananas Curbing Muscle Cramps : More than Oranges and Bananas. Retrieved March 22, 2019, from https://ihsaa-static.s3.amazonaws.com/Sports_Medicine_Wellness/Injury_Prevention_Treatment/GSSI-

Curbing_Muscle_Cramps.pdf

Randy Eichner, M. D. (2003b). Muscle Cramps: The Right Ways for the Dog Days. Retrieved March 22, 2019, from https://www.fhsaa.org/sites/default/files/orig_uploads/health/pdf/gatorade_musclecramps.pdf

Schwellnus, M. P. (2009). Cause of Exercise Associated Muscle Cramps (EAMC) - Altered neuromuscular control, dehydration or electrolyte depletion? *British Journal of Sports Medicine*, *43*(6), 401–408. https://doi.org/10.1136/bjsm.2008.050401

Schwellnus, M. P., Drew, N., & Collins, M. (2011). Increased running speed and previous cramps rather than dehydration or serum sodium changes predict exercise-associated muscle cramping: A prospective cohort study in 210 Ironman triathletes. *British Journal of Sports Medicine*, *45*(8), 650–656. https://doi.org/10.1136/bjsm.2010.078535

Shirreffs, S. M., & Maughan, R. J. (1997). Whole body sweat collection in humans: an improved method with preliminary data on electrolyte content. *Journal of Applied Physiology (Bethesda, Md. : 1985)*, *82*(1), 336–341. https://doi.org/10.1152/jappl.1997.82.1.336

Stone, M. B., Edwards, J. E., Stemmans, C. L., Ingersoll, C. D., Palmieri, R. M., & Krause, B. A. (2003). Certified Athletic Trainers' Perceptions of Exercise-Associated Muscle Cramps. *Journal of Sport Rehabilitation*, *12*(4), 333–342. https://doi.org/10.1123/jsr.12.4.333

Sulzer, N. U., Schwellnus, M. P., & Noakes, T. D. (2005). Serum electrolytes in ironman triathletes with exercise-associated muscle cramping. *Medicine and Science in Sports and Exercise*, *37*(7), 1081–1085. https://doi.org/10.1249/01.mss.0000169723.79558.cf

Summers, K. M., Snodgrass, S. J., & Callister, R. (2014). Predictors of Calf Cramping in Rugby League. *The Journal of Strength & Conditioning Research*, *28*(3). Retrieved from https://journals.lww.com/nsca-jscr/Fulltext/2014/03000/Predictors_of_Calf_Cramping_in_Rugby_League.24.aspx

Valentine, V. (2007). The importance of salt in the athlete's diet. *Current Sports Medicine Reports*, *6*(4), 237–240. Retrieved from http://www.fitday.com/fitness-articles/nutrition/healthy-eating/the-importance-of-salt-in-your-diet.html

Workout Tips for Exercise in the Heat. (2005). Retrieved March 22, 2019, from http://www.ucdenver.edu/academics/colleges/medicine/sportsmed/cusm_patient_resources/Documents/Workout Tips for Exercise in the Heat.pdf

Chapter 5 - Discussion

Study Adaptation

As subject compliance and participation declined, rendering a statistical analysis impossible, a case study series approach was applicable. The controlled nature of the original study combined with the detailed nutrition data collection has provided an opportunity to explore CHO availability, energy intake, electrolytes, and hydration on EAMC occurrence in the context of free-living, recreational, endurance runners.

Energy Intakes

When compared to best-practices one male subject greatly exceeded total energy intake at 127%-172% of needs. The remaining three subjects varied considerably with a gender bias towards s suboptimal to poor energy intake, 43-80% of needs met, among the female participants when compared to predictions. Both participants with a history of EAMC displayed sub-optimal three-day energy intakes 43-58% and 59-80% of estimated needs.

Carbohydrates and Fat

The growing body of evidence against electrolyte loss as cause for EAMC and in the favor of neuromuscular fatigue (NMF) underlies the need to reassess nutritionally modifiable causes.[1,9] CHO and glycogen availability, a well-known determinant in muscle fatigue, is good starting point.[24] As a percent of total daily energy, the average CHO intake recorded for three days prior to the event ranged from 39%-63%. While the use of percentages as a basis for macronutrient recommendations has been replaced with g/kg guidelines, percentages remain a valuable data point for displaying a nutrient in the context of a whole diet. When expressed as g/kg the range of CHO intake for three days was 2.1-9.0 g/kg. The lowest value (2.1 g/kg) of

CHO intake was not associated with the lowest total contribution of CHO within the three-day energy intakes (39%). Among subjects (n=4) one EAMC was experienced in the calf of subject S6 who reported the lowest three-day CHO intake of 39% (2.6 g/kg). Both participants with a history of EAMC displayed sub-optimal three-day CHO intakes (2.1 and 2.6 g/kg).

On-course-race CHO intakes are key to mitigating glycogen depletion, lowering RPE, and delaying fatigue. Current practice recommendations are 30-60g CHO/h for 1.0-2.5 hours up to 90g CHO/h beyond 2.5 hours in duration.[29] Only two of the four subjects met the guidelines for CHO intake during activity. Those that did not meet recommendations did not experience EAMC.

It should be noted that estrogen enhances lipid oxidation during activity bestowing a benefit to women in participating in extended endurance events. [34] This indicates a potential need for higher fat and lower CHO intakes at this race pace and distance, but is dependent on the phase of the menstrual cycle during activity.[35] In some studies it has been shown that female participants do not utilize glycogen during exercise the same as their male counterparts.[35] CHO kinetics are also dependent on the menstrual phase similar to FAT oxidation. These gender differences in macro nutrient use during exercise would underscore the need for more individualized CHO recommendations with female endurance participants.

Intensity and Duration

The (NMF) theory provides an alternative explanation to the cause of EAMCs by implicating a combination of muscle fatigue and exogenous fatigue variables that affect the central nervous system.[1,6,36] Intensity and duration of activity are two of the proposed fatigue variables in addition to CHO availability and hydration status. The occurrence of EAMC can be associated with over-reaching of the participant by exceeding muscular endurance capabilities, sustaining paces beyond athletic potential, or both.[36,37,38]

RPE for three of the four subjects was relatively high; scoring 7-8 on a scale of 1-10. None of the high RPE subjects, B2, M4 and R5, reported experiencing an EAMC during the study race. Ironically, the lowest RPE report of 4-6 was associated with the slowest race time of 2h:39m for subject S6; who experienced an EAMC in the calf.

Hydration

It has been well established that fluid balance and loss of total body mass from sweating can decrease performance.[39,40] One of the possible mechanisms behind muscular fatigue leading to performance degradation is hypohydration. The exact cause is unclear however hydration status is a component in several performance oriented functions such as; core temperature regulation, cardiac output, and rate of glycogen utilization.[41] Subjects in this study saw significant levels of dehydration ranging from 3.6-5% of total body mass. Among running studies for 1-hour runs, 10K and Half-Marathon distances the average body weight mass decreases from sweat losses ranged between 1.7-3.1%.[42–44] The greatest amount of body mass loss (5%) was experienced by S6 who also possessed the longest completion time of 2h:39m and experienced an EAMC. Subject M4 who reported a race time of 2h:31m did not experience EAMC with a body mass loss of 4.3% despite a high RPE rating of 7-8.

Electrolytes

In this study, a sweat analysis was not done. Instead, an estimation of electrolyte losses during race was constructed using Shirreff & Maughan's average sweat concentration data.[31] These losses were then compared to estimated body whole body stores of K and exchangeable Na. K calculations were based upon 1759 mg/kg for adults. [45] Exchangeable Na was approximated using 40mmol/kg for males and 47 mmol/kg females.[32] The cramping participant (S6) in this study exhibited the greatest range of possible Na loss 2.2-11.7%. Similarly, both participants reporting a history of EAMC had the greatest potential for Na losses at 10 and 11.7%.

K losses at the estimated maximum rate of excretion was 1% or less of total body stores for all subjects and varied little between minimum and maximum loss rates. Na loss estimations varied greatly between the extremes; ranging from 1% up to 12% of exchangeable body stores. This rate of Na loss reflects a rate of 460-1840 mg/L and is similar to other findings.[31,46] Both K and Na loss predictions are adjusted for on-course race intake of reported food and beverages. Due to the variability and individuality of Na losses few recent recommendations for Na intake are available for comparative purposes and, in some cases, have been replaced with suggestions for individualized assessment of the participant's needs. 2007 generalized recommendations for Na intake were 0.5-0.7g/L.[47]

History and Occurrence of EAMC

History of prior EAMC was documented and raises interesting questions when viewed with data from this study. For example, two of the four study participants reported a previous history of EAMC, and the two who experienced cramps reported the lowest CHO intakes, reported total energy intakes well below recommendations, and had the longest duration of activity. This observation leads one to ask whether there may be an association between EAMC and chronic suboptimal nutrition.

The one participant who experienced an EAMC reported a history of prior EAMC, experienced the greatest body mass loss, experienced the greatest estimated Na loss, and reported suboptimal energy and CHO intakes. While this observed case appears to be in keeping with the traditional belief that dehydration and/or electrolyte loss are the main contributors to EAMC, it also generates questions regarding the potential contribution of suboptimal energy and CHO intakes.

Confluence of Possible Predictors

While seemingly consistent with the dehydration/electrolyte loss theory, the finding of the current case study combined with emerging studies indicating possible muscle fatigue with PNS interactions in EAMC provide reason to assess nutritional factors alongside non-nutritional factors as part of a multifactorial process in the EAMC. Figure 1 depicts this possible process.

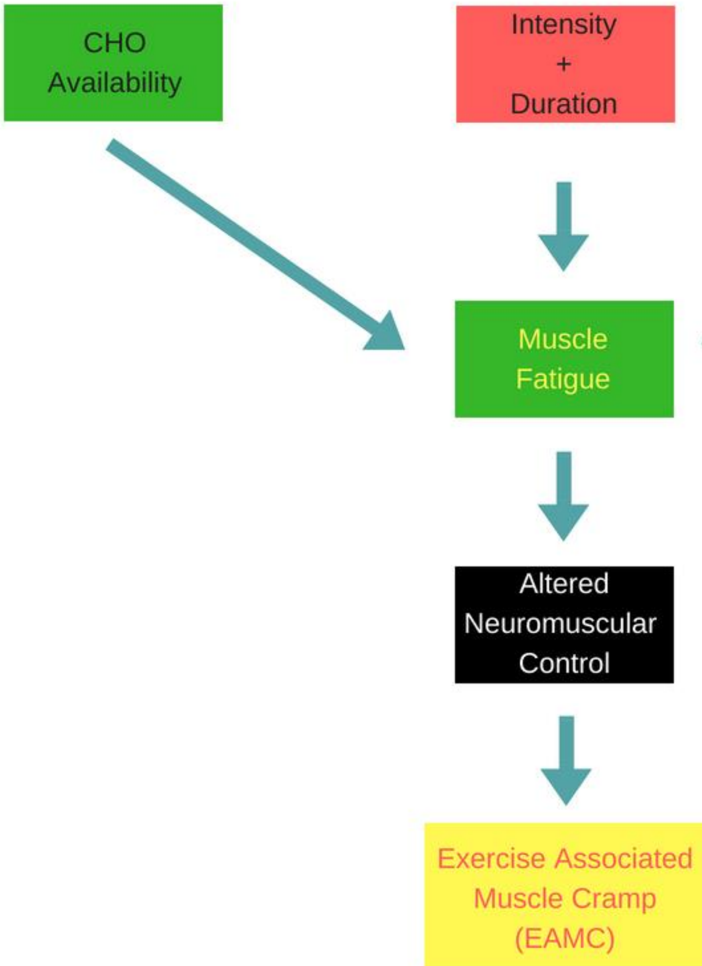

Figure 1 Hypothesized Interactions of EAMC Predictors

Strengths and Limitations

It is beyond the scope of this case study approach to prove or disprove the validity of any single proposed predictor of EAMC. It lacks statistical strength due to low participation (n=4) and prevents hypothesis testing. However, a case study approach such as this one balances the aggregate data of all recent and relevant research on EAMC within the context real-world outcomes and its impact on decision-making in practice. The mixture of qualitative research and quantitative data collection provides a good foundation for exploration into the idea of multiple predictors contributing to EAMC with indications for future hypothesis testing.

An additional strength of this case study approach was the use of MyFitnessPal (MFP) for food logging. MFP provided a level of detail in diet recall for three days in free-living participants not typically available. However, limitations in self-reported nutrition logs exist. Such as; inaccurate portions, tendency to report socially desirable portions, delaying reporting resulting on poor recall, and conscious dietary changes during reporting period.

Limitations of this study included the inability to obtain nude post-race weights to control for soaked clothing resulting in weight and body mass loss calculations assuming an error factor of up to 10%. Sweat concentration analysis rather than estimates based on weight loss alone would have provided a more precise measure of electrolyte loss concentrations. The inability to control aid station fluid intake for participants prevents accuracy in electrolyte and body mass loss data. Self-reported height reduces the precision in calculation. Lastly, volume and intensity of training was not documented. This would have provided insight into whether energy intakes for the participants were adequate, as well as providing a means of comparison for RPE on race day.

Conclusion

Each participant had different approaches to nutrition and hydration before and during the race. This highlights variability in nutrition practices among athletes and the need to understand their nutritional habits when reviewing EAMC occurrence. In many cases athletes do not meet nutritional guidelines, especially females.[48,49] This study founds similar results. For example, when compared to best-practices one subject greatly exceeded total energy intake at 128%-172% of needs. The remaining three subjects reflected suboptimal to poor energy intake ranging from

40%-80% of needs. Fat and PRO were less variable between participants and fell within or just outside of recommended intakes. CHO intake for all but one participant fell below the 5-8 g/kg recommendation associated with endurance sports lasting less than three hours per day during race season.

Hydration status was well below the goal of limiting body mass loss to less than 2% of total loss and ranged from 3.6-5%. Estimated Na loss reinforced the need for individual assessment and replacement strategies, because the ranges were too vast to base any practical recommendations upon. Na loss estimations varied greatly between the extremes; ranging from 1% up to 12%. K estimations were far below the researcher's expectations; reflecting 1% or less of total body K loss.

Intensity combined with duration proved to be a confounding variable. This is likely to due to the variance in the participant's level of fitness which was not queried as well as unseasonably warm weather conditions. Unexpectedly, EAMC occurred in the participant with the lowest reported RPE.

This study highlights the need for case study approaches such as this that illustrate the importance of evidence-based practice for the novice practitioner. The volume of research on any one topic makes it difficult to remain current. Combined with specific populations and use-case scenarios applying current literature to decision making becomes complicated. Furthermore, the exploratory nature of case study approaches helps generate questions and identify specific questions for future hypothesis testing. For example, from this study one possible avenue for future research could be to assess the occurrence of EAMC and the presence of chronic sup-optimal nutrition. Another would be to determine where nutritional and physiological predictors converge and how their confluence exerts pressure on the central nervous system leading to muscle fatigue and ultimately EAMC.

Electrolyte loss estimates based on weight loss do not provide the best measure of electrolyte loss concentrations. The inability to control aid station fluid intake for participants prevents accuracy in electrolyte and body mass loss data. Self-reported height reduces the precision of calculations. Lastly, volume and intensity of training was not documented. This would have provided insight into whether energy intakes for the participants were adequate, as well as providing a means of comparison for RPE on race day.

It is beyond the scope of this case study approach to prove or disprove the validity of any single proposed predictor of EAMC. It lacks statistical strength due to low participation (N=4) which prevents hypothesis testing. However, a case study approach such as this one balances the aggregate data of all recent and relevant research on EAMC within the context real-world outcomes and its impact on decision-making in practice. The mixture of qualitative research and quantitative data collection highlights the exploratory nature of a case study approaches which helps to generate questions and identify specific questions for future hypothesis testing. While the observations of this study are not inconsistent with the dehydration/electrolyte loss theory, several possible avenues for future research present themselves. Such future research undertakings include assessing the occurrence of EAMC and the presence of chronic sup-optimal nutrition, quantifying muscle glycogen stores in the muscle bellies of cramping muscles or determining where nutritional and physiological predictors converge and how their confluence exerts pressure on the peripheral nervous system leading to muscle fatigue and ultimately EAMC.

References

1. Schwellnus MP. Cause of Exercise Associated Muscle Cramps (EAMC) - Altered neuromuscular control, dehydration or electrolyte depletion? *Br J Sports Med*. 2009;43(6):401-408. doi:10.1136/bjsm.2008.050401
2. Jung AP, Bishop PA, Al-Nawwas 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.
3. Murray D, Miller KC, Edwards JE. Does a Reduction in Serum Sodium Concentration or Serum Potassium Concentration Increase the Prevalence of Exercise-Associated Muscle Cramps? *J Sport Rehabil*. 2016;25(3):301-304. doi:10.1123/jsr.2014-0293
4. 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*. 2013;47(11):710-714. doi:10.1136/bjsports-2012-091501
5. Sulzer NU, Schwellnus MP, Noakes TD. Serum electrolytes in ironman triathletes with exercise-associated muscle cramping. *Med Sci Sports Exerc*. 2005;37(7):1081-1085. doi:10.1249/01.mss.0000169723.79558.cf
6. Schwellnus MP, Drew N, Collins M. Increased running speed and previous cramps rather than dehydration or serum sodium changes predict exercise-associated muscle cramping: A prospective cohort study in 210 Ironman triathletes. *Br J Sports Med*. 2011;45(8):650-656. doi:10.1136/bjsm.2010.078535
7. Summers KM, Snodgrass SJ, Callister R. Predictors of Calf Cramping in Rugby League. *J Strength Cond Res*. 2014;28(3). https://journals.lww.com/nsca-jscr/Fulltext/2014/03000/Predictors_of_Calf_Cramping_in_Rugby_League.24.aspx.
8. Miller KC, Stone MS, Huxel KC, Edwards JE. Exercise-Associated Muscle Cramps: Causes, Treatment, and Prevention. *Sports Health*. 2010;2(4):279-283. doi:10.1177/1941738109357299
9. Miller KC. Rethinking the Cause of Exercise-Associated Muscle Cramping: Moving beyond Dehydration and Electrolyte Losses. *Curr Sports Med Rep*. 2015;14(5):353-354. doi:10.1249/JSR.0000000000000183
10. Stone MB, Edwards JE, Stemmans CL, Ingersoll CD, Palmieri RM, Krause BA. Certified

Athletic Trainers' Perceptions of Exercise-Associated Muscle Cramps. *J Sport Rehabil*. 2003;12(4):333-342. doi:10.1123/jsr.12.4.333

11. Handbook A. *Heat Illness: A Handbook for Medical Officers*.; 1991.
12. Valentine V. The importance of salt in the athlete's diet. *Curr Sports Med Rep*. 2007;6(4):237-240. http://www.fitday.com/fitness-articles/nutrition/healthy-eating/the-importance-of-salt-in-your-diet.html.
13. Casa DJ, Lawrence AE, Susan HK, et al. National Athletic Trainers' Association Position Statement: Fludi Replacement for Athletes. *J Athl Train*. 2000;35(2):212-224.
14. Muscle Cramping In the Heat. https://depts.washington.edu/shsi/article/muscle-cramping-in-the-heat-2/. Accessed March 22, 2019.
15. Bergeron MF. Heat cramps: Fluid and electrolyte challenges during tennis in the heat. *J Sci Med Sport*. 2003;6(1):19-27. doi:10.1016/S1440-2440(03)80005-1
16. Randy Eichner MD. Muscle Cramps: The Right Ways for the Dog Days. Florida High School Athletic Association. https://www.fhsaa.org/sites/default/files/orig_uploads/health/pdf/gatorade_musclecramps.pdf. Published 2003. Accessed March 22, 2019.
17. Randy Eichner MD. Curbing Muscle Cramps : More than Oranges and Bananas Curbing Muscle Cramps : More than Oranges and Bananas. Gatorade Sport Science Institute. https://ihsaa-static.s3.amazonaws.com/Sports_Medicine_Wellness/Injury_Prevention_Treatment/GSSI-Curbing_Muscle_Cramps.pdf. Published 2003. Accessed March 22, 2019.
18. 49ers Fitness Corner: Nutrition. https://www.49ers.com/news/49ers-fitness-corner-nutrition-549320. Published 2005. Accessed March 22, 2019.
19. Workout Tips for Exercise in the Heat. University of Colorado Sports Medicine. http://www.ucdenver.edu/academics/colleges/medicine/sportsmed/cusm_patient_resources/Documents/Workout Tips for Exercise in the Heat.pdf. Published 2005. Accessed March 22, 2019.
20. Talbott BYJH, Michelsen J. Heat cramps: a clinical and chemical study. *J Clin Invest*. 1932;12(3):533-549. doi:10.1172/JCI100516
21. EDSALL DL. A disorder due to exposure to intense heat, characterized clinically chiefly by violent muscular spasms and excessive irritability of the muscles. preliminary note. *J*

Am Med Assoc. 1908;LI(23):1969-1971. http://dx.doi.org/10.1001/jama.1908.25410230055001m.

22. Maughan RJ. Exercise-induced muscle cramp: a prospective biochemical study in marathon runners. *J Sports Sci*. 1986;4(1):31-34. doi:10.1080/02640418608732095

23. Parisi L, Pierelli F, Amabile G, et al. Muscular cramps: Proposals for a new classification. *Acta Neurol Scand*. 2003;107(3):176-186. doi:10.1034/j.1600-0404.2003.01289.x

24. Hearris MA, Hammond KM, Fell JM, Morton JP. Regulation of muscle glycogen metabolism during exercise: Implications for endurance performance and training adaptations. *Nutrients*. 2018. doi:10.3390/nu10030298

25. Ørtenblad N, Westerblad H, Nielsen J. Muscle glycogen stores and fatigue. *J Physiol*. 2013;591(18):4405-4413. doi:10.1113/jphysiol.2013.251629

26. Baranauskas M, Stukas R, Tubelis L, et al. Nutritional habits among high-performance endurance athletes. *Medicina (Kaunas)*. 2015;51(6):351-362. doi:10.1016/j.medici.2015.11.004

27. Bergeron MF. Hydration and thermal strain during tennis in the heat. *Br J Sports Med*. 2014;48(SUPPL. 1):1-7. doi:10.1136/bjsports-2013-093256

28. Centers for Disease Control and Prevention. About adult BMI, healthy weight. https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html. Accessed December 27, 2017.

29. Burke LM, Hawley JA, Wong SHS, Jeukendrup AE. Carbohydrates for training and competition. *J Sports Sci*. 2011;29(SUPPL. 1). doi:10.1080/02640414.2011.585473

30. Karpinski CRC. *Sports Nutrition: A Handbook for Professionals*. 6th ed. (Karpinski C, ed.). Chicago: Academy of Nutrition and Dietetics; 2017.

31. Shirreffs SM, Maughan RJ. Whole body sweat collection in humans: an improved method with preliminary data on electrolyte content. *J Appl Physiol*. 1997;82(1):336-341. doi:10.1152/jappl.1997.82.1.336

32. Alpers D; Stenson W; Taylor B; Beir D. *Manual of Nutritional Therapeutics*. Philadelphia: Wolters Kluwer - Lippincott Williams & Wilkins; 2008.

33. Morton D, Callister R. Exercise-Related Transient Abdominal Pain (ETAP). *Sport Med*. 2014;45(1):23-35. doi:10.1007/s40279-014-0245-z

34. Rossi KA. Nutritional Aspects of the Fe ma le At h l et e. 2017;36:627-653.

35. Wismann J, Willoughby D. Gender Differences in Carbohydrate Metabolism and Carbohydrate Loading. *J Int Soc Sports Nutr*. 2006;3(1):28. doi:10.1186/1550-2783-3-1-28

36. Shang G, Collins M, Schwellnus MP. Factors Associated With a Self-Reported History of Exercise-Associated Muscle Cramps in Ironman Triathletes: A Case–Control Study. *Clin J Sport Med*. 2011;21(3):204-210. doi:10.1097/JSM.0b013e31820bcbfd

37. Schwellnus MP, Drew N, Collins M. Muscle Cramping in Athletes-Risk Factors, Clinical Assessment, and Management. *Clin Sports Med*. 2008;27(1):183-194. doi:10.1016/j.csm.2007.09.006

38. Schwellnus MP, Allie S, Derman W, Collins M. Increased running speed and pre-race muscle damage as risk factors for exercise-associated muscle cramps in a 56 km ultra-marathon: A prospective cohort study. *Br J Sports Med*. 2011;45(14):1132-1136. doi:10.1136/bjsm.2010.082677

39. Maughan RJ, Shirreffs SM. Development of hydration strategies to optimize performance for athletes in high-intensity sports and in sports with repeated intense efforts. *Scand J Med Sci Sport*. 2010;20(SUPPL. 2):59-69. doi:10.1111/j.1600-0838.2010.01191.x

40. Von Duvillard SP, Braun WA, Markofski M, Beneke R, Leithäuser R. Fluids and hydration in prolonged endurance performance. *Nutrition*. 2004;20(7-8):651-656. doi:10.1016/j.nut.2004.04.011

41. Sawka MN, Cheuvront SN, Kenefick RW. Hypohydration and Human Performance: Impact of Environment and Physiological Mechanisms. *Sport Med*. 2015;45(1):51-60. doi:10.1007/s40279-015-0395-7

42. Dion T, Savoie FA, Asselin A, Gariepy C, Goulet EDB. Half-marathon running performance is not improved by a rate of fluid intake above that dictated by thirst sensation in trained distance runners. *Eur J Appl Physiol*. 2013;113(12):3011-3020. doi:10.1007/s00421-013-2730-8

43. Wenk C, Kunz P, Steiner G. [Methodological studies on estimating the loss of sodium, potassium, calcium and magnesium exemplified by a 10-km run]. *Schweiz Z Sportmed*. 1993;41(4):159-163. http://www.ncbi.nlm.nih.gov/pubmed/8303250.

44. O'Neal EK, Davis BA, Thigpen LK, Caufield CR, Horton AD, McIntosh JR. Runners greatly underestimate sweat losses before and after a 1-hr summer run. *Int J Sport Nutr*

Exerc Metab. 2012;22(5):353-362. http://www.ncbi.nlm.nih.gov/pubmed/23011653.

45. Potassium Fact Sheet for Health Professionals. https://ods.od.nih.gov/factsheets/Potassium-HealthProfessional/%0D.

46. Lara B, Salinero JJ, Areces F, et al. Sweat sodium loss influences serum sodium concentration in a marathon. *Scand J Med Sci Sport*. 2017;27(2):152-160. doi:10.1111/sms.12637

47. Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. Exercise and fluid replacement. *Med Sci Sports Exerc*. 2007;39(2):377-390. doi:10.1249/mss.0b013e31802ca597

48. Masson G, Lamarche B. Many non-elite multisport endurance athletes do not meet sports nutrition recommendations for carbohydrates. *Appl Physiol Nutr Metab*. 2016;41(7):728-734. doi:10.1139/apnm-2015-0599

49. Baker LB, Heaton LE, Nuccio RP, Stein KW. Dietitian-observed macronutrient intakes of young skill and team-sport athletes: adequacy of pre, during, and postexercise nutrition. *Int J Sport Nutr Exerc Metab*. 2014;24(2):166-176. doi:10.1123/ijsnem.2013-0132

Appendix A - **IRB Approval**

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Dr. Jennifer Hanson
Food, Nutrition, Dietetics, and Health
212 Justin Hall

Proposal Number: 9404

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 08/23/2018

RE: Proposal Entitled, "Comparison of carbohydrate intake and incidence of exercise-associated muscle cramping among endurance athletes"

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §46.101, paragraph b, category: 2, subsection: ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

203 Fairchild Hall, Lower Mezzanine, 1601 Vattier St., Manhattan, KS 66506-1103 | 785-532-3224 | fax: 785-532-3278
comply@k-state.edu | k-state.edu/research/comply

Appendix B - **Informed Consent**

Informed Consent - EAMC Study

INFORMED CONSENT

TITLE OF STUDY
Comparison of carbohydrate intake and incidence of exercise-associated muscle cramping among endurance athletes

PROJECT APPROVAL/EXPIRATION DATE
Approved:
Expires:

LENGTH OF STUDY
Approximate participation time is 4 hours over 3 day period - Sept 20th to Sept 22nd 2018

PRINCIPAL INVESTIGATOR
Dr. Jennifer Hanson
Kansas State University
Department of Human Ecology
Kansas State University
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CONTACT DETAILS FOR PROBLEMS/QUESTIONS
Andrew Dole, 303 870-7194, apdole@ksu.edu
Dr. Jennifer Hanson, 785-532-5508, jhanson2@ksu.edu

PURPOSE OF STUDY
You are being asked to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information.

The purpose of this study is to find a link, if any, to carbohydrates consumption and exercise cramping.

STUDY PROCEDURES
Participants have already independently agreed to participate in the half-marathon event. In addition to this as a participant in this study you will be asked to complete the following:

1. Complete a short pre-race questionnaire sent electronically and submitted online
2. Complete a three day food log utilizing MyFitnessPal
3. Complete a short post-race questionnaire

4. Agree to be weighed immediately post race

RISKS
You will be asked to provide personal information such as name, height, weight, age, gender, race, and ethnicity. This information is private and will be handled with safe guards to prevent loss of this information.

- All forms will be secured in a locked office
- All digital forms will be secured on a HIPAA compliant cloud service
- Any use of the data will be done anonymously with no connection to the subject

You may decline to answer any or all questions and may stop/terminate your involvement at any time without penalty or consequence.

BENEFITS
As a participant you will be offered a free hydration consultation with a sports dietitian within 6 months of completing the race. Additionally, through your participation we hope to find a nutritional link between carbohydrate and exercise cramping in hopes of creating more effective preventative guidelines for athletes.

CONFIDENTIALITY
Every effort will be made by the researcher to preserve your confidentiality.

- You will be identified on written questionnaires through first initial and last name
- Online food logs will be accessed with a pre-made user id and password provided to you
- Online data will be secured on a HIPAA compliant cloud service that provides appropriate safeguards for personal information

CONTACT INFORMATION
If you have questions at any time about this study you may contact the researcher whose contact information is provided at the beginning of this consent form. If you have questions about your rights as a research participant or concerns you feel unable to discuss with the research you can contact the institutional review board:

For the subject should he/she have questions or wish to discuss on any aspect of the research with an official of the university or the IRB. These are: Rick Scheidt, Chair, Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224; Cheryl Doerr, Associate Vice President for Research Compliance, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224.

If you withdraw from the study before data collection is completed your data will be destroyed.

IS COMPENSATION OR MEDICAL TREATMENT AVAILABLE IF INJURY OCCURS?
No compensation of medical treatment will be available by the researchers if injury occurs while participating in this study.

CONSENT
Terms of participation: I understand this project is research, and that my participation is voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop

participating at any time without explanation,penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

I verify that my signature below indicates that I have read and understand this consent form, and willingly agree to participate in this study under the terms described, and that my signature acknowledges that I have received a signed and dated copy of this consent form.

Participant Name - Printed*

Date Informed Consent Signed

Signature

(This will require your client's signature)

Appendix C - **Food Log Data Capture**

Your Food Diary For: **Thursday, September 20, 2018**

Breakfast

	Calories kcal	Carbs g	Fat g	Protein g	Sodium mg	Sugar g
Egg - Egg, 2 large	143	1	10	13	142	0
Peanut Butter, 2 tbsp	190	8	16	7	140	3
Oranges - Orange, 1 c	62	15	0	1	0	12
Ezekiel sprouted wheat bread - Ezekiel Bread, 2 slice	160	30	1	8	150	0
Oat - Oat Meal, 2 cup	600	108	12	20	0	4
Almond Milk - Almond Milk - Vanilla - Unsweetened, 18 oz	90	3	8	3	540	0
Add Food | Quick Tools	1,245	165	47	52	972	19

Lunch

	Calories kcal	Carbs g	Fat g	Protein g	Sodium mg	Sugar g
Heb - Pistachios, 1/2 cup w/shells	170	7	14	7	115	2
Carrots, raw, 2 cup chopped	105	25	1	2	177	12
Mini Peppers - Bell Peppers, 3 peppers	25	5	0	1	0	3
Peas - Peas, 80 g	70	12	1	5	370	4
Apples - Apples, 1 medium apple	80	22	0	0	0	16
Barley, hulled, 0.5 cup	326	68	2	11	11	1
Spelt, uncooked, 1 cup	588	122	4	25	14	12
Buckwheat, 0.5 cup	292	61	3	11	1	0
Goya Red Lentils (Boiled) - Red Lentils Boiled, 1 cup	230	17	0	18	0	0
Add Food | Quick Tools	1,886	339	25	80	688	50

Dinner

	Calories kcal	Carbs g	Fat g	Protein g	Sodium mg	Sugar g
Kirkland - Olive Oil, 1 tbsp	125	0	14	0	0	0
Potato - Russet Potatoes, 592 g. / 5.3 oz.	440	104	0	12	0	4
Sweet Potato, 1.5 cup (133 g)	171	41	0	3	110	9
BBQ sauce - Bbq Sauce, 4 tbsp	120	30	0	0	480	24
Egg - Egg, 2 large	143	1	10	13	142	0
Add Food | Quick Tools	999	176	24	28	732	37

Snacks

Add Food | Quick Tools

	Calories kcal	Carbs g	Fat g	Protein g	Sodium mg	Sugar g
Totals	**4,130**	**680**	**96**	**160**	**2,392**	**106**