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Do Ten Year Trends in Emergency Department Diagnoses of Rhabdomyolysis in Young Adult Males Parallel the Growth in Long Distance Ultra Running?

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A doctoral project submitted to the faculty of the Medical University of South Carolina in partial fulfillment of the requirements for the degree Doctor of Health Administration in the College of Health Professions

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In Partial Fulfillment of the Requirements for the

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Committee: Sandra Brotherton, PhD

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Ultra running, a sport that consists of races above the marathon marker of 26.2 miles, has rarely been studied in depth. Little peer-reviewed scientific information examines the morbidity or disease prevalence associated with long-distance ultrarunning. Furthermore, there is an increase in reports of rhabdomyolysis within the ultrarunning community, which may coincide with an increase in the demand for long-distance ultrarunning races. This study examined the rate of hospital or emergency room admissions with a diagnosis of rhabdomyolysis and assesses if the incidence of rhabdomyolysis events in young males parallels the growth of ultrarunning. We hypothesized that:

- ED diagnoses of rhabdomyolysis in young adult males parallel the growth in ultrarunning.
- There are geographic and seasonal variations in the population rate of ER, which correspond to locations and times where most training for ultrarunning events occurs.

A regression test to trend the races & rhabdomyolysis frequencies/rates over time was conducted using patient data from NIS database and racing data from Ultrarunning.com. Our research has demonstrated a rise in the rates of rhabdomyolysis that mirror the rise of long-distance ultra running in young adult males.

CHAPTER 1
INTRODUCTION

Background and Need

There is little peer-reviewed scientific information available on morbidity or disease prevalence associated with long-distance ultrarunning. Ultrarunning, also known as ultramarathoning, is defined by UltraRunning Magazine (2013) as:

> "…anything past the marathon, or 26.2 miles. However, the shortest standard distance that is considered an ultra is the 50 kilometer distance, or 31.07 miles. Other standard distances are the 50 mile, 100 mile, 100 km, and a series of events that last for specified time periods such as 6 hour, 12 hour, 24 hour, 48 hour, and 6 days" (para. 1).

Discussions and details about morbidity and adverse effect occurrences have been disseminated through informal forums, most recently, through social media. Social media became the platform to really push the ultrarunning agenda and increase popularity of the sport. According to Seiss (2012), "the number of [ultrarunning] trail races has more than tripled since 2000 to 2,400 events, and the number of participants has grown from 90,000 to 230,000" (para. 6). Furthermore, "UltraRunning Magazine reported the number of runners who finished ultra-length trail races increased from 15,500 in 1998 to 52,000 in 2011" (Seiss, 2012, para. 6). Thus, the sport of ultrarunning is clearly diffusing into the mainstream of running.

One adverse event that may be associated with ultrarunning is rhabdomyolysis. Rhabdomyolysis can have several causes, however exertional rhabdomyolysis (ER) in ultrarunning is an overuse injury that results from breakdown and necrosis of striated skeletal muscle and cell death. The resulting release of intracellular content causes muscle pain and swelling and may result in acute renal failure, intravascular coagulation, cardiac arrhythmia and death (Tietze and Borchers, 2014). Thus, rapid diagnosis and treatment is required for severe rhabdomyolysis. Information about rhabdomyolysis prevalence in young males in the peer-reviewed literature is sparse and is frequently linked to social media reports. An Ovid/MEDLINE search produces only twenty-seven articles related to running and rhabdomyolysis, and a refined search produces twenty-two papers when narrowing the parameters by males only.

There is an increase in reports of rhabdomyolysis within the ultrarunning community, which may coincide with an increase in long-distance ultrarunning races over the last 10 years. There were reports of 293 races in 2004 with growth to 1296 in 2014 (n.d., 10 year growth of ultrarunning events and races, 2014). This can also be illustrated through the ratio of races to events, which has increased from 1.25 in 2004 to 1.53 to 2014; a 20% ascension (n.d., 10 year growth of ultrarunning events and races, 2014). “Events are defined as an individual contest, whereas races are the number of races (of varying distances) at each event (n.d., 10 year growth of ultrarunning events and races, 2014). The UltraRunning website also details a gender breakdown by finishes which shows male finishers making up 98.46% in 1978 to a decrease of 69.21% in 2014 (n.d., Ultrarunning finishes by gender , 2014). However, even with this gender shift, more than two thirds of ultrarunners are male, and little is known about the incidence of rhabdomyolysis within this population.

Problem Statement

The incidence of severe, potentially life threatening cases of exertional rhabdomyolysis has not been extensively studied within the sport of ultrarunning. This study will examine the rate of hospital or emergency room admissions with a diagnosis of rhabdomyolysis and assess if the incidence of rhabdomyolysis events in young males parallels the growth of ultrarunning, defined as events longer than a marathon distance of 26.2 miles.

Research Questions and Research Hypothesis

The primary research question is do ten year trends in emergency department (ED) diagnoses of exertional rhabdomyolysis in young adult males parallel the growth in long distance ultrarunning? We hypothesize that:

1. ED diagnoses of rhabdomyolysis in young adult males parallel the growth in ultrarunning.
2. There are geographic and seasonal variations in the population rate of ER, which correspond to locations and times where most training for ultrarunning events occurs.

Population

We will use the National Inpatient Sample (NIS) data set, which is part of the Healthcare Cost and Utilization Project (HCUP) hospital discharge data set, as developed by the Agency for Health Care Research and Quality (AHRQ). The NIS provides a national sample of hospital admissions. We will examine data for the years 2000 through 2012. The population for this study will consist of young adult males who present to the ED with a primary diagnosis of exertional rhabdomyolysis. Young adult males will be limited to men, 18 to 40 years of age. ER will be defined by an emergency admission to the hospital with an ICD-9 code of 728.88. Population rates for admissions for ER will be calculated using the census count of each states population of males age 18-40. Patients who may be likely to present with rhabdomyolysis, which is non-exertional, will be excluded from our sample.

CHAPTER 2
LITERATURE REVIEW

Introduction

Upon review of the literature, a quantitative approach to the subject of "Do Ten Year Trends in Hospital Emergency Diagnosis of Rhabdomyolysis for Young Males Parallel Growth in Ultrarunning" has begun to emerge. Skenderi, Kavouras, Anastasiou, Yiannakouris, and Matalas (2006) used blood analysis, and statistical analysis to describe their results. In their study, "Pre and post-race values were compared by paired t-tests. The relationship of finishing time with liver and muscle damage markers was tested by performing single regression analysis" (Skenderi, Kavouras, Anastasiou, Yiannakouris, & Matalas, 2006, p. 1055). Another study produced a similar use of quantitative data and analysis to display their results. McCullough et al. (2010), used blood urea nitrogen and serum creatinine levels to describe the increase in these markers in runners post marathon racing. Statistically, McCullough et al.'s (2010) data had comparisons that "…were made using the paired two-sample *t*-test or the paired Wilcoxon rank sum test for variables that were not normally distributed" (p. 195).

Numerous design methods have been used in previous research and case studies. Mettler, Rusch, Frey, Bestman, Wenk, and Colombani (2008) wrote an article titled "Hyponatremia Among Runners in the Zurich Marathon", which used an experimental design to describe their process and research. The authors recruited runners during the pre-race procession where they took blood samples to test plasma sodium levels, weight measurements, and fluid intake. Statistical analyses were performed using linear correlation plots with the SigmaPlot software program and the Statistical Analysis System (SAS) (Mettler, et al., 2008). In another study, Knechtle et al.'s (2011) used an observational field approach and again drew blood samples from runners' pre, during, and post-race. In this study, the authors also took urine samples and weight measurements. For statistical analyses, "Bonferroni-corrected paired t-tests were applied to detect a significant change from one period to the other" (Knechtle, et al., 2011, p. 228). Typically, studies are quantitative in structure with observational assessments to support the data.

In much of the research, authors measured quantitative variables using statistical analysis and biological samples. "Because of the small sample size, the Friedman test was used to determine changes in biochemical data from plasma and urine specimens at prerace, immediately postrace, and 1 day postrace" (Kao, et al., 2014, p. 2). As with most studies, a specific software program was used for statistical analysis. In the case of Kao et al.'s study, SPSS 18.0 was used (Kao, et al., 2014). Along with the statistical methods used to aggregate the data, field observational variables were captured. Both prospective and retrospective captures of the qualitative data were described in the literature. Study questions were also noted to be similar in structure and presentation. Kao et al.'s study boasted the title "Effects of 100-km Ultramarathon on Acute Kidney Injury" while Knechtle et al.'s study was titled "Prevalence of Exercise-Associated Hyponatremia in Male Ultraendurance Athletes." Most studies did not possess a question in their title but used a statement instead. The question(s) were typically generated in the body of the studies. For example, Mydlik, Derzsiova, and Bohus (2012) in their paper "Renal

Function Abnormalities After Marathon Run and 16-Kilometre Long-Distance Run" asked what are the essential renal functions in runners before and immediately after the marathon run and after the 16-kilometre run at the end of the introduction (Mydlik, Derzsiova, & Bohus, 2012).

For this literature review, the following databases were searched: PubMed, Cochrane, Google Scholar, and Scopus. Key words used in the search strategy included:

- run(ing)
- marathon(s)
- ultramarathon(s)
- ultrarun(ing)
- rhabdomyolysis
- acute renal failure
- kidney injury

Filters and limits (e.g., article type, publication date, age, etc.) included:

- articles in English
- published within the last 20 years
- research-based
- patients aged 20-40 years' old
- males

Rhabdomyolysis

Rhabdomyolysis, as defined by Tietze and Borchers (2014), is "…the breakdown and necrosis of striated skeletal muscle after engaging in physical activity" (p. 336). Skeletal muscle cell damage and death can be attributed to several different mechanisms but the common final pathway is characterized by an elevation in intracellular free ionized calcium levels that are higher than normal in cytoplasm and mitochondria (Tietze & Borchers, 2014). The causes of rhabdomyolysis have historically been associated with traumatic conditions, but recently, non-traumatic conditions have become more prevalent (Efstratiadis, et al., 2007). According to Efstratiadis, Voulgaridou, Nikiforou, Kyventidis, Kourkouni, and Vergoulas (2007), seizures, drug and alcohol abuse, the crush syndrome, and specific metabolic derangements are the most common factors that lead to rhabdomyloysis (p. 129). Table One outlines the different causes of rhabdomyolysis.

Table 1

Physical Exertion	Intense physical activity; tetanus; electric shock; severe agitation; status epilepticus
Direct Muscle Injury	Natural disasters; industrial & car accidents; crush trauma; deep burns; lightening injury; physical abuse
Muscle Ischemia	Generalized ischemia; shock; air emboli; arterial thrombosis; vascular occlusion during operation; sickle cell crisis; prolonged immobilization; crush injury syndrome; reperfusion injury; compartment syndrome
Temperature Extremes	Frostbite injuries; hypothermia; heat stroke; malignant hyperthermia; malignant neuroleptic syndrome; serotonergic syndrome
Drugs-Toxins-Venoms	Ethanol; drugs of abuse; statins; fibrates; anesthetic drugs; salicylates; antibiotics; chemotherapeutics; immunosuppressants; corticosteroids; antipsychotics; antidepressants; venoms
Metabolic	Hypokalemia; hyponatremia; hypophosphatemia; hypernatremia; hyperglycemic hyperosmolar non ketoic coma; diabetic ketoacidosis;
Endocrinologic	Addison disease; hyperaldosteronism; pheochromocytoma; thyrotoxicosis; hypothyroidism

Genetic	Metabolic myopathies; muscular dystrophies
Infectious	Viral; bacterial; parasitic
Autoimmune	Polymyositis; dermatomyositis

(Efstratiadis, et al., 2007).

For the purpose of this research, exercise induced rhabdomyolysis is of particular interest. Specifically, symptomatic athletes may present with the following complaints post physical activity:

- Pain
- Tenderness
- Weakness
- Muscle swelling

  (Tietze & Borchers, 2014)

Researchers Tietze and Borchers (2014) categorize athletes into two brackets as it pertains to their probability of being diagnosed with exertional rhabdomyolysis: high-risk and low-risk. Table 2 provides the attributes associated with each category.

Table 2 High-Risk Athletes	**Low-Risk Athletes**
Delayed recovery (longer than 1 week)	Rapid clinical recovery and creatine kinase (CK) normalization after exercise restrictions
Persistent elevation of CK despite rest for 2 weeks	Sufficiently fit or well-trained athlete with a history of intense training/exercise
Acute renal injury to any degree	No personal or family history of rhabdomyolysis
Personal or family history of exertional rhabdomyolysis	Existence of other group or team-related cases of exertional rhabdomyolysis during the same exercise sessions
Personal or family history of recurrent muscle cramps	Suspected or documented concomitant viral illness

Personal or family history of malignant hyperthermia	Ingestion of a drug or dietary supplement that could contribute to the development of exertional rhabdomyolysis
Personal or family history of sickle cell trait	
Muscle injury after low to moderate workout activity	
Personal history of significant heat injury	
Serum CK peak of greater than 100,000 upper limit (U/L)	

(Tietze & Borchers, 2014)

Athletes may be predisposed to exertional rhabdomyolysis due to changes in their workout routines, sickle cell anemia, certain medications (both stimulants and NSAIDs), any preexisting illness, and autoimmune or metabolic disorders (Tietze & Borchers, 2014). Athletes can develop hematologic profiles that are consistent with exertional rhabdomyolysis but may not develop the clinical condition (Tietze & Borchers, 2014). Hematologic, and other blood profiles, are groups of tests that measure different chemicals and/or disorders (National Institutes of Health, 2012). A study of ultra-marathon runners showed myoglobinuria in 25 of 44 participants with a mean increase in creatinine kinase of 2400 U/L 48 hours post-race (Tietze & Borchers, 2014). In this study, none of the ultra-marathoners developed any clinical symptoms of exertional rhabdomyolysis or renal failure (Tietze & Borchers, 2014). The Consortium for Health and Military Performance (CHAMP) provides guidelines for when to return to sport following a diagnosis of exertional rhabdomyolysis. The CHAMP guidelines follow three phases:

Phase 1

- Rest for 72 hours and encouragement of oral hydration

- 8 hours of sleep nightly
- Remain in a thermally controlled environment if the episode of ER was in relation to heat illness
- Follow-up after 72 hours with a repeat serum CK level and urinalysis (UA)
- If the CK has dropped to below 5 times the upper limit of normal and the UA is negative, the athlete can progress to phase 2; if not, reassessment in 72 additional hours is warranted
- Should the UA remain abnormal or the CK remain elevated for 2 weeks, expert consultation is recommended

Phase 2

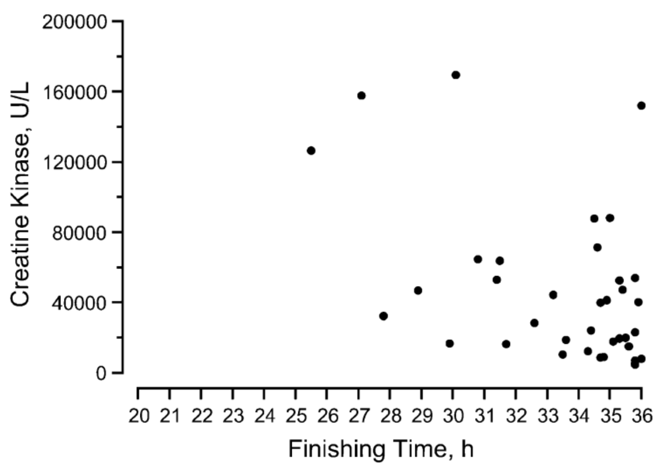
- Begin light activities, no strenuous activity
- Physical activity at own pace/distance
- Follow-up with a care provider in 1 week
- If there is no return of clinical symptoms, the athlete can progress to phase 3; if not, the athlete should remain in phase 2 checking with the health care professional every week for reassessment; if muscle pain persists beyond the fourth week, consider expert evaluation to include psychiatry

Phase 3

- Gradual return to regular sport/physical training
- Follow-up with care provider as needed

(Tietze & Borchers, 2014)

The CHAMP recommendations provide a framework for returning to sports, but there are no hard, evidence-based guidelines according to Tietze and Borchers (2014). Skenderi, Kavouras, Anastasiou, Yiannakouris, and Matalas' (2006) study was "…the first to investigate the influence of continuous, moderate-intensity, ultraendurance exercise on the status of skeletal muscle and hepatic enzymes" (p. 1055) but does not definitively assess the prevalence of rhabdomyolysis. Their study focused largely on the change in blood serum levels, particularly creatine kinase and provides a table that depicts the relationship between finishing time and serum creatine kinase activity post-race:



(Skenderi, Kavouras, Anastasiou, Yiannakouris, & Matalas, 2006).

Mettler, Rusch, Frey, Bestman, Wenk, and Colombani (2008) recruited runners during the pre-race procession where they took blood samples to test plasma sodium levels, weight measurements, and fluid intake. Data were analyzed using linear correlation plots with the SigmaPlot software program and the Statistical Analysis System (SAS) (Mettler, et al., 2008). Knechtle et al. (2011) used an observational field approach and again drew blood samples from the runners but drew these samples pre, during, and post-race. In this study, the authors also drew urine samples and weight measurements.

Hew-Butler et al. (2015) discussed the reported incidences of asymptomatic and symptomatic exercise-assciated hyponatremaia (EAH). The authors noted a race where the incidences of asymptomatic EAH ranged from 0% to 51% (Hew-Butler, et al., 2015). Specifically, an ultramarathon yielded a 67% incidence rate of hyponatremic racers who were asymptomatic at some point during the race (Hew-Butler, et al., 2015). However, only 27% of the racers finished with a serum sodium level <135 mmol/L, which is considered to be below the normal range. Less common are the incidences of symptomatic EAH. Hew-Butler et al (2015) reported that only a few these cases have occurred in marathons, Ironman triathlons, ultramarathons, and military training exercises. Reports of incidnces in symptomatic EAH have been as high as 23% and 38% in athletes seeking care during an Ironman Triathlon and ultramarathon, but most endurance events report no cases, especially in distances at the marathon length or shorter (Hew-Butler, et al., 2015). In a study that examined large samples of data, 669 161-km ultramarathon runners or 0.1% of the study's participants presented with symptomatic EAH during the 5-year sampling period (as compared to 13% who were aysmptomatic EAH) (Hew-Butler, et al., 2015). However, "…considering the total number of race participants over this time period, the actual incidence of symptomatic EAH was approximately 0.06%" (Hew-Butler, et al., 2015, p. 306). Lastly, the authors provided a table outlining the risk factors for the development of EAH, which includes:

- Overdrinking water, sports drinks, and other hypotonic beverages
- Weight gain during exercise
- Exercise duration >4 h

- Event inexperience or inadequate training
- Slow running or performance pace
- High or low body mass index (BMI)
- Readily available fluids

(Hew-Butler, et al., 2015).

A separate study by Knechtle et al. (2011) examined the prevalence of EAH in male ultraendurance athletes. Of the 95 ultramarathoners and the 25 mountain ultramarathoners in their study, five of the ultramarthoners (5%) deveopled asymptomatic EAH, while 2 mountain ultramarathoners developed symptomatic EAH (Knechtle, et al., 2011). None of the mountain ultramarathoners demonstrated any clinical signs, and the prevalence of EAH was 8% (2 of 25) (Knechtle, et al., 2011). The authors concluded the prevalence of EAH would be higher in ultraendurance athletes due to the slower running pace and increaed fluid intake. However, data aggregation from all athletes in the study showed no significant statistical prevelance of EAH in ultraendurance athletes as compared to existing reports involving martathoners, Ironman triathletes, and ultramarathoners (Knechtle, et al., 2011).

Alpers and Jones (2010) conducted a military-based study that examined the incidence of rhabdomyolysis. They performed a descriptive retrospective case series with patients that were diagnosed with rhabdomyolysis from May 2002 to September 2007. The case series was constructed by using a diagnostic code-based search into the Wilford Hall Medical Center’s records which included both military and non-miltary patients (Alpers & Jones, 2010). These cases were organized according to causes that met the case definition of exertional rhabdomyolysis as listed below:

Causes of 177 cases of rhabdomyolysis

Cause	Number (%)
Exertion	63 (35.5)
Trauma	37 (20.1)
Toxin	23 (13.0)
Unknown	13 (7.3)
Infection	13 (7.3)
Heat Illness	12 (6.8)
Seizure	7 (4.0)
Genetic (metabolic myopathy)	5 (2.8)
Endocrine	4 (2.3)
Multiple Causes	15 (8.5)

(Alpers & Jones, 2010).

The reserachers conducted their analysis using JMP v8.0 (SAS Institute) software and ccomparisions for ordinal variables used a Fisher's exact test while continuous variables were analysed using a Wilcoxon's rank sum test (Alpers & Jones, 2010). A logistic regression analysis was used to evaluate the effects of age on the risk of acute renal failure with patients who had exertional rhabdomyolysis against those from other causes of rhabdomyolysis (Alpers & Jones, 2010). Last, a multivariate model was constructed to evaluate the effects of age, gender, and body mass index agaisnt the risks of exertional rhabdomyolysis in military trainees (Alpers & Jones, 2010). As was previously stated, the results showed that the most common cause of rhabdomyolysis in this population was exertional and that this exertional rhabdomyoylsyis was characterized by a low incidence rate in the active population (Alpers & Jones, 2010). Alpers and Jones (2010) provided a table outlining the comparision of millitary trainees with extertional rhabdomyolysis versus those without it and demonstrated that no significant differences were noted between the two groups:

	Trainees with exertional rhabdomyolysis (*n*=44)	**Trainees without exertional rhabdomyolysis (*n*=198,399)**	**Odds ratio (95% CI)**	***P*-value**
Mean age, years (95% CI)	20.5 (19.8–21.3)	20.5 (20.5-20.5)		0.86
Gender, % male	88.6	75.5	2.53 (0.99-6.41)	0.052
Mean BMI, kg/m^2 (95% CI)	24.3 (21.4–27.1)	23.2 (23.1-23.2)		0.08
Training during summer months, %	45.5	40.2	0.81 (0.45-1.46)	0.54

(Alpers & Jones, 2010).

Overtraining Syndrome

Overtraining Syndrome (OTS), as defined by Budgett (1998), "…is a condition of fatigue and underperformance, often associated with frequent infections and depression which occurs following hard training and competition" (p. 107). Consequently, OTS does not resolve despite adequate rest and no identifiable medical cause (Budgett, 1998). Signs and symptoms of OTS begin with an abnormal response to training when fatigue becomes so significant that rest does not alleviate the symptoms. These signs and symptoms range from hypotension, reduced maximum oxygen consumptions, postural rise in the heart rate, heavy muscles, depression, sleep disturbances, increased emotional ability, anxiety, irritability, and excessive sweating (Budgett, 1998). Frequently, athletes may endure upper respiratory tract infections or other minor infections when they try to return too quickly to training (Budgett, 1998). Only recently has OTS become a commonplace term in the field of ultrarunning. An article published by Outside Magazine

(2015) highlighted several athletes whose struggles with OTS have impaired their training, racing, and livelihoods in different ways. According to the article, research is still very early in its findings and the focus for doctors has been primarily on determining the physiological causes of the condition (Brown, 2015). However, there is still not consensus on the defining markers of OTS, which makes it difficult to diagnose, and many doctors are more comfortable ruling out other possibilities before discussing OTS, according to Brown (2015).

National Inpatient Sample (NIS)

The NIS database is a fraction of a family of databases and software tools that were developed by the Healthcare Cost and Utilization Project (HCUP) (Healthcare Cost and Utilization Project, 2015). This database possesses the largest publicly available all-payer inpatient healthcare information in the United States (Healthcare Cost and Utilization Project, 2015). Furthermore, the database contains more than seven million hospital stays each year (unweighted). When census data is considered weighted, it is estimated that the NIS covers more than thirty-six million hospitalizations (Healthcare Cost and Utilization Project, 2015). The NIS was developed by the Agency for Healthcare Research and Quality (AHRQ) through a Federal-State-Industry partnership, which now informs decisions made at the national, state, and community levels (Healthcare Cost and Utilization Project, 2015). Key features of the most recent NIS from 2012 include:

- The NIS is drawn from all States participating in HCUP, representing more than 95 percent of the U.S. population.
- The NIS approximates a 20-percent stratified sample of discharges from U.S. community hospitals, excluding rehabilitation and long-term acute care hospitals.

- The self-weighting design of the new NIS reduces the margin of error for estimates and delivers more stable and precise estimates than previous versions of the NIS.
- The NIS protects patient confidentiality because State and hospital identifiers are no longer provided.
- The new NIS retains a large sample size, which enables analyses of rare conditions, uncommon treatments, and special patient populations.

  (Healthcare Cost and Utilization Project, 2015).

NIS data are used to describe incidences of specific diagnoses in healthcare.

Day, Lau, Ong, Williams, Ramsey, and Kurtz (2010), used the NIS database to examine trends in upper extremity arthroplasty in the United States as a function of race, age, gender, and census region. Their study examined surgical procedures identified from discharge records by using the International Classification of Diseases, 9th Revision Clinical Modification (ICD-9-CM) and highlighted codes 81.80 (total shoulder arthroplasty, 81.81 (hemishoulder arthroplasty), and 81.84 (total elbow arthroplasty). Using a Poisson regression model, age, race, census region, gender, and calendar year were used as covariates to account for any differences in prevalence among population subgroups and changes over time (Day, et al., 2010). To calculate surgery prevalence, the authors divided the number of estimated procedures from the NIS population subgroups by the corresponding population estimates and Census Bureau projections. They found national trends and projections in upper extremity arthroplasty were comparable to total knee arthroplasty and that this rising number of arthroplasty procedures, in conjunction with increasing charges, had the potential to increase financial strains on healthcare systems (Day, et al., 2010).

In a subsequent case study, Karmacharya, Pathak, Aryal, Giri, and Donato (2015) studied the seasional variation in acute gouty arthritis using the NIS database. The authors examined the variation in incidences of acute gout by identifying patients over age eighteen with a primary diagnosis of acute gouty arthritis, as classified by the ICD-9-CM coding system, during hospitalizations that occurred from 2009-2011. An Edward's recognition and estimation method was used to show cyclic trends, while a a Z-test was used to compare the seasonal incidences. The results showed a peak incidence of acute gouty arthritis in November, while overall, the hightest number of hospitlizations was in the autumn months (peak/low ratio = 1.34% versus 1.29-1.38%) (Karmacharya, Pathak, Aryal, Giri, & Donato, 2015). The lowest incidence was observed in the Spring with a peak/low ratio of 28.12% versus 23.13% (Karmacharya, Pathak, Aryal, Giri, & Donato, 2015).

International Classification of Diseases, 9th Revision Clinical Modification (ICD-9-CM)

The Centers for Disease Control and Prevention define ICD-9-CM as "…the official system of assigning codes to diagnoses and procedures associated with hospital utilization in the United States" (Centers for Disease Control and Prevention, 2013, para. 1). ICD-9-CMs were also used in the coding and classification of mortality data from death certificates until 1999, at which point a switch to ICD-10 occurred (Centers for Disease Control and Prevention, 2013). ICD-9-CM is comprised of:

- A numerical list of the disease code numbers in tabular form
- An alphabetical index to the disease entries; and

- Classification system for surgical, diagnostic, and therapeutic procedures (alphabetic index and tabular list)

  (Centers for Disease Control and Prevention, 2013, para. 2).

Both the National Center for Health Statistics (NCHS) and the Centers for Medicare and Medicaid Services are the United States government agencies who are responsbile for managaing any changes and modifications to the ICD-9-CM (Centers for Disease Control and Prevention, 2013).

To specifically define rhabdomyolysis, we will need to evaluate ICD-9-CM code 728.88. Secondarily, we will need to exclude acute renal failure (ARF), ICD-9-CM 584, and its subclassifciations, as this disease process and sequelae are too broad. Polderman (2004) wrote “Rhabdomyolysis can develop in any circumstances where energy demands in muscles exceed the available energy supplies; it accounts for between 2 and 5% of all cases of acute renal failure in the ICU” (p. 1030). Rhabdomyolysis is infrequent but still an important cause of renal failure in the critical care setting (Polderman, 2004).

ICD-9 Codes were chosen for this study to maintain a consistent link to the diagnoses that were obtained from 2001 through 2013. The United States recently switched to a new coding system of ICD-10, which foundationally alters the coding patterns.

United States (US) Census Bureau

The US Census Bureau, formed in 1942, is a part of the US Department of Commerece and is overseen by the Economics and Statistics Administration (The United States Census Bureau, 2015). The Bureau’s mission “…is to serve as the leading source of quality data about the nation's people and economy. We honor privacy, protect confidentiality, share our expertise globally, and conduct our work openly” (The United

States Census Bureau, 2015, para. 1). Operating under US Codes Title 13 and Title 26, the Bureau collects six different forms of data and information:

1. Decennial Census of Population and Housing - The U.S. Census counts every resident in the United States. It is mandated by Article I, Section 2 of the Constitution and takes place every 10 years.
2. Economic Census - The Economic Census is the U.S. Government's official five-year measure of American business and the economy.
3. Census of Governments - Identifies the scope and nature of the nation's state and local government sector including public finance and public employment and classifications.
4. American Community Survey (ACS) - The American Community Survey (ACS) is a mandatory, ongoing statistical survey that samples a small percentage of the population every year.
5. Our Surveys and Programs - Our surveys provide periodic and comprehensive statistics about the nation, critical for government programs, policies, and decision-making.
6. Economic Indicators - The Census Bureau releases fourteen different reports on key economic indicators. Each indicator is released on a specific schedule. (The United States Census Bureau, 2015).

A US Census search from 2013 yields a result of 46,807,902 (Margin of Error +/- 3,3770 and 18,413) males between the ages of 18 and 40 (The United States Census Bureau, 2013). This result will provide the denominator for this study, as the NIS data for rhabdomyolysis will provide the numerator. With this information, we will calculate the rate of injury in a state per 100,000 males.

Emergency Department Coding

Part of the Federal Balanced Budget Act of 1997 required the Centers for Medicare and Medicaid Services (CMS) to create a new Outpatient Prospective Payment System (OPPS) for Medicare, which is similar to Medicare's prospective payment system, called Diagnosis Related Groups (DRG) (American College of Emergency Physicians, 2011). Emergency Departments also have Ambulatory Payment Classifications (APC), which are the government's form of payment for a facility's outpatient services in Medicare (American College of Emergency Physicians, 2011). Research into the coding practices of Emergency Departments (ED) in the U.S. show that there is no national standard for hospital assignment of evaluation and management (E&M) code levels in the ED (American College of Emergency Physicians, 2011). However, the use of Healthcare Common Procedure Coding System (HCPCS) codes must reasonably relate the intensity of a hospital's resources and the hospital may bill visit codes based on their own coding guidelines (American College of Emergency Physicians, 2011). The American College of Emergency Physicians (ACEP) states coding guidelines should promulgate clear and accurate payments, only required documentation that is clinically necessary to facilitate patient care, and should not promote any sort of upcoding or gaming (American College of Emergency Physicians, 2011). E codes are an additional set of codes ED's use to "…capture the external cause of injury or poisoning, the intent and the place where the event occurred" (American College of Emergency Physicians, 2014, para. 11). The use of these codes is dependant upon the individual institution and state, but are generally not mandatory (American College of Emergency Physicians, 2014). It is important for institutions to contact their current and prospctive payers to ensure they will process these codes. For this research, possible E codes may include:

- E001: Activities involving walking and running
    - E001.1: Activities involving running
- E927: Overexertion and strenuous movements
    - E927.2: Excessive physical exertion
    - E927.3: Cumulative trauma from repetitive motion
    - E927.4: Cumulative trauma from repetitive impact
    - E927.8: Other overexertion and strenuous and repetitive movements or loads
    - E927.9: Unspecified overexertion and strenuous and repetitive movements or loads

(ICD9Data.com, n.d.).

Summary

The literature review found an assortment of research studies, but none that provide an in-depth, analyses into the prevalence of ultrarunning in young adult males. This research will determine the magnitude of ultrarunning rhabdomyolysis and any patterns that may group patients geographically and by age.

CHAPTER III
METHODOLOGY

Research Design

Our research study will use a retrospective analysis on historical emergency department patients admitted with the diagnosis of rhabdomyolysis, provided by HCUPS data. With this data, we will have the ability to present 10 year trends for each state from 2001 to 2011, and how these rates parallel the growth of ultrarunning in the United States over time. The two research questions to be studied will be:

1. Does ED diagnoses of rhabdomyolysis in young adult males parallel the growth in ultrarunning?
2. Are there geographic and seasonal variations in the population rate of ER, which correspond to locations and times where most training for ultrarunning events occurs?

National ED admission data from each state will use ICD-9-CM code of 728.88. All patients with a diagnosis of infection, cancer, trauma, diabetes, or heart disease were excluded from the data set.

Data Analysis

The data analysis will consist of a multi-variant regression analysis to assess the rhabdomyolysis trends over time. U.S. Census data will be used to calculate a population rate for rhabdomyolysis by state. Data from UltraRunning.com will be used to calculate the number of events per year. The ten-year trends in time for the prevalence of ultrarunners with rhabdomyolysis will be compared to the growth of ultrarunning using a run-time graph

CHAPTER IV
RESULTS/FINDINGS

The results of the study were analyzed using a retrospective analysis on historical emergency department patients admitted with the diagnosis of rhabdomyolysis from years 2004 to 2012, as provided by HCUPS. The frequencies of rhabdomyolyses were compared to 2009 through 2013 U.S. Census data to calculate a population rate for rhabdomyolysis by state. Data from UltraSignUp.com were used to calculate the number of races in each state by month, from November 2015 through to planned races in December of 2016. Table 3 demonstrates the aggregation of these data using Microsoft Excel. Once the frequency was obtained, a rhabdomyolysis rate was calculated for each state using a simple calculation of (frequency/state population)*100,000. Table 3 demonstrates the aggregation of these data:

Table 3

2015/2016 PLANNED RACES (50K, 50M, 100K 100M)																	
	JAN	FEB	MAR	Q1	APR	MAY	JUN	Q2	JUL	AUG	SEP	Q3	OCT	NOV	DEC	Q4	Tot
AK		2	2	4				0				2				0	**6**
AL	2	2		8	1	2		3				0			1	4	**15**
AR				3				1				0				1	**5**
AZ	2			10	2	1		3		1	3	4	3	3		6	**23**
CA	7	15	9	31	13		8	38	9		10	36	15	10	6	31	**136**
CO				0	3	2		9		3		15	1		1	2	**26**
CT				0				2				0				0	**2**
DC				0				0				0				1	**1**
DE				1				0				0				0	**1**
FL		2	2	8	1	2	1	4			1	1	2	2		7	**20**
GA	2			5	3	3		6	1	2	2	5				5	**21**
HI				1				0				0				1	**2**
IA				0				2				0			1	2	**4**
ID			1	1				4		1		5				2	**12**
IL	1			1				2	1		1	2		1	1	4	**9**
IN				0				0				0				2	**2**
KS				0	2	1	2	5	2		2	4				4	**13**
KY				1				2				0				2	**5**
LA				1				1				1				2	**5**
MA	1			1		1	1	4		1		3	1	1		2	**10**
ME				0				1				1				2	**4**
MD		1	1	2	1			1	1	1		2		1		3	**8**
MI	1			1				0	1	1		4				0	**5**
MN				0			1	3		1		5	1			1	**9**
MO		1		1		1		4			1	1		1		4	**10**
MS				1				0				0				0	**1**
MT				0				1				3				0	**4**
NC	1		2	3	2			6	1			5		1		4	**18**
ND				1				0				1				0	**2**
NE				0				0				1				1	**2**
NH				0				0				2				1	**3**
NJ				0				2				0				1	**3**
NM				1				2				0				2	**5**
NV			1	3				2	1			3	1	1		2	**10**
NY	1			1				3	1			9	1	1	2	4	**17**
OH	1		1	2	1			7	1			3		1	1	2	**14**
OK				2				0				1				0	**3**
OR		1	2	3			2	5	2	2		8				6	**22**
PA			1	1	2		2	8	1		1	5				4	**18**
RI				0				1				0				0	**1**
SC	1	1		4	1			5	1			1	1		1	4	**14**
SD				0				2				1				1	**4**
TN	2		1	3	2	1		3				6		1	2	7	**19**
TX	1	1	1	3	2			2	1	1		2			2	8	**15**
UT	1		2	3				8		3	3	12	3	1		4	**27**
VA		1		5	2			5	1	2	2	5		1	1	5	**20**
VT				1				1				1				0	**3**
WA	1	2	2	5			4	14		2		13		1	2	8	**40**
WI				0				1				0				2	**3**
WV				0				0				2				0	**2**
WY				0		1		1				2				0	**3**
	33	**38**	**51**		**64**	**66**	**44**		**46**	**59**	**72**		**83**	**43**	**28**		**627**

As the data show, California leads in overall volume of races, peaking in May and August, which avoids the extreme heats of summer. October and May are the most populous in regards to their number of races. This in effect is due to the historically cooler months in Washington (September), Oregon (October), and Colorado (September). Conversely, historically cooler states such as Alaska (August), Montana (August), & Utah (July) see their peak in races in the middle of the year. California remains an outlier as their races spread the spectrum of the calendar with February, May, August, and October all sharing almost equal volume in the number of races they host.

Table 4

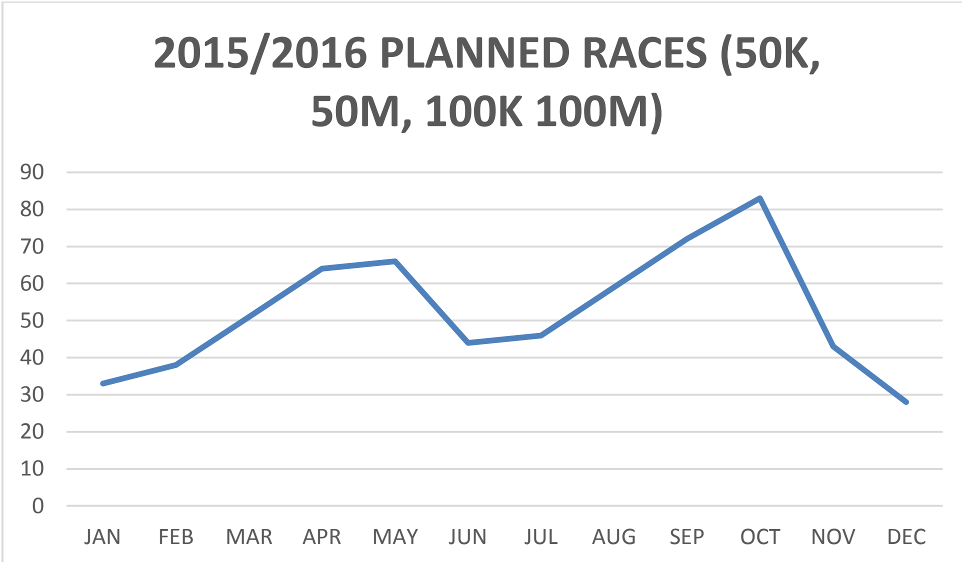
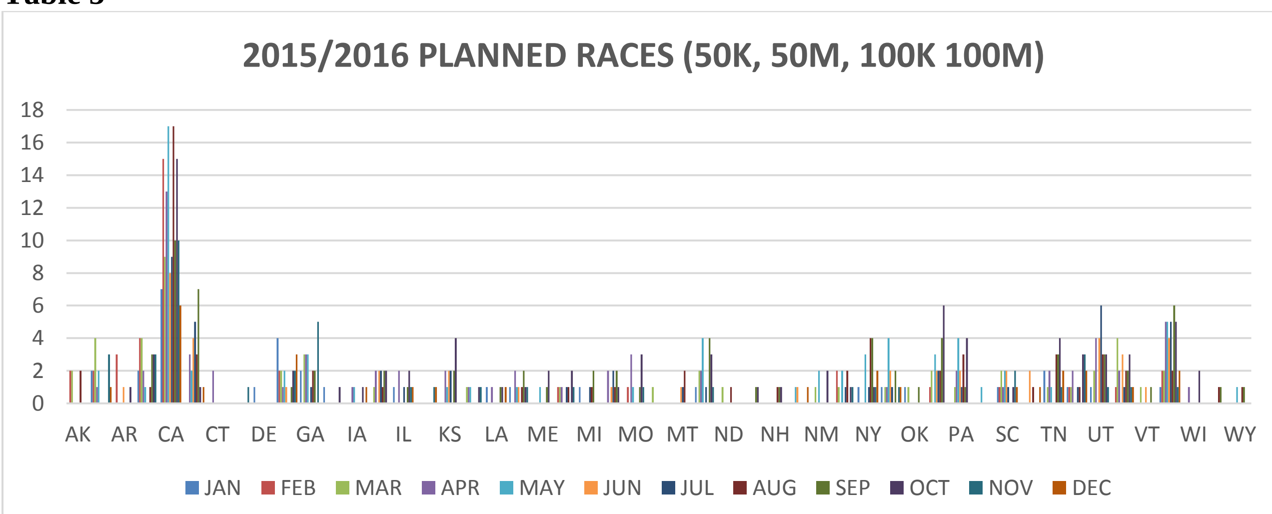


Table 5 shows the distribution of races by state and month:

Table 5



In Table 6, we see that the U.S. Census population data from 2009 through 2013 were used to calculate an overall race rate by state and quarter for males 18-40 per 100,000.

Table 6 Race Rate by State and Quarter

	Pct races	in quarter			Male 18-40	per 100000
State	Q1	Q2	Q3	Q4	POP	RaceRate
AK	0.67	0.00	0.33	0	122581	4.89
AL	0.53	0.20	0.00	0.27	688854	2.18
AR	0.60	0.20	0.00	0.20	426132	1.17
AZ	0.43	0.13	0.17	0.26086957	984907	2.34
CA	0.23	0.28	0.26	0.23	6115573	2.22
CO	0.00	0.35	0.58	0.07692308	828498	3.14
CT	0.00	1.00	0.00	0	490711	0.41
DC	0.00	0.00	0.00	1	122725	0.81
DE	1.00	0.00	0.00	0	129288	0.77
FL	0.40	0.20	0.05	0.35	2663799	0.75
GA	0.24	0.29	0.24	0.24	1504137	1.40
HI	0.50	0.00	0.00	0.50	217489	0.92
IA	0.00	0.50	0.00	0.50	446068	0.90
ID	0.08	0.33	0.42	0.17	235549	5.09
IL	0.11	0.22	0.22	0.44	1952756	0.46
IN	0.00	0.00	0.00	1	957472	0.21
KS	0.00	0.38	0.31	0.31	433171	3.00
KY	0.20	0.40	0.00	0.4	638352	0.78
LA	0.20	0.20	0.20	0.4	698248	0.72
MA	0.10	0.40	0.30	0.20	970033	1.03
ME	0.00	0.25	0.25	0.50	169616	2.36
MD	0.25	0.13	0.25	0.38	851793	0.94
MI	0.20	0.00	0.80	0	1380703	0.36
MN	0.00	0.33	0.56	0.11	788957	1.14
MO	0.10	0.40	0.10	0.40	872478	1.15
MS	1.00	0.00	0.00	0.00	435606	0.23
MT	0.00	0.25	0.75	0.00	143253	2.79
NC	0.17	0.33	0.28	0.22	1428661	1.26
ND	0.50	0.00	0.50	0.00	115956	1.72
NE	0.00	0.00	0.50	0.50	276756	0.72
NH	0.00	0.00	0.67	0.33	175155	1.71
NJ	0.00	0.67	0.00	0.33	1249688	0.24
NM	0.20	0.40	0.00	0.40	308753	1.62
NV	0.30	0.20	0.30	0.20	426430	2.35
NY	0.06	0.18	0.53	0.24	2956969	0.57
OH	0.14	0.50	0.21	0.14	1615651	0.87
OK	0.67	0.00	0.33	0.00	577116	0.52
OR	0.14	0.23	0.36	0.27	575965	3.82
PA	0.06	0.44	0.28	0.22	1789247	1.01
RI	0.00	1.00	0.00	0.00	155271	0.64
SC	0.29	0.36	0.07	0.29	687354	2.04
SD	0.00	0.50	0.25	0.25	123160	3.25
TN	0.16	0.16	0.32	0.37	926768	2.05
TX	0.20	0.13	0.13	0.53	4110864	0.36
UT	0.11	0.30	0.44	0.15	483904	5.58
VA	0.25	0.25	0.25	0.25	1242247	1.61
VT	0.33	0.33	0.33	0.00	86153	3.48
WA	0.13	0.35	0.33	0.20	1058154	3.78
WI	0.00	0.33	0.00	0.66666667	823667	0.36
WV	0.00	0.00	1.00	0	255697	0.78
WY	0.00	0.33	0.67	0	137573	2.18

Subsequently, these U.S. Census data were then used to calculate rhabdomyolysis rates by state for years 2004 to 2012. An average of for each year was totaled at the bottom of the graph.

An aggregation of the racing data, combined with the U.S. Census population data, demonstrate an increase in Quarter 3 overall racing and a rate of 0.27 per 100,000 of males 18-40. This result accepts the study's hypothesis that there are geographic and seasonal variations in the population rate of ER. Similarly, there are seasonal variations with the locations and times where most training for ultrarunning events occur. Geographic variation is illustrated in both Tables 3 and 4. The seasonality and geographic trends share similar peaks in volume with the states that see a large volume of races and rhabdomyolysis diagnoses.

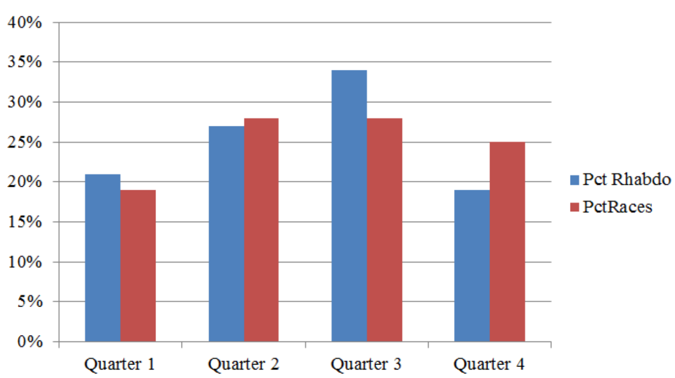
In order to answer the second hypothesis, Does ED diagnoses of rhabdomyolysis in young adult males parallel the growth in ultrarunning, the researchers established Table 7 which calculates the rhabdomyolysis frequency and rate for years 2004 to 2012 using the basis of 2013 U.S. Census data as the denominator.

Table 7

RhabFreq 2004	RhabRate 2004	RhabFreq 2005	RhabRate 2005	RhabFreq 2006	RhabRate 2006	RhabFreq 2007	RhabRate 2007	RhabFreq 2008	Rhabdo Rate 2008	RhabFreq 2009	RhabRate 2009	RhabFreq 2010	RhabRate 2010	RhabFreq 2011	RhabRate 2011	RhabFreq 2012	RhabRate 2012
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	2.45	3	2.45
NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!
14	3.29	23	5.40	19	4.46	18	4.22	29	6.81	22	5.16	22	5.16	36	8.45	183	42.94
54	5.48	146	14.82	75	7.61	101	10.25	76	7.72	83	8.43	147	14.93	156	15.84	838	85.08
154	2.52	163	2.67	196	3.20	179	2.93	171	2.80	203	3.32	248	4.06	240	3.92	1554	25.41
19	2.29	25	3.02	15	1.81	34	4.10	16	0.19	52	6.28	25	3.02	49	5.91	235	28.36
25	5.09	21	4.28	51	10.39	31	6.32	27	5.50	27	5.50	25	5.09	20	4.08	227	46.26
NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!
NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!
162	6.08	239	8.97	252	9.46	221	8.30	321	12.05	340	12.76	297	11.15	261	9.80	2093	78.57
53	3.52	108	7.18	94	6.25	94	6.25	87	5.78	116	7.71	134	8.91	82	5.45	768	51.06
6	2.76	4	1.84	3	1.38	5	2.30	3	0.14	1	0.46	6	2.76	0	0.00	28	12.87
10	2.24	2	0.45	6	1.35	6	1.35	10	2.24	5	1.12	14	3.14	22	4.93	75	16.81
NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!	NO DATA	#VALUE!
59	3.02	54	2.77	57	2.92	67	3.43	85	0.44	51	2.61	75	3.84	92	4.71	540	27.65
23	2.40	21	2.19	20	2.09	46	4.80	32	3.34	33	3.45	44	4.60	61	6.37	280	29.24
8	1.85	6	1.39	6	1.39	4	0.92	17	3.92	4	0.92	16	3.69	26	6.00	87	20.08
42	6.58	20	3.13	44	6.89	38	5.95	35	0.55	22	3.45	44	6.89	38	5.95	283	44.33
0	0.00	0	0.00	0	0.00	0	0.00	20	2.86	42	6.02	40	5.73	38	5.44	140	20.05
38	3.92	51	5.26	40	4.12	47	4.85	57	5.88	26	2.68	31	3.20	43	4.43	333	34.33
0	0.00	0	0.00	0	0.00	2	1.18	3	0.18	0	0.00	0	0.00	0	0.00	5	2.95
67	7.87	55	6.46	70	8.22	67	7.87	92	10.80	43	5.05	65	7.63	75	8.80	534	62.69
29	2.10	33	2.39	26	1.88	44	3.19	53	3.84	43	3.11	36	2.61	56	4.06	320	23.18
11	1.39	6	0.76	24	3.04	14	1.77	22	0.28	9	1.14	7	0.89	21	2.66	114	14.45
24	2.75	50	5.73	34	3.90	24	2.75	35	4.01	44	5.04	60	6.88	80	9.17	351	40.23
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	24	5.51	39	8.95	63	14.46
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	2.79	2	1.40	2	1.40	8	5.58
72	5.04	84	5.88	94	6.58	91	6.37	73	5.11	82	5.74	116	8.12	118	8.26	730	51.10
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.72	2	1.72
3	1.08	4	1.45	2	0.72	4	1.45	3	0.11	5	1.81	6	2.17	4	1.45	31	11.20
7	4.00	4	2.28	4	2.28	4	2.28	6	3.43	10	5.71	0	0.00	0	0.00	35	19.98
47	3.76	78	6.24	78	6.24	75	6.00	71	5.68	66	5.28	85	6.80	93	7.44	593	47.45
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.97	12	3.89	31	10.04	46	14.90
35	8.21	17	3.99	56	13.13	60	14.07	41	9.61	35	8.21	53	12.43	35	8.21	332	77.86
129	4.36	137	4.63	176	5.95	150	5.07	135	4.57	198	6.70	215	7.27	234	7.91	1374	46.47
31	1.92	52	3.22	57	3.53	75	4.64	70	0.43	113	6.99	73	4.52	105	6.50	576	35.65
0	0.00	22	3.81	41	7.10	23	3.99	25	4.33	39	6.76	30	5.20	34	5.89	214	37.08
13	2.26	9	1.56	16	2.78	16	2.78	18	3.13	18	3.13	9	1.56	27	4.69	126	21.88
0	0.00	0	0.00	0	0.00	0	0.00	80	0.45	68	3.80	144	8.05	131	7.32	423	23.64
3	1.93	5	3.22	6	3.86	1	0.64	7	4.51	5	3.22	5	3.22	11	7.08	43	27.69
14	2.04	36	5.24	29	4.22	29	4.22	39	5.67	26	3.78	21	3.06	50	7.27	244	35.50
1	0.81	0	0.00	1	0.81	2	1.62	0	0.00	1	0.81	0	0.00	7	5.68	12	9.74
51	5.50	39	4.21	48	5.18	34	3.67	55	5.93	53	5.72	39	4.21	82	8.85	401	43.27
184	4.48	211	5.13	238	5.79	229	5.57	196	4.77	232	5.64	188	4.57	327	7.95	1805	43.91
10	2.07	11	2.27	22	4.55	9	1.86	16	0.33	12	2.48	20	4.13	19	3.93	119	24.59
51	4.11	0	0.00	47	3.78	56	4.51	56	4.51	72	5.80	70	5.63	104	8.37	456	36.71
7	8.13	4	4.64	6	6.96	4	4.64	2	2.32	1	1.16	5	5.80	8	9.29	37	42.95
26	2.46	11	1.04	17	1.61	19	1.80	25	0.24	27	2.55	55	5.20	28	2.65	208	19.66
9	1.09	13	1.58	29	3.52	16	1.94	16	1.94	32	3.89	26	3.16	27	3.28	168	20.40
3	1.17	21	8.21	8	3.13	16	6.26	14	5.48	13	5.08	25	9.78	15	5.87	115	44.98
0	0.00	0	0.00	0	0.00	2	1.45	3	0.22	1	0.73	1	0.73	3	2.18	10	7.27
997	2.60	1054	2.67	1296	3.41	1268	3.29	1402	2.94	1433	3.57	1642	4.39	2066	5.67	11158	29.32

These rates are further displayed graphically, and seasonally, in Table 8 to show trends in the data:

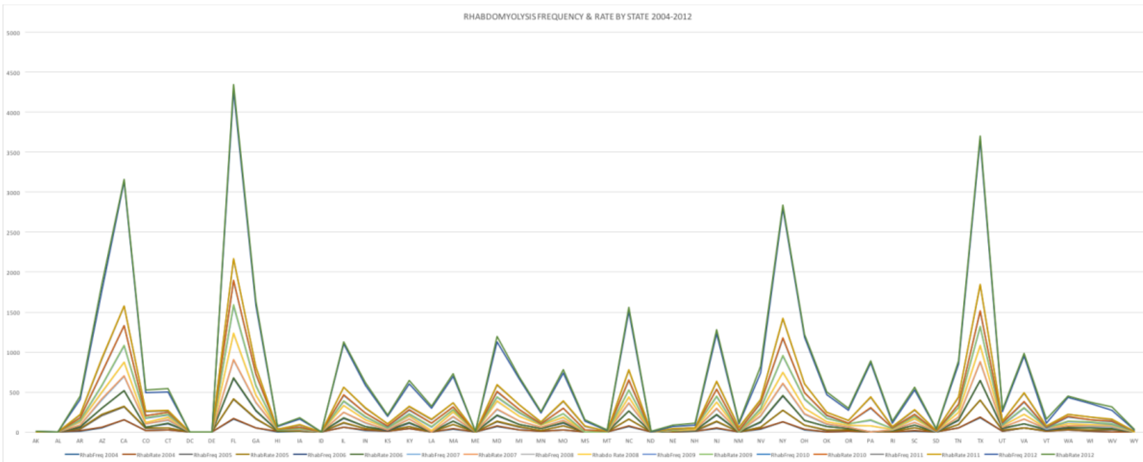
Table 8



* Races in 2014 and rhabdomyolysis cases in 2012 and 2014

Table 9 shows both the frequency and rate of rhabdomyolysis diagnoses by state for each corresponding year:

Table 9



Using SPSS software, we were able to calculate a linear regression using ANOVA to capture significance. The table below demonstrates the significance values for years 2004 through 2012:

Table 10

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.713[a]	.508	.438	6.47722

a. Predictors: (Constant), Races

ANOVA[a]

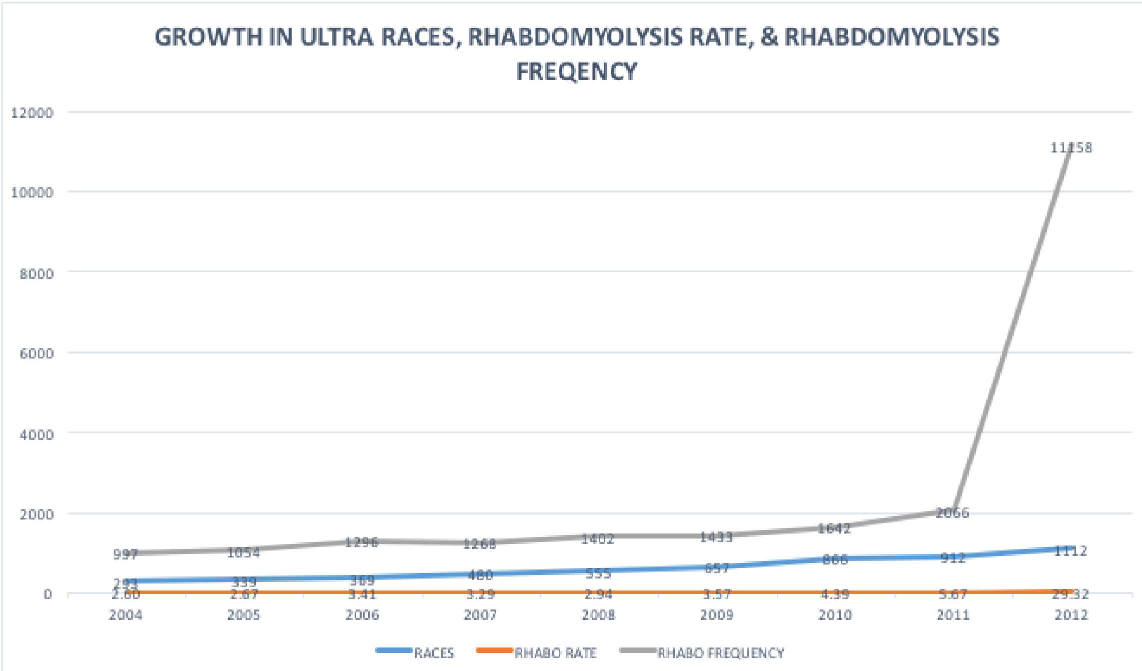
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	303.157	1	303.157	7.226	.031[b]
	Residual	293.680	7	41.954		
	Total	596.837	8			

a. Dependent Variable: RhabRates

b. Predictors: (Constant), Races

Last, the data were assembled on a single run-time chart to depict an overlay of races, rhabdomyolysis rate, and rhabdomyolysis frequency. This chart accepts the second hypothesis as noted in Table 11:

Table 11



CHAPTER V
DISCUSSION

Discussion of Results

As we noted in Chapter Four, our research has demonstrated a rise in the incidence of rhabdomyolysis that mirrors the rise of long-distance ultra running. The ten-year trends favor both a gradual increase in rhabdomyolysis rate and ultra running races but we have realized a significant increase in the frequency of rhabdomyolysis from 2011 to 2012. As one would anticipate, the states with the largest amount of races, typically accounted for the largest number of rhabdomyolysis frequencies and rates. Specifically, California and New York are exemplary but Colorado and Utah (both with high levels of races) have lower rates and frequencies of rhabdomyolysis. Texas, Florida, and North Carolina's rates/frequencies could be explained by their overall populations and favorably warmer climate. In Chapter Two, we discussed extreme temperatures such as heat, which can induce rhabdomyolysis and rhabdomyolysis symptoms. The Alpers and Jones (2010) study noted that of their 177 subjects, 35.5% of them had rhabdomyolysis caused by physical exertion. That association discussed in their study could lend to speculation that a significant portion of the rhabdomyolysis rates and frequencies were caused by physical exertion, and particularly the type of extreme physical exertion that is associated with long-distance ultra running. Last, a Significance of 0.031 was noted using SPSS software (version 23).

Limitations

A number of limitations implicated our study as we have outlined:

1. U.S. Census Bureau Community Survey data for 2009 through 2013 were used as the denominator to calculate statewide rates by year. Further studies should expand this denominator to sample a larger population.
2. The number of ultra running races was only obtained through one website's database from years 2015 to 2016. Further studies should be expanded to include multipole databases and historical information to properly calculate these races over time.
3. The study was limited by the use of ICD-9 Codes that do not contain a direct association with ultra running induced rhabdomyolysis. To truly understand whether the rise in rhabdomyolysis diagnoses in young adult males is directly correlated to the rise in ultra running, we will need a classification system that provides granular levels of diagnosis codes, such as ICD-10, and the use of E-codes in the Emergency Department.
4. A secondary study should further examine the specific biomarkers as they pertain to the diagnosis for rhabdomyolysis. Skenderi, Kavouras, Anastasiou, Yiannakouris, and Matalas' (2006) have begun this process but ideally, these biomarkers would be drawn throughout the race, pre, and post in large sample sizes to draw meaningful conclusions and any correlations to distance, seasonality, and exertion.

Summary

This body of research provides an introductory examination into the ten-year trends in emergency department diagnoses of rhabdomyolysis in young adult males, and whether or not these diagnoses parallel the growth in long distance ultra running. We concluded that they do parallel each other but this research lends itself to limitations that require further analysis. Furthermore, we were able to capture the average cost for a hospital admission of rhabdomyolysis, $9,946 USD (SD $19,659). If we hypothesize multiplying the $9,946 by the 22,316 occurrences of rhabdomyolysis, then there exists a potential for $221,954,936 USD in cost-avoidance that requires a deep analysis into the societal impacts of diagnosis.

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