**Femoral Stress Fracture in a Collegiate Male Basketball Player:**
**A Case Report**

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**Objective:** We present a case of a femoral stress fracture in a male Division I basketball player. **Background:** During post-season conditioning, the athlete (21 years, 200 cm, 102.3 kg) presented to the team physician with anterior mid-thigh pain. He reported intense pain that had progressively increased a month before he sought medical advice. The athlete indicated that the pain had spread from his upper thigh to his knee and lower leg and reported no numbness or tingling. Upon evaluation, the team physician ordered diagnostic testing to rule out the presence of a femoral stress fracture. **Differential Diagnosis:** Results of the thigh radiograph were negative for hip dislocation, femoral neck fracture or arthritis, but a bone scan revealed a posterior medial femoral stress fracture. **Treatment:** Sports restrictions were specified for the first 3 weeks to discontinue jumping and running. At the initiation of pre-season conditioning, four months after his initial evaluation, the athlete was given full clearance to participate in team practices. **Uniqueness:** Documentation of femoral stress fractures in the general population is commonly observed secondary to predisposing pathologies or in the elderly population; however, it has only been documented among females and marathon runners in the athletic or military population. **Conclusion:** Athletic Trainers must be aware of factors that place athletes at an increased risk of stress fractures and able to recognize the signs and symptoms in order to rule out a femoral stress fracture.

Stress fractures are micro-fractures within the bone matrix and are most commonly caused by repetitive stress. Competitive athletes are often predisposed to stress fractures due to repetitive sport-specific motions, lengthened seasons, and continuous years of participation. Stress fractures are well documented in the military setting and in collegiate athletics and have been reported in every major sport as well as almost every bone. Stress fractures are more prevalent in the lower extremity, occurring most in the tibia and bones of the foot; however, femoral stress fractures occur less frequently. Femoral stress fractures are overuse injuries caused by repetitive stresses, with two major possible etiological pathophysiologies. First, during periods of high-intensity training without rest, bone formation as a result of stressful demands is unable to keep up with bone resorption. Further, muscle attaches to bone and repetitive muscle contractions may cause pulling forces at the attachment sites, initiating uncompensable stress.

Several factors may lead to the development of stress fractures. First, hormonal imbalances may predispose athletes to weakened bone structure. Research has indicated a decrease in estrogen levels in women, often caused by menstrual irregularities, is a risk factor for stress fractures. Additionally, low levels of male sex hormones are a predisposing factor for stress fractures as testosterone encourages a reduction of osteoclast formation. Low testosterone levels are often found in male long-distance endurance runners. Additionally, irregular gait patterns or leg-length discrepancy may lead to stress fractures as abnormal and asymmetrical forces are imposed upon the bone. Finally, most importantly, stress fractures are often found as
a result of overtraining and a lack of cross-training.\textsuperscript{2} High-intensity workouts, performed without sufficient rest periods, are a considerable factor in uncompensable bone reformation.\textsuperscript{2} These risk factors are often indicators for the development of stress fractures in marathon runners or females (specifically characterized by the female athlete triad: eating disorder, amenorrhea, and osteoporosis).\textsuperscript{1-5}

A paucity of data exists on femoral stress fractures in young, physically active male athletes. Femoral stress fractures have been closely associated as sequela related to primary pathologies\textsuperscript{4} or in elderly populations.\textsuperscript{7} We found only one case reporting a stress fracture in a healthy, active male athlete, also a basketball player.\textsuperscript{8} The purpose of this investigation was to describe a unique case of a femoral stress fracture in a male collegiate basketball player.

\textbf{Case Report}

\textbf{Patient History}

A 21-year old male collegiate basketball player (21 yr, 200 cm, 102.3 kg) reported to the team physician complaining of medial thigh pain during his fourth year of Division I basketball. The athlete started playing basketball at 12 years of age. Between his sophomore and junior years of high school, he began to play intensely during his summer breaks including participating in summer camps, Amateur Athletic Union leagues, and city leagues. After beginning college basketball, he spent his summers working coach’s camps, weight lifting, and playing pick-up basketball nearly every day. The athlete reported an approximate 2-week break from basketball each summer when he would go home. Throughout the athlete's college career, he sustained numerous injuries in his lower extremities including sprains, strains, bursitis, and tendonitis; he additionally underwent surgeries on both shoulders and experienced anteriorly herniated lumbar discs. The athlete had red-shirted the previous year due to shoulder surgery and had one remaining year to play. The team’s basketball season had ended in early March after play-offs and after two weeks of rest, the team began intensive post-season workouts. The athlete reported the training was more rigorous than previous years and included weight lifting, individual basketball workouts, and vigorous conditioning sessions. Because the team was in their off-season at the end of April, the athlete chose not to see an athletic trainer and instead took it upon himself to go directly to the team physician. Upon evaluation by the team physician, the athlete reported intense pain along his thigh. The athlete reported that the pain began approximately 2 weeks after the beginning of post-season conditioning, and over the course of a month, the pain in his thigh had increased in intensity and spread out over a larger area including his knee and lower leg. The athlete denied previous leg injury, radiating pain, numbness, and tingling. To rule out a stress fracture as a differential diagnosis, the physician ordered diagnostic testing. No record indicating the athlete’s diet, mineral intake, or supplement consumption was found. At this point in time, two other severe overuse injuries occurred on the basketball team: debilitating shin splints and compartment syndrome that eventually required surgery.

\textbf{Differential Diagnosis}

The differential diagnosis was hip dislocation, fracture of the femoral neck, degenerative arthritis, quadriceps contusion, quadriceps strain, myositis ossificans, leg length discrepancy, coxa vera, or a femoral stress fracture. Plain film radiographs ruled out hip dislocation, femoral neck fracture, and degenerative arthritis. Spin echo axial, coronal, and sagittal magnetic resonance imaging was performed to rule out muscle injury and demonstrated no significant findings in the thigh. Since radiographs are not sensitive for stress fracture, a bone scan was indicated. A technetium-99m bone scan revealed a focal area radiotracer uptake indicating
increased cortical activity within the posteromedial aspect of the distal metaphyseal-diaphyseal junction of the right femur consistent with a stress injury.

Treatment and Denouement

The team physician instructed the athlete to limit activity by restricting running and jumping for three weeks. He was permitted to do seated calf raises and knee extension and flexion strengthening. The athlete completed bike and pool workouts on a daily basis to maintain cardiovascular endurance. Three weeks after the initial evaluation, the athlete returned to the team physician for a follow up appointment. The athlete reported an increase in thigh pain from the first visit. He now also reported night pain and pain with ambulation. Upon physical examination, a fulcrum test was positive, a Thomas test was positive, and a straight leg raise was negative. The athlete demonstrated a hamstring lag of 30°. The athlete was put on crutches and instructed to take 1500 mg of calcium per day. The athlete continued bike and pool workouts until he returned to the team physician for his second follow up appointment. Five weeks after the initial evaluation the athlete was still reporting thigh pain and had pain simply sitting on the examining table with his leg dangling off. He was still exhibiting a positive fulcrum test, and now had a positive hop test. He was instructed to continue restraining from running or jumping but was allowed to continue to do pool and bike workouts, which he completed five days a week.

Two months after being diagnosed, the athlete returned for evaluation by the team physician, and the athlete was cleared to jog and participate in shooting drills. He was instructed to progress slowly and to back off with pain. The physician also stressed the need for continued off-season strengthening. By the time the team began pre-season conditioning, four months after the initial diagnosis, the athlete reported his thigh was only sometimes painful. The athlete was cleared for sports and was told to stretch aggressively. New bone scans indicated fracture healing.

Discussion

Identifying Femoral Stress Fractures

Although femoral stress fractures occur less frequently than stress fractures in other lower extremity bones, some femoral stress fractures have been identified in athletes participating in unsuspecting sports. Therefore, athletic trainers need to be aware of and rule out stress fractures as a differential diagnosis for thigh pain. Since the femur is located deep to muscle, symptoms do not necessarily include the normal fracture characteristic of palpable point tenderness. Instead, athletes with a femoral stress fracture may experience pain with weight-loading and pain with range of motion. Deep stress fracture pain can be described as deep, burning, or lingering. Although symptoms overlap with and may indicate several pathologies, a stress fracture or other fracture should be ruled out via diagnostic tests.

Femoral Stress Fracture as a Result of Over-training

We suggest that playing basketball year-round may predispose basketball athletes to femoral stress fractures. As previously established, stress fractures are the result of repetitive stress to bone. In addition to providing structural support, one of bone’s primary functions is to help absorb forces. Jumping is one of the distinguishing characteristics of basketball. Thus, jumping everyday in practice and games causes repetitive, heavy force stress through the weight-bearing bones, including the seldom-injured femur.

We also suggest that in addition, over-training and years of playing competitive basketball with very little rest increase the chances of a stress injury in a stronger, less frequently injured bone, such as the femur. Further compounding any predisposing factors, many
basketball players do not participate in cross-training, which is conditioning with other sporting options such as swimming, biking, or rowing. Two decades ago, many athletes often played two to four sports every year in both high school and college. While this does not provide for overall rest, playing different sports allows for a time of cross-training and periods of decreased jumping intensity. At the collegiate level, and now often at the high school level, athletes focus on and play only one sport. Also, in the summer and off-season months, athletes often participate in competitive camps, leagues, or play pickup games every day. Many serious basketball players now play basketball year-round from high school through college. Jumping year round for continuous years may increase the risk of basketball players obtaining overuse injuries, such as femoral stress fractures.

Prevention of Stress Fractures with Cross-Training

Periodization is a year plan designed to emphasize and develop sport-specific exercises enabling the athlete to come to his or her physical peak during their competitive season. The phases of periodization include preparatory, competitive, and transition. Due to the competitive nature of athletics, many athletes have shortened their transition stage or fail to give their bodies appropriate rest during the transition stage. Collegiate basketball players are recommended to have a transition period between the months of May and June, before starting again in July with sport-specific conditioning. During the transition months, basketball players could maintain their level of conditioning by swimming, biking, or elliptical machine training. Activities such as sprint workouts, track workouts, and plyometrics should be avoided during this period. While athletic trainers are well aware of the dangers of over-training, many coaches and athletes may not understand the concepts and importance of transition phases and cross-training in over-use injury prevention. The athletic trainer should educate coaches, emphasizing the need for cross-training, and recommend appropriate periodization schedules for athletes participating in competitive summer camps or leagues. Also, the athletic trainer should warn the athlete against playing pick-up games on a consistent basis as a training method and emphasize the importance of cross-training.

Uniqueness of This Case

It is not disputed that femoral stress fractures are not a rare injury. In fact, a plethora of evidence is found in the literature on femoral stress fractures in the general population, specifically in the elderly. Also, femoral stress fractures are well documented as a secondary problem or in concomitant to existing pathologies such as leg length discrepancy, coxa vera, or knee arthroplasties. Femoral stress fractures are well documented in the athletic and military populations; however published case studies are typically found reporting the injury in females or in long distances runners. There is only one other published case of a femoral stress fracture diagnosed in a male participating in a sport other than long-distance running. Previous case reports indicated the rarity of a stress fracture in a male who is not a long-distance runner. In a ten-year study of a Division I athletic program, only seven femoral stress fractures were recorded. Of the seven femoral stress fractures reported, five occurred in females and two were sustained by male athletes. Both of the male athletes diagnosed with femoral stress fractures were distance runners.

Clinical Implications

Athletic trainers are responsible for the prevention, treatment, and rehabilitation of athletes as well as educating athletes about healthy behaviors. Part of the responsibility of recognizing injuries is to determine the cause of pain and pathology in order provide the correct treatment for the athlete. Athletic trainers may need to consider unlikely or improbable causes of
injuries when assessing an athlete's injury. Understanding and considering possible exceptions to normal predisposing factors to a variety of injuries can aid in the evaluation and assessment of stress fractures. In this case, the exceptions were an uncommon femoral stress fracture in an unlikely athletic population. Further, athletic trainers should stress to athletes, especially basketball players, the importance of cross-training in the prevention of over-use injuries.

References

**Effectiveness of Research Mentoring at a Large, Urban Research University**

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**Objective:** The purpose of this study was to evaluate the effectiveness of a research mentoring program and research mentors. **Design and Setting:** The Research Mentoring Program is a component of a required course within the Advanced Masters in Athletic Training/Sports Medicine Program used in this investigation. Two scholarly writing projects are required; students prepare these projects for submission at local, regional, and national symposia. **Participants:** Participants were purposefully sampled as all participants were enrolled in the Research Mentoring Program. Eleven participants (91.7%; six female, five male) completed the Research Mentor Evaluation (mean age=24±2.13yr; range=22-29yr). Four mentors (three female, one male) were identified (mean age=28.4±4.72yr; range=24-35yr). **Measurements:** An electronic survey containing 34 Likert-type questions was used. Seven open-ended questions solicited further responses. Data were analyzed using open-coding and closed-coding techniques by the primary investigator and a co-investigator. **Results:** The Likert-type questions revealed that participants “somewhat agreed” with responses in each of the thematic areas: Intellectual Growth and Development (mean=3.89±.16), Research Skill Development (mean=4.06±.35), Professional Career Development (mean=3.81±.59), Academic Guidance (mean=3.85±0.83), and Personal Communication (mean=4.34±.66). Participants reported their mentors had the ability to provide constructive criticism, a willingness to help others, showed genuine interest in mentees, made themselves available to all students, provided excellent feedback, and explained concepts without making people feel inferior. **Conclusions:** Because the profession of athletic training is very new and we struggle for respect and ownership over our skills, the mentorship of future researchers and professionals is vital. Continued investigations of this unique mentorship process with semi-structured interviews are planned. **Key Words:** mentorship, post-certification graduate athletic training education program, higher education

Mentorship is said to be at the center of graduate education.1,2 Mentorship relationships develop when older, more experienced professionals provide guidance, support, and socialization opportunities to a less experienced protégé.1-4 This role includes teaching the technical aspects of the profession, collaboration with research, assistance with job placement, networking, and professional development,1 as well as providing support, understanding, positive role modeling, and protection.4 Several educational researchers and educators have conveyed their experiences in scholarly journals to demonstrate positive characteristics of their mentorship relationships.3-5 One researcher stated that his relationship with his mentor motivated him to take action, but allowed him the space to be his own person and create his own professional identity.3 Another researcher reported that he was mentored by a leader in his profession and that his mentor had exposed him to a series of professional and personal principles: value of collaboration, value of the research process, valuing educational research, productivity, and humility.5 These researchers had journeyed from a mentorship relationship to a partnership.

Research suggests that all graduate students should be exposed to mentorship, especially women, minorities, and international students. Some research has investigated the role of mentorship mostly in relation to different fields within higher education; however, no present research exists investigating the role of research mentoring in post-certification athletic training education programs. As such, we developed and implemented a research mentoring program in a post-certification athletic training education program at a large, urban research university. We sought to evaluate the effectiveness of a research mentoring program and research mentors to better understand the characteristics of an effective mentor.

Methods

Research Mentoring Program

The Research Mentoring Program is a component of the required Graduate Research Seminar course within the Advanced Athletic Training/Sports Medicine Masters of Science Program used in this investigation. Two scholarly writing projects are required for the course, a clinical research project and empirical research project. Students prepare these projects for submission at local, regional, and national symposia. During the development of these research projects, the Research Mentoring Program involves three layers of mentorship. Each participant is a member of a Research Group which includes peers, senior students, and a doctoral resident. The first layer of mentorship occurs among peers within the Research Group. The second layer of mentorship involves the guidance of the Research Group Leader who is a doctoral resident. A faculty member provides the third level of mentorship and this relationship is often developed in the second semester or second year of coursework.

Participants

Participants were purposefully sampled as all participants were enrolled in the Research Mentoring Program and asked to evaluate whomever they considered their research mentor (doctoral resident and/or faculty). Institutional Review Board approval and informed consent were obtained prior to the investigation. Twelve participants were enrolled in the Research Mentoring Program at this urban institution. Eleven participants (91.7%; six female, five male) completed the Research Mentor Evaluation and their ages ranged from 22 to 29 years (mean age= 24±2.13 yr). Four mentors (three female, one male) were identified with an age range of 24 to 35 years (mean age= 28.2±4.32 yr). Seven of eleven, or 63.6% of the mentees reported that a doctoral student served the mentorship role. The remaining participants (46.4%, n= 4) reported that a faculty member acted as their mentor, but all four participants were in their second year of coursework.

Instrumentation

In this pilot investigation we sought to evaluate our electronic survey to determine its effectiveness. Five common themes of mentorship were identified and used to evaluate the effectiveness of the mentor. The survey contained 34 5-point Likert-type questions, ranging from “Strongly Disagree” to “Strongly Agree” with an option of N/A (Not applicable). Seven open-ended questions solicited further responses. Five faculty members and two doctoral residents reviewed the survey for construct and content validity and readability. Revisions were made accordingly.

Data Analysis

Data were analyzed using open-coding and closed-coding techniques by the primary investigator and a co-investigator. A colleague with expertise in qualitative methods conducted a peer review by examining the coding sheets and summary of the findings. The peer review established the effectiveness of the research instrument and the trustworthiness of the findings.
Results

The Likert-type questions revealed that participants “somewhat agreed” with responses in each of the thematic areas: Intellectual Growth and Development (mean= 3.89±.16), Research Skill Development (mean= 4.06±.35), Professional Career Development (mean=3.81±.59), Academic Guidance (mean=3.85±0.83), and Personal Communication (mean= 4.34±.66). The themes that were used for the Likert-type questions were also helpful in describing the aspects of research mentoring that were influential, both effectively and ineffectively in the open-ended questions. In addition, respondents provided characteristics of the research mentor that were effective and ineffective; therefore, we developed a theme describing personality characteristics. 

Intellectual Growth and Development

Mentors furthered the intellectual growth and development of their mentees. Mentees reported that their mentors “stimulated thought” and promoted a “desire to learn” that positively influenced them. By providing “constant encouragement”, participants were “inspired to look at research from a new perspective and find enjoyment.” Mentors promoted creative, critical, and innovative thinking that are important tools within allied health professions. The most obvious trend reported by respondents was that mentors encouraged students to challenge themselves.

Research Skills Development

A fundamental aspect of the relationship between mentor and mentee in a research mentoring program is obviously the development of strong research skills. According to mentees, research mentors demonstrated a strong understanding of research skills and knowledge in the commonly researched areas within the program. Mentees reported that they developed or strengthened writing, editing, and presentation skills under the guidance of their mentors. Mentors often aided in the brainstorming and development of the empirical research project. Mentors and Research Groups helped to provide avenues for finding research resources and created a pool of research resources. One mentor used examples of her own work to help students understand the research process. Second year students reported having mentors who taught them how to use equipment in the research lab and instructed them on the use of the equipment in order to conduct their research projects. Mentors were also vital in instructing mentees on the use of software for data analysis, analyzing data, understanding findings, and the development and completion of the research project.

Professional Career Development

Mentors should provide students with avenues to progress within the profession. Several respondents reported that their mentor discussed publishing their work. One student reported that the mentor encouraged the publication of both her empirical research project and clinical case report upon graduation. Mentees stated that mentors should set a good example of how to present one’s self professionally. One participant stated that their mentor was “a good example of how to try to present oneself as a professional at all times.” Another student commented that the mentor “has encouraged me to rethink the importance of having a Masters in Athletic Training,” which is a current issue in the profession. Mentees also suggested that the mentors were strong advocates of the profession.

Academic Guidance

Students within the Academic Program at this institution enroll in courses taught within the department, but are also encouraged to take courses in other colleges and departments to fulfill an area of specialization. Mentors often provided academic guidance for classes taught both in other departments and within the Exercise and Sport Science program area. Participants reported that one mentor offered “personal time to tutor for an anatomy class.” Also,
respondents reported that the mentor provided useful information for success in classes. Mentors provided confidential, individual meetings to help students develop their program of study and discuss academic issues. While helping students shape their program of study, one mentor encouraged students to take “interdisciplinary courses for professional development.”

*Personal Communication*

Participants as well as investigators believed that personal communication is an important aspect of the mentorship relationship. Not only was the communication between the mentor and the mentee important, but also the encouragement of other professional relationships through communication was a central theme. Mentees suggested that their mentors had taught them the value of effective and continuous communication by themselves providing continued email and phone communication. When mentors provided immediate and quality feedback, they demonstrated good examples for students to follow which transferred into the dynamic of the research groups. Respondents stated that the research group provided them with almost “instantaneous feedback” on their writing, which strengthened their writing and editing skills. Mentees often respected their mentors because they were able to provide constructive criticism. One mentee reported that the mentor was willing to “tell you when you are messing up, but will as easily tell you when you have done a good job.”

*Characteristics of a Mentor*

Participants were asked about the effective and ineffective characteristics of their mentors, and they were also asked about the characteristics of their mentors that have influenced them to become mentors. Participants reported that their mentors were approachable, honest, knowledgeable and experienced, exemplified strong research skills, were versatile, good listeners, and have a passion for discovering new ideas. One participant stated that the mentor was “very intelligent, not only within our profession, but in academics as well.” One mentor had influenced her students “not by what she has spoken, but by her actions and her willingness to help others.” Participants reported several actions that influenced them positively; ability to provide constructive criticism, willingness to help others, showing genuine interest in her mentees, making herself available to all students, providing excellent feedback, and explaining concepts without making people feel inferior.

*Discussion*

Constructive relationships between graduate students and their mentors are essential for the promotion of excellence in graduate education. As previously stated, no current research was found investigating the effectiveness of mentorship in post-certification athletic training education; however, one investigation explored the role of mentorship in entry-level (or undergraduate) athletic training education. The researchers demonstrated that athletic training students believed effective mentors were approachable and accessible. Athletic training students sought mentors who demonstrated similar values to their own, trust, and a willingness to engage in personal relationships. Athletic training students believed that their mentors should facilitate knowledge and skill development, individualize learning, and encourage different professional perspectives. This information is important in understanding the expectations of students as they progress from undergraduate into graduate education. Accessibility and approachability are vital in igniting the mentorship relationship, but often the relationship is continued through similar interests and professional aspirations.

The development of research skills was essential for both the mentor and mentee in this investigation. Waxman reported that one of the most important lessons he learned from his mentor was the value of understanding the research process. Understanding the research process
propelled he and his mentor into a collegial relationship beyond the faculty-student mentorship he once described. Understanding the need for research in athletic training is in itself unique and therefore very important to the mission of this Research Mentoring Program.

**Conclusions**

This pilot investigation revealed the need for further research of mentorship among graduate students in post-certification athletic training education programs. The survey tool was ineffective in obtaining the deep, rich experiences of our participants. The Likert-type questions allowed for a thorough evaluation of certain characteristics within graduate education; however, we believe interviewing participants will allow us to gain a deeper understanding about aspects of the program that are effective or ineffective. The interpretation of data revealed positive experiences reported by respondents. We intend to continue the investigation of mentorship in graduate athletic training education beyond this initial investigation with a semi-structured interview to gain more insight into this unique, layered mentorship process.

**Table 1. Open-Ended Response Questions from Survey Instrument**

- Please provide at least FIVE perceptions about the effectiveness of the research groups:
- Please provide at least FIVE perceptions about the ineffectiveness of the research groups:
- Please provide FIVE or more ways your mentor has influenced you in the following areas: Intellectual Growth and Development, Research Skill Development, Professional Career Development, Academic Guidance, Personal Communication:
- What mentoring activities have you found useful? Should they be continued?
- What mentoring activities have not been useful? How could they be improved?
- What are some characteristics of your mentor that influence you positively?
- What are some characteristics of your mentor that influence you negatively?
- How has your mentoring experience encouraged you to be a mentor?

**References**

Effects of Body Weight Squats on Balance and Upright Mobility in Participants with Incomplete Spinal Cord Injury

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**Background:** Few exercise interventions have been designed to improve the lower body strength of individuals with incomplete spinal cord injury (SCI). Such improvements could improve balance and upright mobility. **Objective:** To determine the effects of a 6-week resistance training program using body weight squats (BWS) on measures of balance and upright mobility in participants with SCI. **Design and Setting:** A single-case design with no between subjects comparison was utilized. Testing and training occurred in an exercise facility used by participants with SCI. **Subjects:** Three males and one female with incomplete SCI participated in the case report. Two of the males and the female were classified as American Spinal Injury Association (ASIA) functional category C and the other male was classified as functional category D. **Intervention:** Participants trained 3 days/week for 6 weeks using 3 sets of 10 reps of BWS. **Measurements:** The three outcome measures included a modified Timed Up and Go Test (mTUG), the Berg Balance Scale, and the Sit to Stand Test. **Results:** All participants completed the training, attending a minimum of twice per week, without injury or complaint of pain. Each participant demonstrated marked improvement in all outcome measures. **Conclusion:** Resistance training using BWS can improve lower body strength in individuals with incomplete SCI which in turn can improve their balance and upright mobility.

The health and performance benefits of resistance training are particularly important for populations with limited mobility, including those with spinal cord injury (SCI). Persons with SCI, for the most part, are extremely inactive and consequently at great risk for cardiovascular disease. While those with SCI adapt well to both aerobic and resistance training programs, their access to different training modes and facilities is usually limited. Moreover, arm ergometry and wheelchair ergometry, the most common modes of training among those with SCI, require expensive equipment and often cause upper extremity injuries that impair one’s ability to perform daily activities.

A challenge for health professionals who work with those who have SCI is to identify modes of training that are safe and accessible. When first working with individuals with SCI many are surprised by the considerable heterogeneity that exists in the functioning ability of those with incomplete SCI. For example, higher motor functioning individuals with SCI are capable of engaging in functional strength training activities that do not require the use of expensive equipment or skilled technicians. One such activity that paraplegics in American Spinal Injury Association’s (ASIA) impairment category D (and some in impairment category C) can perform is the arm assisted body weight squat (BWS). This activity requires rising out of a chair while pulling on bars in front of the chair and lowering oneself back to the seated position using the arms as little as possible. It is hypothesized that the lower body strength gained from BWS would not only facilitate chair transfers but could also improve ambulation with a walker and several other active daily living (ADL) tasks requiring balance. Therefore, the purpose of...
this study is to examine the effectiveness of arm assisted BWSs among those with SCI in improving performance in rising out of a chair, ambulating using a walker, and maintaining balance in selected ADL activities. Should this exercise prove to have the functional benefits expected, it could be an important activity to include in a comprehensive fitness program for selected individuals with incomplete SCI.

Methods

Participants

Three males and one female with chronic (>2 years since injury), incomplete SCI volunteered for the study. To be included in this study, a participant needed to be medically stable, and be able to rise from their wheelchair to a walker with some assistance. Thus, participants needed to belong to impairment categories C or D as defined by the ASIA’s Standards for Neurological Classifications. Category C implies motor function is partially preserved below the neurological level and more than half the key muscles below the neurological level have a muscle grade of less than 3, while Category D implies that motor function is partially preserved below the neurological level and at least half the muscles below the level have a grade of 3 or more. Participants were informed of the purpose, benefits, and protocol of the study. Subjects completed an informed consent form, which along with the protocol, was approved by the University of Miami Medical Sciences Subcommittee for the Protection of Human Subjects. Relevant descriptive characteristics are presented in Table 1.

Testing Procedures and Instrumentation

The testing protocols consisted of three ADL performance measures conducted in the following order: a) the Modified Timed Up and Go Test (mTUG); b) the Berg Balance Scale; and c) the Sit to Stand Test. The Modified Timed Up and Go Test measured the time required to rise out of a chair, walk 5 m, turn around, and return to the starting line using a walker. The Berg Balance Scale assessed the ability to maintain balance while performing 14 common, everyday tasks, including moving from sitting to standing, transferring from a chair, turning to look back, etc. The Sit to Stand Test measured the ability to rise out of their chair while relying as little as possible on the use of their arms. The contribution of the arms was assessed using mounted dynamometers.

Training Intervention

Participants underwent 6 wk of functional resistance training, performed three times weekly on non-consecutive days. The participants worked up to a target of 3 sets of 10 repetitions of the BWS. The exercise was performed from the participant’s chair which was situated in the Seated Dip Station of the Equalizer 7000 Multi-Station Exercise System. The station was modified by inverting the vertical bars so that they pointed upward and would give the participants upright bars to hold. We instructed the participants to gently grasp the vertical bars, rise out of the chair relying mostly on the legs and pulling minimally with the arms.

Results

All participants completed the six weeks of resistance training, attending a minimum of twice per week, without injury or complaint of pain, and demonstrating marked improvement throughout the training.

Participant 1. Participant 1 had the lowest level of motor functioning which prevented him from completing the mTUG test. However, on the pretest he required considerable help in rising from the chair and was unable to take a single step, but on the posttest he was able to get out of the chair unassisted and take a few steps. While difficult to quantify the improvement, it was notable. Participant 1’s initial score on the Berg Balance Scale was 7 and his posttest score...
was 19, which reflected an improvement in the quality and quantity of tasks performed. As expected, the greatest improvement was observed on the Sit to Stand Test. On the pretest, the participant was only able to rise from the chair depending heavily on the use of the arms with the knees at an angle of 125 degrees of extension. On the posttest, he was able to rise from the chair at an angle of 110° of knee extension with a significant reduction in the pulling force of the arms (i.e. 86.5 lb on the ascent and 55 lb on the descent).

**Participant 2.** Participant 2 had a pretest time of 2 min and 3 s on the mTUG and on a posttest time of 1 min and 32 s (25% improvement). The participant’s score on the Berg Balance Scale improved from a pretest score of 11 to a posttest score of 14. The pretest scores on the Sit to Stand Test were not compared to the posttest scores because the investigators realized, after the fact, that participant 2 had used a technique on the pretest which greatly underestimated the score.

**Participant 3.** Participant 3’s pretest time on the mTUG test was 1 min and 25 s and her posttest time was 1 min and 13 s (14% improvement). The participant’s pretest score on the Berg Balance test was 12 and the posttest score was 21. As expected the greatest improvement was seen in the Sit to Stand Test. The participant demonstrated 18% and 12% improvements on the ascent and descent, respectively.

**Participant 4.** Participant 4 had a pretest time of 1 min and 29 s on the mTUG test and a posttest time of 1 min and 11 s (20% improvement). His pretest score on the Berg Balance Scale was 25 and his posttest score was 43. On the Sit Up and Stand pretest, he began with a combined pulling force of 20 lb on the ascent and 26 lb on the descent. On the posttest, he showed marked improvement using only an average of 7 lb on the ascent and 14 lb on the descent. Notably, on one posttest trial he rose without the use of the arms and on two trials he rose using only one hand on the ascent.

**Discussion**

A limitation of the study was the small sample size and the considerable heterogeneity in the functional ability of the participants which made it appropriate to report the results in a case study format using descriptive statistics. However, an examination of the descriptive data suggests that all the participants showed large percent improvements in gait speed, stability, and the ability to rise out of a chair. It is hypothesized that with severe restrictions in mobility (which can result from aging, disease, or injury) that there is a rapid, substantial loss in neuromuscular control. However, despite this immediate substantial loss in neuromuscular control, the ability to regain much of this control is present in many cases. At the time of this writing there were no published studies that investigated the effects of resistance training on the lower body strength of paraplegics. Nor were there any studies related to the effects of lower body resistance training on the performance of ADLs in persons with incomplete SCI. One of the authors of this study, however, conducted an investigation of the effects of an upper and lower body resistance training program on strength and ambulatory performance. This study revealed that persons with SCI can achieve significant improvements in strength in both the lower body and upper body. Moreover, these improvements in strength could improve the time required to ambulate a short distance with the assistance of a walker. While there are no published studies investigating the effects of resistance training on participants with SCI, there is a small body of related literature investigating the effects of resistance training on the strength and performance of individuals with peripheral neuropathy. For example, Aitkens et al. found that a low to moderate intensity resistance training program improved both upper and lower body strength in those with Charcot-Marie-Tooth (CMS) syndrome, the most common peripheral
neuropathy. Similarly, Chetlin et al.⁶ found that a 12 wk, home based resistance training program improved strength and ADLs equally in men and women with CMS.

**Conclusion**

The very large percent changes achieved by each of the participants suggests that BWSs are of value in the conditioning of individuals with incomplete SCI. The results indicate that BWSs can improve both balance and mobility in this population. Future research should include a larger sample size of both ASIA categories. Also, future research might study both strength and performance measures over a longer period of time.

**Table 1.** Characteristics of the Four Participants with Incomplete Spinal Cord Injury

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Gender</th>
<th>Weight</th>
<th>Level of Injury</th>
<th>ASIA* Score</th>
<th>Years Post Injury</th>
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<tbody>
<tr>
<td>1</td>
<td>46</td>
<td>M</td>
<td>203.8</td>
<td>C5</td>
<td>C</td>
<td>19</td>
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<tr>
<td>2</td>
<td>42</td>
<td>M</td>
<td>196</td>
<td>L2-L5</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>42</td>
<td>F</td>
<td>137.8</td>
<td>C4-C5</td>
<td>C</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td>M</td>
<td>161</td>
<td>C5-C6</td>
<td>D</td>
<td>2</td>
</tr>
</tbody>
</table>

*American Spinal Injury Association

**References**

Objective: The objective of this investigation was to identify characteristics and perceived effectiveness of a sports medicine magnet program and determine the effectiveness of our research tool in gaining information about magnet programs. Design and Setting: Our investigation utilized a pilot semi-structured interview to analyze the effectiveness of one magnet program for Sports Medicine specializations. We utilized purposive sampling for this investigation, a magnet program in the South Florida area; however, we intend to expand our sampling population in future investigations to include magnet programs across the nation to increase the external validity of our findings. Subjects: One magnet program coordinator was interviewed regarding program operation and efficacy. The coordinator provided insight into the operations and regulations of the program. Measurements: The interview was tape-recorded and the data transcribed. Key phrases were analyzed and compared to current research regarding various magnet programs. Results: Student interest in pursuing the allied health professions with a focus on the athletic population has increased over the years. The program coordinator reported that almost 60% of current students were interested in pursuing health careers, an increase of approximately 20% from the previous year. The program coordinator believed student perception of efficacy was high; however, no structured evaluation had been conducted. Conclusion: As a result of the local magnet program, student understanding of and interest in athletic training as a career increased. Our pilot investigation revealed a need for further research and the use of a more structured interview to gain insight into the development and implementation of magnet programs. Key Words: athletic training, mentorship, specialization

Although athletic training is gaining recognition among allied health professions, the general population is less familiar with this facet of sports medicine. Few students are pursuing allied health professions, and even fewer are entering the field of athletic training due to a lack of knowledge of the general public and often their misperceptions about allied health professions. Researchers suggest parent perceptions revere physicians and physical therapist among the more “prestigious” professions, while other allied health professions rank lower. Magnet programs have been utilized to increase public knowledge, improve perceptions, and remove the common misnomers associated with the profession of athletic training.

A magnet program is a comprehensive program offering multiple classes concentrating on various aspects of a desired specialization. For example, science magnet programs expose students who excel in the sciences to various science-based or health professions. Science programs have demonstrated that students exposed to concepts within allied health show aspirations of entering the medical profession, even when the curriculum does not emphasize one profession over another. Magnet programs usually include a sequence of elective and non-elective classes tailored toward an area of specialization throughout high school. Today, many health related magnet programs involve mentorship and allow for specialization (focused learning). Mentorship provides professional role models for students to observe and seek professional guidance. Specialization tailors student learning toward a specific field or category.

of career options. The combination of these two characteristics makes magnet programs of interest to the profession of athletic training.

In the collegiate setting, students studying athletic training are able to obtain knowledge through coursework and advanced skills through assigned clinical residencies and mentorship by approved clinical instructors. In the high school, students may learn basic skills and obtain knowledge pertaining to athletic training or sports medicine but may not have the opportunity to apply this knowledge or observe its operation in the clinical setting. The incorporation of mentorship and specialization in the high school would mimic that of the collegiate setting and more importantly allow students more experiential learning opportunities than cannot be taught in the classroom alone. In the high school environment, clinical experiences correspond to mentorship and affiliations in which students observe and assist various health care professionals. Although not allowed to assist in evaluations or treatment of patients, students will be encouraged to critically think, problem solve, and stimulate discussion. As a result of these interactions not exclusive to athletic training, students may have a better understanding of the uniqueness of the profession and become more aware of various health career options.

We sought to identify the benefits of a magnet program for high school students progressing into the profession of athletic training. We utilized a semi-structured interview to gather information regarding magnet program funding, curriculum development and program requirements from one magnet program coordinator. As this is a pilot study, we interviewed one program coordinator to test our research tool and strengthen our interviewing skills.

Methods

Our investigation utilized a semi-structured interview to analyze the effectiveness of magnet programs for Athletic Training or Sports Medicine specializations. A pilot interview is a practice interview which allows the investigator to practice interview questions and gain feedback on the interview method and questions themselves. To our knowledge, there exists only one magnet program in the South Florida area; therefore, we used purposive sampling for this investigation. We interviewed the program coordinator at an urban secondary school in South Florida and sought to gather her perceptions about the effectiveness of the program and to gain in-depth information about the development of the curriculum and implementation of experiential hours (Table 1).

Results

Our pilot interview revealed important information about the Health and Wellness Magnet Program at this urban secondary school. We asked the program coordinator to tell us about the development and implementation of this program. She informed us that although the school itself is not a magnet school, administration implemented the Health and Wellness Magnet Program which constitutes approximately 5% of the school population. Interested students complete the magnet program application and if they satisfy several eligibility requirements the students are admitted into the program. If there are more applicants than available seats, a lottery system is utilized for selection purposes. Students take classes within the school to satisfy graduation requirements along with specified core classes for their area of specialization within the magnet program. To fulfill graduation requirements of the program, students must complete 20 hr of community service in the athletic training room and 20 hr at an additional facility. The program coordinator labeled this structure as a “school within a school” as students are in separate classes from the rest of the student population with the exception of core courses necessary for graduation.
The Health and Wellness program is financially independent from the school as funding is received by the government for edifying program development and enhancing student learning experiences. The program coordinator reported that financial freedom allows her leeway in deciding what activities students should be involved in (field trips, equipment purchases, etc.). In addition to financial freedom, the program coordinator is not guided by any state mandates at this time for curriculum development. As such, the coordinator and other faculty gathered input and developed broad subject matter by exploring various aspects of different health professions. The program’s autonomy has positively influenced its success and development, as faculty members were able to mold the program into various areas of specialization for interested students. In the early stages of development, courses offered evolved from psychology and other general subject matter, to more concentrated courses such as nutrition, kinesiology and sport specific weight training. Available courses were modeled after college courses in the health sciences at a local university. The material was simplified for secondary school students; however, students had the opportunity to take advanced placement courses for college credit in similar areas of study. The program prides itself on its dual enrollment option in which students attend both high school and college classes, thereby obtaining college credit while still completing their high school requirements. The program coordinator reported that she and other faculty provide assistance to the students in searching for colleges and scholarships as they near the end of their enrollment. In addition, the program provides class field trips and requires students to volunteer at local agencies for community service hours to gather knowledge about various allied health professions.

Our pilot investigation revealed the perceived effectiveness of the program as reported by the coordinator. Initially the graduates of the program were not as interested in pursuing a field in the health professions but over the years, student interest in allied health professions increased. Almost 60% of current students are interested in pursuing health careers as opposed to 40% last year and even fewer in years past. Many students were interested in pursuing a field related to sports medicine but were not sure which avenue they would follow. The program coordinator reported that students returned and stated that the program has helped them prepare for college by providing coursework that provided insight into future college courses. Students gained work experience as supervisors in the strength and conditioning room and through assisting the athletic trainer in clinics overseeing rehabilitation exercises for injured athletes. Students provided feedback about their enrollment in the program by returning to the school; however, there was no official program evaluation implemented within this program.

**Discussion**

A magnet school program is one in which the entire school has a curricular specialty. A specialization provides students with opportunities to explore various aspects of the health sciences although this is not the focus of the school as a whole. A health science magnet program provides students with the visions of their future in college health science education programs and places them ahead of their peers in preparing for college. The local magnet program observed in this pilot study modeled their courses after college courses in the health sciences at a local university. Because students have the opportunity to take advanced placement (AP) courses, any college credit received can be credited toward college graduation requirements, allowing them opportunity for future electives to explore more options in college. Also, the dual enrollment aspect of this particular program was beneficial for the college application process.
Many health profession-inspired magnet programs involve mentorship which has been identified as a key component of informing and educating high school students about their career options. Mentors in the health profession serve as a support system by providing insight, guidance and expertise on career options. Affiliation mentors are available in the athletic training room, neighboring hospitals, rehabilitation clinics, athletic arenas or other athletic organizations and may play an important role in the development and maintenance of athletic training magnet programs.

For years, many high school initiative programs have utilized collaborative efforts with mentors from local agencies and have reported success. Mentors may also volunteer to be guest speakers in classes or allow students to observe them at clinical sites. At the high school observed, the most prominent mentor was the head athletic trainer, one of the founding members of the magnet program and also instructor of several program courses. Although students may superficially recognize allied health professions, their knowledge of these careers is rather limited. The head athletic trainer may help to improve student understanding of sports medicine and clarify common misconceptions. Research has demonstrated that mentorship strongly influences students’ perceptions of a profession and their decision to pursue that profession.

Program affiliations and mentorship initiatives serve to ensure quality educational and clinical experiences for students as they learn basic or remedial skills and information in sports medicine and first aid through lectures and clinical experiences. The local program integrated CPR certification into their curriculum, which benefits not only the students but also their clinical affiliation. The combination of theoretical and experiential learning at the local magnet program provides students with basic skills in the classroom and allows for the evaluation and discussion of these skills in a practical setting. This incorporation of experiential learning allows students to observe health care professionals and gain advanced knowledge and recognition of skills. Students not only have a clinical advantage upon entering college compared to their counterparts but also educational advantages.

We were able to gather information from the program coordinator through simple conversation with the interjection of direct questions throughout the interview. We believe a structured interview would be more beneficial for future data analysis. As a result of this pilot study, we found that the research tool requires more guided questions, as well as additional follow-up questions. We intend to integrate triangulation, or gathering information from students within the magnet program, as well as faculty to obtain a more complete picture of the effectiveness of this program. Valuable information was obtained from the interview. In the future, additional interview questions will be developed to gather further information.

Conclusion

Magnet programs are beneficial to the athletic training profession because they provide exposure of the profession to a captive audience. In these magnet programs, interested high school students are educated about allied health professions. Students become exposed to various health professions and mentorship by active professionals. Students from these programs who pursue degrees in an allied health profession may attribute their career decision to the magnet program.

Students enrolled in magnet programs gain exposure to demanding courses and the utilization of problem-based learning could potentially improve standardized test scores. In addition, these students may become eligible for scholarships as they have built a strong academic and extra-curricular portfolio throughout their enrollment in the program. The portfolio not only provides students with a sense of accomplishment but also increases their
competitive edge in the college application process. Further research is necessary to explore magnet or specialization programs across the country to promote the profession of athletic training and other allied health professions. The effectiveness of many programs should be evaluated to observe if there is a connection or to suggest changes to improve programs.

Table 1. Sample Interview Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Sample Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow-up</td>
<td>What motivated you to create a magnet program?</td>
</tr>
<tr>
<td>Follow-up</td>
<td>What guidelines did you use for program implementation?</td>
</tr>
<tr>
<td>Question</td>
<td>Are there state guidelines for developing curriculum?</td>
</tr>
<tr>
<td>Follow-up</td>
<td>How have you tried to improve the program over the years?</td>
</tr>
<tr>
<td>Follow-up</td>
<td>Was student feedback a key component to program improvement?</td>
</tr>
<tr>
<td>Question</td>
<td>How did you obtain student feedback?</td>
</tr>
<tr>
<td>Follow-up</td>
<td>Do students in the program assist in the athletic training room?</td>
</tr>
<tr>
<td>Follow-up</td>
<td>Does the program have other clinical site affiliations outside of the high school?</td>
</tr>
<tr>
<td>Follow-up</td>
<td>Are there requirements for professional certifications (i.e. CPR, First Aid)?</td>
</tr>
</tbody>
</table>

References

**Effects of Active Hyperthermia on Upper- and Lower-Extremity Anaerobic Muscular Power**

Sean E. Garvey, Michelle A. Cleary, Lindsey E. Eberman, and Zevon Stubblefield
Florida International University, Miami, FL

**Objective:** We aimed to identify negative implications for performance of anaerobic muscular power elicited by active hyperthermia. **Design and Setting:** The independent variable was thermal condition (normothermic and hyperthermic) elicited by both upper-extremity (UE) and lower-extremity (LE) heat stress trials (HST) designed to elicit a core body temperature ($T_b$) exceeding 38.0 °C (mean ambient temperature=34.3±1.4 °C; mean relative humidity=51.5±7.6 %; mean wind speed=1.94±1.11 mph). The dependent variables were UE and LE mean and peak power. **Participants:** Eight adult males (age=24.9±3.2 yr; height=123.0±46.8 cm; body mass=89.9±10.5 kg) participated in a familiarization session and a LE-HST. Only five participants completed the UE-HST. **Measurements:** Upper body Wingate test was performed prior to and following the LE-HST and a lower body Wingate test was performed prior to and following the UE-HST. **Results:** During the UE-HST, $T_b$ was significantly (t=7.846, p=0.001) increased 2.4% ($T_b=38.2±1.1^\circ$C) and 5.3% during the LE-HST ($T_b=39.3±3^\circ$C) (t=-11.755, p<0.001). Following the LE-HST, upper-body mean power was significantly (t=2.892, p=0.023) decreased by 12.22% from the normothermic (4081.13±1175.94 W·kg$^{-1}$) compared to the hyperthermic (3582.38±863.64 W·kg$^{-1}$) condition. **Conclusions:** Moderate hyperthermia elicited by LE exercise significantly affected mean power of the upper-body whereas mild hyperthermia elicited by UE exercise demonstrated a trend toward decreased lower-body mean and peak power. LE exercise used larger muscle groups and yielded higher $T_b$ resulting in decreased UE mean power. We attribute our findings to varying levels of hyperthermia, the effects of actively elevating $T_b$ on blood distribution and muscle metabolism, and the differences in the muscle masses of the UE and LE. **Key Words:** heat stress, Wingate, peak power

Hyperthermia is any elevation in core body temperature ($T_b$). Hyperthermia occurs when the body is unable to dissipate heat quickly enough to maintain the homeostatic temperature of 37 °C. Increases in $T_b$ greater than 40°C can cause damage within the internal organs, most notably the brain and liver potentially leading to death. More common are the hyperthermic side effects that disrupt normal function and impact performance. Explosive power is the ability to make a forceful contraction of muscles to produce a powerful movement over a short duration of time and is necessary for successful athletic performance. Investigators have suggested that hyperthermia adversely affects muscular performance but few investigators have scrutinized the effects of hyperthermia on explosive power.

Explosive power is the ability to produce a maximal muscular contraction over a short period of time and is a measured by the amount of work produced in a certain amount of time. As explosive power is the combination of strength and quickness, it is required in athletic performance. Recent literature established a tendency of researchers to demonstrate the effects of passively induced hyperthermia on explosive power, but have yet to establish the impact of active hyperthermia. A hyperthermic condition maybe created in the laboratory setting either

passively or actively. Passive hyperthermia involves individuals sitting passively in a sauna for a determined amount of time until the $T_b$ increases to a hyperthermic level. Research has demonstrated that muscular endurance and strength has decreased with passive hyperthermia while explosive power increases. Passive localized hyperthermia is achieved through submerging a limb or limbs in hot water to increase the temperature of the tissues only within that limb of limbs, therefore preventing a rise in temperature of the torso and brain. Although passive hyperthermia, both localized and whole body are beneficial in increasing core body temperature, the methods do not simulate sport specific activity and may lack generalizability within athletics. We therefore suggest that inducing hyperthermia actively is the most appropriate method for generalizing laboratory findings with athletics and as such, the purpose of this investigation was to reveal the effects of active hyperthermia on muscular power.

**Methods**

**Research Design**

A test-retest design with two experimental conditions and two within-subjects variables were utilized for this investigation. The independent variables were thermal condition (normothermic and hyperthermic) and extremity exercised (upper-extremity (UE) and lower-extremity (LE)) during a heat stress trial (HST) (mean ambient temperature=34.3±1.4 °C; mean relative humidity=51.5±7.6%; mean wind speed=1.94±1.11 mph) designed to elicit a $T_b$ exceeding 39.5 °C. The dependent variables were UE and LE mean and peak power. The upper-body Wingate test was performed prior to and following the LE-HST and a lower body Wingate test was performed prior to and following the UE-HST.

**Participants**

Eight college aged (age=24.9±3.2 yr; height=123.0±46.8 cm; body mass=89.9±10.5 kg) healthy males participated in the study. Participants were aerobically/anaerobically trained with no history of heat-induced illness, chronic health problems, orthopedic limitations, musculoskeletal injuries, cardiovascular disease, metabolic disease, or respiratory disease within the last year. This study was approved by the Florida International University’s Institutional Review Board and informed consent was obtained prior to participation.

**Instrumentation**

**Heat stress trial.** Participants completed randomly assigned UE-HST and LE-HST designed to increase $T_b$ while wearing an American football uniform in a hot, humid environment. For each HST, participants warmed up with a 15 min run at 50% of their maximal heart rate followed by three shuttle runs of 10 meters or upper body ergometer exercise at a heart rate of 70-80% of the age-predicted heart rate range. Participants had free access to cool water throughout the HST. Participants continued the sets of 10 repetitions until a core body temperature of 39.5 °C or the $T_b$ plateaued for three consecutive sets.

**Wingate test.** The 30-sec protocol was performed on a cycle ergometer following a standard protocol. Peak power was determined by number of pedal revolutions in the first 5 sec of frictional load. Mean power output was determined by averaging the six, 5-sec mean power output values. Resistance for the Wingate test was set at 7.5% of the participant’s weight and for the lower body and at 5% of the participant’s weight for the upper body. The peak power of the Wingate anaerobic test has been shown to have high test-re-test correlation with a strong inter-tester reliability ($r = 0.99$). The mean power of the Wingate anaerobic test also has a high test-re-test reliability ($r = 0.89$).
Experimental Protocol

Familiarization session. Participants were familiarized with the parameters of the investigation and completed a health history questionnaire prior to participation. We then gathered and recorded baseline measures and participants were randomly assigned to either HST. After familiarizing the participants with the testing protocols, participants were instructed on how to properly ingest the CorTemp™ pill the night before the testing session. Participants were instructed to abstain from the use of alcohol and caffeine 48 hours prior to the testing date to negate any adverse effects on hydration or metabolism.

Data Collection. For data collection (4-8 days after the familiarization session), the participants reported to the FIU Sport Science Research Laboratory. Participants voided urine which was measured for volume, color, and specific gravity and then followed by a body mass measurement. Participants’ resting heart rate, resting blood pressure and core body temperature were recorded. After pre-exercise measurements were established, participants performed either a UE or LE Wingate test followed by either the UE or LE-HST. Participants continued the HST until they reached a core $T_b$ of 39.5°C or until they reached a plateau in three consecutive sets of exercise at which time exercise was terminated. Two minute rest breaks occurred between sets of exercise and the researchers gathered $T_b$, heart rate, blood pressure, RPE, and environmental conditions were recorded. Upon completion of the HST participants removed the football uniform and performed either the UE or LE Wingate test. Participants were monitored until heart rate, blood pressure, hydrations status, and $T_b$ return to baseline levels and then participants were discharged from the lab.

Statistical Analyses

Dependent t-tests were used to analyze $T_b$ and anaerobic mean and peak power for each HST. Descriptive statistics were performed for the anthropometric, thermoregulatory response, cardiovascular response, and environmental conditions measures. Data was analyzed using the SPSS 13.0 for Windows Statistical Package (SPSS, Chicago, IL). Significance was set at $P < .05$ for all statistical analyses.

Results

During the UE-HST, $T_b$ was significantly ($t_4=−7.846, p=0.001$) increased 2.4% ($T_b=38.2±1.1°C$) and 5.3% during the LE-HST ($T_6=39.3±3.3°C$) ($t_5=−11.755, p≤0.001$). Following the LE-HST, upper-body mean power was significantly ($t_7=2.892, p=.023$) decreased by 12.22% from the normothermic (4081.13±1175.94 W·kg$^{-1}$) compared to the hyperthermic (3582.38±863.64 W·kg$^{-1}$) condition. Following the LE-HST, upper-body peak power was not significantly ($t_7=1.638, p=.146$) changed, but decreased 13.39% from the normothermic (868.13±269.51 W·kg$^{-1}$) compared to the hyperthermic (751.88 W·kg$^{-1}$) condition. Following the UE-HST, lower-body mean power was not significantly ($t_4=1.437, p=.224$) changed, but decreased 9.45% from the normothermic (6191.40±975.01 W·kg$^{-1}$) to the hyperthermic (5606.40±647.86 W·kg$^{-1}$) condition. Following the UE-HST, lower-body peak power was not significantly ($t_4=.454, p=.673$) changed, but decreased 4.7% from the normothermic (1249.20±266.95 W·kg$^{-1}$) to the hyperthermic (1190.40±226.49 W·kg$^{-1}$) condition.

Discussion

We investigated the effect of hyperthermia induced at the LE on the anaerobic power of the UE, as well as hyperthermia induced at the UE on the anaerobic power of the LE. Our work contradicts previous research demonstrating upper body strength was unaffected by LE cycling. Participants cycled to exhaustion reaching a mean temperature of 38.8°C, and the researchers suggested their findings indicated that the central nervous system is capable of distinguishing
between the muscles that work during exercise and the muscles that do not work during exercise. Our results challenge this concept of central nervous system control or identification of working muscles, but we do suggest there is a central nervous system effect occurring during hyperthermia. Changes in the levels of neurotransmitters, acetylcholine, dopamine and serotonin, coincide with prolonged exercise and a consequential rise in $T_b$. Most specifically, increases in serotonin have been associated with loss of motor drive and lethargy. Conversely the increase in dopamine during exercise directly activates motor pathways and may delay the fatiguing effect by inhibiting the synthesis of serotonin. During exercise the combined effects of altered neurotransmitter levels changes are not thoroughly understood but may have a detrimental consequence on central fatigue and muscular performance.

Hyperthermia alters blood chemistry by lowering crucial energy substances for muscles. Studies found an inverse reaction of blood glucose to blood lactate levels when hyperthermia was achieved actively in controlled environments; as core body temperatures rise blood glucose decreases and blood lactate increases. Glucose is an essential element for ATP production, the major element in energy production. The rate at which blood circulates suggests a decrease in blood glucose should affect muscle production in both the upper and lower body Wingate tests equally. Glucose and lactate levels have also shown this inverse reaction in active muscles explaining the findings of previous studies where UE was unaffected by LE exercise with an increased $T_b$ but LE muscle function was negatively affected. It is obvious that changes in muscle metabolism will have an adverse effect on local muscle output but it should not affect muscles in the opposite extremity. In the current study we eliminated the local fatiguing effect of exercise by testing the opposite extremity but still found deficits in muscle production. We suggest that the chemical changes that occur in the blood stream resulting from hyperthermia following the HST could be associated with decreases in anaerobic power.

As previously mentioned, levels of glucose, glycogen and ATP fall more severely during active hyperthermia possibly contributing to the decrease in muscle power. Active hyperthermia has more devastating effects on the body as compared to passive hyperthermia. During active hyperthermia the body not only has to combat the effects of the environment on the body but also the depletion of blood and muscle substances along with the stress of metabolic heat produced by the muscle.

**Limitations**

Limitations to the study include the relatively small sample size; thus future replications of this study should incorporate a larger sample size to increase validity of the results. Another limitation of our study was the UE-HST ($T_b = 38.2 \pm 1^\circ C$) did not produce hyperthermic levels consistent with the LE-HST ($T_b = 39.3 \pm 3^\circ C$). We believe a major contributor to this fact was the size of the muscles producing the work to achieve hyperthermia. This suggests that the larger leg muscles produce far more metabolic heat than the smaller arm muscle counterparts. Further research is warranted.

**Clinical Implications**

The negative affect of hyperthermia on anaerobic power has important clinical implications. Muscular power and performance are most crucial to individuals in athletic competition and our findings are of great importance. As athletes near hyperthermic levels, muscular power will deteriorate and performance will suffer. This deterioration in muscular performance combined with the fatiguing effects of competition will not only lead to a decrease in athletic performance but can place the individual at an inherent risk for injury.
Conclusions

Our findings suggest that an increase in $T_b$ can have negative performance implications. Coaches, athletes, parents and athletic trainers should be wary of extended periods of exercise in hot, humid conditions. A hyperthermic athlete’s performance will suffer. More extreme levels of hyperthermia severely affect anaerobic power and can lead to poor performance, as well as dangerous participant conditions.

References

Differences in Closed-Loop Control of Cutting Movements Between Collegiate Athletes and Non-Athletes
Sam Kryklywec, Kimitake Sato, J.G. Cremades
Barry University, Miami Shores, FL

Background: The ability of athletes to make quick adaptations or adjustments in their movement is based on the closed-loop control system. One area of interest in athletic performance is the ability for athletes to perform cutting movements in unpredictable environments. Objective: To determine the interactions of two groups of participants and cutting angles in vertical ground reaction forces (GRFs) and time of foot contact in a closed-loop environment. The study also compared the two given time-frames to process feedback between athletes and non-athletes. Design and Setting: Measurements of the time of foot contact and the active vertical GRF were recorded to compare the movement efficiency. Collegiate athletes and healthy young adults were used for base samples. Subjects: Ten participants (5 collegiate soccer players and 5 healthy young adults) volunteered. Measurements: The time of foot contact and the active vertical GRF were measured in a total of 8 trials in 4 different angles and two different time-frame conditions. Data were analyzed using two 2*4 mixed-design ANOVA, p<0.05.

Results: The athletes performed higher active vertical GRF in the shorter time of foot contact, compared to the non-athletes. The results did not show significant interactions with the angles and the participants in the vertical force ($F_{3,24} = .789, p>.05$). Significant interaction was found with the angles and the participants in the time of foot contact ($F_{3,24} = 4.48, p<.05$). Conclusion: The athletes had overall movement efficiency as well as superior information processing system in the closed-loop condition as compared to the non-athletes. Key Words: motor-control, information-processing, force

In the realm of sports, athletes are often seen making quick decisions during the events of an athletic contest, while maintaining the appearance of fluidity. The decisions made are translated into quick adaptations of movement based on the changing environment. Information received by the brain based on the environment is rapidly assessed by the motor system and changes are made in movement based on the new information. The ability of athletes to make quick adaptations or adjustments in their movement is based on their closed-loop motor control system. The closed-loop motor control system is used to integrate constant changes in the environment to the adjustments made in movement used to adapt to those changes. The motor control system is the central processing unit that takes in new input from the environment and sends feedback to the brain, which in turn sends the new information to the nervous system to make the proper changes in movement.$^1$ This processing unit is essential when the environment in which we perform in is changing constantly. In the realm of sport and athletic performance, the closed-loop system is important for the ever-changing environment. In order for athletes to be successful, they must be able to make adjustments in their movement. During the course of a contest, the unpredictability of the opponent forces the athlete to rapidly make changes to their movement, as well as momentum.

Recent literature has examined the closed-loop control system in athletes’ function when performing tasks. The closed-loop system in soccer players was examined during penalty kicks.

in order to determine an optimum time for penalty kickers to change the direction of their desired kick based on the movement of the goalkeeper. It was concluded that the “point of no return” for changing direction of the kick was 240-245 ms before striking the ball. However, for the penalty kicker to show 100% reliability in performance, 450-500 ms before the kick was needed. This study suggests that the more time an athlete has to make a decision, the better chance the feedback loop has to make adjustments in movement. In addition, several studies have compared reaction time and simple reaction time of athletes and non-athletes. The bulk of these studies indicated that response time was faster and more effective in athletes than in non-athletes. Moreover, one research study also attempted to show how the closed-loop system is much more effective in athletes than that of untrained or unfit individuals. The effects of aerobic fitness and age were examined in an attempt to show how age and fitness levels impacted response time in closed-loop tasks. This study showed that as age increases and fitness decreases, the ability for the closed-loop control system to be affected also decreases.

The purpose of this study was to determine the interactions of two groups of participants (athletes & non-athletes) and cutting angles in active vertical ground reaction force (GRF) and time of foot contact at the closed-loop environment. This study also compared two given time-frames to process feedback between athletes and non-athletes. The hypothesis of this study was that there would be a higher failing rate in 1 meter line (1M-line) sign change than in 3 meter-line (3M-line) sign change. Furthermore, athletes were predicted to have less chance of failing trials than non-athletes because of the decision making experience in closed-loop situations. In addition, it was hypothesized that the active vertical GRF was assumed to be a similar amount between 3M and 1M sign changes, as well as, a time of foot contact for the athletes at the time direction change as compared to the non-athletes.

**Methods**

A total of 10 participants volunteered for this study. Five collegiate soccer players (age, 18.6 ± 0.5 yr.; height, 170.4 ± 3.2 cm; weight, 68.4 ± 3.1 kg; all reportedly right foot dominant) and five healthy young adults, all reported right-foot dominance (age, 20.2 ± 1.3 yr; height, 176.0 ± 5.3 cm; weight, 74.2 ± 5.3 kg) volunteered for this study.

**Procedure**

All participants reported to the Barry University Biomechanics Laboratory at the date of the data collection. After an adequate amount of stretching and warm-up, the participants started at a distance of 4 m from the force plate, and then ran to step on the force plate with the foot opposite of the direction they were guided to go by the instructor. The active vertical GRF (push-off phase of the vertical GRF) was measured by an AMTI force plate (Advanced Medical Technologies, Inc., Watertown, MA) that sampled at 600 Hz. The Peak Motus software (version 8.2, ViconPeak, Centennial, CO) was used to reduce the data with Fast Fourier Analysis. The active vertical GRF was converted from Newton to body weight (BW) and averaged for the groups. To maximize the concepts of closed-loop control in cutting movement, the investigator provided a direction sign (e.g., left (L) 30°, L60°, right (R)30°, R60°) prior to the start, and then switched the sign to the different directions at the 3M-line as condition I, and then again at the 1M-line as condition II before reaching the force plate. Visual demonstration and verbal instruction were provided to place a foot on the force plate properly. Participants were instructed to run with a comfortable pace (2-2.5m/s), and were also allowed to practice until they felt comfortable with a proper foot placement and running speed. A total of 8 trials were given to each participant, as the signs were assigned randomly.

**Statistical Analysis**
Microsoft Excel (Microsoft, Inc. Seattle, WA) was used to generate graphs to simplify the comparison between the average active GRF and the average time of foot contact of both conditions in the athletes and the non-athletes. The results of this study were analyzed using two separate 2*4 (athletes/non-athletes x 4 cutting angles) mixed-design ANOVA performed in the Statistical Package for Social Sciences (SPSS). The test was performed for each dependent variable: the active vertical GRF and the time of foot contact.

**Results**

The results showed that the athletes had a higher active vertical GRF to push-off their body when changing the directions with shorter time of foot contact as compared to the group of non-athletes in Condition I (Figures 1 and 2). The average active vertical GRF of 60° directions (L & R) from the athletes was $2.14 \pm 0.32 \times \text{body weight (BW)}$, as compared to the non-athletes with $1.81 \pm 0.11 \times \text{BW}$. The average time of foot contact of 60° directions (L & R) from the athletes was $0.21 \pm 0.06 \text{s}$, whereas the group of non-athletes was $0.30 \pm 0.05 \text{s}$. The average active vertical GRF of 30° directions (L & R) from the athletes was $2.11 \pm 0.21 \times \text{BW}$, as compared to the non-athletes with $1.85 \pm 0.15 \times \text{BW}$. The average time of foot contact of 30° directions (L & R) from the athletes was $0.27 \pm 0.06 \text{s}$, whereas the group of non-athletes was $0.29 \pm 0.04 \text{s}$. A 2*4 mixed-design ANOVA was calculated to examine the effects of the participants (athletes vs. non-athletes) and angles (L30°, L60°, R30°, R60°) on the active vertical GRF. No significant main effects or interactions were found. The angles and participants interaction ($F_{3,24} = .789$, $p>.05$), the main effect for angles ($F_{3,24} = .324$, $p>.05$), and main effect for participants ($F (1,8) = 6.47, p<.05$) were not significant. The active vertical GRF was influenced by neither participants nor angles. A 2*4 mixed-design ANOVA was calculated to examine the effects of the participants (athletes vs. non-athletes) and angles (L30°, L60°, R30°, R60°) on the time of foot contact. A significant angles and participants interaction was present ($F_{3,24} = 4.48$, $p<.05$). In addition, the main effect for angles was not significant ($F_{3,24} = 2.44$, $p>.05$). The main effect for participants was significant ($F_{1,8} = 4.97$, $p<.05$). Upon examination of the data, it appears that soccer players showed shorter time of foot contact (Figure 3). The results showed that the group of non-athletes failed all trials when the sign was changed at 1M-line from the force plate. This indicated that the participants recognized the sign change, but the motor process cannot activate quick enough to go in the guided directions. On the other hand, the group of athletes succeeded a total of 18 out of 20 trials (90% success rate) in the same condition. Due to all failing trials among the non-athletes, only the data from the group of the athletes was used to compare between condition I (3M-line) and condition II (1M-line). The active vertical GRF was higher when the sign was changed at 3M-line than when the sign was changed at 1M-line due to the faster running velocity prior to reaching the force plate. When the sign was changed at 1M-line, participants were forced to decrease running speed that caused to reduce the active vertical GRF during the cutting maneuver. In addition, among the group of athletes, the results also showed that the average time of the foot contact was shorter when the sign was changed at 3M-line (30°, 0.27 s; 60°, 0.20 s) as compared to the 1M-line (30°, 0.33 s; 60°, 0.29 s).

**Discussion**

When observing the results, there was significantly less failure in Condition I (3M sign change) as compared to Condition II (1M sign change), which supports the first hypothesis of this study. In addition, it was concluded that the athletes’ performance is superior to non-athletes when having only 1M to change their decision, which ultimately supports our second hypothesis. However, because no data could be compiled in Condition II for the non-athletes due to the 100% failing rate of all trials; we could not compare groups and therefore were unable to support
our third hypothesis. The third hypothesis was not supported due to the fact that the active vertical GRF was higher and the time of foot contact was shorter when the sign was changed at the 3M-line as compared to the 1M-line. The results also indicated that athletes produced a longer time of foot contact when the sign was changed to R30° than any other angle or direction. The findings reported by Etnier and colleagues indicated that trained individuals might have faster response time than untrained individuals.³ The present study supported the findings and indicated that because of the traits a trained person may have, as well as their experiences, their closed-loop control system functions more effectively than that of non-athletes. Other studies have been done to find the “point of no return” in which individuals cannot send feedback of a desired movement fast enough to make a change in their movement pattern. The findings reported by Morya and associates stated that the point of no return was 240-245 ms before the movement was needed in order to effectively change directions of a penalty kick in soccer.² The 100% failing rate at the 1M-line by the group of non-athletes in the present study may indicate that somewhere between 1M and 3M lies the “point of no return” for non-athletes to effectively make fluid changes in an unpredictable environment. The point of no return may be closer than 1M in the athletes because of the high success rate.

When the athletes were guided to R30° in Condition I, the time of foot contact was longer than when they moved in all other directions. When the athletes used their non-dominant foot to move to the right, their time of foot contact was longer especially at the 30° acute angle as compared to all other angles and directions. This may have an indication as to how dominant as compared to non-dominant foot can affect force production during cutting movements in different directions. Overall, the athletes showed improved movement efficiency by performing the cutting maneuver with higher active vertical GRF in shorter time of foot contact as compared to the non-athletes.

**Figure 1.** Comparison of active ground reaction force between athletes and non-athletes at the 3M sign change
Figure 2. Comparison in time of foot contact between athletes and non-athletes at the 3M sign change

Figure 3. Comparison in the average time of foot contact in four angles between athletes and non-athletes
References
Severe Dehydration with Cramping Resulting in Exertional Rhabdomyolysis in a High School Quarterback

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Objective: We present a case of a unique pathophysiological injury involving severe dehydration, muscle cramping, and resultant rhabdomyolysis in a high school football player. Background: A 16 y old male football player (body mass = 69.1 kg, height = 175.3 cm) reported to the ATC after the morning session on the second day of two-a-days complaining of severe muscle pain and cramping. Upon arrival to the emergency department, intravenous (IV) fluid was administered and blood analysis revealed creatine kinase (CK) that peaked at 3363 IU·L⁻¹ (normal range=26-174 IU·L⁻¹). Following initial testing, the athlete was transported to a children’s hospital for differential diagnosis.

Differential Diagnosis: The physician suggested severe dehydration, exertional rhabdomyolysis, or myositis. CK testing revealed elevated levels indicating mild rhabdomyolysis. Treatment: Eight liters of IV fluid was administered within the 48 hr hospitalization period. Early fluid replacement is the key to managing acute exertional rhabdomyolysis. Uniqueness: To our knowledge, no reports of exertional rhabdomyolysis in an adolescent athlete have ever been reported. In addition, increased CK levels have been reported in contact football during preseason practices but players were participating in contact drills. Our athlete developed rhabdomyolysis even after being well conditioned and acclimated for exercising in pre-season non-contact conditioning practice. Conclusions: The athlete was released from the children’s hospital in stable condition on Day 5 post-incident with a CK level of 1550 IU·L⁻¹. The athlete was cleared and returned to practice on Day 7, participated in all activities and was monitored for any return of symptoms. Key Words: heat illness, creatine kinase, acclimatization

Acute exertional rhabdomyolysis is a problem encountered by athletes as a result of extreme or novel physical demands placed on the musculoskeletal system. Exertional rhabdomyolysis results from the degeneration of skeletal muscle caused by excessive or unaccustomed eccentric exercise.¹ Athletes participating in hot and humid environments are even at greater risk due to the effects of dehydration and hyperthermia on skeletal muscle. Muscle damage and necrosis mostly occur in dehydrated, untrained individuals during downhill walking, running, or resistance-training exercises.¹² Rhabdomyolysis has also been reported in long distance runners, weight lifters, football players³ and recently in a correctional facility.⁴ Rhabdomyolysis has many underlining causes, some of which are genetically inherited while others are acquired. In the United States, 26,000 cases are reported annually, but most of the cases involve military personnel, law enforcement, and fire department trainees.⁵ We found few reports of exertional rhabdomyolysis in athletes and none in adolescent American football players. We present a case that occurred on the second day of high school pre-season football training in a 16 year old male (mass = 69.1 kg, height = 175.3 cm) quarterback who initially presented to the Certified Athletic Trainer with severe muscle cramps.

Case Report

Case History

The athlete reported to pre-season practices well acclimatized with indoor (primarily)/outdoor conditioning for the previous eight weeks and reported no previous history of hospitalization for exertional heat illness, medical conditions recent illnesses, medications, or sport supplementation. Participation in pre-season practice consisted of team conditioning and non-contact, position specific drills with approximately 7.5 min water breaks every 45 - 60 min. On the first day of pre-season conditioning, the team was educated on the importance of rehydration. The athlete reported to the ATC after the morning session on the second day of two-a-days complaining of severe muscle pain and cramping in the lower legs and hamstrings that progressed into the lower back and abdominal muscles. The athlete reported that throughout the 3.5 hr practice, he consumed water during the three breaks and estimated to have drunken approximately 6-8 oz at each break. The treatment consisted of copious water and carbohydrate-electrolyte beverage consumption and mild stretching of the affected muscles. During treatment, painful and spasmodic involuntary contractions began to affect the larger muscles groups of the lower back and abdominal muscles, along with the previously mentioned lower legs. Ice bags were then immediately placed on the cramping muscle groups to desensitize the involuntary muscle contractions. Vital signs were closely monitored every 15 min for approximately 1 hr and were considered within normal limits. The emergency medical response unit was contacted bringing the total elapsed time from initial evaluation to hospitalization to approximately 3 hr.

Upon arrival to the emergency department, intravenous (IV) fluid was administered and complete urinalysis, hematology, and chemistry reports were ordered. The urinalysis report was negative for hemoglobinuria and the urine (volume=700 mL; specific gravity≤ 1.005 µG) was clear and had a straw colored appearance. Blood analysis revealed creatine kinase-MB levels at 17.2 ng·mL⁻¹ (normal = 0.6–6.3 ng·mL⁻¹) and creatine kinase (CK) peaked at 3363 IU·L⁻¹ (normal range = 26-174 IU·L⁻¹). Blood urea nitrogen (24 mg·dL⁻¹) and creatinine (1.6 mg·dL⁻¹) were also elevated above normal ranges. Calcium was slightly elevated at 10.8 mg·dL⁻¹ (normal = 8.6-10.3 mg·dL⁻¹) and potassium was within its normal limits. The athlete was maintained on a fluid replacement therapy and two additional blood reports were ordered throughout the course of the evening. The athlete received 8000 mL of intravenous saline in addition to 900 mL by mouth, bringing the total fluid intake to 8900 mL with 700 mL excreted by the urinary system. The athlete’s additional blood analysis continued to demonstrate elevated CK-MB and CK levels, at which time the attending physician opted to transport the athlete to the children’s hospital for further treatment of dehydration and to rule out rhabdomyolysis as a differential diagnosis.

Differential Diagnosis

Admission to the children’s hospital occurred approximately 15 hr after emergency department admission. Upon physician evaluation, the athlete maintained strict volume intake of 120 mL·hr⁻¹ of IV fluid. A new series of laboratory exams followed to rule out rhabdomyolysis. The results of the urinalysis for our athlete produced no traces of myoglobinuria, hematuria, or hemoglobinuria, and a 1.015 µG specific gravity with a clear and yellow color. Although urine specific gravity appeared to be normal, patients suffering from renal dysfunction tend to have urine specific gravity equal to that of blood plasma (1.008 - 1.010 µG) regardless of changes in the patient’s sodium and water intake.⁶ Physicians suggested a differential diagnosis of severe dehydration, exertional rhabdomyolysis, or myositis. The CK test, also known as the total CK, is a laboratory exam
ordered if a patient complains of muscle pain or general body weakness or if a myocardial infarction is suspected. Testing for CK is the most reliable diagnostic indicator for rhabdomyolysis. In our case, CK analysis revealed CK levels peaking approximately 12 hr after the end of exercise and then declining around 24 hr. The CK levels at 36 hr had further reduced. The athlete’s electrolytes were within normal limits and the athlete was discharged after consultation with a nephrologist on the second day of hospitalization.

Case Evolution and Denouement

The athlete was cleared and returned to practice on Day 7 and participated in all activities although he had a 2.75% body mass loss at the time of return to activity and sustained a maximum loss of 4.6% body mass throughout the course of the condition and treatment. The ATC was advised to monitor the athlete’s return of symptoms. The ATC encouraged the athlete to take frequent water breaks throughout practices and consume supplemental fluids while at home. For approximately two weeks after his return to full activity, the athlete consumed 16 oz of carbohydrate-electrolyte beverage prior to and following each practice to supplement water intake. The athlete’s return to participation has not stimulated any additional bouts of muscle cramping or dehydration.

Discussion

Dehydration and Heat Cramps

Dehydration in athletics occurs because of inadequate replacement of sweat loss during and following training and competition. While performing physical exercise in hot weather, it is essential that athletes replace the fluids lost through sweat by drinking equal quantities of water. Sweat occurs independently of fluid intake and if sweat losses are not replaced by fluid intake, dehydration negatively impacts athletic performance. Dehydration levels as low as 2% impair the cardiovascular and thermoregulatory system causing a negative impact on the capacity to perform exercise.

Heat cramps are extremely painful muscle spasms that occur most commonly in the calf and abdomen, although any muscle can be involved. Although conclusive evidence is lacking, heat cramps are likely the result of a sodium chloride deficit. Heat cramps are also one of the most common clinical problems encountered by medical professionals dealing with athletes, especially marathon and triathlon athletes.

Etiology of Exertional Rhabdomyolysis

Exertional rhabdomyolysis is one of the most common forms of rhabdomyolysis, and is characterized by muscle necrosis and release of intracellular contents such as myoglobin and creatine kinase into the bloodstream. Clinically, rhabdomyolysis is characterized by symptoms of nausea, vomiting, agitation, weakness, and muscle pain, along with tea-colored urine. Acute renal failure is one of the most serious late-stage complications of rhabdomyolysis occurring in 33% of patients.

Dehydration causes muscle damage and necrosis especially in untrained participants performing unaccustomed exercise in high temperature ambient environments. During exercise, heat is generated and blood is drawn away from the gastrointestinal tract and kidneys and is shunted toward the skin to aid in heat dissipation. This thermoregulatory response to exercise causes tissue and muscle hypoxia, depletion of adenosine triphosphate, and eventually muscle cell necrosis and cell death if the process is not reversed in time.

Eccentric exercise has been associated with elevated levels of plasma CK in the circulatory system, as CK is one of the proteins that is released into the blood stream from the skeletal muscle when injury to the muscle occurs. An elevated CK level provides the most
sensitive enzyme marker for muscle damage\textsuperscript{14} and is extremely important in the diagnosis of rhabdomyolysis. In patients suffering from severe cases of rhabdomyolysis, CK levels may increase to 100,000 IU/L\textsuperscript{13} or more, with normal levels ranging from 26 to 174 IU·L\textsuperscript{-1}. In addition to elevated levels of CK, rhabdomyolysis typically includes elevated levels of blood urea nitrogen and creatinine as a result of pre-renal causes of acute renal failure from dehydration and myoglobinuria.\textsuperscript{13}

\textit{Treatment and Prognosis of Exertional Rhabdomyolysis}

Once rhabdomyolysis is diagnosed, early fluid replacement is necessary to preserve renal function and to prevent acute renal failure.\textsuperscript{13} Initially, rhabdomyolysis is treated with high-volume IV fluid replacement, administered at a rate of 1.5 L·hr\textsuperscript{-1}, which is usually about 200 cc·hr\textsuperscript{-1}·liter\textsuperscript{-1} bag. Patients may require as much as 4 to 10 L of normal saline in the first 24 hr to maintain circulation and stabilize blood pressure.\textsuperscript{15} Skeletal muscles can recover from episodes of rhabdomyolysis with minimal permanent damage and the overall survival rate after rhabdomyolysis is approximately 77%.\textsuperscript{13}

\textit{Uniqueness of Our Case}

In most cases of exertional rhabdomyolysis, strenuous exercise is the primary etiological factor because of lack of patient experience and fitness level, unaccustomed intensity levels, unaccustomed duration levels, or the type of muscle contraction performed during the exercise. In our case, a 16 y old male athlete was participating in a typical pre-season football camp when he developed severe dehydration and a mild case of exertional rhabdomyolysis. The athlete was acclimatized and had been participating in conditioning consisting of running sprints and non-contact football specific drills, most of which would not be classified as eccentric contractions. To our knowledge, this case is the first documented case of severe dehydration and rhabdomyolysis occurring in an adolescent athlete.

\textit{Clinical Implications}

The physiologic effects of exercising in hot and humid environments have been widely studied and continue to be explored today. Exertional rhabdomyolysis is the most common form of rhabdomyolysis and, if not detected, can lead to severe complications such as renal failure and even death. Dehydration, high ambient temperatures, and high humidity levels are all risk factors for developing exertional rhabdomyolysis; all of which are fairly common in football. Athletic trainers are the life line needed for an athlete unaware of the signs, symptoms, and dangers of dehydration. Athletic trainers should be suspicious of rhabdomyolysis when symptoms of dehydration or severe acute muscle soreness are present. Furthermore, it is critical that during intensive conditioning programs, such as two-a-day practices, athletes are educated and closely monitored for signs and symptoms of dehydration and that appropriate re-hydration opportunities are provided before, during, and after training.

\textbf{References}

Objective: To present a biomechanical examination of trunk and pelvic rotation in the sagittal and frontal planes during running and to demonstrate how dysfunction in the core and pelvic-hip complex muscles may affect the running cycle and increase the risk of injury during running. Background: Injuries pertaining to the back, pelvis, hip and thigh account for approximately 25 – 30% of injuries sustained by runners. Lumbo-pelvic support during running comes from the four key stabilizing mechanisms of the core: thoracolumbar fascia; intra-abdominal pressure; the paraspinal muscles (interspinales and intertransversarii) and the deep lumbar musculature (multifidus, lower longissimus and iliocostalis). Contraction of these muscles produces trunk and pelvic rotation in both the sagittal and frontal planes during running. Weakness of core and pelvic-hip musculature may result in poor coordination of lumbo-pelvic force couples, faulty trunk and pelvic rotational mechanics, inadequate transfer of forces up the kinetic chain and increased risk of injuries. Recommendations: Clinicians and coaches should appreciate how to effectively include exercises that promote correct coordination and recruitment pattern of core muscles. Exercises should include spinal stabilization and integrated core exercise patterns. Conclusion: Adequate stabilization during running allows the trunk musculature to effectively respond to external forces and teaches the athlete to better brace the trunk while initiating powerful movements. Adequate stabilization may also resist shear and compressive forces during sporting activities and allow for optimal rotational mechanics and a reduced risk of lumbar and lower-extremity injuries during running. Key Words: core stabilization, lumbo-pelvic-hip complex, injury risk

There are a variety of joint actions, compressive forces and rotational movements that occur during running, placing great stress on connective tissues throughout the body.1 Runners are aware of these risks and train to decrease the likelihood of injury by progressively increasing exercise intensity and performing resistance training exercises. However, the saying “what you don’t know can hurt you” holds true when it comes to considering what runners understand about the effects of weak core and pelvic stability on the running cycle and what type of training is needed to create functional strength in this area.

We will refer to the term ‘core’ as the muscles of the abdominal wall and lumber musculature as well as the associated hip and pelvic musculature. We will present the functional anatomy of the core musculature (as it relates to core support and control), examine the rotational biomechanics between the trunk and pelvis in the sagittal and frontal planes during running, and demonstrate how muscle dysfunction in the core can affect the running cycle, decrease athletic performance, and increase the risk of injury during running.

Injuries pertaining to the back, pelvis, hip and thigh account for approximately 25 – 30% of injuries sustained by runners.1,2 Other common pathologies affect the foot, ankle, knees and shins. Most of these injuries tend to become recurrent, which creates a challenge for both the clinician and coach.1
Background

We will describe lumbo-pelvic-hip complex motion with respect to the phases of the running cycle. A complete running cycle is made up of stance and swing phases. The stance phase can be subdivided into periods of propulsion and absorption. Absorption begins at foot strike and finishes at midstance, while propulsion begins at mid stance and finishes at toe off. The swing phase can be subdivided into periods of initial and terminal swing. Initial swing commences after toe off and finishes at midswing, whilst terminal swing commences at midswing and finishes at foot strike. The various phases of stance and swing make up approximately 40 and 60% of the running cycle respectively.

Lumbo-pelvic support during running comes from key stabilizing mechanisms of the core: thoracolumbar fascia; intra-abdominal pressure; the paraspinal muscles (interspinales and intertransversarii) and the deep lumbar musculature (multifidus, lower longissimus and iliocostalis). The thoracolumbar fascia (TLF) can provide a tensile support (‘hoop tension’) to the lumbar spine by way of internal oblique (IO) and transversus abdominis (TVA) activation. The TVA and IO inserts into the thoracolumbar fascia. This fascia encircles the spine creating an indirect link between the TVA, IO and TLF. Contraction of the TVA and IO increases tension in the TLF, which in turn creates an extension force on the spine, thereby enhancing its stability. Intra-abdominal pressure (IAP) provides a stabilizing effect for the entire lumbar area. Synergistic contraction of all abdominal muscles, which occurs during running, creates tension on the rectus sheet in the abdomen. This sheet encloses the rectus abdominis (RA) and attaches to the IO and TVA. Tension within the sheet increases abdominal air pressure through movement of the viscera and diaphragm. This results in decompression of the lower lumbar spine, and may reduce compression and shear forces acting on the spine by as much as 30%.

Zatsiorsky argues that IAP is active during running along with TVA activation. Additionally, the deep lumbar muscles are active throughout full lumbar spine motion and during movements of the lower and upper limbs. The external oblique (EO) has clinical significance in an unstable pelvis as well as in lumbo-pelvic positioning during running since it has the ability to both stabilize and rotate the pelvis posteriorly.

It is evident that the TVA, multifidus, IO, EO, paraspinals, and pelvic floor musculature play an important role in stability of the pelvis and lumbar spine during running. Richardson and Jull have demonstrated that with quick movements of legs or arms the TVA fires 30 ms before shoulder movements and 110 ms before leg movements. They suggested that the TVA anticipates dynamic forces acting on the spine and it should be specifically trained to coordinate with muscles of the lower and upper extremity.

Rotational Mechanics of the Trunk during Running

Sagittal trunk rotation during running, termed flexion and extension, ranges between 2.3 to 23 degrees for speeds of 2-7 m/s. Kinematic three-dimensional (3D) analysis suggests two full oscillations of flexion and extension, with respect to vertical, during a running cycle. Researchers have demonstrated that the position of minimal trunk flexion tends to occur at or just prior to foot strike. The trunk then flexes during stance phase with maximum trunk flexion occurring during mid to late stance. Investigators have also demonstrated that as speed increases, the position of minimal trunk flexion occurs during the air-borne period preceding stance, so that by foot strike the trunk has already commenced flexion. Since flexion occurs during moments of stance, the core muscles should demonstrate sufficient strength to stabilize
the spine and minimize unnecessary flexion loads. This may allow for optimal flexion and extension during the running cycle.

The trunk also rotates side to side during running in the frontal plane.\(^1\text{-}^3\) Maximal internal bending of the trunk to the left occurs just prior to foot strike, whereas maximal overall tilting to the left of the trunk segment with respect to the vertical occurs during early stance phase on the left. Thorstensson et al. found that as running speed increased from 2 to 6 m/s, the net angular displacements of the internal bending of the trunk increased from 11 - 20 degrees to 5 - 11 degrees respectively.\(^2\text{-}^3\) This may suggests that as speed increases, there is an increased demand for the obliques and other stabilizing core muscles to synergistically control and allow for optimal frontal plane mechanics of the trunk.\(^2\text{-}^3\)

### Rotational Mechanics of the Pelvis during Running

Rotation of the pelvis occurs in the frontal plane and is termed pelvic obliquity.\(^6\text{-}^9\text{,}^1^1\) Pelvic obliquity plays a role in shock absorption and in controlling descent and ascent of the body’s center of gravity.\(^1\text{-}^1^1\) At midstance the pelvis becomes horizontal, then continues to elevate on the opposite side, reaching a maximum downward obliquity on the stance side during toe off. During the swing phase periods, the pelvis then begins to rise on the initial swing (same) side and lower on the terminal swing (opposite) side as it approaches foot strike. The rotational movements occurring at the trunk and pelvis are thought to play an important role in decoupling intense lower extremity motion from shoulder and head motion.\(^8\text{-}^5\) This minimizes head and shoulder movement allowing lateral balance to be maintained.\(^8\) Muscle weakness/dysfunction in the core such as facilitated iliopsoas or tight quadratus lumborum and weak oblique muscles can negatively impact pelvic obliquity and shock absorption. A facilitated muscle is one that biases the motor neuron pool and therefore becomes overactive during activities that require synergistic use.\(^4\) This would reduce the efficiency of the running cycle and possibly increase the risk of lumbar, pelvic and lower extremity injuries.\(^5\)

### Discussion and Conclusions

Poor lumbo-pelvic stability during running has been cited as being a contributor to lower back pain in athletes.\(^5\text{-}^1^0\) Researchers have demonstrated that the lumbar spine is the pivotal point of the lower extremity lever system during running\(^1^1\text{-}^1^2\) and that there is a coordinated motor pattern between the movements of the trunk and hip during the propulsion period of stance.\(^1^1\text{-}^1^2\)

The ground reaction forces and inertial forces acting on the body during running need to be controlled and dispersed by muscles tendons, ligaments and joint capsules. Many authors have reported a relationship between disturbances to the normal kinematic pattern of the hip and lumbar spine during running.\(^1^\text{-}^5\text{,}^1^2\) Weak TVA and RA muscles coupled with a tight iliopsoas may increase hip flexion angle at foot strike, which may lead to excessive stress placed on the hamstrings with an increase risk of hamstring injuries.\(^1^4\text{-}^1^0\) It has been argued that there is a biomechanical link between poor core stabilization and injuries such as posterior tibial tendinitis, medial shin splints, chondromalacia patellae, planatar fascitis, hamstring tears and other musculoskeletal injuries (especially during functional lower extremity movements).\(^1\text{-}^5\text{,}^1^1\) Many such pathologies share a common risk factor, overpronation, which can be the result of dysfunction in the kinetic chain emanating from the core.\(^4\text{-}^5\text{,}^8\text{-}^1^1\)

Since motor patterns are centrally generated, evaluation of recurring lower extremity injuries may also warrant an evaluation of the strength and stabilizing ability of the core musculature. Clinicians and coaches should be encouraged to think outside the box and understand how dysfunction in any part of the kinetic chain can lead to a variety of
musculoskeletal problems. Many of these problems can be reduced by simply learning to coordinate the muscles of the deep abdominal wall during functional movements.4

To reduce the likelihood of lower extremity injuries, runners and other athletes need to include exercises that emphasize core stability during dynamic movements. This would teach them to maintain neutral alignment of the vertebrae with muscular control, and allow for force dissipation throughout the axial skeleton.4 Maintaining neutral spinal alignment during dynamic lower extremity movement provides the ideal biomechanical advantage for the trunk musculature to effectively respond to external forces as it trains the athlete to resist shear and compressive forces during sporting activities. Therefore, clinicians and coaches should understand how to include exercises that effectively train the coordination and recruitment pattern of core muscles. Exercises should include spinal stabilization and functional open-and closed-chain integrated core exercise patterns. This may help to maintain adequate lumbo-pelvic stability, allow for optimal rotational mechanics, and reduce the risk of running injuries.

References
Background: Neuromuscular control is critical for providing protection from injury during dynamic activities. Running injuries have been associated with high ground reaction forces (GRF) which may be related to poor lower extremity stability in runners. Objective: To identify the relationship between peak active vertical GRF (VGRF) measured during running and Star Excursion Balance Test (SEBT) scores in a group of recreational runners. Design and Setting: Subjects were assessed for lower extremity stability using the SEBT, and for peak active VGRF while running across a force plate in a laboratory setting. Subjects were then correlated. Subjects: Seventeen healthy adults who ran at least 15 miles/wk were recruited. Measurements: The reaching length of the SEBT was measured from 3 directions (anterior, lateral, & posterior) of each foot, and the peak active VGRF was measured from the left foot while running across a force plate. Data were reduced using Pearson correlation coefficient, p < 0.05. Results: While the previously injured runners produced higher active VGRF (2.48 v 2.24 BW) and lower SEBT scores (45.09 v 51.83cm) as compared to the previously non-injured runners, there was no significant correlation between stability level and peak active VGRF, (r (14) = -.273, p > .05). Conclusion: Lower extremity stability as measured by the SEBT is not related to peak active VGRF in recreational and competitive runners. However, those with previous injury had markedly decreased stability and slightly higher active force than those without injury. Key Words: neuromuscular control, dynamic stability, balance

As the number of recreational runners has increased over the last decade, so has the number of running-related injuries.1 The most common running-related injuries are stress fractures, shin splints, plantar fasciitis, and iliotibial (IT) band syndrome.2 These conditions are believed to occur from excessive running distance or intensity, running surface type,3 abnormal anatomical structure (high/low arch)4 and poor running mechanics.5 The biomechanical analysis of running mechanics started over 30 yr ago, and since observational study was not reliable enough to identify probable causes of injuries, the force plate has become one of the most popular instruments to measure the impact force and collect reliable data to identify the amount of force the body produces during a foot contact.3 It was also reported that impact (initial heel contact) or active (push-off phase) vertical ground reaction force (VGRF) during jogging is 2 to 3 times body weight.3 Recent studies demonstrated that higher VGRF is typically found in runners with longer stride length,5 older runners,6 and running downhill.7 In addition, excessive running distance and intensity may have major contributions to running-related injuries. One study reported that more than half of runners have experienced running-related injuries during their first year of committed running training.5 These data indicate that novice runners may lack knowledge regarding running routines and proper progression as compared to experienced runners. Moreover, this also indicates that novice runners’ lower extremity muscles may not be necessarily adapted properly to run the distance or handle the intensity repetitively. One study stated that novice

runners are increasing distance too rapidly, and they also tend to overly engage in high intensity training.9 Anatomical structure has a major role in running mechanics, especially when differentiating mechanics and injury risk between male and female runners.4 Female runners reported twice as many as running-related injuries as male runners.1 Greater quadriceps angle is often seen in women, which causes internal rotation of knee joint and tibia during running.10 This type of abnormal anatomical structure causes high stress in the lower extremity that ultimately leads to overuse injuries.5 Finally, the findings were reported by Ferber et al that female runners actually produced greater kinetic activities in the lower extremity during running, as compared to male runners.11

The Star Excursion Balance Test (SEBT) is a clinical test that has been used to assess lower body stability and dynamic balance in recent years.12,13 Its' reliability is 0.67 to 0.87.14 Olmsted et al.13 reported that when instability of the lower extremity is diagnosed by using the SEBT, those participants generally produce less power, and possess balance and body control which may lead to a higher risk of injuries from athletic activities. Thus, poor stability may cause excessive kinetic forces, fatigue, and faulty movement pattern, which ultimately associate with overuse running-related injuries. Although these reviewed studies discuss the VGRF and its relation to running-related injuries, the direct relationship between the VGRF and the stability level of the lower extremity based on a clinical stability test has not been studied. Therefore, the purpose of this study was to identify the relationship between the peak active VGRF and lower extremity stability level as measured by the SEBT, in a group of recreational runners. Further, scores were examined between those in the group who have sustained a previous running-related injury, and those who have not. We hypothesized there may be a correlation between the high active VGRF and the low stability level of the lower extremity based on the SEBT score in runners. In addition, previously injured runners may display higher active VGRF and lower SEBT scores compared to healthy runners.

Methods
Seventeen recreational and competitive rear-foot strike runners (6 males, 11 females) volunteered for this study (age = 32.8±8.9 yrs, height = 166.7±9.2 cm, mass = 65.6±16.1 kg). They answered specific questions regarding their training strategies and past history of lower extremity injuries to identify their running background. Based on individual history, this study had 11 previously injured runners and 6 no previous injury runners prior to the test. All data collection was performed at a selected laboratory. The SEBT measured dynamic stability of the lower extremity. Since verbal instruction and visual demonstration increases the reliability of the SEBT, each participant was given these along with 3-5 practice trials.14 Eight lines, each 75 cm in length, were placed at 45-degree angles (Figure 1). The test was performed without shoes to eliminate influence from shoes according to the past studies.12–14 After an adequate amount of warm-up by stretching, each participant placed his or her left foot on the center of 0-180 degree line. Then, participants reached their toes as far as possible to the directions of 0, 90, and 180 degree lines while maintaining balance (Figure 2). Participants performed the same sequence with their right foot. All participants followed the same procedure. Each participant performed 3 trials for each foot and their best reaches were recorded manually. The investigator visually observed that participants were in static position for at least 3 s to ensure their ability to stabilize their bodies before recording the data. The lengths of the reaching toes and the toe of the opposite foot were measured manually. The scores of the SEBT were recorded with the longest lengths of all 3 directions averaged to be the total score.

This study simulated the real running speed for all participants to measure the active VGRF (push-off phase of the VGRF). Participants performed at least two trials and made
left foot contact on the force plate at a comfortable running speed (2.65-3.35 m/s = 8-10 min per mile pace) after having warmed up for 1 mile outdoors at a self-selected pace. If participants had abnormal steps prior to reaching the force plate, the trial was not recorded and they were asked to perform another trial. The active VGRF were measured by an AMTI force plate (Advanced Medical Technologies, Inc., Watertown, MA) that sampled at 600 Hz. The Peak Motus software (ver. 8.2, ViconPeak, Centennial, CO) was used to reduce the data with Fast Fourier Analysis. The active VGRF were obtained at the push-off phase of foot contact, normalized to body weight (BW), and averaged for the groups. The active VGRF and the SEBT scores were input into SPSS (SPSS Inc. Chicago, IL) and analyzed using Pearson correlation coefficients, p<.05.

**Results**

A Pearson correlation coefficient was calculated for the relationship between the scores of the SEBT and the peak active VGRF. No significant correlation was found in the relationship between the scores of the SEBT and the active VGRF ($r (14) = -.273, p > .05$), indicating a non-linear relationship between the two variables. The previously injured runners displayed lower average in reaching length of the SEBT, as compared to the previously non-injured runners (45.09 cm vs. 51.83 cm) (Figure 3). The previously injured runners also displayed a higher average in peak active VGRF in average of 2.48 body weight, whereas the previously non-injured runners produced in average of 2.24 body weight (Figure 4).

**Conclusion**

The results did not support the hypothesis that there was no correlation of low scores of the SEBT with higher peak active VGRF. However, the results supported one hypothesis that previously injured runners produced higher active VGRF and lower stability in the lower extremity based on the SEBT. The participants who had multiple running-related injuries in their past scored the lowest. The results related to some reviewed literatures’ findings. This study related to the previous study by Olmsted et al.\textsuperscript{13} that previous injuries affected SEBT performance and scored poorer than those who have no previous injuries. This study cannot determine how injuries, low stability, nor high peak active VGRF happens to each individual, but running-related injuries may have caused the decrease in stability of the lower extremity which may also lead to the risk of re-injury. Based on the results of this study, we conclude that impairments in stability are not necessarily associated with higher peak active VGRF during running. However, those with previous injuries showed lower stability and higher active VGRF than those without injury. Runners may be able to reduce the active VGRF or improve their stability level in the lower extremity by performing proper training in the long term, and may reduce the risk of injuries from running activities. Further research will be needed to investigate other GRF variables (impact VGRF, medial/lateral GRFs, and posterior/anterior GRFs) and its relation to the stability level of the lower extremity.

![Figure 1. Layout of the Star Excursion Balance Test](image.png)
Figure 2. Lateral Reach on the Star Excursion Balance Test

![Graph showing average scores of Star Excursion Balance Test (cm) for previously injured runners (N = 11) and no previous injury runners (N = 6).]

**Figure 3.** Comparison between two characters

![Graph showing average of active vertical ground reaction force (BW) for previously injured runners (N = 11) and no previous injury runners (N = 6).]

**Figure 4.** Comparison between two characters

References

Effects of Active Hyperthermia on Cognitive Performance
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Objective: Active hyperthermia elicited by a heat stress trial (HST) was hypothesized to negatively impact higher-order cognitive ability. Design and Setting: A test-retest design with one within-subjects variable was utilized for this investigation. The independent variable was thermal condition (normothermic and hyperthermic) and the dependent variables were four factors of cognitive performance (working memory, attention, response speed, and processing speed) with associated subtests. Participants completed practice tests and returned at least 24 hr later to perform the tests before and after the HST. Subjects: Eight healthy adult males (age= 24.9±3.2 yr; height= 123.0±46.8 cm; body mass= 89.9±10.5 kg) volunteered. Measurements: We assessed cognitive performance via the Headminder™ Cognitive Stability Index administered using a laptop computer online via a wireless secure internet browser in the normothermic and hyperthermic conditions. Core body temperature was measured via ingestion of a CorTemp™ Ingestible Core Body Temperature Sensor (HT150002, HQ Inc., Palmetto, FL). Results: The memory factor revealed a significant (t7= 4.675, p= .002) 12.22% decrease in number correct for the hyperthermic (mean correct= 7.155±1.478) compared to the normothermic (mean correct= 8.151±1.60) condition. Memory subtest 1 revealed significant (F2,14= 9.196, p=.003) decreases in performance over time. The memory subtest 2 also revealed significant (F2,14= 4.920, p=.024) decreases over time. No other significant differences were found. Conclusion: Our findings suggest that hyperthermia decreases working memory. Response speed, processing speed and attention are less vulnerable to the effects of elevated Tb. Therefore, athletic trainers should be aware of the detrimental effects of hyperthermia on working memory as they relate to injury prevention and evaluation. Key Words: heat stress, memory, processing speed

Hyperthermia refers to an elevated body core temperature (Tb) and is commonly categorized as mild (Tb = 37.7 - 39.4 °C) to severe (Tb usually greater than 40 °C). Some degree of hyperthermia accompanies exertional heat illnesses such as heat cramps, heat exhaustion, and heat stroke. A recent review of the literature revealed that signs of exertional heat illness included confusion, altered state of consciousness, decreased mental acuity, and an overall decrease in central nervous system function. Between 1960 and 2003, heat stroke, resulting in severe hyperthermia, has been the cause of 101 deaths in young American football players with 21 occurring in the last eight years. Since 1974 a dramatic reduction in heat stroke deaths has been observed with the exception of 1978, 1995, 1998, when there were four each year, and 2000 when there were five. In the southeastern United States, athletic events occur in hot, humid environments throughout the spring and summer months into the early fall. The average South Florida temperature between May and August is 82.8 °F with a mean morning relative humidity of 85%. In addition to environmental factors, football uniforms contribute significantly to the heat load on a player. Tb in football players during an actual football practice fluctuates with activity and with level of equipment worn. Tb increases during the periods of intense exertion with full equipment, and

decreases during rest periods. These conditions are considered unsafe for football activities by the Inter-Association Task Force on Exertional Heat Illness Consensus Statement. The recommendations include a work/rest ratio of 15-20 min of work to 5-10 min for water/rest break and practices should be in shorts only.

Excessive heat retention causes changes in brain function and metabolism. The underlying link between the thermal information processing system (located in the hypothalamus) of the central nervous system, hyperthermia, and brain dysfunction is not clearly understood; however, it appears that the extent of nervous tissue injury depends on the duration and intensity of heat exposure. Increased permeability of the blood-brain barrier allows brain edema formation. This breakdown of the blood-brain barrier is similar in nature to what occurs to the central nervous system following trauma indicating that signs and symptoms of hyperthermia can mimic a concussion.

Furthermore, the literature is lacking research in regards to how active hyperthermia influences cognition in physically active males. Since American football practices occur in hot, humid environments it is important that athletic trainers understand and recognize subtle changes in mental performance that accompany hyperthermia in order to make more educated decisions regarding player safety and sport performance. To our knowledge our study was the first to use this tool to identify the effects of active hyperthermia on cognition in a hot, humid environment. Therefore, the purpose of this study was to examine the effects of active hyperthermia on cognitive performance, using the Headminder™ Cognitive Stability Index (CSI), in physically active males.

Methods

Experimental Design

A test-retest design with one within-subjects variable was utilized for this investigation. The independent variable was thermal condition (normothermic and hyperthermic) and the dependent variables were four factors of cognitive performance with associated subtests. Participants completed practice tests and returned at least 24 hr later to perform the tests before and after the heat stress trial (HST). We expected to find reduced cognitive performance, specifically higher-order cognitive ability, based upon previous research in heat stroke patients, workplace employees, and in experimentally induced dehydration.

Subjects

Participants were eight healthy, physically active volunteers (age = 24.9 ± 3.2 yr; height = 123.0 ± 46.8 cm; body mass = 89.9 ± 10.5 kg) recruited from Florida International University and the surrounding community. Participants signed the approved informed consent form, were informed of potential risks, and informed that their participation was voluntary. The study was approved by the Institutional Review Board.

Instruments

Cognitive performance. The Headminder™ Cognitive Stability Index (CSI) test is an internet-based test designed to monitor cognitive status in healthy, at-risk, and afflicted populations. The Headminder™ CSI subtests measured reaction time, processing speed, memory, and attention/executive functioning, and reported strong concurrent validation with standard paper-and-pencil neuropsychological tests. Test-retest reliability was adequate for the four factors between the first and second administrations (response speed; r = .80, processing speed, r = .78; memory, r = .68; attention, r = .73). Spatial and working memory were measured via subtests: Memory Cabinet 1 and 2.

Thermoregulatory measures. Core body temperature was measured via ingestion of a
CorTemp™ Ingestible Core Body Temperature Sensor (HT150002, HQ Inc., Palmetto, FL) which was tracked prior to, during, and following the HST with the CorTemp™ Miniaturized Ambulatory Data Recorder (HT150016, HQ Inc., Palmetto, FL).

Cardiovascular measures. Heart rate was measured using a Polar® heart rate monitor (Polar Electro Inc., Woodbury, NY). Blood pressure was assessed using a stethoscope and sphygmomanometer (American Diagnostics, West Babylon, NY) and mean arterial pressure was calculated. Resting heart rate and blood pressure was recorded after resting prone on a table for 5 min, and exercise measures was recorded at 0 min, and at 15 min intervals throughout the practice. Rating of perceived exertion (RPE) was also measured throughout the practice. The use of the Borg scale\textsuperscript{14} was implemented to measure RPE which is reproducible (no bias between trials)\textsuperscript{15} in a three trial series and a reliable (r=0.78)\textsuperscript{15,16} measure of exertion.

Hydration measures. Body mass was measured using a digital medical platform scale (model BWB-800S, Tanita Inc., Brooklyn, NY). A urine color chart (Human Kinetics, Champaign, IL) was used to determine urine concentration with closest color on the chart or half point color recorded. Urine specific gravity was measured using a clinical refractometer (Model 300CL Atago Inc., Japan).

Procedures

Familiarization session. During a familiarization session (6-8 days prior to data collection), potential participants read and signed the health/injury history and physical fitness readiness questionnaires and the informed consent form. During the familiarization session data were collected as baseline measures and CSI was performed three times to reduce a learning effect.

Research trial period. On the day of data collection, each participant was asked to completely void urine and body mass data were recorded. A euhydration body mass was confirmed as less than $\pm 1\%$ of baseline body mass. Participants then performed the pre-test/normothermic CSI. Each HST commenced with a 15-min jog warm up at 60$\%$ of the participant’s heart rate range on a level, mowed grass surface. For the lower extremity HST, each participant exercised at 75-80$\%$ of their heart rate range across a minimum of 10 sets of 10 repetitions of 30 yard sprints (approximately 15-sec in duration) with a 10-sec rest period between sprints and a 2-min rest between sets. The exercise task was performed on a level grass field with two cones placed 9.1 m (10 yards) apart.

The HST was performed in a subtropical hot, humid environment (mean ambient temperature= 34.3$\pm2.2$ °C; mean relative humidity = 50.8 $\pm 9.9\%$; mean wind speed = 1.9 $\pm 1.2$ mph) with each participant wearing a full American football uniform. Core body temperature ($T_b$) was assessed prior to, during, and following the HST. After reaching the target $T_b = 39.0$ °C each participant performed the post-test/hyperthermic CSI. Participants removed the helmet and shoulder pads and rested in an air conditioned environment until $T_b$ returned to baseline levels at which time the post-test/normothermic CSI was performed.

Statistical Analysis

Statistical analyses were conducted on the participants’ cognitive performance factor scores and subtest raw scores. Dependent t-tests were used to identify differences between the normothermic and hyperthermic conditions on factor scores of processing speed, response speed, memory, and attention and each associated subtest. A post hoc one-way ANOVA with repeated measures on the time factor (normothermic, hyperthermic, post-test normothermic) with a Bonferroni correction was performed for the factor scores found to be significant. Data were analyzed using the SPSS 13.0 for Windows Statistical Package (SPSS Inc., Chicago, IL).
statistical analyses, an $\alpha$-level of $p < 0.05$ was used.

Results

Participants were significantly ($t_{7} = 9.032, p \leq .001$) hyperthermic (mean $T_b = 38.8 \pm 4$ °C) following the HST compared to the normothermic (mean $T_b = 37.2 \pm 1$ °C) condition. The memory factor revealed a significant ($t_{7} = 4.675, p = .002$) 12.22% decrease in number correct for the hyperthermic (mean correct = 7.155±1.478) compared to the normothermic (mean correct = 8.151±1.60) condition. The memory cabinet 1 subtest revealed significant ($F_{2,14} = 9.196, p = .003$) decreases in performance over time. Compared to the normothermic condition (mean correct= 8.1250 ±1.458), in the memory cabinet 1 subtest participants demonstrated a 27.69% decrease in the hyperthermic (mean correct = 5.875 ±2.232) condition and a 21.54% decrease in the post-test normothermic (mean = 6.375 ±1.847) condition. The memory cabinet 2 subtest also revealed significant ($F_{2, 14} =4.920, p = .024$) decreases over time. With the memory cabinet 2 subtest, participants demonstrated a 22.39% decrease in the post-test normothermic (mean correct = 6.500 ±.824) condition when compared to the normothermic (mean = 8.375 ±.625) condition.

Discussion

The HST and environmental conditions were successful in eliciting elevated $T_b$ in the exercising participants. The hyperthermia achieved by anaerobic exercise in a hot, humid environment had negative effects on cognitive performance. Of the four factors comprising cognitive performance (response speed, attention, memory, processing speed), we found working memory to be most vulnerable to elevated $T_b$. Spatial memory was also impaired in the hyperthermic condition. Our results pertaining to memory deficits, specifically spatial memory supported our hypotheses. These findings coincide with a current trend in the literature that the more simple functions such as response speed and reaction time are less affected while the more complex functions such as processing speed and memory are more vulnerable to the adverse effects of hyperthermia.

Substantial research has been performed in the field of heat stress and its effects on cognitive performance. Unfortunately, the body of research has not been detailed in a systematic manner because of the thermal, experimental, and participant variables. The variables include task type, duration of heat exposure, skill, and acclimatization level. One study that employed the Headminder™ CSI with actively dehydrated physically active males found inconclusive evidence in comparison to other studies that found decrements in cognitive performance. Functional brain image recordings have demonstrated an increase in amplitude and a decrease in latency, suggesting an increase in the utilization of neural resources or effort by subjects to maintain the same level of performance as under thermally neutral conditions. It may be this increased neuronal utilization that lead to decreased cognitive performance in our participants.

Our participants informally reported sensations of fatigue upon reaching the required 39.5 °C core body temperature. Theoretically, the level of hyperthermia elicited in our participants may have been accompanied by some perception of central fatigue; however, we were unaware of a good method to clinically measure this CNS phenomenon. We did not monitor blood content changes in the present study. Plasma concentrations of the hormones cortisol and adrenaline are better indicators of cognitive activity than the plasma concentrations of the neurotransmitters noradrenaline and serotonin, although changes in plasma concentrations of noradrenaline did predict changes in perceptions of fatigue post-recovery. Changes in cortisol concentration have been demonstrated to be a significant indicator of cognition in the post-
treatment condition and is indicative of high levels of anxiety so would appear that, in these conditions, cognition is predicted by central perceptions of the stress rather than the activity of adrenaline and noradrenaline in their roles as regulators of heat stress peripherally.19

Clinical Implications

Based on how our findings relate to current literature and cognitive performance theory, we can draw several clinical conclusions. First, athletic trainers and coaches should understand that a hyperthermic athlete may not be able to function mentally as efficiently as a normothermic athlete. Impairments in memory may result in sacrificed safety and performance in the later stages of a competition. For example, a hyperthermic quarterback may not be able to remember plays as they are sent on to the field or may not be able to read and adjust to the opposition. This type of mental breakdown could lead to a sacrificed personal safety. Secondly, hyperthermia may affect administration of concussion testing in that it could confound the effects of a concussion, primarily amnesia. It is necessary for the athletic trainer or other allied health professional to measure and address the athlete’s thermal condition at the time of testing. Athletic trainers may need to record T_b as part of concussion testing protocol in order to accurately determine the cause of symptoms. Therefore, we should be aware of the detrimental effects of elevated T_b on cognitive performance as they relate to sport performance, athlete safety, and concussion testing.

References
Objective: We investigated the Continuous Quality Improvement (CQI) model as a paradigm for evaluation of a Post-Certification Graduate Athletic Training Education Program (PC-GATEP). Design and Setting: Students were asked to complete a summative assessment of their perceptions of learning outcome achievement, evaluation methods, available resources, and program outcomes for each course and the overall PC-GATEP. Participants: Twelve students enrolled in a PC-GATEP participated. First year \( (n = 5) \) students completed 4 Core Course Surveys. Second year \( (n = 7) \) students completed 9 Core Course Surveys and both completed 1 Overall PC-GATEP Survey. Measurements: Course syllabi and stated program outcomes were used to create 10 Core Curriculum Course Surveys and one Overall PC-GATEP Survey. Likert scale (1= Strongly Disagree; 2= Disagree; 3= Agree; 4= Strongly Agree; and N/A= Not Applicable) and open responses were obtained. Descriptive statistics were calculated for data analysis. Results: Means and standard deviations revealed that in all curriculum courses students agreed that: the learning outcomes were achieved (3.2±0.2); evaluation methods (3.0±0.10) and resources (3.2±0.2) were adequate and fair to achieving the learning outcomes; and core courses required by the PC-GATEP assisted students in achieving the program outcomes (3.1±0.2). Overall, students agreed that the PC-GATEP provided them with skills beyond that of an entry-level certified athletic trainer (3.1±0.6). Conclusions: This facet of CQI is commonly referred to as “closing the loop” and ensures that programs use assessment data to improve student learning, the ultimate purpose of program assessment. Our findings support the use of the CQI model as an appropriate paradigm for assessment and improvement of a PC-GATEP. Key Words: Total Quality Management, accreditation, and higher education.
continuous loop with data being collected, analyzed, and trended to identify if changes are needed in the athletic training education program. The data may identify additional areas that need to be assessed or suggest changes in the tools to obtain more accurate data. The assessment plan and process should be fluid and dynamic with trended data providing an outlook of the program over a period of time. These data are most useful during program review and accreditation processes and provide evidence that may be used to enhance the quality of educational experiences for students.

The purpose of this study was to report findings of the use of the continuous quality improvement (CQI) model as a paradigm for evaluation of learning outcomes of a post-certification graduate athletic training education program (PC-GATEP) preparing for the accreditation process.

Methods

Research Design
We used a descriptive approach to report the findings of implementing our program assessment instruments to evaluate a PC-GATEP. The program is a two-year, 36 credit hour program consisting of nine core courses, which were evaluated in the current study, and nine electives. Two primary instruments were utilized. The Curriculum Course Evaluations included items about meeting learning outcomes for the required PC-GATEP courses. To maintain reliability, all questions were identical in three of the four domains. The fourth domain consisted of questions regarding learning outcomes adapted based on the syllabus for each course. The Overall PC-GATEP Survey included items to assess the ability of the PC-GATEP to achieve the program outcomes (Table 1). We administered the instruments to students enrolled in the PC-GATEP at the time of the investigation and tabulated the findings to be used in program evaluation for the purposes of program improvement and accreditation. First year students who had completed one semester of coursework at the time of the investigation were administered four Curriculum Course Evaluations and the Overall PC-GATEP Survey. Second year students were administered nine Curriculum Course Evaluations and the Overall PC-GATEP Survey.

Participants
A purposeful sample of 12 students currently enrolled the PC-GATEP participated in the study: five first-year students in their first semester of study and seven second-year students in their third semester of study. Response rates for each instrument are provided in Table 2. Compliance was achieved by incorporating the study into a normal class time. All participants signed an informed consent form prior to beginning the study which was approved by the FIU Institutional Review Board.

Instruments
We developed two instruments adapted from the program assessment surveys from The College of Mount St. Joseph Athletic Training Program student course assessment to accommodate a PC-GATEP. The instruments were created and administered using Microsoft Share Point software (Microsoft, Inc. Seattle, WA), which is a secure internet website that collects and exports data to a spreadsheet for analysis. The Likert scale consisted of the corresponding responses: 1 = Strongly Disagree; 2 = Disagree; 3 = Agree; 4 = Strongly Agree; and N/A = Not Applicable. Neutral was not included to force a response from the participant or N/A would be indicated. Prior to conducting the study, the instruments underwent qualitative reviews with feedback provided by a panel consisting of an Athletic Training Education Graduate Program Director, Director of Clinical Education, Director of Entry-Level Graduate Athletic Training Program, and three athletic training doctoral students. Upon completion of the
 qualitative review, ambiguous or confusing items were identified and adjusted accordingly to the panel’s suggestions.

**Curriculum Course Evaluations.** Ten Curriculum Course Evaluations were created for the required PC-GATEP course to ascertain the students’ perceptions of achieved learning outcomes as well as the perceived strengths and problem areas within each course. The instruments were developed based upon the course syllabi to accurately adapt each question to the learning outcomes listed on the syllabi. Survey questions were separated into one of four domains: Learning Outcomes, Evaluation Methods, Resources, and Program Outcomes.

**Overall PC-GATEP Survey.** The Overall PC-GATEP Survey was created to examine the students’ perceptions of the program achieving the overall goals and objectives based upon the Standards and Guidelines as outlined by the National Athletic Trainers’ Association Post-Professional Education Committee (NATA-PPEC).

**Experimental Procedures**

Participants arrived during normal class time reserved. With the course instructor absent to avoid bias, the primary investigator explained the objectives, procedures, risks, and benefits of the study. Potential participants were instructed to read the instructions before signing the informed consent form and participants were separated into two rooms based on class year. Each student was seated at an individual desktop computer connected to the internet with a browser open to the evaluation instrument website. Only navigational type questions were answered by the administrator. No talking was permitted during the response time. Participants had an unlimited amount of time to complete each evaluation and were permitted to leave upon completion. Total time required of each participant was 1.5 hr.

**Statistical Analysis**

Data reduction consisted of calculating means and standard deviations as a single score for the Overall PC-GATEP Survey and for each of the four domains for all Curriculum Course Evaluations. Since responses were whole numbers (no decimal response), questions with responses below a mean of 2.9 were identified as “disagreed” and responses above 3.0 were rounded up and identified as “agreed”.

**Results**

Data reduced from the Overall PC-GATEP Survey indicated that students agreed (3.1±.6) that the PC-GATEP provided students with the skills beyond that of an entry-level Certified Athletic Trainer. Examination of the means and standard deviations from the Curriculum Course Evaluations indicated that in all courses students agreed that the learning outcomes listed on the course syllabi were achieved (3.2±.2), that the evaluation methods (i.e. assignments, time required) of the courses were adequate and fair for achieving the learning outcomes listed on the syllabi (3.0±.1), that the resources in the course or department were sufficient to achieve the learning outcomes listed on the course syllabi (3.2±.2), and that the courses required by the PC-GATEP assist them in achieving the program outcomes (3.1±.2). Table 2 displays the individual course responses to the Curriculum Course Evaluations.

**Discussion**

The purpose of this investigation was to evaluate student perceptions of the achievement of course and program learning outcomes for accreditation. The sample was small, purposeful, and non-random sample that may limit generalization of the results. Non-compliance was identified in 2 of the 10 Curriculum Course Evaluations. Additionally participant bias of course instructors may have influenced positive or negative responses to the surveys.
The assessment was designed to identify areas of strength and areas in need of improvement relating to course content, resource availability, and ability of the program to produce advanced skills for the Certified Athletic Trainer. Overall, the responses to the evaluation were positive and indicated that students do consider the individual courses and the program to achieve the learning outcomes.

Courses that scored the highest in the Curriculum Course Evaluations were courses that students perceived as the introduction of new material or advanced practitioner skills. The objectives of these courses were to present material in structured formats and consisted of traditional lectures, assignments, tests, and grading scales. These high scoring components also included a laboratory component allowing students to gain hands-on, interactive experiences. Students commented on strengths of each course. Examples of students comments cited in the higher scoring courses included: “The laboratory provided an opportunity to dissect a human cadaver and explore first hand what things really look like” and “we learned application which is necessary for the profession.” The high scoring courses demonstrated a trend toward high scores in the Learning and Program Outcomes domains, but lower scores in the Resources and Evaluation domains. Students perceived the courses as successful in achieving Learning Outcomes and ultimately contributed to the achievement of the PC-GATEP Program Outcomes.

Courses that scored the lowest on the Curriculum Course Evaluations were courses that presented material in an unstructured format. This unstructured format may have confused students’ perception relating to advanced practitioner skills as being irrelevant discussions. Furthermore, the courses may have scored low due to amount of credit earned related to the volume of class assignments given to students. Both factors may have been the cause of low total mean scores. The Resources domain on all Curriculum Course Evaluations revealed that the required and suggested textbooks were underutilized and unhelpful in facilitating understanding of the course content. These findings suggest the courses with mean responses less than 3.0 did not achieve the learning outcomes as set forth on the course syllabi and did not equip the students with the skills necessary to achieve the program outcomes. These courses will require the Program Director to focus his/her attention on making required text changes for the future.

Further analysis of questions in each survey may be compared to the NATA-PPEC Standards and Guidelines to address the problem areas of the PC-GATEP. The cyclic (continuous loop) process of program evaluation requires continuous data collection, analysis, and synthesis to identify changes that are needed in the athletic training education program.

Table 1. Example of Questions in the Curriculum Course Evaluations and Overall PC-GATEP Satisfaction Survey

**Sample Questions**

**Curriculum Course Evaluation**
- LEARNING OUTCOMES – The course presented the latest information dealing with the educational and clinical foundations of Athletic Training.
- LEARNING OUTCOMES - I increased my knowledge of upper-extremity orthopedic special tests.
- LEARNING OUTCOMES - The course facilitated the scholarly writing process through the use of research groups and peer review.

**Overall PC-GATEP Satisfaction Survey**
- The program encouraged the development of my interpersonal skills.
• The program provided me with ample opportunity to apply my research skills
• The research experience provides students with in-depth knowledge, skills, and practices beyond those of an entry-level ATC.

Table 2. Mean responses to individual Curriculum Course Evaluations

<table>
<thead>
<tr>
<th>Course</th>
<th>N</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Orthopedic and Biomechanical Assessment of the Upper-Extremity</td>
<td>6</td>
<td>3.5 ± 2</td>
</tr>
<tr>
<td>Clinical Anatomy of the Trunk and Limbs</td>
<td>12</td>
<td>3.3 ± 1</td>
</tr>
<tr>
<td>Human Performance in Extreme Environments</td>
<td>7</td>
<td>3.3 ± 3</td>
</tr>
<tr>
<td>Foundations of Educational Research</td>
<td>5</td>
<td>3.0 ± 3</td>
</tr>
<tr>
<td>Survey of Research (Interdisciplinary Inquiry I)</td>
<td>7</td>
<td>3.2 ± 2</td>
</tr>
<tr>
<td>Survey of Research (Interdisciplinary Inquiry II)</td>
<td>7</td>
<td>3.1 ± 1</td>
</tr>
<tr>
<td>Athletic Training/ Sports Medicine Seminar I</td>
<td>12</td>
<td>2.9 ± 1</td>
</tr>
<tr>
<td>Athletic Training/ Sports Medicine Seminar II</td>
<td>7</td>
<td>3.0 ± 2</td>
</tr>
<tr>
<td>Masters of Science Research Seminar I</td>
<td>12</td>
<td>3.0 ± 2</td>
</tr>
<tr>
<td>Masters of Science Research Seminar II</td>
<td>6</td>
<td>2.9 ± 1</td>
</tr>
</tbody>
</table>

Note. Likert scale consisted of the corresponding responses: 1= Strongly Disagree; 2= Disagree; 3= Agree; 4= Strongly Agree; and N/A= Not Applicable.

References