

Effects of Weight-Cutting Tactics on Clinical Concussion Measures in Division One
Collegiate Wrestlers

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ABSTRACT

AMANDA FRIEDLINE: Effects of Weight-Cutting Tactics on Clinical Concussion Measures in Division I Collegiate Wrestlers
(Under the direction of Kevin M, Guskiewicz)

Our purpose was to look at the effects of weight-cutting tactics on clinical concussion measures in Division I collegiate wrestlers. Scores on clinical concussion assessment tools were analyzed at baseline and pre and post practice. Concussion tools included The SCAT2, the SAC, the BESS, the GSC, and SRT computerized test. All subjects completed the same test battery at baseline and before and after a practice. Significant differences were observed for SCAT2 when pre and post-practice measures were compared to baseline ($P < 0.05$) and BESS scores between baseline and post-practice ($P < 0.05$). Significance was also observed for GSC when pre and post-practice were compared to baseline ($P < 0.05$). A difference was further observed between pre and post-practice. Our results suggest that it is important for wrestlers to be tested in a euhydrated state in order to ensure weight-cutting tactics are not influencing the outcome of the clinical measures.

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CHAPTER I

INTRODUCTION

Six thousand males participate in collegiate wrestling each year (Vicente, 2007). In 2006-07, over 255,000 males and 5,000 females participated at the high school level (NFHS, 2006). Due to the nature of this sport, however, injuries in wrestling are rather common. At the collegiate level, injury rates per 1,000 athlete-exposures (A-E) during competition are second only to spring season football (Jarret, Orwin, & Dick, 1998). In collegiate wrestling, an injury rate of 7.25/1,000 A-E is reported (Yard, Collins, Dick, & Comstock, 2008). Wrestling has even been ranked third behind lacrosse and ice hockey for the most concussions sustained during competition (Covassin, Swanik, & Sachs, 2003).

It is believed that injuries, particularly concussions, are more likely to be sustained during a match because there is more direct contact with the opponent's head, elbow, and knee during a poor takedown attempt (Agel, 2007). Takedowns account for the most injuries in wrestling (41.9%) because both wrestlers begin in a neutral position at the start of the match, and performing a takedown is encouraged in order to score points (Yard, et al., 2008). Though concussions happen more during matches because of direct contact between opponents, takedowns are practiced frequently because they are such a vital aspect to the sport. Therefore, the risk of injury is still prevalent during practices. It is also important to note that while more injuries seem to take place during matches, injuries during preseason are twice as likely to occur than during the regular season (Agel, 2007).

Wrestling is a sport with significant risk for injury, but it also places significant stress on a wrestler's weight. It is perceived that competing at the lowest possible weight class will give the athlete an advantage over their smaller opponent. This mentality causes wrestlers to practice various weight-cutting techniques, including fluid and food restriction, exercising in excessively warm environments, wearing vapor impermeable suits under cotton warm-ups, and using laxatives or diuretics. All of these tactics result in dehydration and water weight loss. A survey found an average weekly weight loss percentage to be 4.3% body mass or 2.9kg for high school and collegiate wrestlers and that 12.1% of Division 1 collegiate wrestlers cycled their weight 6% or more (Oppliger, Steen, & Scott, 2003). This means wrestlers were repeatedly losing and regaining 6% or more of their body mass per week. Due to rule changes, wrestlers now have one hour in between weigh-in and competition in dual meets. One study noted that rehydration cannot be reached by hydrating an hour between weigh-in and competition by water alone in wrestler's that cut 5% or more of their total body weight (Popowski, et al., 2001). This means that if wrestlers aren't properly rehydrating, they are very likely competing in a dehydrated state though they have had time following weigh-in to consume fluids and food.

Current literature has elucidated the effects of dehydration on several variables. One study found that mental and psychomotor abilities decreased during a 24 hour progressive voluntary dehydration protocol (Derave, De Clercq, Bouckaert, & Pannier, 1998). Using a test battery that objectively measures psychological performance, subject's reaction time, accuracy, and mental endurance decreased 3 hours post fluid deprivation and total test solving time increased 6 hours post fluid deprivation (Petri, Dropulic, & Kardum, 2006). Another study found that following a 28 hour fluid restriction with food intake restricted to

those that contain less than 75% water content, there was no decrease on cognitive-motor performance. The authors, therefore, believed that young adults could adapt to slow progressive dehydration up to 2.6% of their total body weight. Subjects of this study did report, however, feeling more tired and less alert following the dehydration protocol (Szinnai, Schachinger, Arnaud, Linder, & Keller, 2005).

Another study found that following a 2-hour bike exercise task, a mean body mass decrease of 1.9kg occurred in a group with no fluid replacement and 0.4kg with fluid replacement. The fluid restriction group presented a higher heart rate and perceived exertion compared to a fluid replacement group. Postural stability was found to be impaired in the fluid restriction group when compared to the group allowed to ingest fluids throughout the workout. Postural tandem sway and center of pressure (COP) were found to be greater in a post test of the fluid restriction group (Derave, et al., 1998).

A study performed by Patel et al. looked at the effects of dehydration on variables used to diagnose and determine concussions in athletics. This study looked at postural sway and found that subjects did not have a statistically significant change between euhydration and dehydration states for the Balance Error Scoring System (BESS). This study also found no significant differences with the Sensory Organization Test (SOT) and Standardized Assessment of Concussion (SAC), which are clinical measures used in concussion assessment. The Graded Symptoms Checklist (GSC), however, did show a significant difference with the dehydrated condition having a higher total symptom severity, number of symptoms, and higher symptoms of balance, dizziness, feeling slowed down, and feeling in a fog (Patel, Mihalik, Notebaert, Guskiewicz, & Prentice, 2007).

In the current research that has been performed, there are some limitations. Several of the studies looked at dehydration on variables, but their populations were not specific to the sport of wrestling and if active dehydration was performed, it was via a bike workout, not a sport specific task ((Derave, et al., 1998; Patel, et al., 2007; Szinnai, et al., 2005). Also, a small sample size was used of male volunteers, an average age of 25 years old, who were not as physically trained as wrestlers. Because of this, the relationship between dehydration and concussion measures in the sport of wrestling is not well understood.

Statement of the Problem

Wrestling is a sport where athletes consistently practice various weight-cutting tactics causing weight fluctuations throughout a season. It is also a sport where injuries are common including concussions due to the direct contact in the sport. Dehydration and concussion share a similar symptomatology, including dizziness, headache, and balance difficulties. It is important for clinicians and medical personnel to understand how weight-cutting tactics affect clinical concussion measures in order to provide appropriate care to the wrestlers. Based on the study findings and an improved knowledge of the effects of weight-cutting tactics, we may suggest having the athletes rehydrate and quit practicing weight-cutting tactics before concussion assessment is performed. This would help ensure that any changes in score are due to injury, not weight-cutting tactics. It would also be important for clinicians to know if clinical concussion measures are not sensitive to weight-cutting tactics. This would give clinicians and medical personal confidence in the sensitivity of concussion assessment tools to be recognizing concussion signs and symptoms. Therefore, the purpose of this study was to look at the effects of weight-cutting tactics on clinical concussion measures in Division I collegiate wrestlers.

Variables

1. Independent Variables:

- Weight-cutting tactics (including practice, which all subjects will go through)

2. Dependent Variables:

- Sport Concussion Assessment Tool (SCAT2) total score
- Standard Assessment of Concussion (SAC) total score
- Balance Error Scoring System (BESS) total score
- Graded Symptom Checklist (GSC) symptom severity score and total number of symptoms endorsed
- Automated Neuropsychological Assessment Metrics (ANAM) Simple Reaction Time throughput score

Research Questions

1. What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on SCAT2 total score?
2. What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on SAC total score?
3. What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on BESS total score?
4. What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on Graded Symptom Checklist symptom severity score and total number of symptoms endorsed?

5. What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on Simple Reaction Time (SRT) throughput scores?

Research Hypotheses:

1. Subjects' SCAT2 scores will be
 - a. Worse at pre-practice when compared to baseline.
 - b. Worse at post-practice when compared to pre-practice.
 - c. Worse at post-practice when compared to baseline.
2. Subjects' SAC scores will be
 - a. Worse at pre-practice when compared to baseline.
 - b. Worse at post-practice when compared to pre-practice.
 - c. Worse at post-practice when compared to baseline.
3. Subjects' BESS scores will be
 - a. Worse at pre-practice when compared to baseline.
 - b. Worse at post-practice when compared to pre-practice.
 - c. Worse at post-practice when compared to baseline.
4. Subjects' Graded Symptom Checklist scores (severity score and number of symptoms endorsed) will be
 - a. Worse at pre-practice when compared to baseline.
 - b. Worse at post-practice when compared to pre-practice.
 - c. Worse at post-practice when compared to baseline.
5. Subjects' Simple Reaction Time (SRT) throughput score will be

- a. Worse at pre-practice when compared to baseline.
- d. Worse at post-practice when compared to pre-practice.
- e. Worse at post-practice when compared to baseline.

Null Hypotheses:

1. H_0 : No difference between subjects' SCAT2 score when compared to baseline, pre practice and post practice scores.
2. H_0 : No difference between subjects' SAC scores when compared to baseline, pre practice and post practice scores.
3. H_0 : No difference between subjects' BESS scores when compared to baseline, pre practice and post practice scores.
4. H_0 : No difference between subjects' Graded Symptom Checklist scores (severity score and number of symptoms endorsed) when compared to baseline, pre practice and post practice scores.
5. H_0 : No difference between subjects' Simple Reaction Time (SRT) throughput score when compared to baseline, pre practice and post practice scores.

Definition of Terms/Operational Definitions

1. Practice was defined during the month of October when athletes are preparing for first competition in November (October 12 and October 19).
2. Weight-cutting tactics could consist of using diuretics, laxatives, food restriction, fluid restriction, excessive exercise, vapor impermeable suits, and/or sweatpants and

sweatshirts. Subjects were allowed to practice any combination or number of these tactics. Which tactics each subject practiced were recorded.

3. Euhydration status for baseline testing defined as urine specific gravity ≤ 1.020 .
4. Flat weight was defined as a wrestler's competition weight.

Assumptions

1. The athletes were able to provide a urine sample pre and post practice though probably dehydrated.
2. The SCAT2 was a reliable and valid clinical concussion measure.
3. The BESS was a reliable and valid clinical concussion measure.
4. The ANAM's Simple Reaction Time subtest was a reliable and valid clinical concussion measure.
5. Subjects were compliant with guidelines and treated it as if they have to weigh-in for competition a day and a half later.
6. Subjects performed to the best of their ability.
7. Subjects were truthful when reporting symptoms.

Delimitations

1. Only male Division 1 collegiate wrestlers from the University of North Carolina at Chapel Hill were used; no females were included.
2. Only current clinical concussion measures at the University of North Carolina – Chapel Hill were used.

Limitations

1. During matches, it may be assumed that subjects are rehydrated since they weigh in an hour before competition to eat/drink, but this study could not be performed on competition days.
2. Possible learning effects/practice effects of clinical measures.
3. Previous concussion history was not collected.
4. Subjects only had to cut weight to 5 pounds within flat weight and never made flat weight, which they would for competition.
5. Specific gravity was used to assess hydration status because it is a cost efficient, on-field measure, though plasma osmolality has been found to better track changes than specific gravity and urine osmolality (Armstrong, et al., 1998; Oppliger, Magnes, Popowski, & Gisolfi, 2005).

CHAPTER II

REVIEW OF LITERATURE

Introduction

Sports concussion or mild traumatic brain injury is an area of medicine that has continued to receive more attention over the past 20 years. More information is known about this injury due to research that has been performed on varying aspects of this topic. Football appears to be the sport at the highest risk for concussion, although other sports are also at risk due to the rules or dynamics of the sport. Wrestling is a sport where points are scored by taking your opponent down to the mat. During this sport, contact with your opponent occurs for a majority of the time, potentially leading to more exposure for injury. During 1997 – 2000, 121 concussions were both diagnosed and reported in collegiate wrestling (Covassin, et al., 2003). Wrestling also poses a risk for severe dehydration. Wrestlers are thought to gain an advantage if they can wrestle at the lowest possible weight. This leads to various methods of weight loss, including dehydration from fluid and food restrictions and extensive exercise in warm climates. A dehydration level of 5% total body weight is not that uncommon in wrestling. Dehydration of this level results in physiological changes, as well as dizziness, postural difficulties, fatigue, headache, lethargy, etc. These are also signs and symptoms commonly reported in mild traumatic brain injury or concussion. With similar signs and symptoms being present in concussions and dehydration, one wonders how dehydration

affects clinical concussion assessment tools, therefore the purpose of this study is to examine the effects of dehydration on clinical concussion measures in Division I collegiate wrestlers.

Sports Concussion/Mild Traumatic Brain Injury

Definition

The definition of sports concussion or mild traumatic brain injury has evolved since the 1960s. Mild traumatic brain injury (MTBI) has been described as a mild diffuse injury resulting from a blow or insult to the head or elsewhere on the body. This blow can result in one or more signs and symptoms (Guskiewicz, et al., 2004). It has also been described as a sudden acceleration or deceleration force to the head, which causes an injury to the brain. This injury leads to immediate, though temporary alterations in brain functions (Guskiewicz, Ross, & Marshall, 2001).

Epidemiology

The incidence of concussion is more common than people may recognize. Over three years, 1,224 concussions were sustained during practice and 1,278 were sustained during games in collegiate sports (Covassin, et al., 2003). This shows that practices can be just as dangerous as competitions/games with regards to sustaining a concussion. During 1997-2000, 15 collegiate sports were analyzed to determine which sports sustained the most concussions and pose the highest risk for injury. Women's soccer reported 192 concussions while football reported 147. Ice hockey reported 126 concussions, men's soccer reported 123, and wrestling reported 121. Men's lacrosse, baseball, and softball were all in the same range of around 80 concussions in three years (Covassin, et al., 2003). This shows that

concussions are a common injury in a number of sports, therefore confirming the importance of understanding more about concussions since they can potentially affect so many people. Furthermore, it has been found that a high school or college football player who sustains one concussion is three times more likely to sustain a 2nd concussion during the same season compared to athletes who have not sustained a previous injury (Guskiewicz, Weaver, Padua, & Garrett, 2000). Athletes could potentially be missing weeks to months of their athletic seasons if concussions are not recognized and managed appropriately.

Biomechanics/Mechanism of Injury

A number of forces and blows can occur to the head, resulting in a concussion. The brain rests in the skull and is surrounded by cerebrospinal fluid, whose primary purpose is to help cushion the brain. When there is a rapid change in velocity of the head over time, acceleration or deceleration of the brain occurs within the skull (Barth, Freeman, Broshek, & Varney, 2001). Acceleration is when there is an increase in velocity while deceleration is when there is a decrease in velocity. This acceleration or deceleration of the brain results in trauma because the cerebrospinal fluid cannot absorb or cushion such a sudden change in velocity. Not all acceleration or deceleration forces occur in the sagittal plane because the cervical spine allows increased mobility as a sacrifice for stability. Due to this increased mobility, the vector of the acceleration to the head can be changed due to a hit, causing rotational forces to the brain, resulting in various injuries (Barth, et al., 2001). Literature classifies two major injuries as the result of impacts. A coup injury is when there is a blow to a resting, moveable head, which results in injury directly beneath the point of impact or contact. A contrecoup injury is when a moving head hits an immovable object. This results

in the brain shifting to the opposite side of impact, causing the brain to hit the skull causing injury (Barth, et al., 2001; Guskiewicz, et al., 2004). Coup-contrecoup combinations can occur and when rotational impacts are also involved, the sites of injury to the brain can be numerous.

When a force is applied to the brain, three particular stresses can occur: compressive, tensile, and shearing. A compressive stress is when the brain is crushed or compressed due to a force while a tensile stress is when the tissue is pulled or stretched apart. A shearing stress is when the force occurs across the parallel organization of the tissue in opposite directions. A compressive force is better tolerated by the brain tissue, resulting in less severe injury, whereas tensile and shearing stresses are not as well tolerated, resulting in more severe injuries.

No two concussions will present in the same manner due to the various forces and stresses that can occur on the brain. Any combination of forces or stresses can occur resulting in injuries of varying severity. Because of this, it is important to be able to recognize, understand, and correctly handle concussions clinically to prevent further injuries or mental detriments.

Signs and Symptoms

For many years, loss of consciousness (LOC) and post traumatic amnesia were the gold standard symptoms for concussion (McCrea, Kelly, Randolph, Cisler, & Berger, 2002). Many of the grading scales used to determine grade and severity of concussion were based on these two symptoms. More studies, however, have been showing that while these are two symptoms that may be present, there are many more signs and symptoms more commonly

present in concussion. A single injury resulted in subjects with an increased report of headache, dizziness, and memory problems at 24 hours and five days post injury when compared to controls subjects. By ten days post injury, these signs and symptoms were no longer significant from baseline values (Macciocchi, Barth, Alves, Rimel, & Jane, 1996). Furthermore, concussed athletes reported headache, dizziness, nausea, balance deficits, drowsiness, photophobia, memory and concentration problems, feeling “slowed down” and “foggy” two hours post injury, but returned to normal at 48 hour post injury (Echemendia, Putukian, Mackin, Julian, & Shoss, 2001). In 1003 football concussions, 86% reported headache, 67% reported dizziness, 59% reported confusion, 48% disorientation, 28.6% reported a positive Rhomberg’s test, 27.7% reported amnesia, and 8.9% experienced loss of consciousness (Guskiewicz, et al., 2000). Furthermore, no postural stability or neuropsychological test differences were found between concussion subjects who experienced loss of consciousness and/or post traumatic amnesia and concussed subjects who did not (Guskiewicz, et al., 2001). All of these studies show that loss of consciousness and/or post traumatic amnesia are not good indicators for concussion. The main concussion signs and symptoms reported are impaired attention, concentration difficulties, information-processing speed, memory, headache, dizziness, nausea/vomiting, tinnitus, impaired eye tracking, balance disturbances, drowsiness, photophobia, feeling “slowed” down, and overall fatigue (Echemendia, et al., 2001; Guskiewicz, et al., 2004; Macciocchi, et al., 1996).

More recently, research has been done looking at the relationship between headache and concussions. Headache has been said to occur in 86% of concussions. Subjects who presented with a headache at initial assessment and one day post concussion displayed an increased number and intensity of symptoms initially post injury and throughout the recovery

period (Guskiewicz, et al., 2000; Register-Mihalik, Guskiewicz, Mann, & Shields, 2007).

Headache was even reported three days post concussion in 42% of athletes, but by five days post injury, had decreased to 25% of athletes (Guskiewicz, et al., 2001).

Management and Return to play/General Guidelines

Assessment of concussions in athletics should include a battery of tests. It is recommended that no one single test should be used to make a decision regarding return to play or further plan of care when dealing with concussions. Each person may present with a concussion in a different manner, therefore a test battery of cognition, postural stability, and self-reported symptoms is recommended (Guskiewicz, et al., 2004). If assessment tools cannot be used following injury, it is recommended that a seven day symptom free waiting period be implemented before allowing an athlete to return to play. An athlete should be disqualified from a game or practice on the day of injury if an athlete is symptomatic at rest or following 20 minutes of exertional activity. Furthermore, a progression of activity should be attempted before returning an athlete back to practice or competition. Athletes should be symptomatic for 24 hours, after which a 20 minute exertional activity should be attempted. If the athlete still does not present with symptoms and his/her baseline neuropsychological and postural stability tests are back to baseline values, the athlete may return to play. If all of these criteria are not met, it is recommended that the athlete be kept out of practice or competition (Guskiewicz, et al., 2004).

Effects on Neuropsychological Function

Concussions have been shown to have an effect on neuropsychological and cognitive function. Several studies have used paper and pencil neuropsychological tests to determine if concussed athletes show a deficit in neuropsychological function. A single concussion in 183 cases showed impaired neuropsychological test performance 24 hours post injury, but at five days post injury, test values matched control subjects (Macciocchi, et al., 1996). Using similar neuropsychological tests, working memory, immediate memory recall, concentration, and rapid visual processing were effected during the initial stage of recovery following concussion in Division I athletes, particularly 24 hours. The Wechsler Digit Span test and Trail-making B test appeared to be the most sensitive when trying to track recovery following concussion (Guskiewicz, et al., 2001). In both studies, athletes and matched controls were assessed at a preseason baseline and at increments post injury. One study looked at the effects of concussion on neuropsychological function two hours, 48 hours, one week, and one month post injury. Using paper and pencil tests, at two hour post injury, concussed Division I athletes performed worse on tests focusing on working memory, attention, concentration, and verbal learning. At 48 hour post injury, concussed athletes performed worse on test assessing working memory, verbal learning, verbal memory, divided attention, and speed of information processing. At one week and one month post injury, there were no significant differences between concussed athletes and matched control subjects (Echemendia, et al., 2001).

The Standard Assessment of Concussion (SAC) is a clinical concussion assessment tool which looks at orientation, immediate memory, concentration, and delayed recall scores. It is believed that these are the areas of neuropsychological functioning that are most

commonly affected following concussion. This tool was used on concussed athletes five minutes and 15 minutes post injury, as well as 48 hours and 90 days post injury. Nearly 85% of subjects did not have post traumatic amnesia or loss of consciousness during injury, but did have deficits in orientation, concentration, and memory functions immediately following injury (McCrea, et al., 2002). At 15 minutes post injury, subjects who did lose consciousness for a period of time remained more impaired than subjects who did not present with loss of consciousness or post traumatic amnesia. At two days post injury, almost all subjects, regardless of LOC or PTA, appeared to have made a full recovery back to baseline data. A limitation to this study, however, is there was only a small sample size of athletes who presented with LOC and/or PTA, therefore it is hard to make generalizations to the population that PTA and LOC show an increase in concussion severity and longer recovery period. Conversely, LOC and PTA were found to not be an indicator for performance on neuropsychological function or postural stability tests (Guskiewicz, et al., 2001). This study, too, however, had a very small sample size of individuals who experienced PTA and/or LOC, making it hard to make generalizations to the population. More research with a greater sample size of subjects who experienced LOC and/or PTA is needed.

Effects on Postural Stability

Postural stability is another area affected by concussion. Balance is an integration of the visual, vestibular, and somatosensory systems. Because it is an integration of these systems, when one system is altered, the other systems are supposed to adapt and allow static posture to be maintained. It is believed that with concussed athletes there are deficits in the exchange of information between these systems, resulting in anterior-posterior sway, medial-

lateral sway, or a combination of both particularly on an unstable surface with or without vision (Guskiewicz, 2001, 2003; Riemann & Guskiewicz, 2000; Riemann, 2000). Therefore, it is important to always include an assessment of postural stability in a concussion assessment. The Rhomberg test was a balance test commonly used to assess postural stability in concussed athletes for several years. Variations to the Rhomberg test have occurred over the years, including one where six test conditions were used. A double leg stance was performed on two surfaces, firm and unstable, on a force plate. For each surface, subjects performed an eyes open, eyes closed, and a visual conflict dome condition (Ingersoll & Armstrong, 1992). The goal of the variation in the Rhomberg test was to remove one of the three systems used to maintain balance and see the affects in closed head injury patients. Severe head injury patients (LOC > 6 hours) were found to have an increased anterior-posterior and medial-lateral sway than other severities of head injury and the control subjects (Ingersoll & Armstrong, 1992). With increased severity of head injury, it would be expected that postural sway would be greater; however, it is important to note that mild head injury, defined as no loss of consciousness, did show varying sway values amongst the six conditions.

Postural stability has also been assessed using the NeuroCom Sensory Organization Test (SOT) and the Balance Error Scoring System (BESS). The SOT involves a double leg stance for three 20-second trials with eyes open, eyes closed, and sway reference on a stable and sway reference surface. The BESS involves three stances (double leg, single leg, and tandem stance) on a foam and firm surface with eyes closed. The SOT in subjects who received a concussion was found to demonstrate a decreased composite score day one post injury when compared to subject's baseline and day three values and a matched control group

(Guskiewicz, et al., 2001; Riemann & Guskiewicz, 2000). Recovery in subjects appeared to occur between day one and day three post injury according to the SOT. The BESS demonstrated that injured subjects had decreased postural stability day one post injury when compared to baseline and day three values as well as to the control group (Guskiewicz, et al., 2001). Using the BESS, the three stances on the firm surface were not found to be significantly different between subjects with mild head injury and control groups, however, significant group differences were noted between the three stances on the foam surface between mild head injury and control subjects (Riemann & Guskiewicz, 2000). The SOT and BESS results following mild head injury were found to parallel each other, confirming that the BESS is an effective clinical measure when the SOT cannot be accessed or is too expensive to afford (Riemann & Guskiewicz, 2000).

Postural stability deficits have even been found in subjects six months following concussion. Thirteen mild traumatic brain injuries with a Glasgow Coma Scale score of 13-15 who were still dealing with signs and symptoms six months post injury were assessed using a force plate. They performed balance tasks with eyes open, while doing an arithmetic task, with eyes closed, weight shifting, and weight shifting while performing an arithmetic task. Subjects showed a reduction in quiet standing and weight shifting control of posture even six months post injury (Geurts, Ribbers, Knoop, & van Limbeek, 1996). This further confirms that postural stability is an area affected by concussion; therefore the assessment of postural stability should always be included in a concussion testing battery.

Sport of Wrestling

Epidemiology

Wrestling is a sport where males, and more recently females, continue to participate at the collegiate and high school levels. Since 2000, approximately 6,000 males participate in wrestling at the National Collegiate Athletic Association level per year (Vicente, 2007). In the year 2006-07, over 255,000 males and 5,000 females participated at the high school level (NFHS, 2006). Wrestling is a unique sport where contact with another player or mat occurs consistently. In order to score points, contact with your opponent is required. Due to this fact, the risk of injury is quite high. The 3 primary injury mechanisms include player contact, contact with a bench, mat, etc, and no contact (Agel, 2007). During wrestling practices, 63.6% of injuries occurred due to contact with another player (Agel, 2007). Contact with another player can lead to shoulder, knee, ankle, and head/face injuries. The most common move in wrestling associated with injuries is the takedown, accounting for 41.9% of injuries (Yard, et al., 2008). A takedown is worth two points and is when one wrestler takes his opponent to the mat from a standing position, usually in a high energy, rapid motion (Yard, et al., 2008). In the sport of wrestling, both wrestlers begin in a neutral position, and in order to score points, performing a takedown is encouraged (Yard, et al., 2008). Takedowns are practiced frequently because they are such a vital aspect to the sport, therefore injuries are likely to occur in practice as well. Injuries during preseason were also found to occur twice as much when compared to regular season. One theory as to why this happens is that athletes are attempting to drop significant body weight before the regular season begins, though data has revealed that there is no relationship between weight division and injury frequency (Agel, 2007).

Wrestling has been found to have an injury rate of 7.25/1,000 A-E in college (Yard, et al., 2008). More specifically, injury rates in matches were found to be second behind spring football per 1,000 A-E (Jarret, et al., 1998). Of all wrestling injuries reported from 1985 through 1996, 37.6% resulted in athletes missing 7 days or more (Jarret, et al., 1998). This shows that wrestlers are sustaining severe enough injuries to cause them to miss a week or more of practice/competition.

Of body parts that are injured in wrestling, concussions are common. Between the years of 1997-2000, 121 concussions were sustained at the collegiate level (Covassin, et al., 2003). Between 1988-1989 through 2003-2004, concussions accounted for 4.8% of total injuries in collegiate wrestling (Agel, 2007). More recently, during the 2005-2006 academic year, 5.8% of concussions at the college level was reported (Yard, et al., 2008). This appears to show that the rate of concussion at the collegiate level has increased over the years.

Weight Classes/Weight Loss Measures

Wrestling is divided into 10 weight classes. These weight classes are 125, 133, 141, 149, 157, 165, 174, 184, 197, and 285 lbs. Opponents are paired based on their weight class. To wrestle at a particular weight class, the wrestler needs to weigh less than the respective weight class 1 hour prior to wrestling in a dual meet. It is perceived and encouraged in the sport of wrestling that there is a competitive advantage to wrestling at a lower weight class. Because of this, wrestlers constantly fluctuate their weight and rely on various measures in order to lose the weight needed to wrestle at their desired weight class. These methods include fluid and food restriction, excessive exercise in a warm climate wearing cotton sweat suits, use of laxatives or diuretics, sitting in a sauna, or wearing vapor impermeable suits

during exercise (Oppliger, et al., 2003). All of these methods result in significant and in some cases, severe dehydration in the athletes and an elevated core body temperature.

Death Due to Weight-Cutting Tactics

In 1997, from November to December, three collegiate wrestlers died from rapid weight loss when trying to make weight for a competition. All three wrestlers were using extreme weight loss methods, including dehydration through excessive perspiration, restricted fluid/food intake, and using vapor impermeable suits underneath cotton warm-ups. For the three athletes, the difference between their preseason weight and their weight class goal for competition was an average of 30 lbs or approximately 15% of their total body mass (Centers for Disease Control and Prevention, 1998). As a result of these three tragic deaths all occurring within one month, the National Collegiate Athletic Association revised the weight loss management guidelines and placed more restrictions on what is and what is not permitted.

The NCAA Rule Changes 1999

In 1999, the NCAA rules committee met to address the weight loss tactics used in wrestling and make necessary changes to try and prevent weight loss related deaths from occurring as did in 1997. The main rule changes included six pounds added to each weight class (i.e. 127 lbs went to 133 lbs) and weigh-ins were moved to one hour prior to competition time for a dual meet. A certification process was implemented and athletes now have to certify at the beginning of the season to determine a minimum allowable competitive weight. For this certification, athletes must be properly hydrated. Also, when there is

multiple day tournaments, athletes must weigh in at the beginning of each day. The NCAA also prohibited the use of vapor impermeable suits, saunas, and laxatives, emetics, diuretics, self-induced vomiting, excessive fluid/food intake, and rehydration via artificial means (i.e. intravenous hydration) (Committee, 1999). These rule changes were meant to place restrictions on weight loss tactics and to limit excessive weight loss in the few days leading up to competition.

The most recent “2009 NCAA Wrestling Rules and Interpretations” include several of the rule changes established in 1999, but also more detail regarding the certification process and consequences for failing to following the rules. A final weight assessment is determined prior to the first official team practice of regular season. This certification process establishes the minimum weight class the athlete can compete at during the season. This weight is determined by urine specific gravity, hydrated body weight, and three skin fold measurements from the triceps, subscapular, and abdominal areas. The NCAA regulates that a specific gravity value of less than or equal to 1.020 shows that athlete is euhydrated and a value of greater than or equal to 1.020 shows a state of dehydration. If the athlete is dehydrated, he cannot receive his certification. This process is usually conducted by the certified athletic trainer or physician. Once this data is entered and the coach and certified athletic trainer verify the data, the lowest weight class for the athlete cannot be changed (NCAA, August 2008).

The NCAA also has a weight-loss plan. This states that wrestlers should not lose more than 1.5% of their total body weight per week. This value is compared to the previous weekly weigh-in number (NCAA, August 2008). The NCAA has an individualized weight loss calculator for each athlete based on their certification data.

The NCAA has strict regulations and consequences for failure to abide by the rules. If a wrestler competes at a weight class which is two weight classes above his certification weight, he forfeits the right to return to his original certification weight class. This is to limit the excessive weight loss attempting to drop two weight classes to return to original weight class certification. There are also penalties to the student/athlete, coaching staff, and institution if unsafe weight loss tactics are used. Some of these penalties include public or private reprimand, disqualification of individual contest(s), financial penalty of \$100 per institution or \$50 per individual, and team records or performances being adjusted (NCAA, August 2008).

The reason for implementing the rule changes of 1999, which have carried over to the recent rules of 2009, are to protect the student-athlete from severe dehydration and the consequences on the body from participating in extreme weight loss tactics. Since the rule changes, collegiate wrestlers participate in less extreme weight loss tactics, however, from a survey of 43 collegiate programs from Division 1, 2, and 3, 25% still use saunas, vapor impermeable suits, and fasting to lose weight (Oppliger, et al., 2003). A weekly weight loss value of 2.9 kg or 4.3% total body weight for Division 1, 2, and 3 has been reported and 12.1% of Division 1 wrestlers reported cycling their weight 6% of their total body weight. This means that the average weight lost in the five days prior to a weigh-in each week was 2.9 kg or 4.3% total body weight (Oppliger, et al., 2003). What typically occurs is the athletes will regain this lost weight within several days following competition before they start the whole process over again. Cycling ones' weight means that 12.1% of Division 1 wrestlers were losing and regaining approximately 6% of their total body weight each week. Wrestler self reported values showed that 26.6% of wrestlers cycled their weight 10 times

during a season (Oppliger, et al., 2003). These values show that while weight loss practices have improved, there are still wrestlers that are practicing extreme methods and losing and regaining significant amounts of weight each week.

Dehydration in Athletics

Definition

Dehydration is when sweat lost due to activity is greater than fluid intake. The body's main method of cooling or dissipating heat is through evaporation or sweating (Casa, 2000). Sweat results in a loss of fluids from the body and this increases when activity occurs in a hot environment, exercise intensity is increased, and when more clothing is worn. When there is an increase in sweat lost and therefore an increase in fluids lost from the body, dehydration can occur more rapidly. Dehydration of 1-2% total body weight has been said to compromise physiological function and decrease performance. Dehydration of 3% or greater has been said to further disrupt physiological function, causing heat illnesses (Casa, 2000). The National Athletic Trainer's Association (NATA) states that minimal dehydration is the loss of 1-3% total body mass and this is equivalent to a urine specific gravity between 1.010 and 1.020. NATA states that significant dehydration is the loss of 3-5% of total body weight, which is equivalent to a urine specific gravity of 1.021-1.030 and that severe dehydration is the loss of 5% or more of total body weight, which is equivalent to a urine specific gravity greater than 1.030 (Casa, 2000). For every 1% body weight lost during activity, an athlete's core body temperature rises an additional 0.15 - 0.20 degrees C (Mountain & Coyle, 1992).

Signs and Symptoms

Signs and symptoms of dehydration include excessive thirst, flushed skin, muscular cramps, apathy, dizziness, headache, vomiting, chills, decreased performance, dyspnea, balance difficulties, feeling slowed down, feeling in a fog, and overall fatigue (Casa, 2000; Patel, et al., 2007). Signs and symptoms progress as the level of dehydration in athletes increases.

Effects on Postural Stability

Dehydration has been shown to have an effect on postural stability. Postural stability assessed via a force plate following fluid restriction and a bike exercise task showed an increase in postural tandem sway and an increase in center of pressure (COP) (Derave, et al., 1998; Gauchard, Gangloff, Vouriot, Mallie, & Perrin, 2002). One study assessed double leg stance versus tandem stance with eyes open (Derave, et al., 1998) and the other study assessed the double leg stance with eyes open and eyes closed (Gauchard, et al., 2002). With and without fluid restriction, following exercise, the tandem stance resulted in a larger COP than the double leg normal stance, showing that the tandem stance, regardless of hydration status is more challenging and results in more sway than the normal double leg stance (Derave, et al., 1998). Furthermore, thermal dehydration from repeated sessions in a sauna did not result in a significant change in center of pressure and postural stability in the double leg stance with and without eyes opened (Derave, et al., 1998). Both studies had a sample size of 10 subjects or less, making it difficult to generalize these findings to the rest of the population.

A computerized postural stability assessment along with a force plate (NeuroCom SOT) was performed on subjects in a euhydrated and dehydrated condition following fluid/food restriction and a bike exercise task. Six conditions which altered the visual, somatosensory, and vestibular domains were performed and found that there was not differences between groups, meaning this measure is unaffected by dehydration in subjects dehydrated to 1.71-4.15% total body weight (Patel, et al., 2007).

Postural stability has also been assessed in hydrated and dehydrated conditions, but a clinical measure rather than a force plate was used. The Balance Error Scoring System with six differing combinations of stance and surface showed that it too is an effective tool that is unaffected by dehydration in subjects dehydrated to 1.71-4.15% total body weight (Patel, et al., 2007).

Effects on Cognitive Function/ Neuropsychological Performance

Dehydration has been found to have an effect on neuropsychological performance and cognitive function. During a progressive voluntary dehydration of 24 hours, a battery of computer generated psychological tests were administered and found that subject's speed or reaction time, accuracy, and mental endurance deteriorated 3 hours post fluid deprivation. Following 6 hours of fluid deprivation, subject's total test solving time was found to increase (Petri, et al., 2006). Only 10 subjects were used in this study, therefore generalizations to the population are difficult to make.

The effects of dehydration on cognitive function have also been studied. Literature has shown that individuals dehydrated to 2% of total body weight or more via a combination of exercise and fluid restriction in a hot environment showed a decrease in short term

memory, attention, arithmetic efficiency, and visual motor tracking (Gopinathan, Pichan, & Sharma, 1988). Heat induced dehydration and treadmill exercise induced dehydration to 2.8% total body mass when compared to a control group were found to have a difference in cognitive function, particularly decision making speed and short term memory. Long term memory, unstable tracking, and reaction time were not affected by either form of dehydration. Overall, there were no significant differences found between the two forms of dehydration (Cian, Barraud, Melin, & Raphel, 2001). In both studies, however, a sample size of 11 or smaller was used, making generalizations to the entire population difficult. Conversely, no decrease in cognitive-motor function was noted following a 28 hour fluid restriction and free food intake with less than 75% water content. Authors believe that young adults are able to adapt to slow progressive dehydration up to 2.6% of total body weight (Szinnai, et al., 2005).

While some of these studies have focused on an exercise task along with dehydration, none have looked at the effects of dehydration in wrestling on cognitive function. Following rapid weight loss after weigh-ins and 18-24 hours prior to competition, wrestlers completed a cognitive test battery. With an average body weight loss of 6.2%, wrestlers scored lower for short term memory, however, did not score lower for attention, visual acuity, and visuomotor skills following rapid weight loss (Choma, Sforzo, & Keller, 1998).

Two cognitive function/neuropsychological tests commonly used for clinical concussion measures were analyzed to test their sensitivity to dehydration in individuals dehydrated 1.71-4.15% total body weight. Both the Standardized Assessment of Concussion (SAC) and Automated Neuropsychological Assessment Metrics (ANAM) composite score were found to have no differences between euhydrated and dehydrated conditions (Patel, et

al., 2007). For the ANAM, dehydration is then believed to not have an effect on reaction time, mental processing speed, mental efficiency, and working memory. There was a significant difference in Matching-to-Sample and Sleep Scale between groups, showing that in the dehydrated condition visual memory and subjective measures of fatigue and tiredness were present. For the SAC, dehydration is then believed to not have an effect on orientation, immediate memory, concentration, and delayed recall.

An important finding is that a reduction in performance for certain cognitive function tests is inversely related to the degree of dehydration, meaning performance will continue to decrease as degree of dehydration increases (Gopinathan, et al., 1988). Therefore, though some studies have not found a decrease in areas of cognitive-motor function, perhaps as dehydration level increases, as in wrestling, a decrease in cognitive-motor function will be seen.

Effects on Subjective Symptoms

The signs and symptoms of dehydration have been mentioned earlier, but research has also been performed to compare such subjective feelings in euhydrated and dehydrated conditions. Fluid restriction over 37 hours with no exercise task showed an increase in perception of thirst, feelings of dry-mouth, headache, tiredness, and difficulty concentrating with a dehydration of 1-2% total body weight (Shirreffs, Merson, Fraser, & Archer, 2004). Similarly, fluid restriction of 28 hours and free food intake with less than 75% water content showed an increase in subjective rating of effort and concentration needed to complete a cognitive function test, as well as an increased feeling of tiredness and decrease in alertness (Szinnai, et al., 2005). Fluid and food high in fluid content restriction for 15 hours along

with a 45-minute bike exercise task showed a higher total symptom severity, number of symptoms, and higher ratings of balance, dizziness, feeling slowed down, and feeling in a fog on the Graded Symptom Checklist (GSC). The GSC is a clinical concussion measure that assesses the presence of 22 concussion-related symptoms, broken down into cognition, somatic, emotional, and sleeping problems clusters. These results show that concussion and dehydration appear to have similar signs and symptoms in subjects dehydrated 1.71-4.15% total body weight, though this study did not analyze a sport related activity, but instead looked at a bike exercise task (Patel, et al., 2007). Furthermore, a subjective questionnaire used for heat stress dehydration, exercise induced dehydration, and a control group found that both forms of dehydration resulted in an increased feeling of fatigue, particularly in the exercised induced group (Cian, et al., 2001).

Methodological Considerations

Hydration Measures

Specific gravity is a common measure used to assess hydration status. It is defined as the density of urine from the sample gathered compared to the density of water (Oppliger & Bartok, 2002). One method of testing for specific gravity include reagent strips, where a strip is dipped into the urine sample and the color is compared to colors found on the strip kit, which allows for some subjective error. A more commonly used method is refractometry. The refractometer is dipped into the urine sample and internally takes into consideration the temperature of the specimen (Oppliger & Bartok, 2002). Refractometers are small, hand held devices and because of this, are portable and easy to use, making hydration assessments in athletes more feasible. The cut-off specific gravity value commonly

used of less than or equal to 1.020 has been said to only deal with the upper range of euhydrated individuals for a range of 1.006-1.020, which was found to symbolize euhydrated. It was suggested that an adjusted cut-off value of 1.015 be used to accurately depict euhydrated individuals (Popowski, et al., 2001). For the cut-off value of 1.020, 31.3% of euhydrated subjects were correctly classified and 80.0% of dehydrated subjects were correctly classified (Oppliger, et al., 2005). This shows that lowering the specific gravity level to 1.015 may more accurately represent euhydrated individuals and ensure that dehydrated subjects with values between 1.015 and 1.020 are not inaccurately being defined as hydrated. This study, however, only had a sample size of 12; therefore more research must be done in this area before the cut-off of 1.020 that is use by many organizations is changed.

Osmolality is another commonly used measure of hydration status and can be analyzed through urine or plasma. It looks at the amount of solute particles per kilogram of solution (Armstrong, et al., 1998; Oppliger & Bartok, 2002). It is measured by a freezing point with an osmometer. Urine osmolality and urine specific gravity have been said to be used interchangeably, which was verified by a study, however, the variance, or possible error, of these two methods increases when specific gravity reaches greater than 1.024 and osmolality reaches greater than $900\text{mOsm}\cdot\text{kg}^{-1}$ (Armstrong, et al., 1998). Urine osmolality in weight controlled sports subjects (boxing and wrestling) was significantly higher during a morning, pre-breakfast urine collection when compared to non-weight controlled sports. This reflects the attempts of the athletes to dehydrate to lose weight for competition (Shirreffs & Maughan, 1998). This same study also looked at euhydrated and dehydrated

conditions and found a significant difference in the dehydrated group, which included an exercise task.

Plasma osmolality is more invasive and expensive than urine collection because blood samples need to be collected intravenously, making this method not very practical for quick hydration status checks in athletes. It has, however, been found to be an effective tool in accurately detecting changes in hydration status during acute dehydration and subsequent rehydration (Oppliger, et al., 2005; Popowski, et al., 2001). Plasma osmolality accurately identified and was more sensitive to changes in hydration status at 1% total body weight dehydration than urine specific gravity and urine osmolality. Once dehydration reached 3-5% total body weight and 30 and 60 minutes following workout (recovery time), urine specific gravity and urine osmolality accurately measured hydration status (Oppliger, et al., 2005). Another study with a similar protocol, found that urine specific gravity also identified appropriate hydration status at 3-5% total body weight dehydration, but urine osmolality did not appear to be significantly different from euhydrated value until a 5% total body weight dehydration level was accomplished (Popowski, et al., 2001). The lag presented by urine specific gravity and urine osmolality is thought to be due to ingestion of 250mL water prior to a dehydration protocol for the study was begun, meaning the renal system was attempting to respond to the influx of water. This could also be present in an athlete that is slightly dehydrated and rapidly ingests water. They could potentially produce a urine sample that would indicate them as hydrated due to the fact that the kidneys are filtering that water. Rehydration following 6% total body weight dehydration was found to require 48-72 hours (Costill & Sparks, 1973). Furthermore, rehydration for 1 hour equaling body weight lost following 5% dehydration did not meet euhydration by consuming water alone (Popowski, et

al., 2001). Both of these studies raise the question of if wrestlers are properly hydrating following weight-ins, and even if they are consuming a sport drink, etc, are they ever reaching euhydration? If they are not, then they are potentially still wrestling in a state of significant dehydration.

Finally, urine color is another method of measuring hydration status that is used and is influenced by changes in urine solutes and water. A six-point likert scale has been validated as a useful, inexpensive method (Armstrong, et al., 1994). It is a pocket sized chart which urine color is compared to, but there is room for subjective error. Urine color has been found to be strongly correlated to urine osmolality and specific gravity in individuals dehydrated approximately 1.8-3.7% total body weight (Armstrong, et al., 1994; Armstrong, et al., 1998). A urine color value of greater than three (Armstrong, et al., 1997) and greater than or equal to four (Shirreffs & Maughan, 1998) on the scale have been said to show dehydration. Rapid fluid rehydration was found to decrease the strength of the relationship between urine color and urine specific gravity and osmolality minimally (Armstrong, et al., 1998). Urine color should be assessed within 20 minutes of collection to avoid altered color, bacteria formation, or changes in density due to sitting or refrigeration (Armstrong, et al., 1998).

Objective Clinical Concussion Measures

A concussion battery should include an assessment of neuropsychological function, postural stability, and symptoms. As briefly mentioned previously, the Standardized Assessment of Concussion (SAC) is a clinical measure used to assess neuropsychological status in concussions. The SAC includes measures of orientation, immediate memory,

concentration, and delayed recall, which are neuropsychological areas thought to be affected by concussion. There are three forms, A, B, and C that are used clinically and it only takes approximately 5 minutes to administer. The words used to test immediate memory and delayed recall are the only difference between forms (Barr & McCrea, 2001). A maximum total score of 30 points is possible. Thirty-three football players in high school and college who suffered a grade 1 concussion, which was defined as brief confusion and no loss of consciousness, were administered the SAC. No difference between high school and college athlete's performance was noted. A significant difference between total SAC scores and section scores for concussed and non-concussed athletes were noted, with concussed athletes scoring lower. Concussed athletes scores were also compared to baseline values and immediately following injury, concussed athletes had a lower total score. Forty-eight hours post injury, concussed athlete's values returned to baseline (McCrea, et al., 1998). Immediately following injury, section scores for orientation, immediate memory, and concentration were significantly lower in concussed athletes compared to baseline values, though subjects apparently were not obviously neurologically impaired. Also, immediately following injury, an average decrease of four points on the SAC was noted for high school and college athletes, meaning that the SAC is sensitive to the immediate neuropsychological deficits of concussion (Barr & McCrea, 2001).

There is also a computerized concussion battery that assesses neuropsychological and cognitive integrity. The Automated Neuropsychological Assessment Metrics (ANAM) is a commonly used computerized test. The ANAM consists of several subtests used to assess reaction time, concentration, visual memory, working memory, mental processing speed, and mental efficiency. Several of these subtests have been validated when compared to the

commonly used paper and pencil tests (Woodard, 2002). The ANAM looks at throughput scores, which analyze a combination of the subject's accuracy and speed of performance. The higher the throughput score, the better the performance. The Simple Reaction Time (SRT) subtest has been found to be one of the most reliable subtests. The SRT test presents subjects with a visual stimulus and requires them to press a mouse as quickly as possible following the stimuli. The SRT has been shown to detect deterioration in subjects between baseline and the first testing interval, where no significant difference was seen in other subtests (Bleiberg, et al., 2004).

Another commonly used clinical concussion tool is the Balance Error Scoring System (BESS). It entails six conditions which are a combination of stance and surface differences. A foam and firm surface are used with a double leg, single leg, and tandem stance. For the single leg stance, the non-dominant foot is stood on and for the tandem stance, the non-dominant foot is positioned behind the dominant foot. Athletes do each trial for 20 seconds with their eyes closed. Athletes receive an error when they lift their hands off their iliac crests, they open their eyes, they step, stumble, or fall, when they move the hip into more than 30 degrees of flexion or abduction, when the heel or forefoot is lifted off the ground, and when they remain out of testing position for more than five seconds. Scores are calculated for each condition and a composite BESS score is calculated. The BESS has been compared to a force plate, which is a measure of postural stability used in the laboratory setting. A correlational statistical significance for error scores and target sway measures were found for single leg firm surface, tandem firm, and single leg, double leg, and tandem for the foam surface (Riemann, Guskiewicz, & Shields, 1999). An intertester reliability coefficient for five out of the six conditions ranged from .78-.96. The Double leg firm

surface, which is also the traditional Rhomberg stance, did not show significant correlation between error scores and target sway. The BESS was performed on three consecutive days and the only condition where a learning effect between day one and day three was noted was the double leg foam surface (Riemann, et al., 1999). The BESS was also compared to the NeuroCom SOT, which is a laboratory measure previously described. The BESS was found to have similar trends and paralleled results to the SOT (Guskiewicz, et al., 2001; Riemann & Guskiewicz, 2000)

The Graded Symptom Checklist is also a commonly used clinical measure for concussion assessment. The Graded Symptom Checklist (GSC) is a self-reported scale of 22 concussion-related symptoms. Subjects can rank each symptom on a 7-point Likert scale where 0 means asymptomatic, 1 means mild, and 6 means severe. The concussion symptoms can be broken down into four main groups, cognition, somatic, emotional, and sleep problems. The Graded Symptom Checklist was found to be a practical measure for monitoring concussive symptoms (Maroon, et al., 2000; McCrory, Ariens, & Berkovic, 2000).

The SCAT, which stands for the Sport Concussion Assessment Tool, was developed in 2005 so clinicians could have a concise assessment tool that addressed some of these areas of interest (McCrory, et al., 2005). The SCAT focused on cognitive features, typical symptoms, and physical signs following concussion. It also provided a return to play progression for athletes to go through and pass with no symptoms before being allowed to return to competition. More recently, the SCAT has further evolved and a SCAT2 is now available as a clinical concussion measure. The SCAT2 contains a symptom score section, which is the same as the Graded Symptom Checklist. It also includes a Physical signs score

and Glasgow coma scale score. The SCAT2 also includes the SAC to assess cognitive function and the sub categories of orientation, immediate memory, concentration, and delayed recall. Finally, the firm surface portion of the BESS is included to assess postural stability. An overall score is collected from each variable and a total of 100 points is possible. The higher the score athletes obtain, the better the performance on the SCAT2. The SCAT2 is a concise, thorough, clinical concussion measure that addresses symptoms, neurocognitive function, and postural stability.

The SAC, BESS, and GSC, and now the SCAT2, are all clinical measures that have been compared to laboratory measures and shown to be comparable. Clinical measurements are important in the initial evaluation of athletes, especially when they can be compared to individuals' baseline values. These measurements can gather valuable information that can be used in conjunction with laboratory tests to determine recovery in athletes and should be used when making return to play decisions.

Rationale for Study

The sport of wrestling presents clinicians with unique challenges due to the dynamics of the sport and weight restrictions. Wrestlers are subjecting themselves to weight-cutting tactics that lead to dehydration and decreased caloric intake and, due to the contact of the sport, are also at risk for concussions. Dehydration and concussions have been reported to have similar signs and symptoms, including dizziness, headache, fatigue, and balance difficulties. The question arises if clinical measures for concussion are accurate when wrestlers who sustain an impact to the head are also potentially dehydrated and practicing various weight-cutting tactics. To the author's knowledge, only one study has looked at the

effects of dehydration on clinical measures of concussion. This study looked at postural sway and found that subjects did not have a statistically significant change between euhydration and dehydration for the Balance Error Scoring System (BESS). This study also found no significant differences with the Sensory Organization Test (SOT) and Standardized Assessment of Concussion (SAC). The Graded Symptoms Checklist (GSC), however, did show a significant difference with the dehydrated condition having a higher total symptom severity, number of symptoms, and higher symptoms of balance, dizziness, feeling slowed down, and feeling in a fog (Patel, et al., 2007). Subjects in this study, however, were only dehydrated to 1.71-4.15% body mass and were physically active individuals; they were not wrestlers and were not be subjected to the demands of the sport. Therefore, the purpose of this study was to look at the effects of weight-cutting tactics on clinical concussion measures during practices in Division 1 Collegiate Wrestlers.

CHAPTER III

METHODS

Study Design

Subjects

Thirty-four NCAA Division I male collegiate wrestlers were enlisted in this study. Exclusion criteria included any subject who had sustained a concussion within one month prior to baseline testing and anyone who sustained a concussion before their involvement in the study was complete (approximately Mid-October). Two subjects were removed from this study: one subject received a concussion during the study time frame and the other subject was unable to complete all test sessions due to sickness. Thirty-two subjects completed all test sessions (age=20.0±1.4 years; height=175.0±7.5 cm; baseline mass=79.2±12.6 kg). Of these 32 subjects, six had been diagnosed with ADHD. Analyses were run with and without these subjects revealing no significant differences. Five of the thirty-two subjects completed the same bike workout in place of regular practice for testing, due to inability to complete practice either due to skin infections or injury. A *priori* power analysis revealed that 20 subjects would provide a power of .80 with the measures that were used in this study; however, this compared concussed and non-concussed subjects. Due to the nature of this study (i.e. studying non-injured athletes), 32 subjects were used as a more conservative estimate.

Research Design

A repeated measures design was used to assess subjects on three separate occasions: a baseline session performed in September 2009, a second session prior to a wrestling practice in October 2009, and a third session following the same practice event.

Instrumentation

Sport Concussion Assessment Tool (SCAT2)

The SCAT2 (Appendix A) was used for this study because it is a concise and relevant clinical concussion evaluation tool that includes a Graded Symptoms Checklist symptom score, the Standardized Assessment of Concussion (SAC) to assess mental status, and the three firm surface conditions of the Balance Error Scoring System (BESS).

The Graded Symptom Checklist assesses 22 symptoms commonly associated with concussion. A 7-point Likert scale is used to rate each symptom as 0 for not present, or 1 for mild and 6 being the most severe. The Graded Symptom Checklist, has been found to be a practical measure for monitoring concussive symptoms (Maroon, et al., 2000; McCrory, et al., 2000)

The SAC measures orientation, immediate memory, concentration, and delayed recall, which are neuropsychological areas thought to be affected by concussion. On the SCAT2, alternate word lists are provided for the immediate memory and delayed recall sections to limit learning effects. The SAC has been found to be sensitive to the immediate neuropsychological deficits of concussion and a reliable, valid clinical measure (Barr & McCrea, 2001; McCrea, 2001; McCrea, et al., 1998)

The three firm-surfaced stances of the BESS are also included in the SCAT2. These conditions include the double leg, single leg, and tandem stances performed on a firm surface. For the single leg stance, the non-dominant foot is stood on and for the tandem stance, the non-dominant foot is positioned behind the dominant foot. Foot dominance is determined by which leg would be used to kick a ball for distance. Athletes do each trial for 20- seconds with their eyes closed. For the sake of this study, the three foam surfaced-stances of the BESS were also performed aside from the SCAT2 analysis (Appendix B). The double leg, single leg, and tandem stances were performed as described above, but on the foam surface. The order of stance performance was as follows: double leg stance, single leg stance, and tandem stance. All firm surface conditions were performed first for the SCAT2. Following completion of the full SCAT2 test battery, the three foam surface-stances of the BESS were then performed. Each 20-second trial is scored by counting the number of errors or deviations from proper stance performed by the athlete. There are six main errors that are being evaluated. These include lifting your hands off the iliac crests, opening your eyes, taking a step, stumbling, or falling, moving your hips into greater than 30 degrees of abduction, lifting your forefoot or rearfoot off the surface, and remaining out of test position for more than five seconds. We observed high intratester reliability using a subset of 20 baseline BESS videos re-evaluated after the completion of the study ($ICC_{3,1}=0.95$; $SEM=1.22$).

The three firm and three foam surfaces of the BESS has been found to correlate with other laboratory measures of balance (Guskiewicz, et al., 2001; Riemann & Guskiewicz, 2000; Riemann, et al., 1999).

The SCAT2 also includes a physical signs section to assess if balance problems or unresponsiveness are present and a Glasgow Coma Scale, which assesses eye, verbal, and motor

responses immediately following injury. A coordination assessment is also included and looks at upper limb coordination through touching a finger-to-nose task.

Automated Neuropsychological Assessment Metrics (ANAM)

In addition to the SCAT2, a subtest of the Automated Neuropsychological Assessment Metrics (ANAM), the Simple Reaction Time (SRT), was used. Subjects completed this subtest on the computer and were asked to click a computer mouse as quickly as possible following a visual stimulus being presented (Bleiberg, et al., 2004). The ANAM, and particularly the SRT subtest, have been found to be valid and reliable measures (Bleiberg, et al., 2004; Cernich, Reeves, Sun, & Bleiberg, 2007).

Refractometer

Refractometry is a method used to measure the specific gravity of urine. Refractometers are small, hand held devices and because of this, are portable and easy to use, making hydration assessments in athletes more feasible. For this study, the same urine collection protocol was followed for all subjects. Subjects were provided with a sterile plastic specimen cup. Subjects were asked to begin urination into the toilet and midway, begin urine collection in the cup. Once urine was collected, the digital refractometer was calibrated by inserting the tip of the refractometer into distilled water. The refractometer should read 1.000. If it did not read 1.000, the tip of the refractometer was re-wiped and recalibrated. Following calibration, the refractometer was inserted into the specimen so that the tip was not touching the bottom of the specimen cup. The urine specimen was then disposed of down a drain. After each urine test, the refractometer was cleaned with a damp, soapy cloth, and wiped dry, making sure no residue was

left. Recalibration was performed at the beginning of each testing day, but not in-between each urine sample.

The National Athletic Trainer's Association (NATA) states that minimal dehydration is the loss of 1-3% total body mass and this is equivalent to a urine specific gravity between 1.010 and 1.020. The NATA states that significant dehydration is the loss of 3-5% of total body weight, which is equivalent to a urine specific gravity of 1.021-1.030 and that severe dehydration is the loss of 5% or more of total body weight, which is equivalent to a urine specific gravity greater than 1.030 (Casa, 2000). Specific gravity measures via refractometers have been found to be reliable and valid measures of hydration status when compared to osmolality and urine color (Armstrong, et al., 1994; Armstrong, et al., 1998). A reliability study was performed and an $ICC_{3,1}$ of 0.996 and an SEM of 0.000564 of the digital probe refractometer (Misco Products Design, Cleveland, OH) was found. Using a separate group of urine samples, we assessed the reliability of urine specific gravity measures for samples at a number of time intervals: immediately after collection, 1 hour post-sample and 6 hours post-sample. This was performed in order to evaluate whether the urine specific gravity readings would fluctuate as a result of time delays between collection of the sample and measurement of the sample urine specific gravity during the study. We observed an $ICC_{3,k}$ of 0.9995 (SEM = .000691), ensuring very high reliability in that any reading of the urine sample within 6 hours of its collection would be consistent with an immediate reading or a reading at any time interval in between.

Procedures

Recruitment

Before recruitment of subjects began, the Principal Investigator contacted the coaches and athletic administrators at UNC-CH to ask for permission to work with their team. Recruitment of subjects consisted of talking with the wrestlers before a practice to inform them about the study and ask for their participation in this study. Subjects had the freedom to withdraw from the study at any time. Given our target population, we were challenged to ensure equal access to participants among women. The only way to capture the data and answer the proposed research questions was to recruit subjects from a pre-selected team, and this team did not include women at the time. Note that we recruited players from a particular team and that we did *not* recruit a team that would require players to participate. Subjects eligible and willing to participate were asked to report to baseline testing.

Baseline

Subjects reported to the Sports Medicine Research Laboratory located in Fetzer Gymnasium in early-September. Subjects were formally introduced to the experiment at this time. Subjects were asked to read and sign a consent form approved by the University of North Carolina at Chapel Hill Institutional Review Board. Subjects reported for baseline testing having consumed at least 250mL of water the morning of the study to ensure hydration (Popowski, et al., 2001).

Subjects were weighed while wearing paper shorts, which were used every time weight was measured. Subjects were also asked what weight class they anticipated wrestling at this competition season. A urine sample was collected and specific gravity was measured with a

digital probe refractometer (Misco Products Design, Cleveland, OH). The same protocol was followed for all urine collections in this study and was described earlier. All subjects in this study were hydrated during baseline testing and did not have to report 24 hours later for testing. Following urine collection, subjects were then administered the SCAT2 with the addition of the BESS foam-surfaced stances. The participants were also asked to complete the Simple Reaction Test (SRT) module included in the Automated Neuropsychological Assessment Metric (ANAM). All trials of the SCAT2 and BESS were videotaped and errors were graded at a later time. An ICC_{3,1} was performed regarding BESS evaluations and a high intratester reliability was found (ICC_{3,1}=0.95095; SEM=1.224). All foam balance trials were performed on a medium-density foam surface 41.6 x 50.8 x 6.3 cm (Balance Pad; Alcan Airex AG, Sins, Switzerland). The number of hours of sleep they received the night before baseline testing was also collected.

Testing order throughout this study was as follows: subjects reported and provided a urine sample and were weighed, in no specific order. Following, subjects were either administered the SRT, followed by the SCAT2 and BESS foam-surfaced stances, or the SRT followed the SCAT2 and BESS. It is important to note, however, that the SCAT2 was always immediately followed by the BESS foam-surfaced stances. If for some reason subjects could not provide a urine sample prior to test administration, their urine sample was collected following clinical test administration.

Pre-practice

Subjects were randomly assigned into two groups of 16 subjects without replacement. One group was tested on a Monday before wrestling practice. The other group went through an identical testing session on a different Monday before wrestling practice. This was just to

account for large subject size and inability to test all 32 subjects on a single day. Within each Monday test group, there were two subgroups. One group consisted of the lighter weight classes and one group consisted of the heavier weight classes. Both groups practiced for the same amount of time and were put through the same physical workout under the same environmental conditions. This was just to account for testing 16 subjects in one day and ensure that all subjects were tested within the proposed time frame.

A few days before the subjects' test session, the subjects were provided several documents that they were asked to refer to at different times during the study. One was a subject safety guideline sheet (Appendix C) which outlines symptoms to be aware of during participation in the study and instructions on how to contact the principal investigator if any symptoms were present. Subjects were also given a log sheet to track food/fluid intake and exercise activity leading up to pre-practice assessments (Appendix D), as well as a food measurement guide (Appendix E). This guide was to help subjects make estimates regarding serving sizes by using commonly found household items.

The temperature in the wrestling room was measured at half hour intervals during practice sessions. Depending on what the temperature was in the room during the first day of testing, necessary steps were taken to ensure similar room temperature on the ensuing test day for the second test group. The same practice outline was also followed to ensure environmental and physical exertion factors were the same for all subjects. The night before testing, subjects were instructed to treat the evening and day leading up to practice as if they had to weigh in for competition the next day (Tuesday). Subjects were instructed to chart any fluid/food intake and exercise activity on a log sheet starting at 7pm the night prior and leading up to practice. Subjects were also asked to keep track of the number of hours of sleep they got that night.

Subjects reported for testing 1 hour prior to practice and were weighed in paper shorts, provided a urine sample for specific gravity measures, and were administered the SCAT2, the BESS, and the SRT.

During Practice

We did not force the athletes to restrict fluids, but were measuring the effects of the fluid restriction practices inherent to the sport. It was expected that the wrestlers would tend to further dehydrate themselves through exercise in warm environments and wearing cotton sweat suits during practice. Subjects were instructed to freely consume water or Gatorade as they would if they were weighing in for competition the next day. This was allowed to simulate a real practice for the subjects. Though they were allowed to freely consume fluids, it was anticipated they would remain dehydrated following practice due to the fact that wrestlers can lose several pounds in a practice. Subjects were also allowed to wear whatever practice clothing they wished (i.e. cotton sweat suits, etc). This again, was to simulate a real practice session and the practice habits of collegiate wrestlers.

Post Practice

Following practice, subjects were not allowed to consume fluids or ingest foods until they had been tested. Subjects were instructed to shower and dry off all water before testing. Weight and urine collection were gathered once the subjects had showered. The subjects were weighed in paper shorts and specific gravity was measured with a refractometer. The SCAT2, three foam-surfaced BESS conditions, and SRT administration were postponed 20 minutes immediately following practice to offset the effects of initial fatigue (Fox, Mihalik, Blackburn,

Battaglini, & Guskiewicz, 2008; Wilkins, Valovich McLeod, Perrin, & Gansneder, 2004). Subjects were also administered a weight-cutting tactics sheet on which they were asked to identify all of the weight-cutting tactics which they practiced throughout the duration of this study. This form was placed in a sealed manila envelope along with the subject's fluid/food/exercise log sheet. This information was viewed briefly by a co-investigator to assess completion (but not analyzed until the end of all data collection was completed). The principal investigator was blinded to this information until the termination of data collection. This information was not shared with anyone outside the immediate research team.

During preseason baseline testing, flat weight was determined by what subjects stated would be their anticipated competition weight class. This was to give subjects a target and goal to help encourage compliance during the study period. To further encourage compliance, subjects were told to be within 5 pounds of flat weight/competition weight prior to the next day's practice (Tuesday). Subjects were only administered concussion tests during pre- and post-practice on Monday and not during the Tuesday weigh-in session.

Data Reduction

With the graded symptom checklist, the 7-point Likert scale was used to rate each symptom as 0 for not present, or 1 for mild and 6 being the most severe. The total number of symptoms was recorded out of 22. All symptoms scores were added together for a total symptom severity score with a maximum score possibility of 132. For the SAC, one point was awarded for each word correctly recited for a total of 15 points possible for immediate memory and five points for delayed recall. For the orientation section, one point was awarded for each correct answer provided out of five points. For the concentration section, athletes were asked to

recite a string of numbers and the months of the year backwards. There were five total points available in this section. The sum of the different sections scores was calculated out of 30 total possible points. For the balance assessment of the SCAT2, the sum of the total number of errors for each firm surface stance was calculated. The total balance examination score was calculated by subtracting the total errors score from 30. For the BESS, errors were counted for each condition and total error score was the sum of these different conditions.

With the physical signs score, one point was given for a negative response to the questions and a total of two points was possible. For the Glasgow Coma Scale, there were 15 total points possible when looking at subjects' best eye response, best verbal response, and best motor response. For the coordination score, 1 point was awarded if subjects could perform a finger-to-nose task five times with each task being completed in less than four seconds.

SCAT2 total score was out of 100 possible points and includes the SAC total score, symptom score, physical signs score, glasgow coma scale score, balance examination total score, and coordination score. The lower a person's score, the worse their performance on the SCAT2. As with other concussion measures, it is important to have healthy baseline testing so it can be compared to their injured scores.

The ANAM calculates throughput scores, which represents a combination of the subject's accuracy and speed of performance for the specific subtest. A throughput score was calculated for the SRT, with the greater the score indicating the better the performance on the test.

Furthermore, percent body mass change was calculated for each subject. Percent body mass change from baseline to pre-practice was calculated by the following: $[(\text{baseline body mass} - \text{pre-practice body mass}) / \text{baseline body mass}] \times 100$. Percent body mass change was also calculated for baseline to post-practice and pre-practice to post-practice using the same equation.

Change in urine specific gravity was also calculated between test sessions. Change between baseline and pre-practice urine specific gravity was calculated by the following: $[(\text{baseline urine} - \text{pre-practice urine}) / \text{baseline urine}]$. The same formula was also used to calculate changes between baseline and post-practice, and pre-practice and post-practice.

Data Analyses

Data were analyzed using SPSS statistical software (version 16.0; SPSS Inc, Chicago, IL). An alpha level of 0.05 was set a priori for each respective test. A totally within-subjects repeated measures analysis of variance (ANOVA) was run to compare baseline, pre and post practice total SCAT2 scores, total SAC scores, total BESS scores, total number of symptoms endorsed, and total symptom severity score. If the omnibus model was significant, Tukey post hoc testing was completed to ascertain whether any test time differences were significantly different from the others.

In order to further explore the possible interaction between weight class and our clinical measures, we performed a secondary set of analyses. These analyses required the categorization of our ten weight classes into three main groups. This classification was driven primarily by identifying those weight classes across which athletes commonly wrestle each other during practice. The ten weight classes were divided into three main groups: lightweight, middleweight, and heavyweight. Lightweight wrestlers consisted of those whose competition flat weight was 125, 133, or 141 pound (N=10). Middleweight wrestlers consisted of those competing in the 149, 157, and 165 pound weight classes (N = 12). Heavyweight wrestlers consisted of 174, 184, 197, and Heavyweight classes (N = 10). Separate mixed model ANOVAs were employed to study the interaction between weight class and each clinical measure of concussion we assessed

in our study. If the omnibus model was significant, Tukey post hoc testing was completed to ascertain where individual differences were observed.

DATA SUMMARY TABLE

QUESTION	DESCRIPTION	DATA SOURCE	COMPARISON	METHODS
1	What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on the SCAT2 total score?	IV: Weight-cutting tactics DV: SCAT2 total score	Baseline, pre practice, and post practice comparison of SCAT2 total scores	1x3 totally within subjects repeated measures ANOVA
2	What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on the SAC total score?	IV: Weight-cutting tactics DV: SAC total score	Baseline, pre practice, and post practice comparison of SAC total scores	1x3 totally within subjects repeated measures ANOVA
3	What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on the BESS total score?	IV: Weight-cutting tactics DV: BESS total score	Baseline, pre practice, and post practice comparison of BESS total scores	1x3 totally within subjects repeated measures ANOVA
4	What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on the total severity score and total number of symptoms endorsed?	IV: Weight-cutting tactics DV: Total symptom score & total severity score	Baseline, pre practice, and post practice comparison of GSC total scores	1x3 totally within subjects repeated measures ANOVA
5	What are the effects of weight-cutting tactics in Division 1 collegiate wrestlers on the SRT throughput score?	IV: Weight-cutting tactics DV: SRT throughput score	Baseline, pre practice, and post practice comparison of SRT throughput scores	1x3 totally within subjects repeated measures ANOVA

*Supplemental mixed model ANOVAs were employed across research questions 1-5 with new weight class as the between subjects factor.

CHAPTER IV

RESULTS

The purpose of this study was to examine the effects of weight-cutting tactics by Division I wrestlers on clinical concussion measures. This was accomplished by studying wrestlers during baseline, prior to wrestling practice, and again following wrestling practice. Five commonly used clinical concussion measures were administered to subjects at each time. Subject demographic information (**Table 1**), a weight class breakdown of subjects and urine specific gravity across test session for each weight class (**Table 2**), and number of subjects that practiced varying weight-cutting tactics (**Table 3**) are provided. Also provided is the ambient temperature in the wrestling room across time (**Table 4**) and percent change in body mass, change in urine specific gravity, and hours of sleep across time (**Table 5**).

Sport Concussion Assessment Tool 2

A repeated measures ANOVA was calculated comparing subjects' SCAT2 total scores across three different test sessions: baseline, pre-practice, and post-practice. A significant effect of time was found ($F_{2,62} = 13.91, P < 0.001$). Scores decreased from baseline ($m = 93.06, sd = 3.88$) to pre- practice ($m = 90.16, sd = 5.01; P = 0.002$) and baseline to post-practice ($m = 87.94, sd = 6.39; P < 0.001$) (**Table 6**).

Balance Error Scoring System

A repeated measures ANOVA was calculated comparing subjects' BESS total scores across three different test sessions: baseline, pre-practice, and post-practice. A significant effect of time was found ($F_{2,62} = 5.69$, $P = 0.005$). Scores increased from baseline ($m = 15.72$, $sd = 5.09$) to post-practice ($m = 18.81$, $sd = 6.68$; $P = 0.015$) (**Table 6**).

Graded Symptom Checklist Severity and Number of Symptoms Endorsed

A repeated measures ANOVA was calculated comparing subjects' GSC total severity scores at three test sessions: baseline, pre-practice, and post-practice. A significant time effect was found ($F_{2,62} = 16.542$, $P < 0.001$). Tukey post hoc analyses confirmed scores increased from baseline ($m = 1.03$, $sd = 2.91$) to pre-practice ($m = 5.41$, $sd = 9.78$; $P = 0.011$), and from baseline to post-practice ($m = 12.69$, $sd = 13.80$; $P < 0.001$) (**Table 6**). Further, GSC severity scores were greater at post-practice when compared to pre-practice ($P = 0.003$).

A repeated measures ANOVA was also calculated comparing subjects' GSC total number of symptoms endorsed at the same three time sessions. A significant effect was found ($F_{2,62} = 18.24$, $P < 0.001$). Tukey post hoc analyses found scores increased from baseline ($m = .44$, $sd = 1.24$) to pre-practice ($m = 2.44$, $sd = 3.69$; $P = 0.036$), and from baseline to post-practice ($m = 5.03$, $sd = 5.23$; $P < 0.001$) (**Table 6**). Further, GSC total number of symptoms endorsed was greater at post-practice when compared to pre-practice ($P = 0.003$).

Standardized Assessment of Concussion

A repeated measures ANOVA was calculated comparing subjects' SAC total scores across three different test sessions: baseline, pre-practice, and post-practice. No significant effect was observed ($F_{2,62} = 2.316$, $P = 0.107$). No significant difference existed among baseline ($m = 27.72$, $sd = 1.91$), pre-practice ($m = 27.06$, $sd = 1.34$), and post-practice ($m = 27.62$, $sd = 2.00$) measures (**Table 6**).

Simple Reaction Time

A repeated measures ANOVA was calculated comparing subjects' SRT throughput scores across three different test sessions: baseline, pre-practice, and post-practice. No significant effect was found ($F_{2,62} = 2.081$, $P = 0.133$). No significant difference existed between baseline ($m = 254.92$, $sd = 18.11$), pre-practice ($m = 259.37$, $sd = 18.12$), and post-practice ($m = 262.82$, $sd = 22.82$) means (**Table 6**).

Supplemental Analyses by Weight Class

We sought to better understand the potential effects that differing weight classes may have on the dependent measures we studied across test sessions. As such, mixed model ANOVAs with test session as the within-subject effect and weight class (lightweight, middleweight, and heavyweight) as the between-subject effect. Regardless of the dependent measure we analyzed, the effect of weight class on these measures was not statistically significant ($P > 0.05$ for all analyses).

Table 1. Age, Height, and Mass Means and Standard Deviations

	Mean	SD
Age (years)	20.0	1.4
Height (cm)	175.0	7.5
Baseline Mass (kg)	79.2	12.6

Table 2. Number of Subjects and Urine Specific Gravity Means Across Test Sessions in Each Weight Class

Weight Class (lbs)	Number of Subjects	Baseline Urine	Pre-Practice Urine	Post-Practice Urine
125	2	1.006	1.028	1.028
133	5	1.007	1.027	1.024
141	3	1.006	1.027	1.033
149	4	1.009	1.022	1.024
157	6	1.007	1.027	1.029
165	2	1.005	1.031	1.028
174	2	1.005	1.020	1.023
184	3	1.003	1.023	1.021
197	2	1.002	1.019	1.020
Heavyweight(≤ 285)	3	1.010	1.020	1.016
Total	32	Mean: 1.006 SD: 0.006	Mean: 1.025 SD: 0.008	Mean: 1.025 SD: 0.008

Table 3. Number of Subjects that Participated in Varying Weight-Cutting Tactics

	Yes	No
Food Restriction	27	5 †
Fluid Restriction	27	5 ‡
Hours Excessive Exercise *	23	9 §
Mean: 1.6 hours		
Sweats	26	6 □

* Excessive exercise is defined as exercise outside of team practice

† Weight class of individuals that did not participate in food restriction: 1-157 lbs, 1-197 lbs, 3 Heavyweights

‡ Weight class of individuals that did not participate in fluid restriction: 1-174 lbs, 1-197 lbs, 3 Heavyweights

§ Weight class of individuals that did not participate in excessive exercise: 1-141 lbs, 2-149 lbs, 2-165 lbs, 1-174 lbs, 1-184 lbs, 1-197 lbs, 1 Heavyweights

□ Weight class of individuals that did not participate in wearing sweats: 1-149 lbs, 1-174 lbs, 1-197 lbs, 3 Heavyweights

Table 4: Ambient Temperature (*F) Measures in the Wrestling Room During Testing

	Start of Practice (SOP)	½ Hr Post SOP	1 Hr Post SOP	1 ½ Hr Post SOP
Group 1, Session 1	83.6	85.1	84.7	84.2
Group 1, Session 2	83.4	83.0	82.7	81.0
Group 2, Session 1	82.3	81.8	83.4	83.4
Group 2, Session 2	83.7	83.3	83.4	83.5

Table 5. Means and Standard Deviations for Percent Change in Body Mass (kg), Urine Specific Gravity, and Hours of Sleep Across Time

	Means	SD
BL – Pre		
<i>Percent change body mass</i>	2.56	3.66
<i>Urine specific gravity</i>	-0.018	0.010
BL – Post		
<i>Percent change body mass</i>	5.03	3.42
<i>Urine specific gravity</i>	-0.018	0.008
Pre – Post		
<i>Percent change body mass</i>	2.52	0.84
<i>Urine specific gravity</i>	-0.0002	0.007
Baseline hrs of sleep	8.12	1.93
Pre-practice hrs of sleep	8.08	1.65

Table 6. Outcome Means and Standard Deviations Across Time Session

	Baseline		Pre-Practice		Post - Practice		F value	P-value
	Mean	SD	Mean	SD	Mean	SD		
SCAT2	93.06	3.88	90.16	5.01	87.94	6.39	13.91	< 0.001*†‡
SAC	27.72	1.91	27.06	1.34	27.62	2.00	2.32	0.107
BESS	15.72	5.09	18.44	6.44	18.81	6.68	5.69	0.005†
GSC Severity	1.03	2.91	5.41	9.78	12.69	13.80	16.54	< 0.001*†‡
GSC Symptom	0.44	1.24	2.44	3.69	5.03	5.23	18.24	< 0.001*†‡
SRT Throughput	254.92	18.11	259.37	22.82	262.82	22.82	2.08	0.133

* Significant difference between pre-practice and baseline ($P < 0.05$)

† Significant difference between post-practice and baseline ($P < 0.05$)

‡ Significant difference between post-practice and pre-practice ($P < 0.05$)

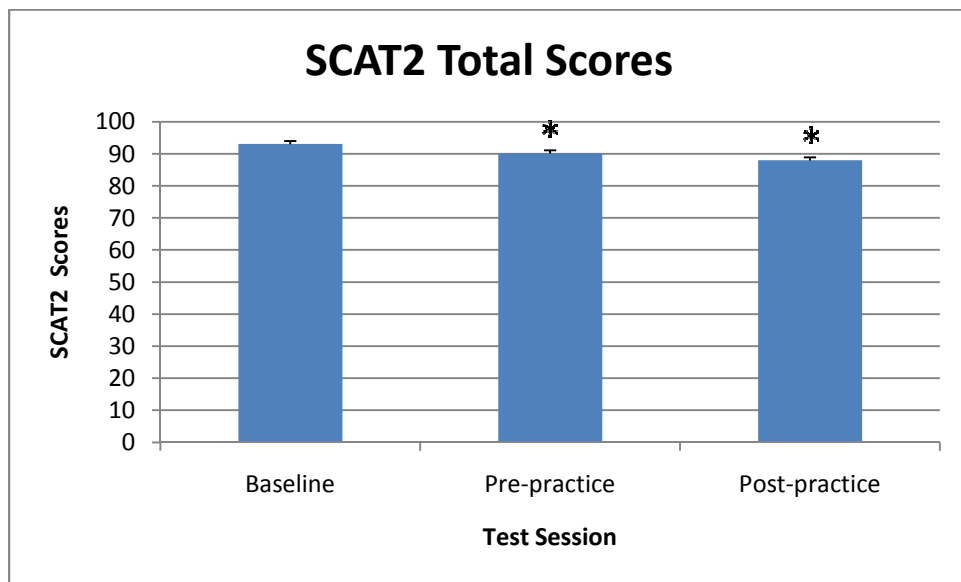


Figure 1. SCAT2 Scores

* Significant difference found between pre and post-practice when compared to baseline, respectively ($P = 0.002$, $P < 0.001$)

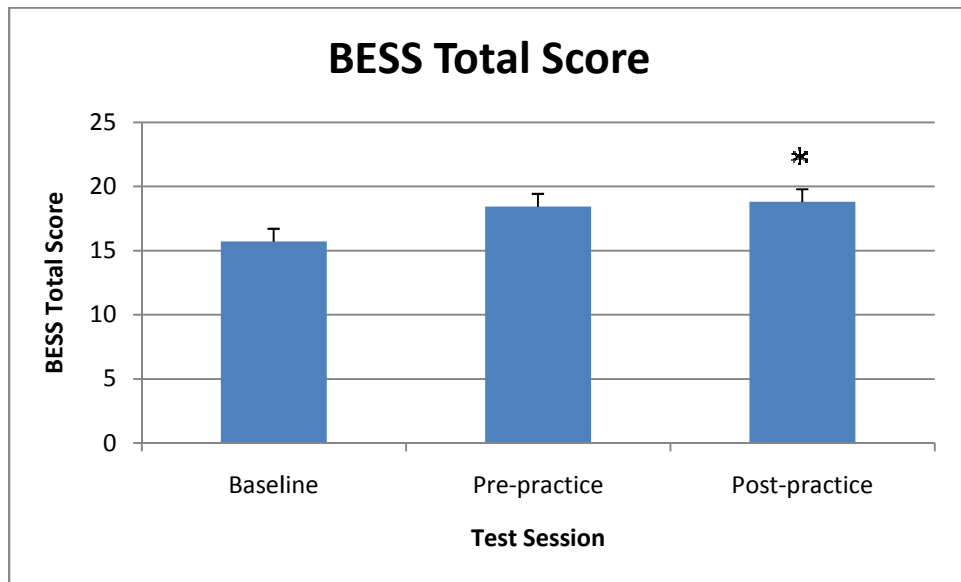


Figure 2. BESS Scores

* Significant difference found between post-practice and baseline ($P = 0.015$).

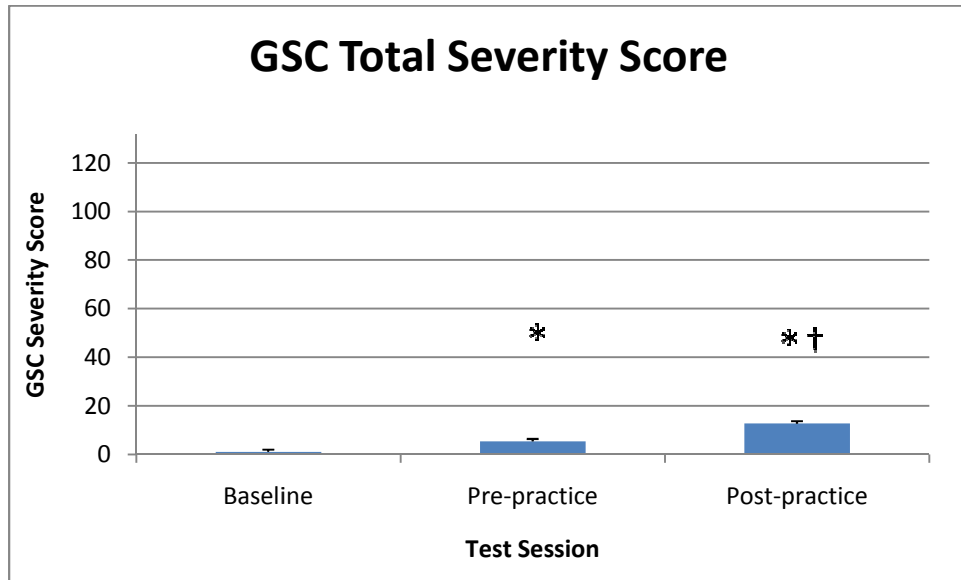


Figure 3. GSC Total Severity Scores

* Significant difference found between pre and post-practice when compared to baseline ($P = 0.036$, $P < 0.001$)

† Significant difference found between pre and post-practice ($P = 0.003$)

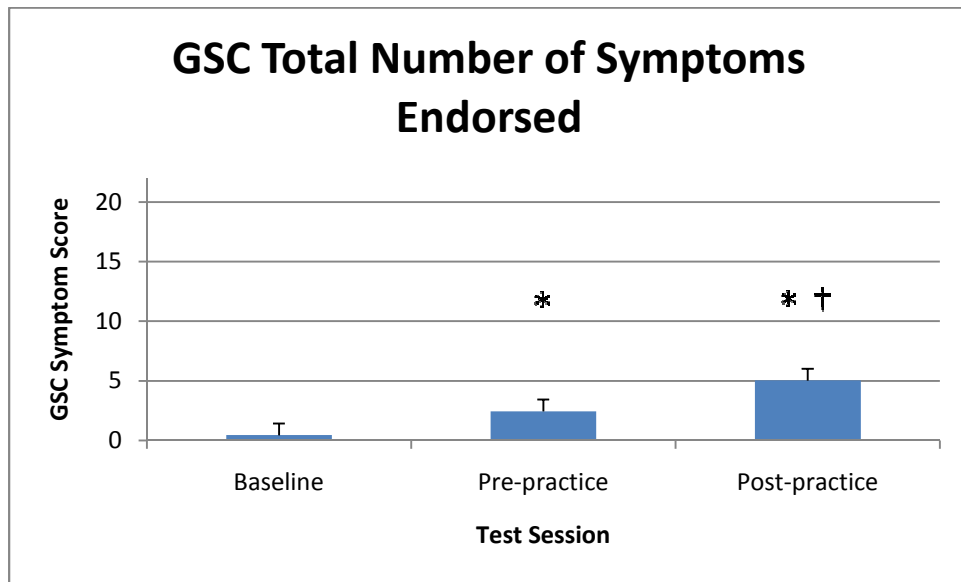


Figure 4. GSC Total Number of Symptoms Endorsed

* Significant difference found between pre and post-practice when compared to baseline ($P = 0.011$, $P < 0.001$)

† Significant difference found between pre and post-practice ($P = 0.003$)

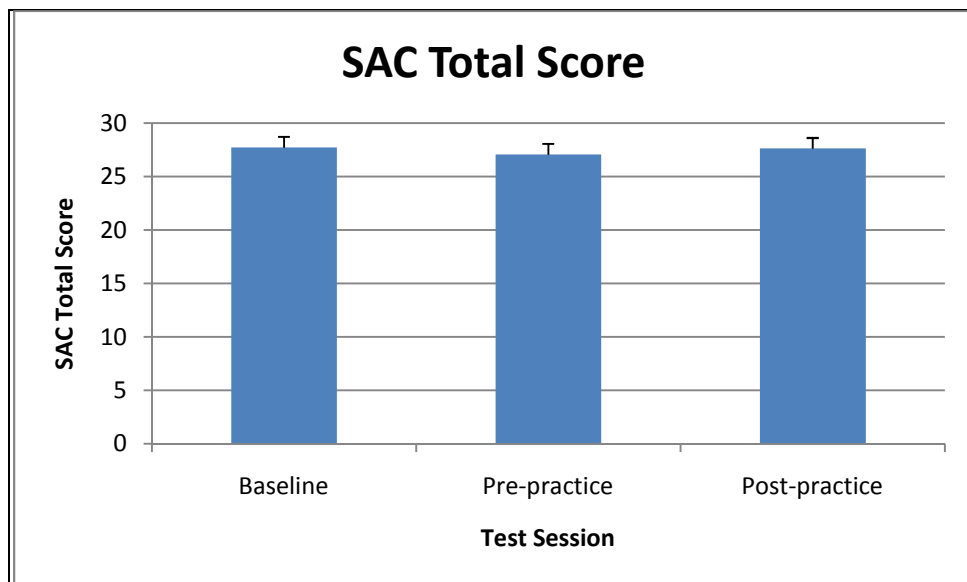


Figure 5. SAC Scores

CHAPTER V

DISCUSSION

To our knowledge, there is only one study that has looked at dehydration effects on concussion measures commonly employed by certified athletic trainers and other medical professionals, and our study is the first to investigate the effects of wrestling weight-cutting tactics on similar measures (Patel, et al., 2007). In studying the effects of weight-cutting tactics in Division I collegiate wrestlers on clinical measures of concussion, we found that it is important for wrestlers to be tested in a fully hydrated (euhydrated) state in order to ensure weight-cutting tactics are not influencing the outcome of the clinical measures. These findings further suggest that following injury, in the absence of an obvious neurological deterioration such as moving toward a semi-comatose state, adequate time should be allowed for the athlete to rehydrate and discontinue practice of weight-cutting tactics. This will improve clinicians' ability to differentiate between change in scores due to injury versus weight-cutting tactics.

Balance Error Scoring System

Our study included the foam conditions of the BESS, in addition to the firm stance conditions employed by the SCAT2 to analyze BESS total error score. The BESS score has been found to detect changes due to concussive injury and to be reliable when compared to measures obtained from more sensitive instrumentation including force platforms (Guskiewicz, 2001, 2003; Riemann, et al., 1999). Our study only observed a significant difference between baseline

and post- practice scores. We did not observe any differences between baseline and pre-practice measures, or between pre-practice and post-practice measures.

In our study, there were at least five to six weeks between the baseline and pre-practice evaluations to offset for any potential learning effects. Our subjects also waited 20 minutes following completion of practice before they were administered the BESS to offset initial fatigue, which has been found to affect BESS outcomes in previous work (Fox, et al., 2008; Wilkins, et al., 2004). While there were no significant differences observed between pre-practice and post-practice scores, the pre-practice score is not clinically relevant in that clinicians would never test a wrestler before practice or a competition unless an injury had occurred.

As stated previously, no significant differences were found between baseline and pre-practice, demonstrating that the effect of weight-cutting tactics alone (without an accompanying practice) did not cause significant changes. A significant difference was found, however, between baseline and post-practice, demonstrating the effects of weight-cutting tactics accompanied by practice. As stated previously, no statistically significant differences were observed between baseline and pre-practice. Given the mean difference between the pre- and post-practice BESS scores (0.37 errors), it could be argued that the effect of weight-cutting tactics alone (without an accompanying practice) may also cause observable impairments in balance performance. These findings between baseline and post-practice mimic a possible dual competition in which a wrestler is cutting weight to compete, and then sustains a potential concussion during the match. This could also relate to a wrestler who sustains an injury during practice while also trying to make weight for a competition to be held a day or two later. This supports the notion that clinicians need to be mindful of potential influences that weight-cutting tactics may have on affecting clinical measures commonly used to evaluate concussion.

While we support a conservative approach to managing concussion, we acknowledge that deficits on clinical measures of concussion may not always represent a concussion. Until a concussion diagnosis can be adequately ruled out, we support the removal from competition of athletes suspected of suffering from head trauma. It is clinically relevant to ensure that all concussion test measures are performed when the athlete is properly hydrated. This will help ensure weight-cutting tactics are not influencing these measures. These findings are also interesting in that perhaps wrestlers need more than 20 minutes following the completion of intense exercise while in a dehydrated state to recover to baseline values in the absence of concussive injury. These findings would be supported by those reported by Wilkins et al (Wilkins, et al., 2004), and be partially supported by Fox et al. (Fox, et al., 2008).

There were no effects of a fluid restriction and active dehydration task on BESS performance in previously published work (Patel et al., 2007). There are distinct differences in this study when compared to ours that could explain possible discrepancies. Patel and colleagues looked at 24 healthy male subjects defined as physically active by completing 45 minutes of aerobic activity three to four times per week. These subjects were dehydrated through fluid restriction and restriction of foods high in fluid content for 15 hours leading up to a 45- minute bicycle ergometer exercise task. In contrast, our study included 32 Division I collegiate wrestlers who practice two to three hours per day for as many as six days per week. Our subjects also completed a practice that is more closely related to actual training when compared to a bicycle exercise task. They could also have been practicing weight-cutting tactics for up to 36 hours. Our mean percent change in body mass between baseline and post-practice was also close to 5%, whereas in their study, individuals were only dehydrated between 1.71% and 4.15%.

Graded Symptom Checklist Severity Score and Total Number of Symptoms Endorsed

The GSC total severity score was collected on the SCAT2 form, however, it was not factored into the SCAT2 total score. For this reason, we decided to analyze GSC severity score separately and found a significant difference between baseline and pre-practice, baseline and post-practice, and pre-practice and post-practice measures. This shows that as the subjects were cutting weight without participating in practice, they reported significantly different symptoms compared to baseline. This was not surprising as subjects had already been practicing weight-cutting tactics for periods ranging from 8 to 10 hours by the time they reported for pre-practice testing. As a result, many were feeling the effects of these tactics, including fatigue and dizziness, among others. As a greater difference was observed in scores post-practice, our data would suggest that participating in practice further intensifies the severity of symptoms reported. An interesting finding was that a significant difference was seen between pre-practice and post-practice measures. It can then be inferred that practice alone caused a significant change in scores when compared to pre-practice values. As with most studies that look at GSC values, we observed values with high standard deviations, but this again supports the practice of baseline testing athletes so a comparison is available. We observed that weight-cutting tactics in wrestlers cause an increase in GSC symptom severity score.

We also looked at the GSC total number of symptoms endorsed across the three time sessions. This value was collected on the SCAT2 form and is factored into the SCAT2 total score. We observed findings similar to the GSC total severity score. A difference was observed between baseline and pre-practice, baseline and post-practice, as well as pre-practice and post-practice measures. The difference between baseline and pre-practice again was not surprising. Subjects were practicing weight-cutting tactics for several hours, which the investigator would

expect to see an increase in total number of symptoms endorsed. It was further expected that once subjects completed an intense practice, the number of symptoms endorsed further increased, causing for a significant difference when compared to baseline and pre-practice.

Our findings are in agreement with previously reported findings. In the work by Patel et al, a higher total symptom severity score and total number of symptoms reported were found for the dehydrated condition when compared to a euhydrated condition. Subjects also reported higher ratings for balance difficulties, dizziness, feeling slowed down, and feeling in a fog following the dehydrated condition. This again was following a 45-minute bicycle ergometer exercise task and fluid and food high in fluid content restriction for 15 hours. We too found a higher severity score and total number of symptoms reported across time sessions, though we did not analyze each GSC variable.

Another study looked at the effects of fluid restriction and euhydration conditions on subjective feelings. An exercises task was not part of their protocol and the subjective feelings were not assessed with the GSC. The fluid and foods high in fluid content restriction was performed for 37 hours. The euhydration condition, subjects were allowed to ingest fluids freely. These authors observed an increase in perception of thirst, feelings of dry-mouth, headache, tiredness, and difficulty concentrating (Shirreffs, et al., 2004). In this study, only 15 subjects were used and only dehydrated approximately 1-3% body mass. Though this study had approximately half as many subjects as ours and did not require an exercise task or food restriction, changes were still seen in variables that are included on the GSC. In both of these studies, though not sport specific to wrestling and different protocols than ours were used, differences were still seen in subjective variable reporting and severity.

Standardized Assessment Concussion and Simple Reaction Time

Our study shows that weight-cutting tactics do not influence the mental status or simple reaction time of Division I collegiate wrestlers. We observed no significance for either neuropsychological test, the SAC and SRT, across time sessions. This shows that weight-cutting tactics appear to have no affect on either of these concussion measures between baseline and pre-practice, baseline and post-practice, and pre-practice and post-practice. This provides clinicians with an important finding that following injury, when scores for both the SAC and SRT are observed compared to baseline values, we can be confident that it is due to injury and not weight-cutting tactics.

Our findings of no significance on the SAC and the SRT are supported by those reported by Patel et al (Patel, et al., 2007). They too found no significance between a euhydrated and dehydrated condition for the SAC and ANAM. While our study only looked at one subtest of the ANAM, Patel and his colleagues looked at a total ANAM composite score. This study also looked at the varying subtests of the ANAM and found that subjects had a worse performance on the Matching-to-Sample module and Sleep Scale Test when dehydrated, but no difference was observed for Simple Reaction Time (SRT). We decided to include the ANAM as a more sensitive testing measure and more specifically, the SRT. The SRT has been shown to detect deterioration in injured subjects between baseline and the first testing interval, where no significant difference was seen in other subtests (Bleiberg, et al., 2004).

In contrast, one study looked at baseline, rapid weight loss, and rehydration scores in 14 male wrestlers compared to 15 controls and found that cognitive function was impaired following rapid weight loss (Choma, et al., 1998). The digit span and story recall tests were found to be significant while the letter cancellation, digit symbol, and trail making A and B test

were not found to be significant. Following rehydration, test scores reached near baseline. This leads the author to believe that psychological and cognitive effects associated with rapid weight loss are reversible once wrestlers are rehydrated(Choma, et al., 1998). Some possible reasons for the discrepancies when compared to our study are that Choma and colleagues required a minimum of 5% body weight loss before rapid weight loss data was collected and had an average of 6.2% body weight lost. In contrast, our subjects had a mean body mass value between baseline and post-practice of around 5%. Though our mean value is close to 5%, we did not want to put a restriction on weight loss as that would take away from the clinical relevancy of our study. With their study, even with a requirement for all subjects to lose a minimum of 5% body weight, several of the paper and pencil tests were still not significant. This again supports the trend that neuropsychological tests do not seem to be drastically affected by dehydration and weight-cutting tactics. This study further supports our recommendation that wrestlers should be rehydrated and not practicing weight-cutting tactics when evaluated for concussion.

Sport Concussion Assessment Tool 2

The SCAT2 is a new clinical concussion tool developed as a result of the Third International Conference on Concussion in Sport (McCrory, et al., 2009). To date, there is no research available looking at how dehydration may affect the outcomes measured by the SCAT2. Since the SCAT2 was designed to include components of other commonly used measures of concussion including the SAC, the GSC and the BESS, we believe it will experience widespread use and be worthy of investigation in the context of this study.

Our study found that the SCAT2 was significant when comparing pre-practice and post-practice values to baseline. There are a few reasons this could have occurred. Our study

observed one component of the SCAT2, the SAC which accounts for 30% of the total score, was not significant across time. We also observed that the BESS total score (firm and foam surface conditions) was only significant across one time session, baseline to post-practice. This shows that the significance in SCAT2 total score may be primarily due to a significant change found between the GSC total symptom score (total number of symptoms endorsed) across time. The GSC symptom score accounts for 22% of the overall SCAT2 score and could influence a large change in score when other areas (SAC) were not found to be significant. As stated previously, we looked at GSC total number of symptoms endorsed and found that it was significant across each time session (baseline to pre-practice, baseline to post-practice, and pre to post-practice). Our data shows that the difference in SCAT2 total score was greatly affected by the significance findings of the GSC total number of symptoms endorsed across time sessions.

There are also other areas that factor into the total SCAT2 score, but were not analyzed independently for this study because everyone received full scores. First, the Glasgow Coma Scale was not analyzed since all of our subjects received a maximum score of 15. Second, since this study did not investigate concussions, all subjects attained a high score of two on the Physical Signs score. Finally, a Coordination Examination was analyzed and factored into the total SCAT2 score. Though our subjects were practicing weight-cutting tactics, all were able to perform the task required for the Coordination Examination without fault and received the one point possible for that section. This again, supports that a majority of the difference found between the SCAT2 total score between baseline and pre-practice and baseline and post-practice was due to the GSC total symptom score. The SCAT2 is comprised of a clinical concussion test battery. While the SCAT2 does provide a total score, our findings show that it is also important

to look at the individual components because a change in total score may be greatly affected by one component when compared to baseline scores.

Prior work in this area found no significant differences in the SAC total score or the BESS total error score compared between euhydrated and dehydrated conditions without subjects (Patel, et al., 2007). The GSC was found to be significant in that there was higher total symptom severity, number of symptoms, and higher ratings of balance, dizziness, feeling slowed down, and feeling in a fog following a dehydration task (Patel, et al., 2007).

Weight-Cutting Tactics

Our subjects practiced weight-cutting tactics commonly employed by collegiate wrestlers. Such tactics as food restriction, fluid restriction, excessive exercises, and wearing sweats are accepted by the NCAA. While our subjects filled out a questionnaire regarding which weight-cutting tactics they practiced, there is a chance that our subjects used the sauna or wore vapor impermeable, which are banned by the NCAA. Our findings also show that there appears to be no effect of weight class on clinical concussion measures. This means that one of our predetermined weight class groupings (light weight, middle weight, and heavy weight) did not seem to influence outcome measures more than other weight classes.

Limitations

While our study yielded some significant clinical findings, it is not without limitations. We could not perform the study on actual competition days with the subjects at competition weight due to availability of subjects, however, we did try and simulate the weight-cutting tactics that

would be practiced leading up to a competition. Subjects weighed in on Tuesday, though no data was collected, and had to be within five pounds of flat weight. This was done to give the subjects a goal and reinforce compliance to the study. Retrospectively, it may have been beneficial to put subjects through the entire study test battery on Tuesday to provide a comparison of time points once subjects made their target weight. Future work, therefore, should study the lasting effects related to weight-cutting tactics in collegiate wrestlers.

Another possible limitation is that we did not outline specifics of what the subjects could eat or drink, which could have lead to some variability in our results. While this may be a perceived limitation, we feel that by allowing the athletes freedom in this regard we were better able to realistically capture the effects of individualized weight-cutting tactics employed by our sample. We also did not collect or analyze subject's previous history of concussion. While this would have been interesting to analyze, our study was a within-subject design; therefore, this did not directly affect our findings. Finally, specific gravity was used to assess hydration status because it is a cost-efficient clinical tool, especially in the sport of wrestling, though plasma osmolality has been found to better track changes in hydration status when compared to urine specific gravity and urine osmolality (Armstrong, et al., 1998; Oppliger, et al., 2005). While there were a few limitations to the study, we believe that our study yields valuable clinical implications regarding weight-cutting tactics in wrestlers on clinical concussion measures.

Further Research

While this study has provided clinicians with some great insight into the area, future research in other areas may continue to provide clinicians with valuable information. Performing a study with an equal number of subjects per weight class may be helpful to look at how weight-

cutting tactics affect concussion tools depending on weight class. Also, to analyze subjects over more sessions, perhaps a week leading up to competition, to see if there are changes among longer time frames may also provide clinicians with more insight.

While our study focused on Division I collegiate wrestlers, we submit that many wrestlers commonly begin practicing weight-cutting tactics at the high school level. In contrast to the 10 weight classes at the collegiate level, high school scholastic wrestling has 14 weight classes consisting of 103, 112, 119, 125, 130, 135, 140, 145, 152, 160, 171, 189, 215 pounds, and heavyweight, which is up to 275 pounds. An overall concussion rate of 0.18 per 1,000 athlete-exposures has been reported at the high school level (Gessel, Fields, Collins, Dick, & Comstock, 2007; Yard, et al., 2008). This is lower when compared to the overall collegiate level concussion rate of 0.42 per 1,000 athlete-exposures, but is still significantly higher than volleyball, boys' basketball, baseball, and softball high school rates (Gessel, et al., 2007). It is also important to note that high school wrestlers practice extreme weight-cutting tactics too. One study found that 33% of subjects competed during season below minimum wrestling weight. Minimum wrestling weight was defined as a body fat measurement of 5% or less (Wroble & Moxley, 1998). While our findings cannot be generalized to the high school population, further research at this level would provide more insight to the effects of weight-cutting tactics on concussion measures in this younger population.

Finally, it may be interesting to apply the theory behind this study to other sports and see if sports that do not purposefully dehydrate themselves like wrestling, see changes on clinical concussion measures.

Clinical Implications

The findings of this study support the practice of using a concussion test battery when determining the presence of concussion and return to play status. Our study shows that the mental status or simple reaction time of Division I collegiate wrestlers does not seem to be impaired after the practice of weight-cutting tactics, however that GSC severity and number of symptoms endorsed, SCAT2, and BESS can be affected. Our findings also support the common practice of baseline testing. The changes seen in GSC severity, SCAT2, and BESS show differences at pre or post-practice when compared to baseline. Baseline testing should always be done in order to have a measure of comparison. It is evident that the results of clinical testing in wrestlers who are cutting weight may be difficult to interpret. In the absence of an obvious deteriorating condition warranting prompt emergency medical care, we recommend evaluating athletes only after they have been properly rehydrated. We know that all subjects were hydrated for baseline testing, and were obviously dehydrated during pre-practice and post-practice (**Table 2**). This allows us to be confident that fluid restriction and dehydration do influence these clinical concussion measures, while other tactics could not be analyzed independently. Testing wrestlers in a euhydrated state can help clinicians feel more confident that potential changes in scores compared to baseline are due to injury versus weight-cutting tactics.

Wrestling is still a unique sport for clinicians in that at the college level, only a minute and thirty seconds is allotted for injury time during matches. This poses the question of what a clinician should do when a wrestler is injured during competition and the clinician only has a few minutes to assess and determine return to play status. The clinician will not have ample time to administer the entire SCAT2, particularly the BESS and SAC, in a hydrated state as we recommend for practice and post match evaluation. The clinician will rely greatly on the

subjective symptoms of the wrestler. Our findings would infer that the wrestler is going to have a greater number of symptoms endorsed and greater symptom severity if he has practiced weight-cutting tactics and is dehydrated even without the presence of injury. It is our recommendation that the clinician's be aware of these findings; however air on the side of caution when dealing with head injuries.

Conclusions

Our data suggest that weight-cutting tactics affect several sideline clinical measures of concussion commonly employed by certified athletic trainers. In general, our pre and post-practice measures of symptomatology and balance were worse compared to baseline measures. We recommend evaluating wrestlers once they have had a chance to rehydrate or are not practicing weight-cutting tactics and using a battery of concussion tests during injury evaluation. This will take into account the possible influence of these weight-cutting tactics on clinical concussion measures. The important clinical consideration is the concussion. Our findings simply identify a condition which may influence our ability as clinicians to evaluate the presence of a concussion.

Appendix A: Sport Concussion Assessment Tool 2 (SCAT2)

SCAT2

Sport Concussion Assessment Tool 2



FIFA®



Name _____

Sport/team _____

Date/time of injury _____

Date/time of assessment _____

Age _____ Gender ☐ M ☐ F

Years of education completed _____

Examiner _____

What is the SCAT2?

This tool represents a standardized method of evaluating injured athletes for concussion and can be used in athletes aged from 10 years and older. It supersedes the original SCAT published in 2005¹. This tool also enables the calculation of the Standardized Assessment of Concussion (SAC)^{2,3} score and the Maddocks questions⁴ for sideline concussion assessment.

Instructions for using the SCAT2

The SCAT2 is designed for the use of medical and health professionals. Preseason baseline testing with the SCAT2 can be helpful for interpreting post-injury test scores. Words in *italics* throughout the SCAT2 are the instructions given to the athlete by the tester.

This tool may be freely copied for distribution to individuals, teams, groups and organizations.

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms (like those listed below) and often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (such as headache), or
- Physical signs (such as unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour.

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.

Symptom Evaluation

How do you feel?

You should score yourself on the following symptoms, based on how you feel now.

	none	mid	moderate	severe			
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

Total number of symptoms (Maximum possible 22) _____

Symptom severity score _____

(Add all scores in table, maximum possible: 22 x 6 = 132)

Do the symptoms get worse with physical activity? ☐ Y ☐ N

Do the symptoms get worse with mental activity? ☐ Y ☐ N

Overall rating

If you know the athlete well prior to the injury, how different is the athlete acting compared to his / her usual self? Please circle one response.

no different

very different

unsure

Cognitive & Physical Evaluation

1 Symptom score 0 = no symptoms

22 minutes (maximum of 30 minutes)

of 22

2 Physical signs score

What time did you last move your arms or legs? hr min

How long have you been lying down?

What time did you last get up and walk?

hr min

hr min

Physical signs score 0 = no signs, 1 = signs

of 2

3 Glasgow coma scale (GCS)

Best eye response (E)

None at all (no eye)

1

Eye opening to speech only

2

Eye opening to speech

3

Eye opening spontaneously

4

Best verbal response (V)

Not at all (no speech)

1

Not at all (no words or phrases)

2

Improper words/phrases

3

Confused

4

Oriented

5

Best motor response (M)

Not at all (no movement)

1

Extension to pain

2

Abnormal flexion to pain

3

Extension to pain to pain

4

Flexion to pain to pain

5

Unresponder

6

Glasgow Coma score (E + V + M)

of 15

0 = no response, 1 = no response, 2 = no response, 3 = no response, 4 = no response, 5 = no response, 6 = no response, 7 = no response, 8 = no response, 9 = no response, 10 = no response, 11 = no response, 12 = no response, 13 = no response, 14 = no response, 15 = no response

4 Sideline Assessment – Maddocks Score

"I am going to ask you a few questions, please listen carefully and give your best effort."

Modified Maddocks questions 0 = no response, 1 = response

What is your name and location?

0 1

What is the date today?

0 1

What is the last name of the president?

0 1

What is the name of the day before yesterday?

0 1

What is the name of the day after tomorrow?

0 1

Maddocks score

of 5

0 = no response, 1 = no response, 2 = no response, 3 = no response, 4 = no response, 5 = no response, 6 = no response, 7 = no response, 8 = no response, 9 = no response, 10 = no response, 11 = no response, 12 = no response, 13 = no response, 14 = no response, 15 = no response

The purpose of the Sideline Assessment is to quickly assess the patient's level of consciousness and orientation. The patient should be asked to answer the questions as accurately as possible. The patient should be asked to answer the questions as accurately as possible. The patient should be asked to answer the questions as accurately as possible.

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5 Cognitive assessment

Standardized Assessment of Concussion (SAC)

Orientation 0 = no response, 1 = response

What time is it?

0 1

What is the date today?

0 1

What is the day of the week?

0 1

What year is it?

0 1

What time is it right now? (to the nearest minute)

0 1

Orientation score

of 5

Immediate memory

"I am going to give you a list of words. I will repeat them a list of words and when I am done, repeat back as many words as you can remember, in any order."

Words 1-5

"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."

The purpose of the Immediate Memory test is to assess the patient's ability to recall a list of words. The patient should be asked to repeat the words back as accurately as possible. The patient should be asked to repeat the words back as accurately as possible.

List	Trial 1	Trial 2	Trial 3	Alternative word list
elbow	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	vanilla, bubble, flower
apple	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	peanut, strawberry, cherry
catfish	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	oyster, perfume, bubble
celery	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	vanilla, vanilla, bubble
bubble	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	<input type="text"/> 0 <input type="text"/> 1	vanilla, bubble, bubble
Total	<input type="text"/>	<input type="text"/>	<input type="text"/>	

Immediate memory score

of 15

Concentration

Digit Backward

"I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."

The purpose of the Digit Backward test is to assess the patient's ability to repeat a string of numbers backwards. The patient should be asked to repeat the numbers back as accurately as possible. The patient should be asked to repeat the numbers back as accurately as possible.

String	0	1	String	0	1
4-2-1-3	<input type="text"/>	<input type="text"/>	5-2-9	<input type="text"/>	<input type="text"/>
4-2-1-3-4	<input type="text"/>	<input type="text"/>	4-2-1-3-4	<input type="text"/>	<input type="text"/>
5-2-9-1-3	<input type="text"/>	<input type="text"/>	1-2-3-4-5	<input type="text"/>	<input type="text"/>
7-1-9-4-2	<input type="text"/>	<input type="text"/>	1-2-3-4-5-6	<input type="text"/>	<input type="text"/>
7-1-9-4-2-3	<input type="text"/>	<input type="text"/>	1-2-3-4-5-6-7	<input type="text"/>	<input type="text"/>

Months in Reverse Order

"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'd say December, November... Go ahead."

The purpose of the Months in Reverse Order test is to assess the patient's ability to recall the months of the year in reverse order. The patient should be asked to recall the months of the year in reverse order.

December, November, October, September, August, July, June, May, April, March, February, January

December, November, October, September, August, July, June, May, April, March, February, January

Concentration score

of 5

The purpose of the Concentration test is to assess the patient's ability to repeat a string of numbers backwards. The patient should be asked to repeat the numbers back as accurately as possible. The patient should be asked to repeat the numbers back as accurately as possible.

The purpose of the Concentration test is to assess the patient's ability to repeat a string of numbers backwards. The patient should be asked to repeat the numbers back as accurately as possible. The patient should be asked to repeat the numbers back as accurately as possible.

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The purpose of the Concentration test is to assess the patient's ability to repeat a string of numbers backwards. The patient should be asked to repeat the numbers back as accurately as possible. The patient should be asked to repeat the numbers back as accurately as possible.

6

Balance examination

The following instructions are to be read aloud to the participant by the assessor. Read the instructions slowly and clearly, and ensure the participant understands the instructions.

Balance testing

"I am now going to test your balance. Please take your shoes off, roll up your pants legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty-second tests with different stances."

(a) Double leg stance:

"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."

(b) Single leg stance

"If you were to kick a ball, which foot would you use?" [It will be the opposite foot.] "Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

(c) Tandem stance:

"Now stand heel to toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

Balance testing – Types of errors

1. Hand lifted off hip/hand
2. Opening eyes
3. Moving feet apart
4. "Heeling up" (heel) dorsiflexion
5. Lifting heel of dominant foot
6. Reaching up or out of arms to touch feet

Each of the above errors will be counted during the 20-second examination. The assessor should count the errors and the examiner will begin counting errors only after the participant is set and in the proper stance/position. The modified RPSS is calculated by adding one error point for each error during the three 20-second tests. The maximum total number of errors for any single condition is 10. The total number of errors is then subtracted from the maximum possible score of 30 to determine the final score. The score for each condition is recorded on the SCAT2 form. The highest possible score for each condition is 10.

Condition tested: ☐ Left ☐ Right ☐ Non-dominant

Condition

Condition	Total errors
Double leg stance	of 10
Single leg stance	of 10
Tandem stance	of 10
Balance examination score	maximum of 30

7

Coordination examination

Upper limb coordination

Examiner says: "Hi! I am going to test your coordination. Now please sit comfortably on the chair with your eyes open and your arm flexed right or left outstretched (shoulder flexed to 90 degrees and elbow and fingers extended). When I give a start signal, I would like you to perform the following task 50 times as quickly and as accurately as possible."

When you are tested: ☐ Left ☐ Right

Start signal: "Go!" (The examiner will say "Go!" and the participant will begin the task. The examiner will count the number of times the participant completes the task accurately and quickly. The examiner will stop the participant when they have completed 50 repetitions.)

Coordination score

of 1

8

Cognitive assessment

Standardized Assessment of Concussion (SAC)

Delayed recall

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Words to be recalled: ☐ List 1 ☐ List 2 ☐ List 3 ☐ List 4 ☐ List 5 ☐ List 6 ☐ List 7 ☐ List 8 ☐ List 9 ☐ List 10

List	Alternative word list		
1. Bear	2. Apple	3. House	4. Tree
5. Apple	6. Chair	7. Table	8. Penny
9. Cat	10. Star	11. Fish	12. Boat
13. Apple	14. Chair	15. Sun	16. House
17. Apple	18. Chair	19. Sun	20. House

Delayed recall score

of 5

Overall score

Test domain	Score
Symptom score	of 22
Physical signs score	of 2
Glasgow Coma score (E + V + M)	of 15
Balance examination score	of 30
Coordination score	of 1
Subtotal	of 70
Orientation score	of 5
Immediate memory score	of 5
Concentration score	of 15
Delayed recall score	of 5
SAC subtotal	of 30
SCAT2 total	of 100
Maddocks Score	of 5

Definitive normative data for a SCAT2 "cut-off" score is not available at this time and will be developed in prospective studies. Embedded within the SCAT2 is the SAC score that can be utilized separately in concussion management. The scoring system also takes on particular clinical significance during serial assessment where it can be used to document either a decline or an improvement in neurological functioning.

Scoring data from the SCAT2 or SAC should not be used as a stand alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion.

Any athlete suspected of having a concussion should be removed from play, and then seek medical evaluation.

Prudent use of a well-thought-out 26-hour-a-week schedule could make the above schedule even more effective.

- There is an effective exponentially small ϵ in our asymptotic expansion and the corresponding distribution is $\delta_{\text{exp}} = \epsilon^{-1} \exp(-\epsilon^{-1} x)$. By using Lemma 3.2 and Lemma 3.3, we obtain the following theorem.

Consult your doctor or a dietitian to develop a safe and effective dieting program.

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Appendix B: Balance Error Scoring System (BESS) Score Card

Balance Error Scoring System (BESS) (Guskiewicz)

Balance Error Scoring System – Types of Errors
1. Hands lifted off iliac crest 2. Opening eyes 3. Step, stumble, or fall 4. Moving hip into > 30 degrees abduction 5. Lifting forefoot or heel 6. Remaining out of test position >5 sec
The BESS is calculated by adding one error point for each error during the 6 20-second tests.

SCORE CARD: (# errors)	FIRM Surface	FOAM Surface
Double Leg Stance (feet together)		
Single Leg Stance (non-dominant foot)		
Tandem Stance (non-dom foot in back)		
Total Scores:		
BESS TOTAL:		

Which **foot** was tested: ☐ Left ☐ Right
(i.e. which is the **non-dominant** foot)

Appendix C: Subject Safety Guideline Sheet

Research Study Participant Safety Instructions

Subjects, please take note of the following in regards to the cutting weight techniques procedures and wrestling practice participation.

Concerning Symptoms:

- 1. Overheating**
- 2. Pain or blood with urination**
- 3. Severe muscle cramping**
- 4. Weakness**
- 5. Confusion and disorientation**
- 6. Blurred vision**
- 7. Flank pain**
- 8. Cold clammy skin**
- 9. Vomiting**
- 10. Nausea**

If you experience any of these concerning symptoms, during cutting weight techniques, practice or following testing, contact **Amanda Friedline IMMEDIATELY**, especially if you normally do not experience them during your common cutting weight techniques.

810-599-1809 (Cell)

Appendix D: Activity/Food/Fluid Log Sheet

Subject Number:

Date:

Exercise/Food/Fluid Log

Starting at 9pm the night before your testing session, please log the amount and type of exercise you do, any food or fluids and amounts that you consume leading up to practice time the next day.

Date	Time	Fluid Item	Food item	Quantity	Activity Type, Duration, Intensity

Your FIST is approximately 1 CUP

You THUMB is approximately 1-TABLESPOON

Your THUMB TIP is approximately 1-TEASPOON

A *serving size* of cereal is approximately 1-Tennis Ball

A *deck of cards* is the size of a 3 to 4 (90-120g) ounce serving of chicken or meat

Appendix E: Food Measurement Guide

Please remember the list below gives *examples* of the size, shape, and/or look of **one serving** of a particular food.

- **A rounded handful** - one 1/2 cup vegetables or fruit, 1/2 cup of cooked rice or pasta, or a snack serving of crisps or pretzels
- **Woman's fist** - another way of visualising a serving of vegetables, or one piece of whole fruit
- **Small handful or [golf](#) ball** - 1/4 cup of dried fruit
- **A matchbox** - a 1 oz serving of meat, or a serving of cheese
- **Deck of cards, or the palm of your hand** (excluding fingers) - a 3oz serving (recommended serving) of meat, fish or poultry, or ten chips/french fries
- **Thin paperback book** - a 8 oz serving of meat
- **Check book** - a serving of fish (approximately 3 oz)
- **Tennis ball** - 1/2 cup of pasta, or a serving of ice cream
- **Computer mouse** - a medium baked potato
- **Compact disc** - one serving of pancake or small waffle
- **Thumb tip or one dice** - one teaspoon of margarine
- **A ping pong ball** - two tablespoons of peanut butter
- **Small milk carton** - 8 oz glass of milk
- **A baseball** - 8 oz cup of yogurt, one cup of beans, or one cup of dry cereal

<http://www.dietrific.com/2007/05/07/a-visual-view-of-serving-size-using-everyday-items-2>

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