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The effect of rapid weight loss on cognitive function in collegiate wrestlers

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THE EFFECT OF RAPID WEIGHT LOSS ON COGNITIVE FUNCTION IN COLLEGIATE WRESTLERS

by

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An Abstract

of a thesis submitted in partial fulfillment
of the requirements for the degree of
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ABSTRACT

This study examined the effect of rapid weight loss on cognitive function in collegiate wrestlers. Wrestlers ($n = 14$) and control subjects ($n = 15$) who were college age males volunteered to participate in the study. Subjects were tested at three different times: baseline (i.e., first session), rapid weight loss (i.e., second session), and rehydration (i.e., third session). Only wrestlers actually practiced rapid weight loss in preparation for competition. At each test session, subjects completed a mood state profile, hypoglycemic profile, and five short cognitive tests. Blood glucose, hemoglobin (Hgb), hematocrit (Hct), plasma volume (PV), body weight and % body fat were also measured. Two-way (2 x 3) analyses of variance (ANOVA) with repeated measures (group x time) and post-hoc t-tests revealed significant differences ($p < 0.05$) between wrestlers and control subjects at the rapid weight loss (i.e., second session) test session in the digit span and story recall tests of the cognitive test battery. ANOVA also revealed between group differences in hypoglycemic symptomology, blood glucose, Hgb, Hct, PV, and body weight at the rapid weight loss (i.e., second session) test session. A significant ($p < 0.008$, Dunn Bonferroni adjustment) increase in mood negativity in wrestlers compared to control subjects was also apparent after rapid weight loss. All physiological and cognitive effects of rapid weight loss were reversible and all measures returned to near baseline values after rehydration. In summary, rapid weight loss in collegiate wrestlers causes significant physiological effects which are accompanied

by a transient impairment of short term memory (STM). The potential negative impact of this practice on the collegiate student-wrestler should be given careful consideration.

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A Thesis Presented to the Faculty of
the School of Health Sciences
and Human Performance
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Requirements for the Degree
Masters of Science

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by
Celeste Wendy Choma
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Ithaca College

School of Health Sciences and Human Performance

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

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submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health Science and Human Performance at Ithaca College has been approved

Thesis Advisor:

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David Ostashower, friend, for encouraging me to follow the stars and seek out my dreams.

DEDICATION

This thesis is dedicated to my mom and dad for instilling in me a sense of ambition, perseverance, and adventure.

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INTRODUCTION

The practice of rapid weight loss, known as "cutting weight", has received much attention by both the medical and sporting communities. Rapid weight loss involves the practices of self-induced dehydration and starvation until target weight is met, and is a common precompetition practice for many collegiate athletes (Brownell, Nelson-Steen, & Wilmore, 1987; Fogelholm, 1994). Wrestlers may endure this routine between 10 and 30 times during a four month period wherein 3.1 to 9.5 kilograms (kg) are repeatedly lost and regained (Coleman, 1989). Both the American Medical Association (AMA) and the American College of Sports Medicine (ACSM), out of concern for high school and collegiate wrestlers, created position statements in opposition to this practice (ACSM, 1976; AMA, 1967).

Numerous physiological responses, which are relatively reversible with adequate rehydration and weight regain, occur each time an athlete "cuts weight". For example, great strain can be placed on the cardiovascular system as plasma volume (PV) loss forces heart rate to compensate for diminished stroke volume (SV). Thermoregulation is also challenged as the skin and active muscles compete for a limited blood volume putting the athlete at risk for heat cramps and heat stroke. Moreover, if one loses more than 8% body weight, there is a risk for renal ischemia due to diminished PV (Ribisl, 1978; Tipton & Tcheng, 1970).

Finally, because the practice of rapid weight loss couples excessive exercise with limited caloric intake, the athlete likely experiences frequent but transient bouts of hypoglycemia.

Hypoglycemia is known to negatively impact on cognitive function. The majority of research on hypoglycemia has been conducted with diabetics (DeFeo et al., 1988; Smith-Holmes, Hayford, Gonzalez, & Weydart, 1983), however a number of studies have examined elementary schoolchildren (Brozek, 1955; Cryer, 1981). In a study involving diabetic patients, short term memory (STM) was significantly reduced during short bouts of hypoglycemia with blood glucose levels of 54 mg/dL (Pramming, Thorsteinsson, Stigsby, & Binder, 1988). Other studies involving diabetic patients have found attention, visual acquity, and visuomotor skills to be significantly impaired during hypoglycemia with blood glucose levels of 45 to 60 mg/dL (Mellman, Davis, Brisman, & Shamoon, 1994; Widom & Simonson, 1990). Research involving elementary schoolchildren, however, suggested that cognition may be maintained in highly motivated individuals during both hemodynamic and symptomologic hypoglycemia with blood glucose levels of 60 to 63 mg/dL (Dickie & Binder, 1982, Pollitt, Leibel, & Greenfield, 1981).

Further details of the effects of hypoglycemia upon cognition are beyond the scope of this introduction. A more complete review of the literature, which addresses the physiological effects of rapid weight loss, cognitive effects of hypoglycemia, and the practice of rapid weight loss in collegiate wrestlers, can be found in Appendix A.

A better understanding of how rapid weight loss affects cognitive function is needed, particularly of collegiate wrestlers who, most importantly, are students. It cannot be assumed that a competitive wrestler reacts cognitively the same as either a hypoglycemic diabetic or child, yet there is no research to date regarding the possible effect of rapid weight loss on cognitive function in collegiate athletes. Wrestlers are typically free of metablic disorders and their competitive nature may allow them to maintain cognitive function despite rapid weight loss and potential hypoglycemia. Accordingly, it may be hypothesized that despite producing a transient hypoglycemic state, the practice of rapid weight loss does not affect cognitive function in collegiate wrestlers. The purpose of this study was to determine the effect of rapid weight loss on cognitive function in collegiate wrestlers during the competitive season.

METHODS

Subjects

Twenty nine male undergraduate students between the ages of 18 and 21 years participated in this study. All wrestlers ($\underline{n}$ = 14) had been competitive for a minimum of three years and were actively competing during the study. Control subjects ($\underline{n}$ = 15) were competitive collegiate athletes training at least five days a week. Control subjects were of stable weight in that they had not lost nor gained more than 4.5 kg in the previous three months and were not intentionally attempting to lose nor gain weight during the study. Refer to Appendix B for the table of subject characteristics. Each subject signed an informed consent form detailing the procedures and purposes of the study (Appendix C) and completed a data information sheet (Appendix D).

Subject Preparation and Screening

Prior to data collection, all subjects participated in two cognitive battery practice sessions and two blood screenings. Practice versions of each cognitive test were completed to ensure procedural understanding and reduce the possibility of a learning effect during subsequent data collection. Blood screening involved two separate blood samplings on different days for the analysis of blood glucose, hemoglobin (Hgb), hematocrit (Hct), and PV. This was done to verify that participants were hemodynamically stable and also established baseline data for the study. Baseline data for blood sampling was an average of the two obtained measurements in subjects who displayed hemodynamic stability. Subjects who were not hemodynamically stable after two blood screenings returned for a third screening session before stability was verified. Because of the potential sensitivity of cognition to dehydration, hypoglycemia, or hyperglycemia, these were important screening procedures.

Test Sessions

Data collection was divided into three test sessions: baseline (i.e., first session), rapid weight loss (i.e., second session), and rehydration (i.e., third session). Baseline data were collected approximately one week prior to the commencement of the official wrestling season. Rapid weight loss data were measured during the official wrestling season immediately following an official weigh-in. Weigh-in typically occurred immediately following practice the evening prior to a meet. The practice of "cutting weight" typically commenced 12 to 36 hours in advance of the weigh-in depending on the amount of weight that the wrestler was expected to lose. Rehydration data were collected approximately 72 hours after weigh-in yet prior to the commencement of any "cutting" techniques for the next meet. Data collection corresponded with each subject's peak weight cut during the season. Preseason, and again immediately postseason, body composition analysis was determined by underwater weighing (UWW) and corrected for residual lung volume. Details of the standard technique used can be found in Appendix E.

Rehydration and food consumption did not commence until the rapid weight loss test session was completed. Food and fluid consumption during rapid weight loss was not controlled by the investigator. However, most of the wrestlers ate normally up until approximately 12 to18 hours prior to weigh-in. At this time, a typical meal was fruit (i.e., one small apple) or a small bowl of cereal. Fluid consumption was kept to an absolute minimum by most wrestlers. However, each wrestler appeared to have his own technique for rapid weight loss, knowing precisely what needed to be done to ensure adequate weight loss prior to the weigh-in.

Previous research indicated that physical performance decrements and physiological change result from a rapid loss of greater than 5% body weight coupled with inadequate rehydration (Hickner et al., 1991; Houston, Marrin, & Green, 1981; Webster, Rutt, & Weltman, 1990). A wrestler typically loses between 5 to 11% body weight. For this study, a minimum of 5% body weight loss was required before rapid weight loss data were collected. Data collection for control subjects mirrored that of the wrestlers. However, control subjects were of stable weight and voluntarily maintaining food and fluid consumption throughout the study.

Testing Procedures

Cognitive testing procedures were conducted under identical test conditions during each of the three test sessions. All testing was done in a quiet environment. One tester and only those subjects undergoing testing were present in the room. All cognitive testing was done by the investigator and one trained assistant.

For each test session, the testing commenced with the completion of a mood state profile and a hypoglycemic profile. The subject then completed the cognitive test battery which required approximately 12 minutes and consisted of five short tests. Blood glucose was tested using a fingertip capillary blood drop sample and analyzed by the Accucheck Easy glucose monitoring system (Boehringer Mannheim, Indianapolis, IN). Venipuncture was performed via an antecubital vein and approximately 3 ml of blood was collected for analysis of Hgb and Hct, and the subsequent calculation of PV (see Appendix F).

Testing Instruments

Mood state was measured using the Profile of Mood State Revised Edition (POMS-R) which evaluates mood according to six specific scales: tension-anxiety (T-A), depression-despair (D-D), anger-hostility (A-H), vigor-activity (V-A), fatigue-inertia (F-I), and confusion-bewilderment (C-B) (EdITS, San Diego, CA). Signs and symptoms of hypoglycemia were measured using the Hypoglycemic Profile (HP), a Likert scale measure of the ten most common hypoglycemic signs and symptoms (Pramming, Thorsteinsson, Theilgaard, Pinder, & Binder, 1986; Widom & Simonson, 1990). Refer to Appendixes G and H for examples of the POMS-R and the HP, respectively.

The cognitive test battery, in the order administered, included the following tests: letter cancellation, digit symbol, trailmaking A and B, digit span, and story recall. Letter cancellation is a test of visual attention and visuomotor skills and involves crossing out target letters found throughout a series of lines of random letters (Lezak, 1983). The digit symbol test entails substituting geometric designs for numbers and also tests visual attention, and is a subtest of the Wechsler Adult Intelligence Scale-Revised (Psychological Corporation, San Antonio, TX). The trailmaking A and B test involves connecting sequential numbers and letters as rapidly and accurately as possible and assessed visual acquity, visuomotor, and attention skills (Lezak, 1983). Digit span requires recalling increasingly longer series of digits in forward and reverse order thereby assessing attention and STM. This test is a subtest of the Wechsler Memory Scale (Psychological Corporation, San Antonio, TX). Lastly, story recall involves remembering as many sequential story components as possible after each of two short stories is read by a tester. This test also assesses STM and is a subtest of the Wechsler Memory

Scale. These tests were selected for their assessment of a range of cognitive functions, brevity, and their documented sensitivity to the hypoglycemic state (DeFeo et al., 1988; Mellman, Davis, Brisman, & Shamoon, 1994; Widom & Simonson, 1990). In addition to the cognitive test batteries used during the two practice sessions (i.e., prior to data collection), three additional versions of the cognitive test battery were administered in counterbalanced fashion to the subjects during the three data collection sessions. Thus, subjects received a different version of the cognitive test battery at each test session. This was done in an attempt to prevent a learning effect and spread the different versions across the test sessions. Examples of the tests in each cognitive test battery can be found in Appendix I.

Statistical Analyses

Two-way (2 groups x 3 times) analyses of variance (ANOVA) with one repeated measure were used to compare cognitive function, mood state, hypoglycemic symptoms, blood glucose, PV, body weight, and body composition (2 x 2) between wrestlers and control subjects at baseline (i.e., first session), rapid weight loss (i.e., second session), and rehydration (i.e., third session) test sessions. For significant interaction of group by time, post-hoc t-tests were used to locate significant differences between groups at each time. A post-hoc Duncan's Multiple Range test was used for a significant main effect of time. A

Dunn-Bonferroni adjustment was used to assess changes in the six subtests of the POMS-R. This adjustment necessitated that differences in POMS-R subtests be achieved at $p < 0.008$. All other data were assessed at the $p < 0.05$ level of significance.

RESULTS

Refer to Appendix J for the data tables. Means and standard deviations for dependent variables at each of the three test sessions can be found in Tables J-1 to J-6. ANOVA tables and post-hoc test results can be found in Tables J-7 to J-11

Cognitive Test Battery

Significant group x time interactions were found for the digit span and story recall subtests of the cognitive test battery (Figures 1 and 2, respectively). With both subtests, wrestlers scored significantly lower than control subjects at the rapid weight loss (i.e., second session) test session (Table J-7). Wrestlers' performance following rehydration was similar to baseline performance as evidenced by visual inspection of the graphs whereas control subjects demonstrated consistent performance during all three test sessions for these subtests.

For the letter cancellation test, the follow-up to a main effect for time showed there was a significant increase in performance from the rapid weight loss to the rehydration test session. Although no interaction existed, this main effect was attributed to a 9.8% increase in this test score by wrestlers and only a 2.7% increase by control subjects. Analyses of the digit symbol and trailmaking A and B tests did not reveal significant interaction or main effects (Table J-7). Performance of the trailmaking A and B test diminished slightly, but not significantly, for

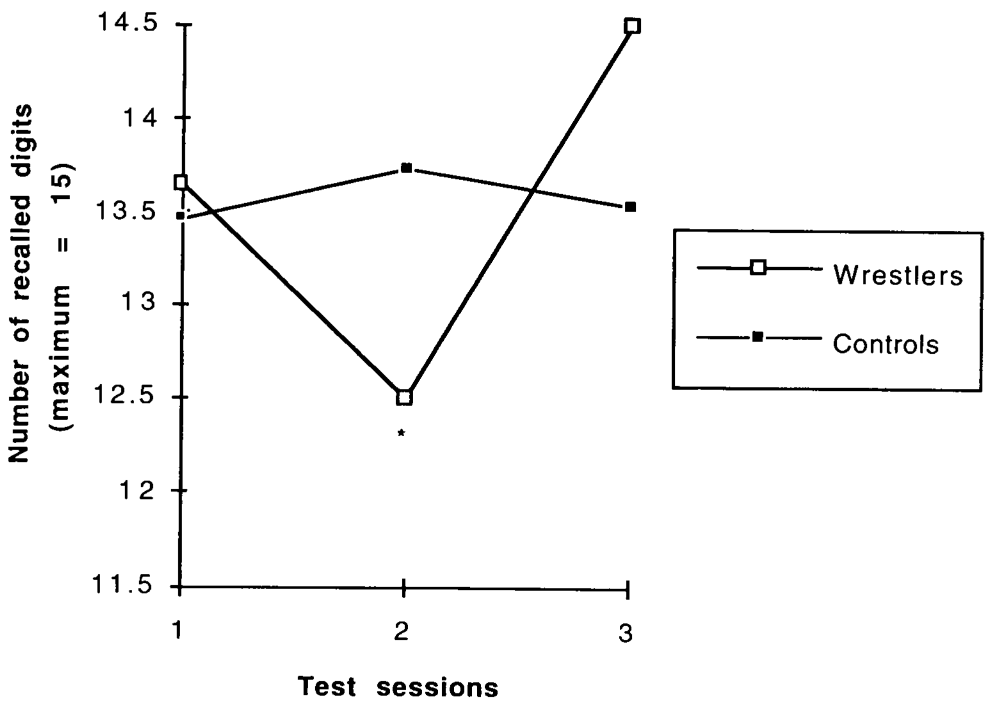

Figure 1. Digit span test scores for wrestlers and control subjects at baseline (1), rapid weight loss (2), and rehydration (3) test sessions.

* $p < 0.05$

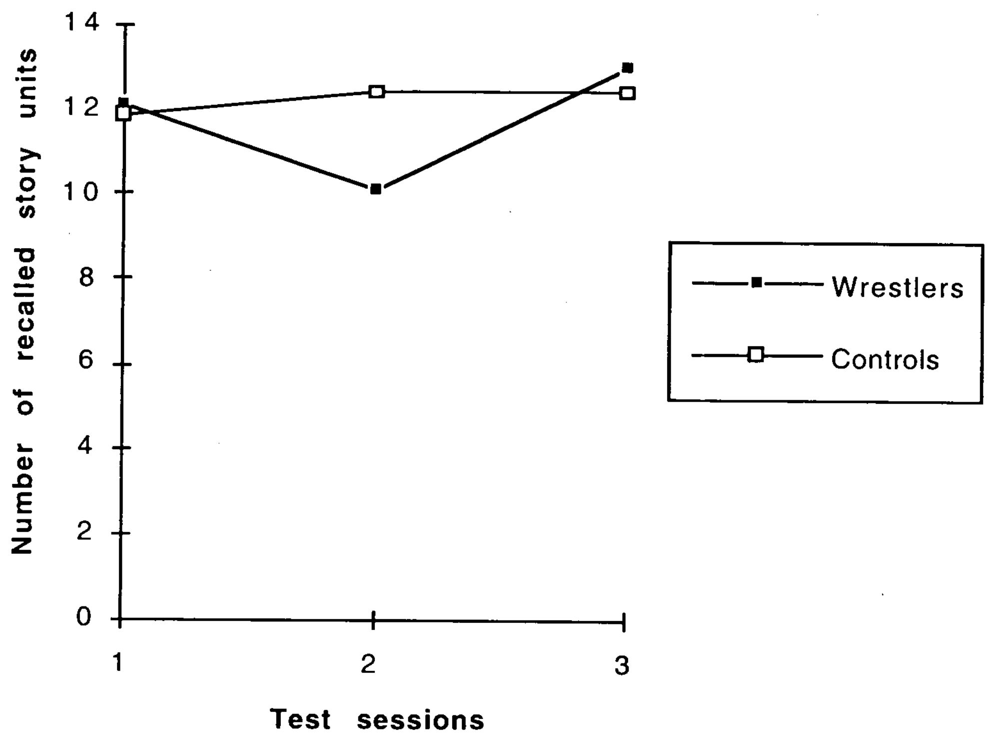

Figure 2. Story recall test scores for wrestlers and control subjects at baseline (1), rapid weight loss (2), and rehydration (3) test sessions.

* $p < 0.05$

wrestlers during rapid weight loss.

Mood State Profile

Significant group x time interactions were found for five of the six POMS-R scales (i.e., T-A, D-D, A-H, F-I, and C-B) as displayed in Figure 3. Analysis for V-A was not significant . The mood state for wrestlers was significantly more negative with rapid weight loss compared to the mood state of control subjects at their second test session (Table J-8). Upon visual inspection of the graph, wrestlers returned to a baseline mood state following rehydration whereas control subjects were consistent in their mood state and did not experience this same mood swing during any of the test sessions.

Physiological Measures

Hypoglycemic Symptomology and Blood Glucose

Significant group x time interactions were found for both hypoglycemic symptomology and measured blood glucose. Wrestlers experienced a lower blood glucose and an accompanying greater increase in hypoglycemic symptomology than control subjects at the rapid weight loss (i.e., second session) test session (Table J-9). Wrestlers experienced a 13.7 mg/dL drop in blood glucose and an accompanying 37% increase ($p < 0.05$) in hypoglycemic symptomology with rapid weight loss whereas control subjects blood glucose dropped only 3.13 mg/dL with no increase in hypoglycemic symptomology at their

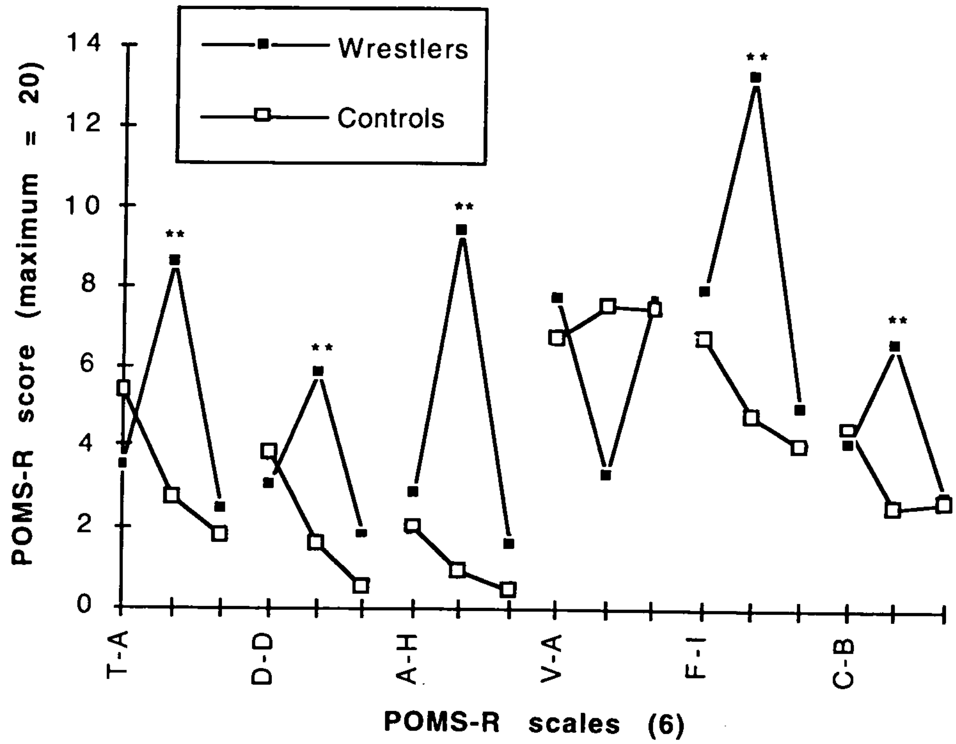

Figure 3. POMS-R scores for wrestlers and control subjects at baseline (1), rapid weight loss (2), and rehydration (3) test sessions (grouped together at each of the six scales). T-A: tension-anxiety; D-D: depression-despair; A-H: anger-hostility; V-A: vigor-activity; F-I: fatigue-inertia; C-B: confusion-bewilderment.

** $p < 0.008$

second test session. Visual inspection of the graph (Figure 4) indicates that wrestlers returned to baseline blood gluose levels following rehydration and food consumption whereas control subjects did not experience fluctuation in either hypoglycemic symptomology or blood glucose with time.

Plasma Volume and Body Weight

Hgb and Hct values can be found in Table J-9. Significant group x time interactions were found for both PV and body weight. Wrestlers experienced a significantly lower PV than control subjects with rapid weight loss (i.e., second session). As represented in Figure 5, the wrestlers PV returned to baseline values following rehydration whereas control subjects PV remained stable throughout the three test sessions. As expected, body weight dropped significantly with rapid weight loss in wrestlers with an average loss of 5.1 kg equaling a 6.2% body weight loss whereas no fluctuation in body weight occurred in control subjects at the second test session.

Body Composition

There was a nonsignificant change in % body fat from preseason to postseason in wrestlers. Although the wrestlers did reduce their % body fat during the season, the change was not statistically significant. However, wrestlers had a lower % body fat than control subjects. Preseason (i.e., first session), wrestlers and control subjects measured

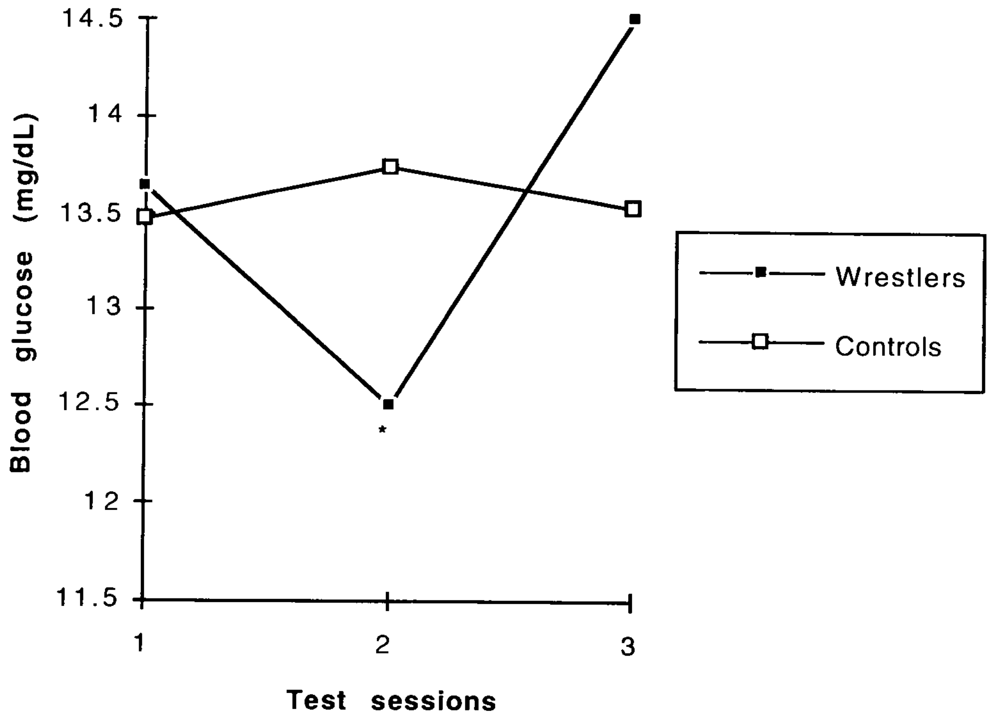

Figure 4. Blood glucose results for wrestlers and control subjects at baseline (1), rapid weight loss (2), and rehydration (3) test sessions.

* $p < 0.05$

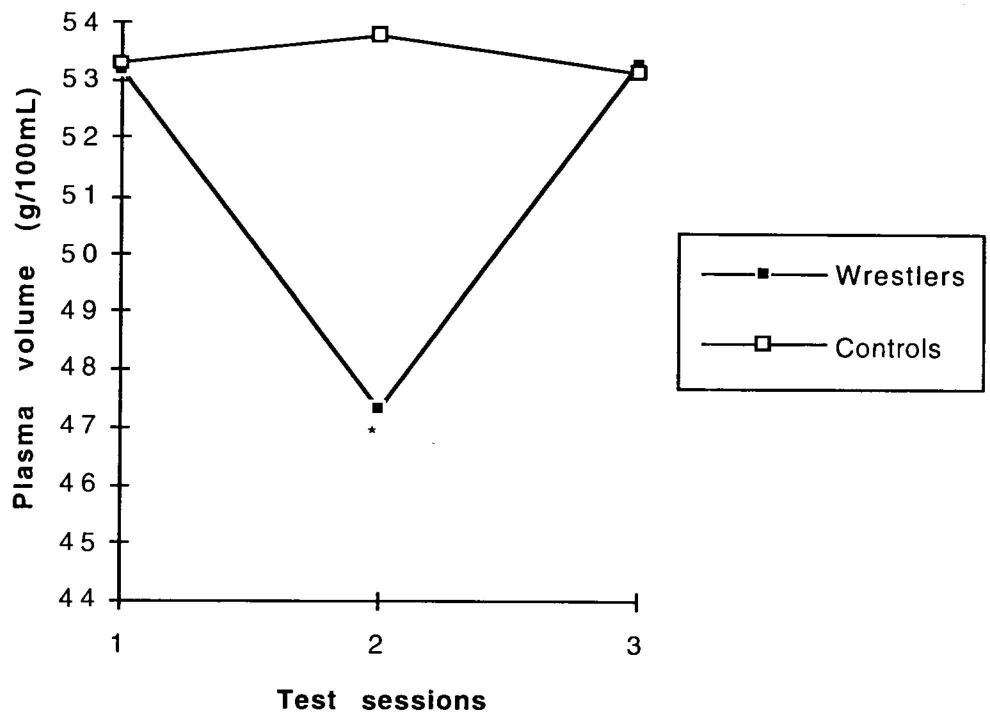

Figure 5. Plasma volume for wrestlers and control subjects at baseline (1), rapid weight loss (2), and rehydration (3) test sessions.

* p < 0.05

7.8% and 10.9% body fat, respectively. Four months later, these groups measured 7.1% and 10.8% body fat, respectively.

DISCUSSION

The main finding of this study was that significant cognitive function impairment, specifically in the domain of STM, occurred in collegiate wrestlers who weight cut at least 5% body weight. Rapid weight loss also negatively impacted mood state. A hypoglycemic state was induced as evidenced by the drop in blood glucose from 84.8 to 71.0 mg/dL coupled with a significantly greater hypoglycemic symptomology during rapid weight loss.

The finding that cognitive function is impaired during hypoglycemia is supported by previous research. However, the blood glucose and hypoglycemic symptomology levels at which cognitive function impairment occurred and hypoglycemic symptomology were not as severe as those in other studies. That is, most previous studies report cognitive effects becoming apparent when blood glucose drops considerably lower than the levels presently observed.

Previous studies using the cognitive test battery to assess STM found significant impairment to occur with blood glucose levels between 50 mg/dL and 60 mg/dL. Corresponding changes in hypoglycemic symptomology occurred at blood glucose levels below 45 mg/dL (Ipp & Forster, 1987; Mellman, Davis, Brisman, & Shamoon, 1994; Widom & Simonson, 1990). In studies using the electroencephalogram to detect the slowing of brain wave activity, which is indicative of cognitive impairment, it was found that significant STM impairment occurred at 46 mg/dL (Pramming, Thorsteinsson, Stigsby, & Binder, 1988; Smith-Holmes, Hayford, Gonzalez, & Weydert, 1983). Another study, using a technique (i.e., the latency P300 auditory wave) considered to be more sensitive than cognitive test batteries or the electroencephalogram in detecting cognitive function impairment, revealed significant STM impairment with blood glucose as high as 72 mg/dL (DeFeo et al., 1988).

It has been suggested that IDDM patients may differ in their cognitive response to hypoglycemia compared to the normal metabolically stable individual in that they appear to develop both a cognitive and symptomology resistance to hypoglycemia whereby they tolerate more severe blood glucose decrements before any alteration in cognition is noted (Widom & Simonson, 1990). This may explain why wrestlers, who are typically metabolically stable individuals when not "cutting weight", experienced a decrement in STM at a higher blood glucose level than those reported in previous studies of cognitive function impairment.

Studies that used the cognitive test battery to assess changes during hypoglycemia consistently reported cognitive function impairment in the domains of attention, visual acquity, and visuomotor skills (Ipp & Forster, 1987; Mellman, Davis, Brisman, & Shamoon, 1994; Widom & Simonson, 1990). In contrast, the present study revealed no change in these domains as assessed by the letter cancellation, digit symbol, and trailmaking A and B subtests. These subtests were timed "paper and pen" tests and of shorter duration than those assessing STM. The subject was active rather than passive as was required while doing the STM tests (i.e., digit span and story recall subtests). Being active and "competing against the clock" may have enhanced the ability of the subject to focus on the task and thus minimize temporarily the effects of hypoglycemia. Thus, the nonsignificant results of several subtests may have been influenced by the competitive nature of the wrestlers. This has been reported elsewhere when, despite experiencing hypoglycemia, highly motivated subjects remained resistent to performance decrement and physiological stressors (Brozek, 1955; Dickie & Binder, 1982; Pollitt, Leibel, & Greenfield, 1981).

In summary, while rapid weight loss appears to impact STM, it does not seem to have a significant effect on attention, visual acquity, and visuo-motor skills as previously measured. The specific alteration in cognitive function may be related to the hypoglycemic state evidenced in the wrestlers and may require a less dramatic alteration in blood glucose levels than that seen in IDDM patients.

According to the results of the POMS-R, wrestlers were significantly more negative in mood during rapid weight loss. Wrestlers indicated an increase in negativity with rapid weight loss and expressed significant feelings of tension, anxiety, depression, despair, anger, hostility, and fatigue. In contrast, wrestlers did not express a significant alteration in vigor and ability to remain active. This may be indicative of the competitive nature of wrestlers in that the rapid weight loss measurements were taken immediately following an official weigh-in which typically followed an intense two hour exercise period in a hot and humid environment. Even though seemingly physically exhausted, wrestlers felt that they could continue activity if deemed necessary.

Measures made 72 hours after rapid weight loss clearly demonstrated that all effects seen were reversible. The significant drop seen in PV was similar to that observed in previous research and the measurements made 72 hours later show that this rapid temporary weight loss simply involves the loss of essential body water with no permanent loss in body fat (Fogelholm, 1994; Horswill, 1992a; Lamb, 1984; Noakes, 1994). With adequate food and fluid intake, body weight, PV, and blood glucose were also restored to normal values. This validates that the rapid weight loss practices of the wrestlers in this study were not unlike the typical rapid weight loss techniques practiced by wrestlers in previous studies (Brownell, Nelson-Steen, & Wilmore, 1987; Coleman, 1989; Fogelholm, 1994; Horswill, 1993; Tipton, 1990; Webster, Rutt, & Weltman, 1990). Similarly, the significant decrease in STM and the significant increase in hypoglycemic symptomology and mood negativity were temporary. Following adequate rehydration and food consumption, the wrestlers' STM, sensation of hypoglycemia, and mood state returned to similar baseline values. The simultaneous reversal of negative cognitive effects and physiological effects (i.e., blood glucose, PV, body weight) further implicates the rapid weight loss process in the observed impairments.

Wrestlers are among the leanest collegiate athletes and typically range from 7% body fat (Nelson-Steen, Opplinger, & Brownell, 1988) to 11% body fat (Tcheng, Bowers, & Johnson, 1986). This study found preseason and postseason body fat to average 7.8 and 7.1%, respectively. Thus, body composition of the wrestlers in this study was typical for athletes in this sport and remained constant throughout the season. According to the recommendations of the ACSM (1976) and AMA (1967), a wrestler's body fat should not fall below 5 and 7%, respectively. This emphasizes that the subjects in the present study maintained an appropriate body composition throughout the competitive season. This lack of change in body composition over the entire season also emphasizes that, although weekly weight loss meant that a large amount of weight was lost over the entire season, this resulted in no permanent loss of weight in the form of body fat.

The physiological changes with rapid weight loss have been well documented in previous research. However, this is the first study to examine the effects of rapid weight loss on cognitive function. One must not forget that collegiate wrestlers are, first and foremost, students. This study found that STM is significantly affected by rapid weight loss. The impact of this cognitive deficit on scholastic achievement during a season of "cutting weight" is of concern and requires investigation. Likewise, the long term effects of rapid weight loss on cognitive function should be examined. We can only speculate that cognitive function impairment as a result of rapid weight loss is always reversible. In conclusion, the practice of rapid weight loss appears to offer little reward or advantage for the collegiate wrestler, whereas the apparent and potential disadvantages may more seriously impact the student who is a collegiate wrestler.

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Appendix A

REVIEW OF LITERATURE

The purpose of this investigation was to observe the effects of rapid weight loss on the cognitive function of collegiate wrestlers. In this review of related literature, the following topics are discussed: (a) rapid weight loss, (b) physiological responses and adaptations to rapid weight loss, (c) cognitive function and rapid weight loss, and (d) summary.

Rapid Weight Loss

Rapid weight loss in wrestlers, known as "cutting weight", is a period of acute weight loss achieved by self-induced dehydration and starvation (Brownell, Nelson-Steen, & Wilmore, 1987). Immediately upon reaching his target weight, or "making weight", the wrestler commences drinking and eating in an attempt to regain all losses and return to his normal weight prior to meeting his first opponent (Coleman, 1989). This pattern of rapid loss and regain of body weight is known as weight cycling and is common practice in the precompetition routine of many collegiate wrestlers (Fogelholm, 1994; Horswill, 1992b; Tipton, 1990). It has been estimated that wrestlers that "cut weight" endure this routine approximately 10 to 30 times in a four month period whereby 7 to 21 pounds (lb) are lost and repeatedly regained (Coleman, 1989).

Wrestling is a weight classed sport. This means that, based on body weight alone, two competitors are as evenly matched as possible

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(Tipton, 1990). Rapid weight loss is thought to provide the wrestler with a competitive advantage over his opponent. Qualifying to compete in a lighter weight class, yet regaining all lost weight prior to competition, may allow the wrestler to compete against a smaller, lighter, and weaker opponent (Hansen, 1978; Ribisl, 1978).

In theory, it appears that rapid weight loss could provide a competitive advantage if firstly, the weight loss is great enough to allow the wrestler to qualify to compete one or two weight classes below his normal weight; secondly, if the wrestler is able to gain back a sufficient amount of the weight loss to ensure no decrement in performance; and lastly, if not all competitors practice rapid weight loss so that a weight discrepancy within the weight classes themselves exists. However, according to a recent study conducted at the National Collegiate Athletic Association (NCAA) Divisions I, II, and III qualifying tournament, it was found that all wrestlers "cutting weight" regained all lost weight in the 20 hours between the official weigh-in and the first round of competition. The average weight loss was 5% body weight and considered significant. Nearly all competitors (i.e., except for heavyweight wrestlers) weight-cycled thus creating a very small and insignificant weight discrepancy of only 3 lb between opponents (Scott, Horswill, & Dick, 1994). In addition, it was found that neither the severity of the weight

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cycle (i.e., amount of weight lost and regained) or the weight discrepancy between opponents influenced the success of the wrestlers (Horswill, Scott, Dick, & Hayes, 1994). Thus, it appears that rapid weight loss does little to create a competitive advantage.

According to the NCAA Wrestling Rules and Regulations (1993), there are 10 weight classes for which wrestlers can attempt to qualify: 118 lb, 126 lb, 134 lb, 142 lb, 150 lb, 158 lb, 167 lb, 177 lb, 190 lb, and heavyweight (up to 275 lb). The wrestler must be at or below the particular weight in order to compete in that weight class. Due to the lengthy competitive season, provisions are given early in the season that permit the wrestler to be slightly heavier yet still compete in a listed weight class. The weight allowance, however, ranges from 3 lb at the beginning of the season to 1 lb at midseason and only applies to certain meets. A full description of these rules can be found in the NCAA Wrestling Rules and Regulations Handbook (NCAA, 1993). Regardless of the weight allowance, wrestlers must qualify or "make weight" before each and every meet. This would be of little cause for concern if most wrestlers competed at their normal body weight. Most, however, weigh-in at a weight 5 to 10% less than their normal body weight (Fogelholm, 1994; Horswill, 1993).

Traditionally, rapid weight loss involved food deprivation over a

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period of days and even weeks. Twenty years ago, wrestlers lost an average of 6 to 9 lb over a period of 7 to 10 days. This, however, left them feeling too weak to even practice prior to competition (Tipton & Tcheng, 1970). Today, the majority of wrestlers “cutting weight” use more acute and aggressive techniques (Horswill, 1992b). A wrestler typically loses weight over a period of hours, depending upon the amount of weight he is required to lose. The average weight loss by a wrestler is 7.8 % of his body weight (Fogelholm, 1994), and is typically lost over a period to 24 to 36 hours (Horswill, 1993).

Cutting weight involves a loss of essential body water (Tipton, 1990; Lamb, 1984). Physiologically, due to the body's large supply of water and the relatively short time duration required to efficiently weight-cut, it is unlikely that there is any fat or muscle loss resulting from rapid weight loss (Fogelholm, 1994; Horswill, 1992a; Noakes,1994). However, a fluctuation in body water alone is a physiological concern and could prove to be detrimental to the body's homeostatic state (Coleman, 1989).

Weight loss through acute dehydration is achieved by minimizing fluid and caloric intake, engaging in excessive strenuous exercise, and creating a hot humid environment often achieved by the use of plastic suits and excess layers of clothing. Most wrestlers use a combination of

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these methods for efficiency in weight reduction. Additionally, a wrestler usually refrains from consuming food or fluid for a period of 4 to 24 hours (Coleman, 1989). A wrestler having to make weight on a regular basis (e.g., weekly) usually has his own routine for weight loss and knows on an individual basis what must be done in order to lose the required weight in the allotted time (Fogelholm, 1994; Fogelholm, Koskinen, Laakso, Rankinen, & Ruokonen, 1992; Horswill, 1991; Webster, Rutt, & Weltman, 1990). In addition, there is documented research of the occasional use of diuretics, laxatives, and saunas in achieving weight loss (Horswill, 1991). These methods, however, are banned from collegiate sport (NCAA, 1993).

The process of regaining all lost weight is commenced following a successful weigh-in. If the wrestler officially "makes weight" he immediately begins consuming both fluid and food with the intention of regaining as much of the lost weight as possible (Tipton, 1990). The amount of time between the official weigh-in and the commencement of competition ranges from one-half hour to 24 hours depending on the type of meet in which the wrestler is competing (i.e., dual meet or tournament). The timing of the weigh-in is an obvious concern for both the wrestlers and coaches and provisions are permitted for mutually agreed upon weigh-in times between all competing teams. A more thorough review

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and explanation can be found in the NCAA Wrestling Rules and Regulations Handbook (1993). According to previous research, it appears that a minimum of 5 hours is usually allowed between weigh-in and competition (Fogelholm, Koskinen, Laakso, Rankinen & Ruokonen, 1992; Horswill, 1991; Horswill, 1993; McMurray, Proctor, & Wilson, 1991; Tipton, 1987). Rehydration is typically done using both water and easily digestable carbohydrate drinks (Coleman, 1989). The amount of time required to regain the weight is directly dependent upon the quantity of body weight lost. The more weight lost, the more weight to regain, and most likely, the more time needed to complete the process (Horswill, 1992a).

As previously mentioned, the goal of rapid weight loss is to create a competitive advantage through wrestling a smaller, lighter, and possibly weaker opponent and qualifying to compete in a lighter weight class than one's normal body weight. However, previous research revealed no real competitive advantage in wrestlers who weight cut and no greater a success rate in winning matches. An obvious question is, therefore, could rapid weight loss be detrimental to performance?

Studies involving rapid weight loss and performance revealed no performance decrement when a minimum of 5 hours was permitted for weight regain of 5% body weight or greater (Horswill, 1993; Klingzing &

Appendix A (continued)

Karpowicz, 1986; Webster, Rutt, & Weltman, 1990). These studies revealed that, although complete weight regain can require up to 20 hours, approximately 75% of lost body water can be replenished within 5 hours. In fact, performance has been found to be maintained with only a 44% regain of lost body water (Klinzing & Karpowicz, 1986).

In contrast, studies involving a minimum 5% body weight loss showed significant performance decrement when weight regain time was less than 5 hours. Anaerobic power and strength decreased significantly under these conditions (Hickner et al., 1991; Houston, Marrin, & Green, 1981; Webster, Rutt, & Weltman, 1990). Because most competitions allow for at least 5 hours of weight regain time between weigh-in and competition, it appears that performance, although not likely enhanced by rapid weight loss, is also not hindered. Thus, the possible chance of wrestling against a potentially smaller, lighter, and weaker opponent keeps the practice of rapid weight loss an important component of the sport.

In summary, weight cycling, or the rapid loss and regaining of a significant amount of body weight, plays a dominant role in the competitive season of most collegiate wrestlers. In theory, rapid weight loss creates an advantage over an opponent, however studies reveal no such advantage. In turn, it may appear that rapid weight loss could

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cause a performance decrement due to the significant amount of body weight lost over just a period of hours. However, previous studies revealed that performance can be maintained despite not always having sufficient time to regain all lost weight. Wrestlers, therefore, continue to take the chance that rapid weight loss will place them in a weight class with smaller, lighter, and weaker opponents.

Physiological Responses and Adaptations
to Rapid Weight Loss

According to scientific research, rapid weight loss accounts for numerous physiological responses and adaptations (Coleman, 1989; Fogelholm, 1994; Fogelholm, Koskinen, Laakso, Rankinen, & Ruokonen, 1992; Horswill, 1992a; Horswill, 1993; McMurray, Proctor, & Wilson, 1991; Tipton, 1990; Webster, Rutt, & Weltman, 1990; Zambraski, Tipton, Jordan, Palmer, & Tcheng, 1974). Despite their relative reversibility with adequate weight regain, it is important to acknowledge these physiological changes that the body repeatedly undergoes with each bout of rapid weight loss. As mentioned previously, the severity of response and adaptation is directly dependent upon the severity of the body weight loss (Horswill, 1992a). It is well beyond the scope and need of this paper to review all of the systems that are affected by rapid weight loss, therefore, only the most important will be discussed.

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Cardiovascular System

Rapid weight loss directly influences the cardiovascular system by reducing both total body water and plasma volume (PV) (Guyton, 1991). Reduced PV leads to a decreased stroke volume (SV). In order to maintain the same cardiac output, the heart rate is forced to work harder (Harrison, 1974; Noakes, 1994). In severe dehydration of greater than 8% body weight, cardiac output may be reduced and blood pressure has the potential to diminish as low as 80/55 mmHg from a norm of 120/80 mmHg (Lamb, Ingram, Johnston, & Pitman, 1984). Rapid weight loss of greater than 8% can also cause arrhythmias directly related to both the alterations in fluid volume and in the essential sodium and potassium balance necessary for normal cardiac rhythm (Dill & Costill, 1974; Harrison, 1974; Horswill, 1992a; Lamb, 1984; Noakes, 1994). The reduction in PV increases circulating blood osmolality stimulating the anterior hypothalamus to signal the pituitary gland to release antidiuretic hormone (ADH). The result is the promotion of water reabsorption at the kidneys (Lamb, 1984; Guyton, 1991).

Thermoregulatory System

The anterior hypothalamus acts as the body's temperature control center. Exercise causes an increase in blood flow to the skin with a corresponding increased rate of sweating as the body attempts to cool and regulate its core temperature. Despite the body's immediate attempt of temperature self-regulation at the onset of exercise, thermoregulatory impairment can occur as early as with a minimal 2% loss in body water (Lamb, 1984). Sustained dehydration of greater than 6% body weight impairs the body's ability to cool through sweating and forces body temperature to rise from its normal range of 97-100°F to 104-107°F with an impending risk of heat cramps, heat exhaustion, and heat stroke (Horswill, 1992a; Guyton, 1991; Lamb, 1984; Noakes, 1994).

Renal Function

Due to the diminished circulating PV, rapid weight loss causes the kidneys to be starved of an adequate blood supply. The result is a limited production of urine with that produced having elevated acidity and specifc gravity (Horswill, 1992a; Tipton & Opplinger, 1984). Urine specific gravity is an accurate measure of the severity of dehydration and has been recommended as a precompetition screening in order to prevent the severely dehydrated wrestler from competing. It has been recommended that urine specific gravity be greater than 1.020 prior to competition (Tipton & Tcheng, 1970). Severe dehydration of greater than 8% body weight has been associated with renal ischemia. While not yet researched, the long term effects of repeated episodes of renal ischemia on life-time renal function in wrestlers has been queried (Ribisl, 1978;

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Noakes, 1994).

In response to the diminished circulating blood volume, the kidneys release renin. Renin is the hormone responsible for stimulating angiotensin. Angiotensin stimulates the release of aldosterone from the adrenal cortex which is responsible for the reabsorption of both sodium and water in the kidneys. Their reabsorption is responsible for maintaining blood volume until the wrestler commences eating and drinking and naturally replaces blood volume (Guyton, 1991; Lamb, 1984; Noakes, 1994).

Metabolic System

The combination of food deprivation and excessive strenuous exercise may lead to reduced liver glycogen stores. However, this does not appear to have a significant effect on performance because of the nature of the sport itself. Wrestling is a strength and power sport relying on adenosine triphosphate (ATP) and creatine phosphate (CP) as a wrestler's preferred fuels. The short intense bursts of activity involved in a wrestling match do not rely heavily on glycogenolysis for energy (Horswill, 1992a).

The acute and chronic effects of rapid weight loss on the resting metabolic rate (RMR) remains debatable. One study comparing wrestlers "cutting weight" to those not "cutting weight", found that RMR in wrestlers was lowered following a season of rapid weight loss (Nelson-Steen, Opplinger, & Brownell, 1988). In contrast, other studies have found neither acute (i.e., the difference between RMR before and after one bout of rapid weight loss) nor chronic alterations (i.e., the difference between RMR before and after repeated bouts of rapid weight loss) in RMR (Horswill, 1993; Melby, Schmidt, & Corrigan, 1990).

Hormonal Secretion

A diminishing blood glucose level due to food deprivation is responsible for the secretion of a number of hormones. In the homeostatic state, the body maintains the important insulin-glucose balance, known as normoglycemia. Insulin is considered the key regulator of plasma glucose (Amiel et al., 1991). When blood glucose levels decrease, the body secretes hormones in attempt to dissipate excess insulin. Glucagon is the first and primary counterregulatory hormone responding to the glucose-insulin imbalance. Should the low plasma glucose levels persist due to a lack of glucagon response or a prolonged glucose deprivation such as in a prolonged fasting state, epinephrine is released. Growth hormone and cortisol are also released in small quantities at approximately the same time as the release of epinephrine. Research suggests that their role, although significant, is of less importance than the crucial release of glucagon and epinephrine

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(Cahill, 1970; Cherrington, Frizzell, Biggers, & Connolly, 1991; Santiago, Clarke, Shah, & Cryer, 1980; Schwartz, Clutter, Shah, & Cryer, 1987).

The release of these four hormones promotes both glycogenolysis and gluconeogenesis in an attempt to return the body to a state of glucose-insulin homeostasis. This is achieved by the central nervous system (CNS) sending efferent signals to the adrenal glands and pancreas for hormone release (Cahill, 1970). It has been suggested that the stimulation of glucose production could also include an increase in sympathetic drive and a decrease in parasympathetic drive to the liver (Cherrington, Frizzell, Biggers, & Connolly, 1991). There is no absolute blood glucose concentration threshold for the activation of these glucose-counterregulatory hormones. Individuals release these hormones at varying plasma glucose levels. However, the magnitude of the counterregulatory response is inversely related to the blood glucose concentration in all individuals (Santiago, Clarke, Shah, & Cryer, 1980).

Body Composition

The practice of rapid weight loss has been identified by both the medical and athletic communities as an unhealthy, unnecessary risk to wrestlers. Both the American Medical Association (AMA) and the American College of Sports Medicine (ACSM) have position statements denouncing the practice of rapid weight loss. Both suggest that proper

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dietary practices need to be emphasized so that body composition, rather than body weight, becomes the focus of attention (ACSM, 1976; AMA 1967).

Among collegiate athletes, wrestlers are the most lean. Body composition measurement by skinfold on several hundred wrestlers, including competitors such as heavyweights who do not “cut weight”, revealed an average of 11% body fat (Tcheng, Bowers, & Johnson, 1986). Other body composition studies found that the majority of wrestlers praciticing rapid weight loss have approximately 7% body fat (Nelson-Steen, Opplinger, & Brownell, 1988; Hirsh, 1976). The ACSM (1976) suggests that body fat be no lower than 5% for collegiate wrestlers whereas the AMA (1967) recommends that body fat be no lower than 7% for the same population. Suggested body fat measures are higher for the high school wrestler. Both the ACSM and the AMA suggest that body composition through skinfold measurement be done preseason and at regular intervals throughout the season (i.e., every two weeks). In addition, each wrestler's minimal weight should be calculated at the start of the season and monitored on a daily basis. A maximal weight loss of 2 lb per week is suggested as a safe and reasonable weight loss goal and should act as a means of assisting the wrestler to maintain weight loss rather than weight cycle (ACSM, 1976; AMA, 1967;

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Barnes, 1987; Horswill, 1992b; Tipton, 1990).

In summary, although rapid weight loss does not appear to have deleterious effects on athletic performance, it causes numerous physiological responses and adaptations, many being potentially deleterious in nature. Although the responses are reversible once weight regain commences, the fact that the body is forced to endure unnecessary and unhealthy stresses on a regular basis should not be overlooked. Generally, the long term effects of this process have yet to be studied. Body composition, rather than body weight, may be of greater importance from both a performance and physiological point of view when assessing wrestling status.

Cognitive Effects of Rapid Weight Loss

The CNS requires a continuous supply of glucose. The brain cannot synthesize glucose, extract glucose from the circulatory system against a concentration gradient, nor store more than a few minutes supply of glucose at any one time. Thus, it is crucial that the body maintain adequate blood glucose concentrations (Cryer, 1981; Cryer et al., 1989; Gerich, Cryer, & Rizza, 1980; Heller & Cryer, 1991; Nathan & Cahill, 1992).

As mentioned previously, a less than normal amount of glucose in the blood plasma is known as hypoglycemia and is usually caused by an

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excessive secretion of insulin in relation to dietary glucose intake in the nondiabetic person (Glanze, 1986). Because signs and symptoms of hypoglycemia occur at varying levels among individuals, it is difficult to define a specific glucose level that predictably causes clinical hypoglycemia. The normal blood glucose level ranges from 75 mg/dL to 145 mg/dL (Krupp, Tierney, Jawetz, Roe, & Camargo, 1985). It is not uncommon for an individual to have clinically low blood glucose levels with no signs or symptoms of hypoglycemia. When manifest, however, hypoglycemia may cause sympathetic nervous system mediated symptomology such as anxiety, sweating, tachycardia, palpitations, tremors, and hunger or as cerebral dysfunction such as confusion, irritability, and headache (Amiel et al., 1991; Cahill, 1970; Cherrington, Frizzell, Biggers, & Connolly, 1991; DeFeo et al., 1988).

Hypoglycemia is normally associated with diabetes whereby, without careful diet control and/or subcutaneous insulin injection, blood glucose levels can become dangerously low. Changes in cognitive function have been noted during episodes of hypoglycemia in nondiabetics, and more prominently in diabetics. This change in cognitive function as a result of hypoglycemia is known as neuroglycopenia (Brozak, 1955; DeFeo et al., 1988; Pramming, Thorsteinsson, Stigsby & Binder, 1988; Smith-Holmes, Hayford,

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Gonzalez, & Weydert, 1983; Widom & Simonson, 1992).

A number of studies involving hypoglycemia and various aspects of cognitive function have been conducted (Brozek, 1955; DeFeo et al., 1988; Dickie & Bender, 1982; Ipp & Forster, 1987; Mellman, Davis, Brisman, & Shamoon, 1991; Politt, Leibel, & Greenfield, 1981; Pramming, Thorsteinsson, Stigsby, & Binder, 1988; Pramming, Thorsteinsson, Theilgaard, Pinner, & Binder, 1986; Smith-Holmes, Hayford, Gonzalez, & Weydert, 1983; Widom & Simonson, 1990). A lack of consistency exists in the types of subjects used (e.g., poorly controlled diabetics versus well controlled diabetics and nondiabetic healthy subjects) and the method used to evaluate cognitive function (e.g., cognitive test batteries, electroencephalograms, and the P300 auditory wave). Hypoglycemia and cognitive function has yet to be researched in the collegiate wrestler practicing rapid weight loss.

In a study involving individuals with insulin dependent diabetes mellitus (IDDM), cognitive function was assessed through a battery of cognitive tests evaluating attention, short term memory (STM), distractability, and visual acquity during four different plasma glucose levels. Blood glucose was dropped by an intravenous injection of insulin until blood glucose levels of 113.5 mg/dL, 52.3 mg/dL, 34.4 mg/dL were achieved. The final cognitive testing was completed with a blood glucose of 109.9 mg/dL. This was achieved by stopping the insulin infusion and allowing blood glucose levels to rise. Cognitive function was significantly impaired when blood sugar was at or below 52.3 mg/dL despite the denial of subjective signs and symptoms of hypoglycemia. It was only when blood sugar was at 34.4mg/dL that subjects admitted to feelings of hypoglycemia (Pramming, Thorsteinsson, Theilgaard, Pinder, & Binder, 1986).

In a study using the same battery of cognitive tests, both IDDM subjects and nondiabetic subjects showed significant cognitive impairment with blood glucose levels below 60 mg/dL (Widom & Simonson, 1990). Both groups showed insignificant change in tests of attention and memory but significant change in tests of visual spatial and visual acquity, such as timed tests requiring the subject to cross out specific letters from a lengthy list or tracing specific patterns with a pen. IDDM subjects and nondiabetic subjects differed only in terms of hypoglycemic symptom identification whereby nondiabetic subjects identified symptoms earlier in the induced hypoglycemia than the IDDM subjects. This may suggest that IDDM subjects adapt and become less sensitive to deleterious hypoglycemic symptoms. This finding may be applicable to wrestlers who weight cut frequently throughout the season in comparison to those who cut weight only a few times during the season. Those practicing rapid weight loss frequently may adapt to the state of hypoglycemia and be more tolerant of the food and water deprivation, whereas the infrequent "cutter" may be less tolerant and suffer throughout the process. This, however, is speculation, as it has yet to be investigated in wrestlers.

An electroencephalogram to evaluate the glycemic threshold at which brain function becomes impaired was used in two studies involving IDDM patients. A slowing of brain wave movement was noted in both studies only when blood glucose levels were below 46 mg/dL. As hypoglycemia continued, there was a continued slowing of brain wave activity suggesting a further decrease in excitatory, with an accompanying increase in inhibitory, post synaptic potentials (Pramming, Thorsteinsson, Stigsby, & Binder, 1988; Smith-Holmes, Hayford, Gonzalez, & Weydert, 1983).

In a study involving nondiabetic subjects, cognitive function was assessed using a test battery which evaluated attention, visual acquity, and STM. Plasma glucose levels decreased from 90 mg/dL to 50 mg/dL over a period of 90 minutes at which time plasma glucose was immediately returned to 90 mg/dL and then diminished by 10 mg/dL every 40 minutes until 50 mg/dL was reached. This was achieved through intravenous administration of insulin. Significant alterations in all tested cognitive domains was experienced when blood sugar reached 50 mg/dL. Nonsignificant changes were noted when blood sugar slowly decreased every 40 minutes. It was also noted that cognitive function was less affected during the second hypoglycemic episode of 50 mg/dL suggesting adaptation occurred to the recurrent hypoglycemia (Mellman, Davis, Brisman, & Shamoon, 1994).

In another study involving nondiabetic subjects, nonsignificant changes in cognitive function were noted during mild and moderate hypoglycemia with blood glucose levels reaching 54mg/dL following administration of insulin. A significant decrement in cognitive function, evaluated through the administration of a short cognitive test battery, was noted only when blood glucose levels reached 40 mg/dL (Ipp & Forster, 1987).

The latency P300 wave, which reflects active cognition and implies both acoustic perception and cognition to stimuli, is considered to be the most sensitive method of evaluating brain cortical function at the onset of neuroglycopenia. The P300 wave sends out acoustic tones of 80 decibels (db) at varying frequencies via earphones to the subject who attempts to count the number of successive tones presented. This technique was used in a study evaluating changes in STM and attention in both IDDM and nondiabetic patients (DeFeo et al., 1988). This study

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revealed significant changes in cognitive function starting at 72 mg/dL although subjective identification of hypoglycemia only occurred with blood glucose levels below 50 mg/dL. Researchers suggested that the P300 wave is much more sensitive than either electroencephalograms or cognitive test batteries, and thus able to more accurately identify changes in cognitive function as early as 15 mg/dL below an individual's resting plasma glucose level.

One of the earliest studies involving neuroglycopenia involved a five day food deprivation period with unlimited consumption of water (Brozek, 1955). Plasma glucose levels decreased from 80 mg/dL to 60 mg/dL. Considering the amount of time in which subjects were without food, this blood glucose level was surprisingly high. Despite experiencing symptoms of hypoglycemia such as weakness, fatigue, and palpitations, subjects showed nonsignificant changes in both cognitive and motor testing and remained resistent to the stress brought about by food deprivation. The researcher suggested that highly motivated individuals, when placed in a testing situation, may be resistent to physiological stressors.

Similar results were found when testing 12 year old schoolchildren in a classroom environment. Researchers evaluating the importance of school breakfast programs studied cognitive function in

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children who habitually skipped breakfast and in those who regularly consumed breakfast. Using a letter cancellation test to evaluate cognitive function, no significant difference was found between breakfast eaters and non-breakfast eaters in terms of their percent change in speed and accuracy. Thus, after a 16 hour fast, it appeared that the schoolchildren were able to sufficiently arouse themselves to perform normally for the short test duration. Researchers suggested that this arousal may have been due to the children's knowledge that they were in a test situation. However, regardless of this knowledge, it was displayed that with adequate motivation, brain function may be quite resistent to food deprivation (Dickie & Binder, 1982).

In another study evaluating the importance of a school breakfast program and cognitive function of schoolchildren, breakfast was withheld and a fast of 18 hours was created for regular breakfast eaters and non-breakfast eaters alike. Mathematical problem solving and STM were assessed through a short battery of cognitive tests. Results revealed an improvement in immediate recall in STM with an adverse effect on problem solving when breakfast was witheld. The schoolchildren, although still able to problem solve, required significantly more time to complete the process. No difference was found between the two groups in terms of cognitive function or change in blood glucose levels. Both

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groups maintained blood glucose levels of approximately 70 mg/dL (Pollitt, Leibel, & Greenfield, 1981).

In summary, cognitive function may be altered during the hypoglycemic state. However, there is no precise blood glucose level at which cognitive changes occur in all individuals. In addition, while blood glucose levels may indicate clinical hypoglycemia, subjective identification of hypoglycemic signs and symptoms may not occur until a more severe hypoglycemic state results. The majority of research conducted in regard to cognitive function and hypoglycemia has been conducted with IDDM patients with varying severity of the disease. In addition, a variety of test protocols have been used such as cognitive test batteries, electroencephalograms, and the P300 wave. These two conditions may be responsible for the lack of consistency in clearly understanding both the plasma glucose level at which cognitive function is altered and the exact domain of cognitive function affected. While it is suggested that cognition can be impaired during hypoglycemia, it has been demonstrated in the classroon setting that the highly motivated person may be resistent to neuroglycopenia.

Summary

Rapid weight loss, or "cutting weight", remains widely practiced among wrestlers despite its apparent inability to create the physical

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advantage that is believed to occur with this process. Wrestlers typically lose between 7 and 21 lb within 36 hours of competition. Once they "make weight", their aim is to return to their normal weight prior to competition.

The deleterious effects of rapid weight loss far outweigh the possible advantage created over an opponent. Both the ACSM and the AMA have position statements denouncing the practice of rapid weight loss. Rapid weight loss alters the essential body water and glucose-insulin balances, thus forcing the cardiovascular, thermoregulatory, and renal systems to respond and adapt.

According to the ACSM and the AMA, body composition, rather than body weight, should be the emphasis. Wrestlers are among the leanest athletes. It is suggested that the minimal body fat measure for a collegiate wrestler be no less than 5% to 7%. Body composition measurement is recommended both preseason and at regular intervals throughout the season to assist wrestlers in using more appropriate means toward long term weight loss.

Hypoglycemia has been shown to affect the CNS and in particular, the domain of cognitive function. A number of studies have been done involving individuals with IDDM and healthy elementary schoolchildren. Research indicates that cognitive function is impaired with blood glucose

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levels of 70 mg/dL yet more commonly when blood glucose levels are at or below 55 mg/dL. Subjective signs and symptoms of hypoglycemia may not accompany diminished blood glucose levels. There is some evidence to suggest that the brain becomes more and more resistent to hypoglycemia with each repeated episode.

Many collegiate wrestlers practice some degree of rapid weight loss during their athletic careers. Optimal performance, both as an athlete and student, can only be achieved with optimal health and well-being. Studies have provided valuable insight on both the common practice and physiological effects of rapid weight loss. However, the possible impact that rapid weight loss has on cognitive function is yet to be evaluated in a research setting in this population. While the physiological effects of rapid weight loss on performance in wrestlers continues to be studied, the research focus must also be directed toward the effect on cognitive function in these athletes who are, first and foremost, students.

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Appendix B

TABLE OF SUBJECT CHARACTERISTICS

Group		Age (yrs)	Hgt (cm)	Wgt (kg)	Years of wrestling
Wrestlers	M	19.50	154.19	75.35	6.29
	SD	1.29	6.46	8.84	1.54
Controls	M	20.36	158.54	83.16	-
	SD	1.15	6.21	12.97	-

Appendix C

INFORMED CONSENT FORM

1. Purpose of the Study: The purpose of this investigation is to examine the effects of rapid weight loss on cognition in such domains attention span, short term memory, concentration, visual acuity, and visuomotor skills.

2. Benefits of the Study: The participants will have the opportunity to have underwater weighing done for body composition. Participants may gain insight into how rapid weight loss affects their own cognitive function.

3. What You Will Be Asked to Do: You will be tested on three separate occasions: preseason (first test session), rapid weight loss (second test session), and 72 hours later following rehydration (third test session). For non-wrestling control subjects, you will be tested in the same time periods. You will firstly complete a mood profile, a hypoglycemic (blood sugar) profile, and five short cognitive tests. You will then be weighed and then have a small blood sample taken from a vein in your arm. Preseason and again at the end of the season, you will be underwater weighed. You will be asked to maximally exhale into a special mouthpiece prior to entering the tank. Once in the tank, you will go under the water about 10 times and maximally exhale for

initials ___________

Appendix C (continued)

approximately 10 seconds each time, allowing the appropriate measurements to be made. To complete the series of testing just explained will take approximately one hour at the preseason test session and approximately 20 minutes at the rapid weight loss and rehydration test sessions.

4. Risks of Participation: There are very few, if any, risks in participating in this study. The cognitive tests are not intelligence tests but rather short aptitude tests indicating current momentary cognitive performance. You will be exposed to and have the opportunity to try samples of these tests prior to the the start of the study. These tests may result in some frustration, however, you should realize that this is normal and short-lived. In terms of the physical testing, only a very small amount of blood will be drawn (less than 3 milliliters) and a complete sterile technique will be maintained at all times. You may experience momentary discomfort due to the torniquet placed on your arm in order to facilitate in making your arm veins dilate along with the initial sensation of the needle. However, all blood samples will be drawn by a trained phlebotomist. You may experience a small amount of bruising at the site of the blood sample, but this will dissipate within a few days. Underwater weighing will be done by experienced testers and thorough instructions

initials __________

Appendix C (continued)

will be given prior to the test itself. Both the room and the water will be at comfortable temperatures. You may experience some shortness of breath as you will be required to give several maximal exhalations when under the water. However, the testers are sensitive to your situation and will always give you adequate time to recover. There is a small ladder and bar for which you can hold onto while at rest in the water tank. At all times, you will be able to communicate with the tester.

5. Confidentiality: Your results will not be made available to anyone other than the investigator(s) and to you upon your request. The results of this study will only be subsequently described in group format.

6. If You Would Like More Information About The Study: If you have questions about the study, or would like to learn about the results of the study following its completion, you can reach Celeste Choma at 277-2807 or Dr. Sforzo at 274-3359.

7. Withdrawal From the Study You may withdraw from participating in the study at any time without any pressure to continue.

I have read the above, understand its contents, and agree to participate in this study. I acknowledge that I am 18 years of age or older.

____________________________ ____________

Participant's Signature Date

Appendix D

DATA INFORMATION SHEET / QUESTIONNAIRE

Please take a few moments to answer the questions on this form. If a question does not pertain to you (i.e., some of the questions may only apply to wrestlers), please indicate that it is not applicable by writing N/A. **If you do not feel comfortable in answering all of the question, please answer only those that you feel you can.**

Name ____________________________ Age _______ DOB___/___/___

Phone ____________________

College Status: Freshman ___ Sophmore ___

Junior ___ Senior ___

Numbers of years of competitive wrestling __________

Are you presently following a special diet (i.e., calorie restricted)?

Yes No

If yes, indicate **type** and **length of time** you have been following this diet.

Are you presently attempting to lose weight?

Yes No

If yes, **how many pounds** and over what **period of time?**

Appendix D (continued)

How many meals do you eat each day? ______/day

How many snacks do you eat each day? ______/day

Circle the hours in which you would typically eat your meals.

AM 12 1 2 3 4 5 6 7 8 9 10 11

PM 12 1 2 3 4 5 6 7 8 9 10 11

Circle the hours in which you would typically eat snacks.

AM 12 1 2 3 4 5 6 7 8 9 10 11

PM 12 1 2 3 4 5 6 7 8 9 10 11

Have you **lost or gained** weight in the **last 3 months?** If yes, approximately how many pounds?

If you have lost or gained weight in the last 3 months, was this **intentional** (diet and/or exercise) **or unintentional** (illness or reason unknown)?

Do you plan on commencing a diet regimen over the next 5 months?

Yes No

Appendix D (continued)

Have you ever attempted to lose a large amount of weight **rapidly** (wrestlers and non-wrestlers may answer)? **If yes**, when was the last time?

If you have lost a large amount of weight rapidly in the past, what was the **average** amount of weight that you attempted to lose? For **how many successive days** did you continue this practice?

What is the **maximum** amount of weight that you have lost through rapid weight loss?

How often (i.e., number of times) do you weight cut in one competitive season?

What is your **routine** or **technique** for "cutting weight"?

Appendix D (continued)

Indicate the practices that you have used to assist in losing weight rapidly.

___ caloric restriction

___ fluid restriction

___ long duration aerobic exercise

___ exercising in rubber suits

___ other (indicate method) ______________________________

___ diuretics

___ laxatives

___ vomiting

___ sauna

How would you rate weight loss in relation to **degree of importance** to your success as a collegiate wrestler .

___ no importance at all

___ little importance

___ some importance

___ importance

___ great importance

___ an absolute must

Appendix E

BODY COMPOSITION ANALYSIS - UNDERWATER WEIGHING

Body density (D) was estimated using densitometry. Subjects completed 7-10 trials of underwater weighing (UWW) in order to minimize each subject's individual variability in UWW scores (Katch, Michael, & Horvath, 1967). Body volume was calculated using the mean of the last three trials. Body mass (Mb) was measured to the nearest 50 g (Detecto Medic, Detecto Scales Inc., Brooklyn, NY). Hydrostatic weight (Mw) was measured using a S-type force transducer (Transducers Inc., Cerritos, CA) coupled to a microcomputer for body composition calculation via an A-D conversion system. This measurement, following correction for residual volume (RV), was used to calculate D as follows:

$$D = (Mb \times Dw / (Mb - Mw - RV \times Dw) \text{ where}$$

$$Dw = \text{water density}$$

The equation of Siri (1956) was used to estimate percent fat (% fat). Lean body mass (LBM) was calculated as follows:

$$LBM = Mb - (Mb \times \% \text{ fat} / 100).$$

Prior to UWW, residual lung volume was determined using the closed-circuit oxygen dilution method (Wilmore, 1969). Subjects were seated in the same posture that would be used during hydrostatic weighing. Two separate trials of RV were completed (Nitrogen Analyzer System Model 5000, Consulting Western Services, Lakewood, CA;

Survey Spirometer, Warren E. Collins, Braintree, MA). The mean of the two trials represented RV.

Katch, F., Michael, E., & Horvath, S. (1967). Evaluation of body volume by underwater weighing: Description of a simple method. Journal of Applied Physiology, 23, 811-815.

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Appendix F

ANALYSES OF VENOUS BLOOD SAMPLES

All blood samples were collected by a trained phlebotomist. Approximately 3 mL of venous blood was collected at each test session (Precision Glide Vacutainer System, Bectin Dickinson & Co., Rutherford, NJ). Hgb (Stat Test System, Stat Chem Inc., Bohemia, NY) and Hct (Read-a-crit Centrifuge, Clay Adams, Division of Becton Dickinson & Co., Parsippany, NJ) were immediately analyzed. PV was calculated using the formulae of Dill and Costill (1974):

$$BV_a = 100(Hgb_b / Hgb_a)$$

$$CV_a = BV_a(Hct_a)$$

$$PV_a = BV_a - CV_a$$

$$PV_b = BV_b - Hct_b$$

Where:

BV_a = blood volume after dehydration in (mL).

100 = blood volume before dehydration in (mL).

Hgb_b = hemoglobin before dehydration in (g/dL).

Hgb_a = hemoglobin after dehydration in (g/dL).

CV_a = red cell volume after dehydration in (mL).

Hct_a = hematocrit after dehydration in (%).

Appendix F (continued)

PV_a = plasma volume after dehydration in (mL).

PV_b = plasma volume before dehydration in (mL).

Hct_b = hematocrit before dehydration in (%).

Dill, D.B., & Costill, D.L. (1974). Calculation of percentage changes in volume of blood plasma, and red cells in dehydration. Journal of Applied Physiology, 37, 247-248.

Appendix G

PROFILE OF MOOD STATE (POMS-R)

Below is a list of words that describe feelings. Fill in the appropriate circle that describes how you are feeling AT THIS VERY MOMENT.

0 1 2 3 4 5

none moderate extreme

TENSE	0 1 2 3 4	NERVOUS	0 1 2 3 4
ANGRY	0 1 2 3 4	LONELY	0 1 2 3 4
WORN OUT	0 1 2 3 4	MUDDLED	0 1 2 3 4
LIVELY	0 1 2 3 4	EXHAUSTED	0 1 2 3 4
CONFUSED	0 1 2 3 4	ANXIOUS	0 1 2 3 4
SHAKY	0 1 2 3 4	GLOOMY	0 1 2 3 4
SAD	0 1 2 3 4	SLUGGISH	0 1 2 3 4
ACTIVE	0 1 2 3 4	WEARY	0 1 2 3 4
GROUCHY	0 1 2 3 4	BEWILDERED	0 1 2 3 4
ENERGETIC	0 1 2 3 4	FURIOUS	0 1 2 3 4
UNWORTHY	0 1 2 3 4	EFFICIENT	0 1 2 3 4
UNEASY	0 1 2 3 4	FULL OF PEP	0 1 2 3 4
FATIGUED	0 1 2 3 4	BAD-TEMPERED	0 1 2 3 4
ANNOYED	0 1 2 3 4	FORGETFUL	0 1 2 3 4
DISCOURAGED	0 1 2 3 4	VIGOROUS	0 1 2 3 4

Educational and Industrial Testing Service (EdITS), San Diego, CA

Appendix H

HYPOGLYCEMIC PROFILE

Please circle the appropriate number which is indicative of how you are feeling AT THIS MOMENT. There are no right or wrong answers.

0	1	2	3	4	5	6	7	8	9	10
none					moderate					severe

CONFUSION

0 1 2 3 4 5 6 7 8 9 10

DIFFICULTY IN THINKING

0 1 2 3 4 5 6 7 8 9 10

FAINTNESS

0 1 2 3 4 5 6 7 8 9 10

DIZZINESS

0 1 2 3 4 5 6 7 8 9 10

BLURRED VISION

0 1 2 3 4 5 6 7 8 9 10

SHAKINESS

0 1 2 3 4 5 6 7 8 9 10

SWEATING

0 1 2 3 4 5 6 7 8 9 10

POUNDING OF THE HEART

0 1 2 3 4 5 6 7 8 9 10

NERVOUSNESS

0 1 2 3 4 5 6 7 8 9 10

FEELING OF BEING DIFFERENT IN ANY WAY

0 1 2 3 4 5 6 7 8 9 10

Appendix H (continued)

Schwartz, N.S., Clutter, W.E., Shah, S.D., Cryer, P.E. (1987). Glycemic thresholds for activation of glucose counterregulatory systems are higher than the threshold for symptoms. Journal of Clinical Investigations, 79: 777-781.

Appendix I

COGNITIVE TEST BATTERIES (3) AND SCORING PROCEDURES

Appendix I

COGNITIVE TEST BATTERY I

Letter Cancellation

NAME ____________________ DATE ___________ SUBJ#______

You have 90 seconds to cross out the bracketed letter each time it appears in that line. At the end of the line, put the total number of times it was crossed out. WORK AS QUICKLY AS YOU CAN.

{H} B K F H E W O H Q C E H U Y K O L D W V H I A C E N M O
{G} H D H T I W V E G R I P O L U H T G R E X W F T U N M G Y
{E} Q D B R U I O E F R N V Z Q A T I E O P L U E V T H E B N I
{D} W Q J U O L P D E G T V U M Y D T O P I F D E S W D R B I
{S} N S G Y R N M K P Q S F V X U O T B F A V S B G S H Y I U
{B} A S Q B V C G N M U O P F B T E N B Y U B J K I E D S B C
{V} M E H Y P O L W D E G V T U Q A X V Y B N E S V E W V Y
{N} O P U P L W D R H G V F R J U K O N E N E W T N U O M H
{Z} Q W H Y O P E F T N Z A F G T H B Z W Q Z E T I Y X Z A Z I
{C} E R U M N Y R C W V E C T B T Q X E V N U M O T B C E U
{Y} Y U N B E Y T W A C S V E Q Y O P L K I M E C T B Y U I M
{F} D W G T B F N J U K I O Q X F E G F R Y H R F E T Y M O I T
{K} K D V G N K M U K O L E F D V E Q X T Y U N I O P W C E I
{R} N Q R Y O P L K M V R B T I O Q C R E R Y T N U M O R F E
{N} S V R B Y J U O S N G T B Y M I O N E B R V Z X W B N U I
{B} W X V E B E H N T M U B R Y T B R W Q C E O P L M N V T
{M} I C B R Y N T E B N V B T M H N U I O L E N T M I U P L R C
{P} T H I K O L P Q D R V Y J I U T H B R W Q V F R T I Y J U T T
{Y} Y W D V G T E S Y H T E C S W D E S E T Y U N Y B T U M

Appendix I (continued)

Digit Symbol

Below is a series of numbers which are individually associated with a particular symbol. AS QUICKLY AS YOU CAN, fill in the empty box with the appropriate symbol. You have 90 seconds. YOU MUST WORK FROM LEFT TO RIGHT AT ALL TIMES.

1	2	3	4	5	6	7	8	9
—	⊥	⊐	L	⊔	O	Λ	X	=

2	1	3	7	2	4	8	2	1	3	2	1	4	2	3	5	2	3	1	4	5	6	3	1	4

1	5	4	2	7	6	3	5	7	2	8	5	4	6	3	7	2	8	1	9	5	8	4	7	3

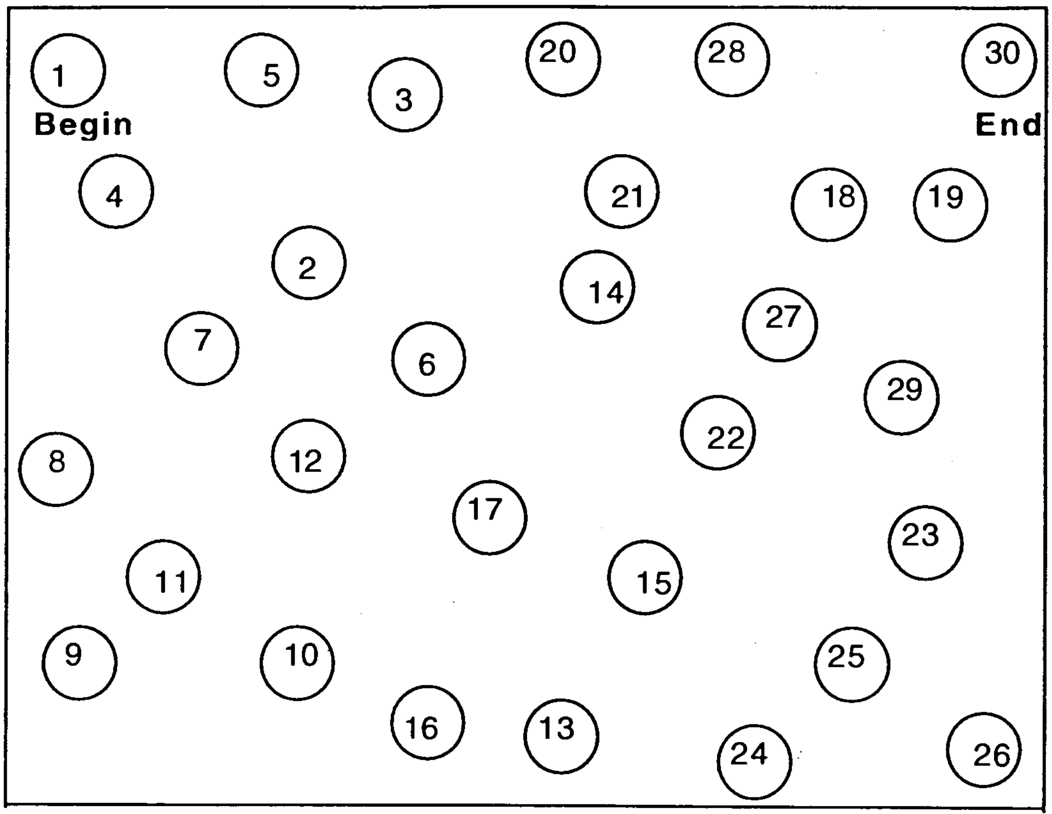
6	2	5	1	9	2	8	3	7	4	6	5	9	4	8	3	7	2	6	1	5	4	6	3	7

9	2	8	1	7	9	4	6	8	5	9	7	1	8	5	2	9	4	8	6	3	7	9	8	6

Appendix I (continued)

Trailmaking A

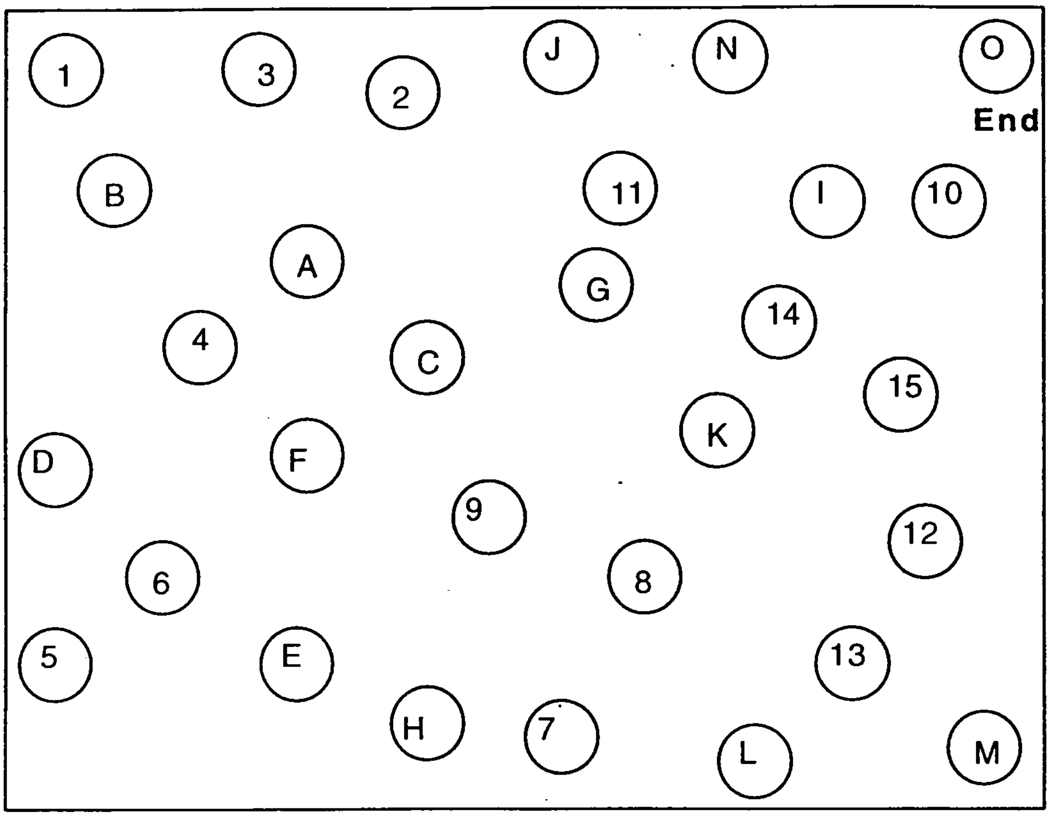
As quickly as you can, connect 1 through 30 with your pen. Ready, set ...



Appendix I (continued)

Trailmaking B

As quickly as you can, alternate and connect 1 - A - 2 - B - 3 - C - 4 - D - ...



Appendix I (continued)

Digit Span

Digit Span Forward Subtest

"I am going to say some numbers and when I am through, I want you to say them back to me in the same order".

(Complete as pairs and then move left to right)

6-4-3-9	4-2-7-3-1	6-1-9-4-7-3
7-2-8-6	7-5-8-3-6	3-9-2-4-8-7
5-9-1-7-4-2-3		5-8-1-9-2-6-4-7
4-1-7-9-3-8-6		3-8-2-9-5-1-7-4

Digit Span Backward Subtest

"I am going to say some numbers and when I am through, I want you to say them back to me in the reverse order in which they were presented. For example, if I say 3-7-6, you should say back to me 6-7-3 ".

(Complete as pairs and then move left to right)

2-8-3	3-2-7-9	1-5-2-8-6
4-1-5	4-9-6-8	6-1-8-4-3
5-3-9-4-1-8		8-1-2-9-3-6-5
7-2-4-8-5-6		4-7-3-9-1-2-8

Appendix I (continued)

Story Recall

"I am going to read to you a little selection of about four to five lines. Listen carefully because when I am through I want you to tell me everything I read in the order in which it was read to you".

Story Recall Subtest A

Anna Thompson / of south / Boston / employed / as a scrub woman / in an office building / reported / at the City Hall / Station / that she had been held up / on State Street / the night before / and robbed / of fifteen dollars /. She had four / little children / the rent / was due /, and they had not eaten / for two days. The officers /, touched by the woman's story /, made up a purse for her /.

Story Recall Subtest B

The American / liner / New York / struck a mine / near Liverpool / Monday / evening /. In spite of a blinding / snowstorm / and darkness /, the sixty / passengers, including eighteen / women /, were all rescued / though the boats / were tossed about / like corks / in the heavy sea /. They were brought into port / the next day / by a British / steamer /.

Appendix I (continued)

COGNITIVE TEST BATTERY II

Letter Cancellation

NAME ____________________ DATE __________ SUBJECT# ______

You have 90 seconds to cross out the bracketed letter each time it appears in that line. At the end of the line, put the total number of times it was crossed out. WORK AS QUICKLY AS YOU CAN.

{R} W D V R Y W T Y Q J K I Y R O P L M N B Q D E R T Y J I P R
{T} Q E T Y N T I O P W D C T N Y C R T I M E Q T I O P N Y M C
{U} A C D V T Y U I P L K M N R T U Q E C T V S C T U K O P G
{K} A C D B N M I U P L Q F E V Y B U I K I K E C E I L P W C X Z
{C} S V F G B J N V I P L I M B C E V B N A X E C T B I P L I C E V
{W} W S V N B T U Y I T D W C R V W T B U N O P N Y I P W Q C
{J} S C R B H N O P Q F R V H S J E T Y U Q A X Z V R B Y M J
{S} X D C W S R V T S W F H U I K N M G B S E C R G S D C J I
{A} U P A W C A V B H N U I M O T R G B A W X C Z V F R U N I Y
{Y} W X E F V T Y N Y N I O P K M N V R Y R Y R E W X Y V R C
{E} G B W C T E G R V Y N T X W E V T N U I O P G H N R E C W
{N} N M N R V Y B U N I M N T V R C W X W V B T N Y M I O Y O
{O} W O P L I J N M T Y O U T V R Y B U N T E Q X E C R V T B O
{H} A V R H Y B U N T B H R V E V Y H U M O P L E Y N T I W E B
{L} Q R B A C E V L K J U L P N M T G J M L P O L D E W G B D E
{B} D M U P L Q S D E V T B Y B R C W D Y N M I P O L U N F E I
{F} C G J B T F W F T U O P L M N H B D C R A D F T F E B Y H T
{S} S B G N K M U L O P S E C A S T H Y I O C D V R A Q S R T I
{A} D H N Y B F E S D W A X W A Q G T H I P O A X C Z F R H U I

Appendix I (continued)

Digit Symbol

Below is a series of numbers which are individually associated with a particular symbol. AS QUICKLY AS YOU CAN, fill in the empty box with the appropriate symbol. You have 90 seconds. YOU MUST WORK FROM LEFT TO RIGHT AT ALL TIMES.

1	2	3	4	5	6	7	8	9
—	⊥	⊐	L	⊔	O	Λ	X	=

2	1	3	7	2	4	8	2	1	3	2	1	4	2	3	5	2	3	1	4	5	6	3	1	4

1	5	4	2	7	6	3	5	7	2	8	5	4	6	3	7	2	8	1	9	5	8	4	7	3

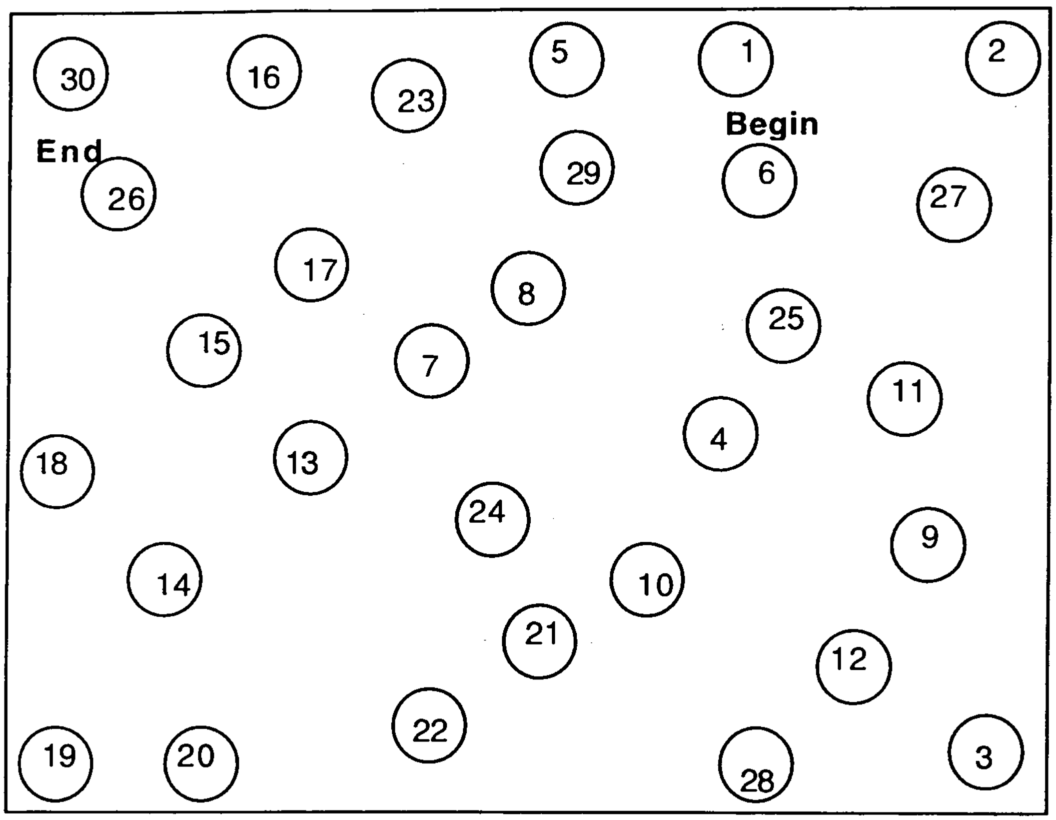
6	2	5	1	9	2	8	3	7	4	6	5	9	4	8	3	7	2	6	1	5	4	6	3	7

9	2	8	1	7	9	4	6	8	5	9	7	1	8	5	2	9	4	8	6	3	7	9	8	6

Appendix I (continued)

Trailmaking A

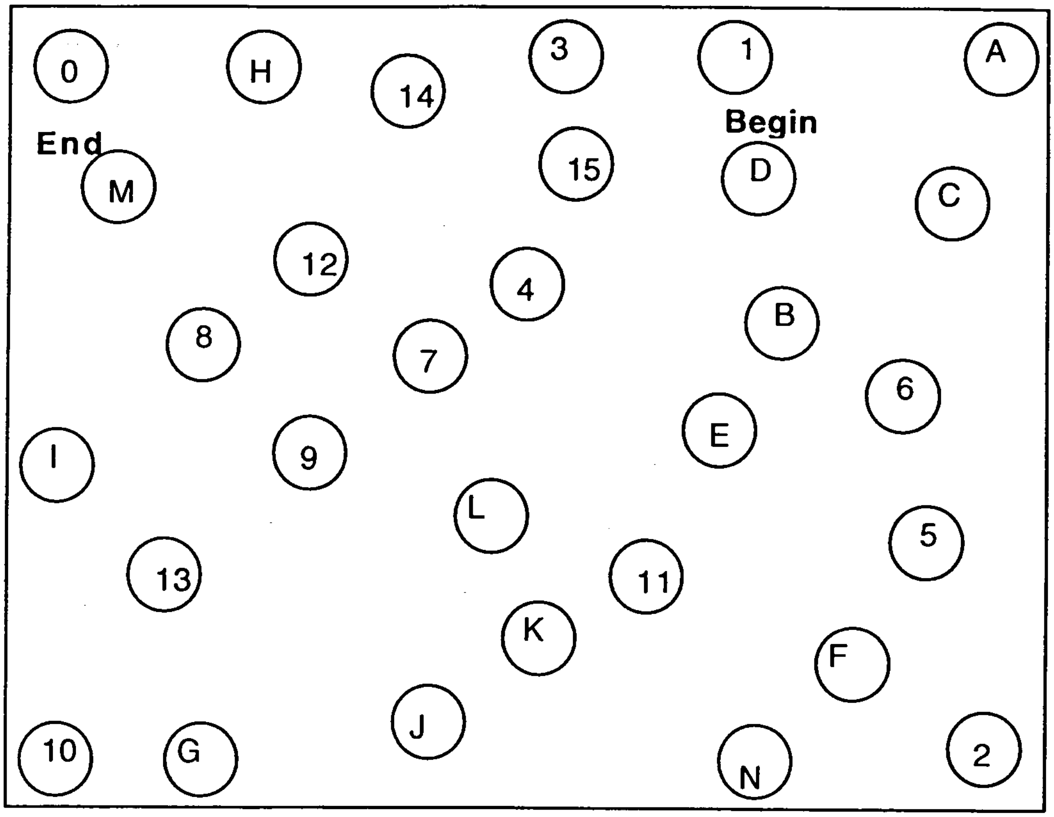
As quickly as you can, connect 1 through 30 with your pen. Ready, set, ...



Appendix I (continued)

Trailmaking B

As quickly as you can, alternate and connect 1-A - 2 - B - 3 - C - 4 - D - ...



Appendix I (continued)

Digit Span

Digit Span Forward Subtest

"I am going to say some numbers and when I am through, I want you to say them back to me in the same order".

(Complete as pairs and then move left to right)

2-8-6-1 5-3-9-4	7-4-2-9-6 8-5-1-6-4	8-4-2-7-5-1 7-2-9-5-3-6
7-4-8-2-5-9-1 8-3-9-6-1-5-2		2-6-9-5-8-3-7-1 3-7-2-9-4-1-5-8

Digit Span Backward Subtest

"I am going to say some numbers and when I am through, I want you to say them back to me in the reverse order in which they were presented. For example, if I say 3-7-6, you should say back to me 6-7-3 ".

(Complete as pairs and then move left to right)

7-5-1 2-9-6	3-5-8-2 9-6-1-7	4-7-1-8-6 3-9-2-6-1
6-3-9-1-5-8 4-8-1-6-3-7		5-4-9-2-7-3-6 2-5-1-9-4-7-3

Appendix I (continued)

Story Recall

"I am going to read to you a little selection of about four to five lines. Listen carefully because when I am through I want you to tell me everything I read in the order in which it was read to you".

Story Recall Subtest A

Dogs / are trained / to find / the wounded / in war time /. Police dogs / are also trained / to rescue / drowning people /. Instead of running / down to the water / and striking out /, they are taught / to make / a flying leap / by which they save / many swimming strokes / and valuable / seconds of time /. The European sheep dog / makes the best / police dog /.

Story Recall Subtest B

Many / school / children / in northern / France / were killed / or fatally hurt /, and others / seriously injured /, when a shell / wrecked / the schoolhouse / in their village /. The children / were thrown / down a hillside / and across / a ravine / a long distance / from the schoolhouse /. Only two / children / escaped uninjured /.

Appendix I (continued)

COGNITIVE TEST BATTERY III

Letter Cancellation

NAME ____________________ DATE __________ SUBJ # ________

You have 90 seconds to cross out the bracketed letter each time it appears in that line. At the end of the line, put the total number of times it was crossed out. WORK AS QUICKLY AS YOU CAN.

{C} A X E C R F G B Y H N I K O L P M N B C D X W C V B T C R
{S} W D S C R V G B T V H Y U J I K O L P W S E D S E D E S E
{M} F V G B H N B V M J M U OI O U T R E W C E Q X E C N M U
{Q} A X C D X Q E R T V T B R C W Q I O P L U Q A S C E Q B H
{G} S C F V G B G B Y J I K O K J H F G R V C E X E V T N J L I T
{J} Z C V B N E C T H B U I M O L P W X R T B A Q C T V D C Y
{U} Z C V E D T B Y N U I K T U O P L M U H R V C W X Y U N T
{D} A X Z C D E V T Y D E F H N M K L O P J U H T G U I N M S
{X} V B N M J H A X S W X V T G U N M O P L I M N X W S A C R
{I} A V F B J N I M O P L M K I U Y T E C X V T Y I M N B A X C E
{O} E T B Y N I M O P L J M N C X Z Q A T Y N H U O G T H U K M
{W} Q W X W R V T B Y B E W X Q C V B N U N Y R W R Y U I K O
{A} E X A Z S V F G H K M I O P L A F G H A W X W Z D R A S D C
{B} E C A X C V B N G N B M J K I L O U Y T E B N V C X B R E C
{E} Q C E D V R T Y U N I M O P L K M Z C D E C Q E F G B Y R W
{Y} Q X Y B R V Y U I M I Y T R E W C X Z V R B T Y N I O Y N I T R
{V} Q C X V F B G V H N J M K I O L P Q C V R T B Y V Y U I M O R
{J} F H J U N M I O P Q X S C F B G T R V G B J M K L A D C E V J
{V} Q C V B N V C X B N M K H N Y T R W Q F B V V D V G N Y Q

Appendix I (continued)

Digit Symbol

Below is a series of numbers which are individually associated with a particular symbol. AS QUICKLY AS YOU CAN, fill in the empty box with the appropriate symbol. You have 90 seconds. YOU MUST WORK FROM LEFT TO RIGHT AT ALL TIMES.

1	2	3	4	5	6	7	8	9
—	⊥	⊐	L	⊔	O	Λ	X	=

2	1	3	7	2	4	8	2	1	3	2	1	4	2	3	5	2	3	1	4	5	6	3	1	4

1	5	4	2	7	6	3	5	7	2	8	5	4	6	3	7	2	8	1	9	5	8	4	7	3

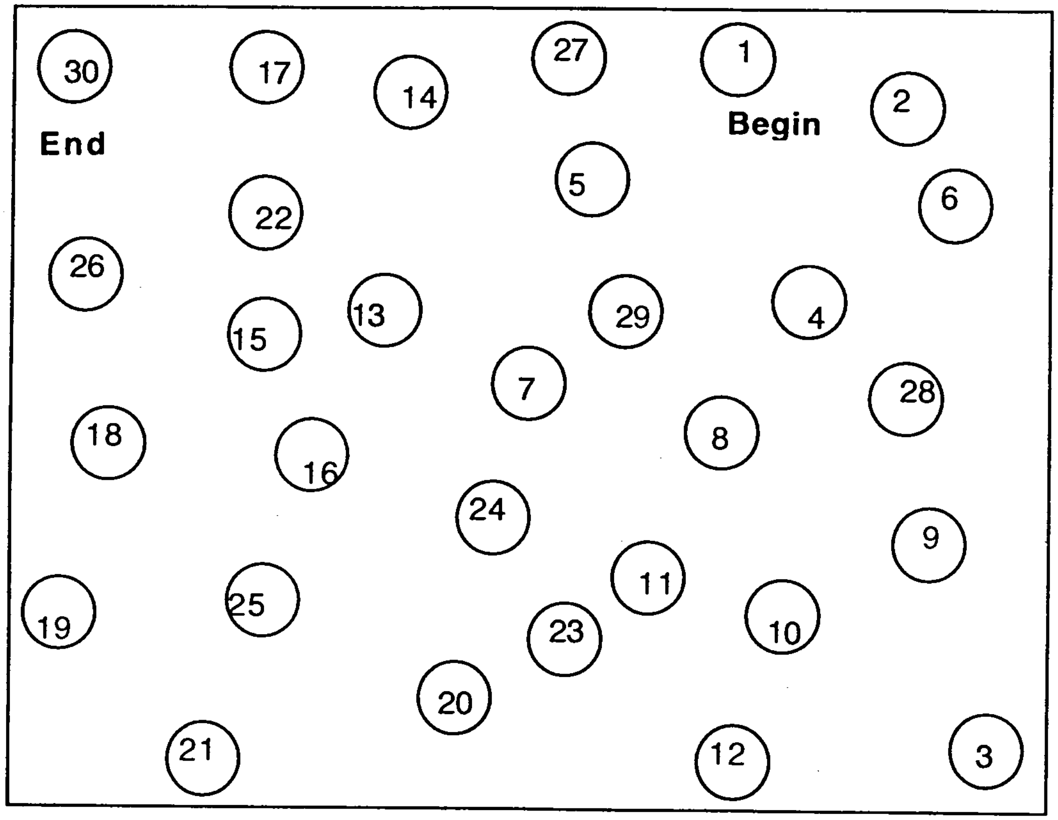
6	2	5	1	9	2	8	3	7	4	6	5	9	4	8	3	7	2	6	1	5	4	6	3	7

9	2	8	1	7	9	4	6	8	5	9	7	1	8	5	2	9	4	8	6	3	7	9	8	6

Appendix I (continued)

Trailmaking A

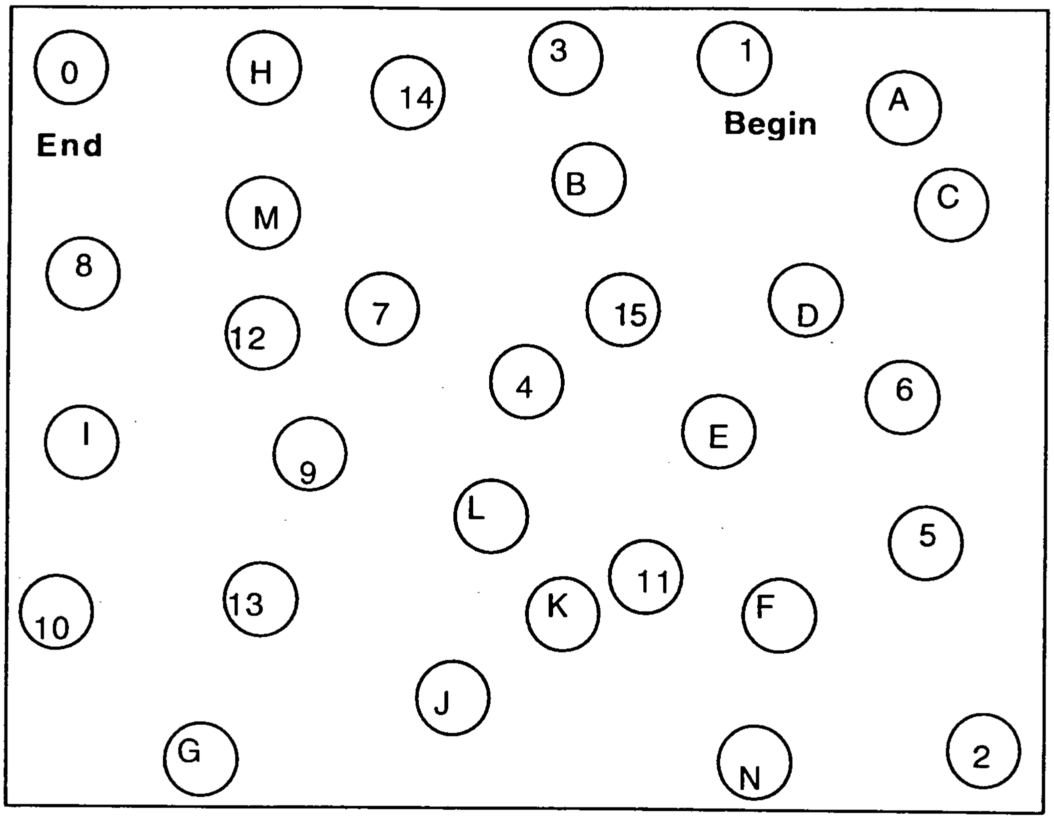
As quickly as you can, connect 1 through 30 with your pen. Ready, set, ...



Appendix I (continued)

Trailmaking B

As quickly as you can, alternate and connect 1-A - 2 - B - 3 - C - 4 - D - ...



Appendix I (continued)

Digit Span

Digit Span Forward Subtest

"I am going to say some numbers and when I am through, I want you to say them back to me in the same order".

(Complete as pairs and then move left to right)

7-2-9-5 8-1-3-7	6-1-2-9-7 5-8-2-4-3	9-1-7-8-4-3 2-9-7-8-4-1
7-1-9-5-6-2-9 9-1-2-7-3-4-5		5-9-7-4-1-2-3-7 8-1-9-2-3-6-7-5

Digit Span Backward Subtest

"I am going to say some numbers and when I am through, I want you to say them back to me in the reverse order in which they were presented. For example, if I say 3-7-6, you should say back to me 6-7-3 ".

(Complete as pairs and then move left to right)

5-1-7 4-9-3	7-9-2-3 9-6-4-8	2-5-1-7-8 3-4-1-6-8
9-3-5-7-6-1 2-7-4-1-3-8		9-6-3-5-8-2-1 1-2-8-3-7-4-9

Appendix I (continued)

Story Recall

"I am going to read to you a little selection of about four to five lines. Listen carefully because when I am through I want you to tell me everything I read in the order in which it was read to you".

Story Recall Subtest A

A cowboy / from Arizona / went to San Fransisco with his dog /, which he left / at a friend's / while he purchased / a new suit of clothes /. Dressed finely, he went back / to the dog /, whistled to him /, called him by name /, and patted him /. But the dog would have nothing to do with him / in his new hat / and coat / and gave him a mournful howl /. Coaxing was of no effect / so the cowboy went away / and donned his old garments / whereupon the dog / immediately recognized his master /.

Story Recall Subtest B

November 22nd /. Last month / a fatal car accident / killed four / and seriously injured / fifteen others / in a small village / 27 miles northwest / of Pittsburgh. No one witnessed / the late night crash / of two / oncoming vehicles. Police say / that sleet may be / to blame / although it does appear / that both / vehicles were speeding /. All involved / were transported by helicoptor / to the hospital / where they were treated / for head injuries / and broken bones.

Appendix I (continued)

Cognitive Test Battery Scoring

Letter Cancellation

The score is the total of number of correctly crossed out letters in 90 seconds.

Lezak, M. D. (1983). Neuropsychological assessment. New York: Oxford Press.

Digit Symbol

The score is the total number of correctly matched pairs of symbols and numbers in 90 seconds.

Psychological Corporation (1976). Wechsler adult intelligence scale - revised. Harcourt Brace Jovanovich, Inc.

Trailmaking A and B

The score is the average time required to complete the test. The subject is given a 30 second break in between Part A and Part B.

Lezak, M. D. (1983). Neuropsychological assessment. New York: Oxford Press.

Digit Span

The score is the summation of the scores of Part A and Part B. The score is the number of digit series correctly repeated by the subject. The maximum score of Part A, Digits Forward, is 8. The maximum score of Part B, Digits Backward, is 7. The test ends when both trials in a series

Appendix I (continued)

are answered incorrectly. If the subject errs in the first trial of a series, continue to the next trial. If he answers correctly, continue to the next series. If he answers incorrectly, the test ends.

Psychological Corporation (1976). Wechsler memory scale. Harcourt Brace Jovanovich, Inc.

Story Recall

The score is the average number of sequentially recalled story components repeated by the subject. The maximum score is 23. The subject is given a 30 second break in between Part A and Part B.

Psychological Corporation (1976). Wechsler memory scale. Harcourt Brace Jovanovich, Inc.

Appendix J

DATA TABLES

Table J-1

Cognitive Test Battery Scores for Wrestlers

Subtest		Test session[a]		
		1	2	3
Letter cancellation	M	57.00	52.93	58.71
	SD	8.10	11.65	9.08
Digit symbol	M	66.29	68.14	70.14
	SD	12.03	12.97	11.41
Trailmaking[b]	M	96.62	99.57	89.91
	SD	20.76	31.35	23.75
Digit span	M	13.64	12.50	14.50
	SD	1.08	2.14	1.16
Story recall	M	12.07	10.07	13.00
	SD	3.25	2.40	2.11

Note. The values represent the mean number of correct responses. [a]1, 2, and 3 refer to baseline, rapid weight loss, and rehydration test sessions, respectively. [b]Timed tracing test measured in seconds (s).

Table J-2

Cognitive Test Battery Scores for Control Subjects

		Test session[a]		
Subtest		1	2	3
Letter cancellation	M	54.13	55.67	57.27
	SD	9.60	11.29	11.34
Digit symbol	M	72.40	73.13	74.00
	SD	8.76	8.36	12.15
Trailmaking[b]	M	98.98	92.51	86.73
	SD	26.16	32.78	26.81
Digit span	M	13.47	13.73	13.53
	SD	1.19	1.49	1.51
Story recall	M	11.80	12.40	12.40
	SD	1.93	1.80	2.13

Note. The values represent the mean number of correct responses. [a]Refer to Table J-1. [b]Timed pattern tracing test measured in seconds (s).

Table J-3

POMS-R Scores for Wrestlers

Scale		Test session[a] 1	2	3
T-A	M	3.50	8.57	2.43
	SD	2.59	4.38	2.10
D-D	M	3.07	5.86	1.79
	SD	4.08	4.82	1.72
A-H	M	2.86	9.36	1.57
	SD	2.98	5.80	1.60
V-A	M	7.71	3.29	7.64
	SD	4.08	2.79	4.24
F-I	M	7.93	13.29	5.00
	SD	4.55	5.06	3.64
C-D	M	4.07	6.57	2.79
	SD	3.08	3.59	1.85

Note. T-A: Tension-Anxiety; D-D: Depression-Despair; A-H: Anger-Hostility; V-A: Vigor-Activity; F-I: Fatigue-Inertia; C-B: Confusion-Bewilderment. Maximum score for each scale = 20. [a]Refer to Table J-1.

Table J-4

POMS-R Scores for Control Subjects

Scale[b]		Test session[a] 1	2	3
T-A	*M*	5.40	2.73	1.73
	SD	3.31	2.69	2.25
D-D	*M*	3.80	1.53	0.53
	SD	3.45	2.45	1.36
A-H	*M*	2.00	0.87	0.47
	SD	2.10	1.30	1.06
V-A	*M*	6.67	7.53	7.47
	SD	5.22	4.09	5.08
F-I	*M*	6.67	4.80	4.00
	SD	5.31	5.12	4.29
C-D	*M*	4.47	2.53	2.67
	SD	2.80	2.00	1.45

Note. [a]Refer to Table J-1. [b]Refer to Table J-3 for explanations of abbreviations.

Table J-5

Physiological Measures for Wrestlers

Variable		Test session[a] 1	2	3
HP[b]	M	8.86	46.57	6.00
	SD	6.90	23.78	6.69
Glucose (mg/dL)	M	84.75	71.07	88.21
	SD	5.42	19.22	15.74
Hgb (g/dL)	M	14.45	15.20	14.45
	SD	0.69	0.95	0.73
Hct (%)	M	46.71	49.78	47.00
	SD	1.84	3.28	1.92
PV (mL)	M	53.17	47.32	53.28
	SD	1.91	4.05	2.29

(table continues)

Variable		Test session[a] 1	2	3
Body Weight (lb)	M	165.78	153.86	164.12
	SD	19.44	19.31	18.73
UWW (% body fat)[c]	M	7.97	-	7.15
	SD	2.40	-	2.51

Note. HP: Hypoglycemic Profile; Hgb: Hemoglobin; Hct: Hematocrit; PV: Plasma volume; UWW: Underwater weight. [a]Refer to Table J-1. [b]Maximum score = 100. [c]UWW was measured only twice during the study.

Table J-6

Physiological Measures for Control Subjects

Variable		Test session[a] 1	2	3
HP[b]	M	12.00	8.33	4.13
	SD	14.89	8.11	2.92
Glucose (mg/dL)	M	88.13	85.00	83.00
	SD	9.31	8.05	9.88
Hgb (g/dL)	M	14.90	14.86	14.97
	SD	0.98	0.86	0.91
Hct (%)	M	45.93	45.66	46.06
	SD	2.01	2.02	2.12
PV (mL)	M	53.33	53.82	53.14
	SD	3.27	3.34	3.42

(table continues)

Variable		Test session[a] 1	2	3
Body weight (lb)	M	183.16	183.18	183.80
	SD	28.54	28.62	28.22
UWW (% body fat)[c]	M	10.97	-	10.83
	SD	3.19	-	2.59

Note. Refer to Table J-5 for explanation of abbreviations. [a]Refer to Table J-1. [b]Maximum score = 100. [c]UWW was measured only twice during the study.

Table J-7

Repeated Measures ANOVA for Cognitive Test Battery

	Letter Cancellation			
Source	df	MS	F	p
Groups	1	6.00	0.02	0.87
Group x Subjects	27	256.94		
Test Session	2	98.98	3.29	0.44
Test Session x Subjects	54	30.08		
Group x Test Session	2	61.49	2.04	0.13

(table continues)

	Digit Symbol			
Source	df	MS	F	p
Groups	1	540.35	1.67	0.21
Group x Subjects	27	323.94		
Test Session	2	104.99	2.50	0.09
Test Session x Subjects	54	20.99		
Group x Test Session	2	9.22	0.44	0.64

(table continues)

	Trailmaking A and B			
Source	df	MS	F	p
Groups	1	154.08	0.10	0.74
Group x Subjects	27	1470.89		
Test Session	2	741.58	1.93	0.15
Test Session x Subjects	54	383.62		
Group x Test Session	2	165.30	0.43	0.65

(table continues)

	Digit Span			
Source	*df*	*MS*	*F*	*p*
Groups	1	0.02	0.00	0.95
Group x Subjects	27	4.10		
Test Session	2	5.39	4.56	0.01
Test Session x Subjects	54	1.18		
Group x Test Session	2	8.99	7.60	0.00

(*table continues*)

	Story Recall			
Source	df	MS	F	p
Groups	1	5.13	0.82	0.37
Group x Subjects	27	6.26		
Test Session	2	14.52	2.99	0.05
Test Session x Subjects	54	4.86		
Group x Test Session	2	18.64	3.84	0.02

Table J-8

Repeated Measures ANOVA of POMS-R

	Tension-Anxiety			
Source	df	MS	F	p
Groups	1	51.82	4.18	0.05
Group x Subjects	27	12.39		
Test Session	2	92.31	12.93	0.00
Test Session x Subjects	54	7.14		
Group x Test Session	2	112.32	15.74	0.00

(table continues)

	Depression-Despair			
Source	df	MS	F	p
Groups	1	56.72	3.05	0.09
Group x Subjects	27	18.60		
Test Session	2	55.74	9.10	0.00
Test Session x Subjects	54	6.12		
Group x Test Session	2	46.93	7.66	0.00

(table continues)

	Anger-Hostility			
Source	*df*	*MS*	*F*	*p*
Groups	1	263.71	24.62	0.00
Group x Subjects	27	10.71		
Test Session	2	117.14	15.87	0.00
Test Session x Subjects	54	7.38		
Group x Test Session	2	136.23	18.46	0.00

(*table continues*)

	Vigor-Activity			
Source	df	MS	F	p
Groups	1	22.07	0.74	0.39
Group x Subjects	27	30.01		
Test Session	2	35.18	2.65	0.08
Test Session x Subjects	54	13.29		
Group x Test Session	2	58.38	4.39	0.01

(table continues)

	Fatigue-Inertia			
Source	df	MS	F	p
Groups	1	278.82	7.42	0.01
Group x Subjects	27	37.58		
Test Session	2	144.56	10.02	0.00
Test Session x Subjects	54	14.42		
Group x Test Session	2	130.69	9.06	0.00

(table continues)

	Confusion-Bewilderment			
Source	df	MS	F	p
Groups	1	34.16	4.16	0.05
Group x Subjects	27	8.21		
Test Session	2	26.79	4.70	0.01
Test Session x Subjects	54	5.70		
Group x Test Session	2	42.58	7.47	0.00

Table J-9

Repeated Measures ANOVA of Physiological Measures

	Hypoglycemic Profile			
Source	*df*	*MS*	*F*	*p*
Groups	1	3297.68	17.90	0.00
Group x Subjects	27	184.26		
Test Session	2	3717.55	25.99	0.00
Test Session x Subjects	54	143.02		
Group x Test Session	2	3693.54	25.83	0.00

(table continues)

	Blood glucose			
Source	*df*	*MS*	*F*	*p*
Groups	1	353.26	2.22	0.14
Group x Subjects	27	159.11		
Test Session	2	585.02	4.15	0.02
Test Session x Subjects	54	140.80		
Group x Test Session	2	665.68	4.72	0.01

(table continues)

	Hemoglobin			
Source	*df*	*MS*	*F*	*p*
Groups	1	0.94	0.46	0.50
Group x Subjects	27	2.03		
Test Session	2	0.98	8.84	0.00
Test Session x Subjects	54	0.11		
Group x Test Session	2	1.64	8.84	0.00

(table continues)

	Hematocrit			
Source	*df*	*MS*	*F*	*p*
Groups	1	82.13	7.15	0.01
Group x Subjects	27	11.47		
Test Session	2	15.20	8.20	0.00
Test Session x Subjects	54	1.85		
Group x Test Session	2	25.72	13.87	0.00

(*table continues*)

	Plasma volume			
Source	df	MS	F	p
Groups	1	102.33	4.59	0.04
Group x Subjects	27	22.25		
Test Session	2	62.82	16.69	0.00
Test Session x Subjects	54	3.76		
Group x Test Session	2	101.74	27.03	0.00

(table continues)

	Body weight			
Source	df	MS	F	p
Groups	1	10633.08	5.96	0.02
Group x Subjects	27	1783.13		
Test Session	2	295.05	72.05	0.00
Test Session x Subjects	54	4.09		
Group x Test Session	2	290.96	71.05	0.00

(table continues)

	Underwater weight			
Source	df	MS	F	p
Groups	1	138.06	9.92	0.00
Group x Subjects	23	13.90		
Test Session	1	1.32	1.28	0.26
Test Session x Subjects	23	1.03		
Group x Test Session	1	0.99	0.96	0.33

Table J-10

Post-hoc t-tests for Group Effects at each Test Session

	Digit Span		Story Recall	
Time[a]	t	p	t	p
1	0.41	0.34	0.27	0.39
2	1.81	0.04*	2.96	0.00*
3	1.92	0.03*	0.76	0.22

	Subtest T-A		Subtest D-D	
Time	t	p	t	p
1	1.71	0.049	0.52	0.303
2	4.36	0.000**	3.07	0.000**
3	0.85	0.199	2.18	0.018

(table continues)

	Subtest A-H		Subtest F-I	
Time	t	p	t	p
1	0.89	0.188	0.68	0.249
2	5.52	0.000**	4.48	0.000**
3	2.20	0.018	0.67	0.

	Subtest C-B	
Time	t	p
1	0.36	0.360
2	3.77	0.000**
3	0.19	0.423

(table continues

	Hypoglycemic Profile		Blood glucose	
Time	_t_	_p_	_t_	_p_
1	0.72	0.23	1.18	0.12
2	5.87	0.00*	2.57	0.00*
3	0.98	0.16	1.07	0.14

	Hemoglobin		Hematocrit	
Time	_t_	_p_	_t_	_p_
1	1.41	0.08	1.08	0.14
2	1.00	0.16	4.09	0.00*
3	1.67	0.05*	1.23	0.11

(<u>table continues</u>)

	Plasma volume		Body weight	
Time	t	p	t	p
1	0.16	0.43	1.90	0.03*
2	4.72	0.00*	3.20	0.00*
3	0.13	0.44	2.19	0.01*

Note. Refer to Table J-3 for explanation of abbreviations. [a]Time refers to the 1st, 2nd, and 3rd test sessions.

* $p < 0.05$

* * $p < 0.008$

Table J-11

Post-hoc Duncan's Multiple RangeTest for Time Main Effects

	Cognitive battery		
Variable	Means		
Letter cancellation	54.34(2)	55.52(1)	57.97(3)
Digit span	13.14(2)	13.55(1)	14.00(3)
Story recall	11.28(2)	11.93(1)	12.69(3)

(table continues)

Variable	POMS-R Means		
Subtest T-A	2.07(3)	4.48(1)	5.55(2)
Subtest D-D	1.14(3)	3.45(1)	3.62(2)
Subtest A-H	1.00(3)	2.41(1)	4.97(2)
Subtest F-I	4.48(3)	7.28(1)	8.90(2)
Subtest C-B	2.72(3)	4.28(1)	4.48(2)

(table continues)

Variable	Physiological Measures Means		
HP[a]	5.03(3)	10.48(1)	26.79(2)
Blood glucose (mg/dL)	78.27(2)	84.19(1)	85.51(3)
Hgb (g/dL)	14.69(1)	14.72(3)	14.50(2)
Hct (%)	46.31(1)	46.51(3)	47.65(2)
PV (mL)	50.68(2)	53.21(3)	53.25(1)
Body Weight (lb)	169.03(2)	174.30(3)	174.77(1)

Note. Value in parentheses denotes the 1st, 2nd, or 3rd test sessions. Means that are underlined are not significantly different. $p < 0.05$