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Acclimatization to Heat during Preseason Football Practices at a Division I University: A Pilot Study

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ABSTRACT
Purpose: The purpose of this study was to examine core temperature (T_C) and markers of dehydration during one-a-day (D1) practices compared to two-a-day (D2) practices. **Methods:** Twenty-five National Collegiate Athletic Association (NCAA) Division I Football Championship Subdivision (FCS) football players volunteered to participate in the study, with thirteen subjects providing data for all four practices. Each subject was measured prior to and following D1 and D2 practices and tested for body mass, core temperature, supine and standing blood pressure, and blood volume changes. Environmental temperature, humidity and barometric pressure were measured at the practice field during the last hour of each practice. **Results:** During moderate environmental temperatures and humidity, body mass was found to decrease following practice. Core temperature increased following both types of practice. Post practice plasma volume was 4% higher following D1 compared to D2 practice type. **Conclusions/Recommendations:** In this study, these NCAA Division I FCS football players remained well-hydrated during preseason practice training. The athletes' plasma volume increased during practice, and even though core temperature increased, it remained lower than levels at which heat illness is indicated. In conclusion, the results of this study indicate that the risk of heat illness in NCAA Division I FCS football players is very low during fall football training practices in conditions of moderate heat and humidity. We recommend that this study should be repeated in various environments, including higher temperatures and/or percent relative humidity where the risk of heat illness may be greater.

INTRODUCTION

Two-a-day practice sessions are often a part of preseason conditioning in American football (FB). While the extra practice time may help accelerate physical conditioning and assist teams in becoming immediately successful, the physiological stress of participating in repeated two-a-day practices early in preseason places athletes at increased risk of heat injury.[1,2] In June 2003, the National Collegiate Athletics Association (NCAA) adopted a new FB preseason practice bylaw (17.11.2) which requires a five-day period to acclimate to equipment and exercise intensity at the start of formal practice and limits the schedule of multiple practices on one day to reduce the risk of injury and heat illness.

While the NCAA rule change is based on prudent thermoregulatory adaptation theory, no information regarding its effectiveness in enhancing acclimatization, improving thermoregulatory capacities, and reducing hyperthermic responses are available. Additionally, there are limited studies involving heat stress in FB players during practice.[3] Furthermore, studies that have addressed FB clothing and equipment and thermoregulation have been conducted under laboratory conditions and have used non-FB players as subjects.[4-6] For example, McCullough and Kenney reported on thermal insulation and evaporative resistance of FB uniforms using manikins.[7]

Athletes, whose training begins in the late summer (as is common with preseason football), are more susceptible to developing heat illnesses.[8-12] Heat exhaustion in athletes can quickly progress to life-threatening exertional heat stroke due to multi-system organ failure.[13] Increased metabolic heat production, coupled with environmental conditions, exceeds the body's ability to dissipate heat, thereby increasing the athletes' core temperature.[14] Therefore, an understanding about how preseason FB practices influence the development of exertional heat-related illness can assist sports medicine professionals in preventing, recognizing, and promptly treating these conditions.

Traditional emergency assessment of an athlete's core temperature requires insertion of a rectal thermometer. However, the use of ingestible temperature sensors allows sports medicine professional to monitor, recognize, and promptly treat athletes participating in sports, and prevent the development of heat-related illnesses such as heat exhaustion and heat stroke. Other than rectal temperature, gastrointestinal core temperatures, measured with ingestible temperature sensors, have been shown to be the only alternative measurement that accurately assesses core body temperature.[15,16] The purpose of this study was to examine core temperature (T_C) and markers of dehydration during one-a-day (D1) practices compared to two-a-day (D2) practices.

METHODS

Subjects

Twenty-five National Collegiate Athletic Association (NCAA) Division I Football Championship Subdivision (FCS) football players volunteered to participate in the study (age = 20.5 ± 1.8 years; height = 187.2 ± 8.3 cm; body mass = 102.7 ± 18.4 kg; body mass index = 29.1 ± 3.7 kg $\cong$ m^{-2}; supine resting systolic and diastolic blood pressure = 122.3 ± 8.3 and 71.2 ± 9.1 mm Hg, respectively.) The study was approved by the University's Institutional Review Board of Human Subjects, and all subjects signed an informed consent form prior to participation. Thirteen of the twenty-five subjects provided data for all four practices.

Research Design

This observational, repeated measures design study used pre- and post-practice measurements to compare thermoregulation during D1 (one practice per day) and D2 (two-practices per day) practices (Table 1). Both practice types were measured during the first and second weeks of the official preseason practice period during the month of August. Practices took place at an elevation of approximately 4,700 feet. During practice, the athletes were allowed unrestricted access to cold water and were given no instructions regarding water consumption.

Table 1. A single group repeated measures 2 x 2 x 2 ANOVA (Practice Type x Practice Number x Practice Time) was used to determine the effects of practice type (single day practice and double day practice) on core temp, body mass , plasma volume, cell volume, and blood volume. (Table shown to clarify data collection)

	D1				D2			
	P1		P2		P1		P2	
Athlete	Pre P	Pos P	Pre P	Pos P	Pre P	Pos P	Pre P	Pos P
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
Practice Time Means								
Practice Number Means								
Practice Type Means								

Measurements

Measurements were taken on each subject prior to and following four football practice sessions, two of which occurred on D1 days and two of which occurred on D2 days. All subjects participated in all four practice sessions where data was collected, but only thirteen subjects provided data for all four practices. Due to lack of compliance and sometimes early elimination of the ingested thermistor, thirteen subjects provided data for only some of the practice days. Data collection took place over a twelve day period. D1 data was collected on days one and six, while D2 data was collected on days seven and twelve. On the D2 days, the pre-measurements were taken prior to the first practice and the post-measurements were taken following the second practice. Subjects dressed in standard practice uniforms during each day, wearing full pads and helmets. Each subject's body mass, core temperature, supine and standing blood pressure, hematocrit, and hemoglobin were measured before and after each practice day when data was collected. Environmental temperature, humidity, and barometric pressure were measured at the practice field during the last hour of each practice.

Core temperature (T_C) as indicated by gastrointestinal tract temperature was measured using an ingestible temperature sensor pill (CorTemp, HQInc., Palmetto, FL). Each participant ingested a sensor capsule approximately twelve hours prior to practice. Temperature was determined via a receiver held near the subject's abdomen and recorded to the nearest 0.01 degrees Fahrenheit.

Body mass was measured on an electronic scale to the nearest 0.1 kg. Blood pressure for the orthostatic stand test was measured either manually with an aneroid sphygmomanometer or with an automated blood pressure system (Avant 2120, Nonin Medical Inc., Plymouth, MN). The Pressure Transducer Accuracy was $\pm$ 3mmHg between 0 mmHg and 300 mmHg for operating conditions between 0° and 50°C as reported by the manufacturer. No measures were taken to determine the differences in reliability between the two different blood pressure measurement techniques.

Approximately 100 µl of blood was drawn from each subject through a finger puncture and analyzed for hematocrit (HCt) and hemoglobin (Hb). HCt was determined by spinning 50 µl capillary tubes in a microhematocrit centrifuge (LWS M24, LW Scientific Inc., Atlanta, GA) for 8 minutes and reading the packed cell volume. Hb was determined using dual wavelength photometry (Hb 201+, Hemocue Inc., Lake Forest, CA). Standard protocols for clinical laboratory testing were used.

Percentage changes in blood volume (BV), red cell volume (CV) and plasma volume (PV) were calculated from values for Hb and HCt using methods described by Dill and Costill.[17]

Statistical Analysis

Analysis was done on thirteen subjects who provided data for all four practices. Means and standard deviations were calculated for all variables. A single group repeated measures 2 x 2 x 2 ANOVA was used to determine the effects of practice type (D1 or D2) on body mass, core temperature, plasma volume, cell volume, and blood volume. Data was analyzed using analysis of variance (ANOVA) for repeated measures. Where appropriate, significant mean differences were located using the Neuman-Keuls multiple comparison test. $P < 0.05$ was considered significant. The Number Cruncher Statistical System (NCSS) (v. 2004, Kaysville, UT) was used for data analysis.

RESULTS

The average environmental temperature during the four practices was 81.5 ± 7.4 ° F, ranging from a low of 70.2 ° F to a high of 87 ° F. The average relative humidity was 27.25 ± 8.6% ranging from a low of 17% to a high of 38%.

There were no significant differences in the change in body mass when comparing D1 to D2 practices (Figure 1). Body mass decreased following each practice. Combined post-practice body mass was significantly lower than pre-practice (100.2 ± 18.0 kg vs. 101.5 ± 18.3 kg., Figure 2). On the second day of each practice type, body mass was significantly lower compared to the first day of each practice type (100.4 ± 17.9 kg vs. 101.3 ± 18.4 kg., Figure 3).

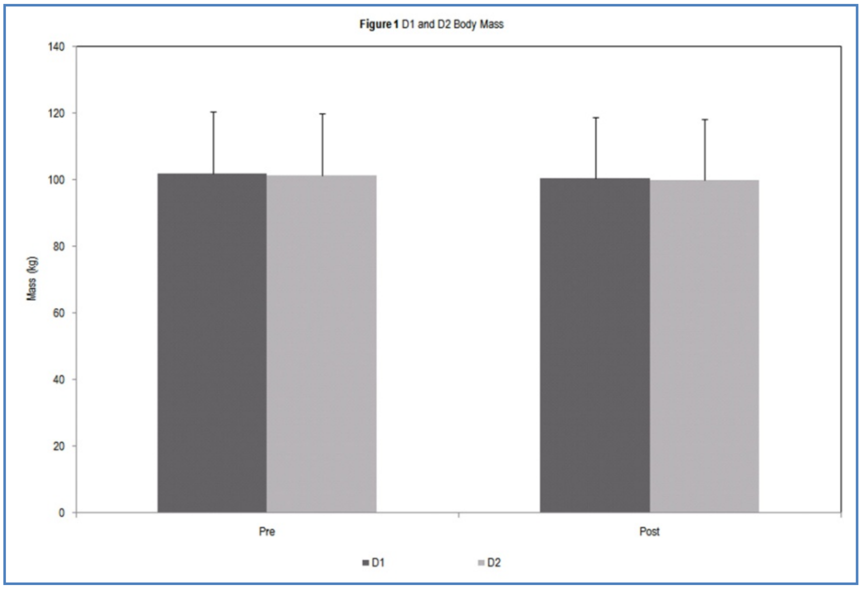

Figure 1. D1 and D2 Body Mass

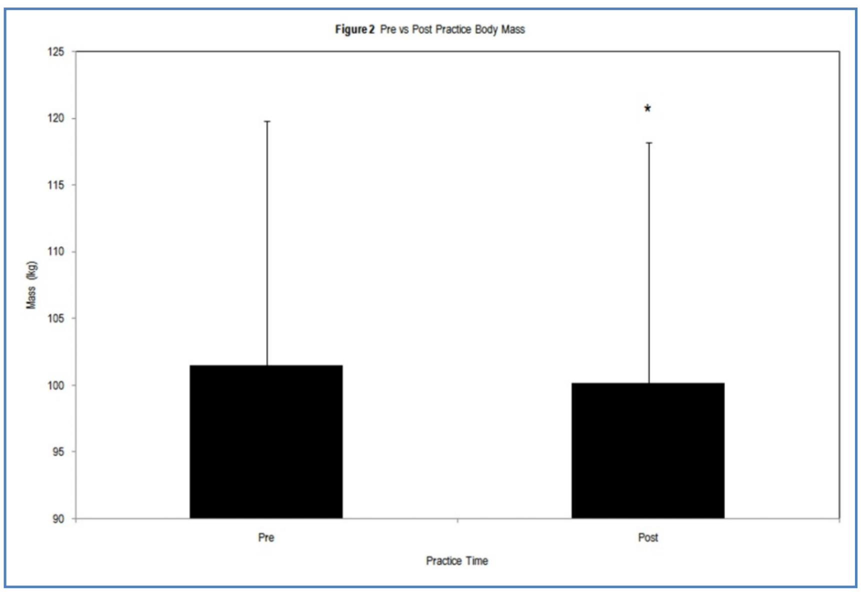

Figure 2. Pre vs Post Practice Body Mass

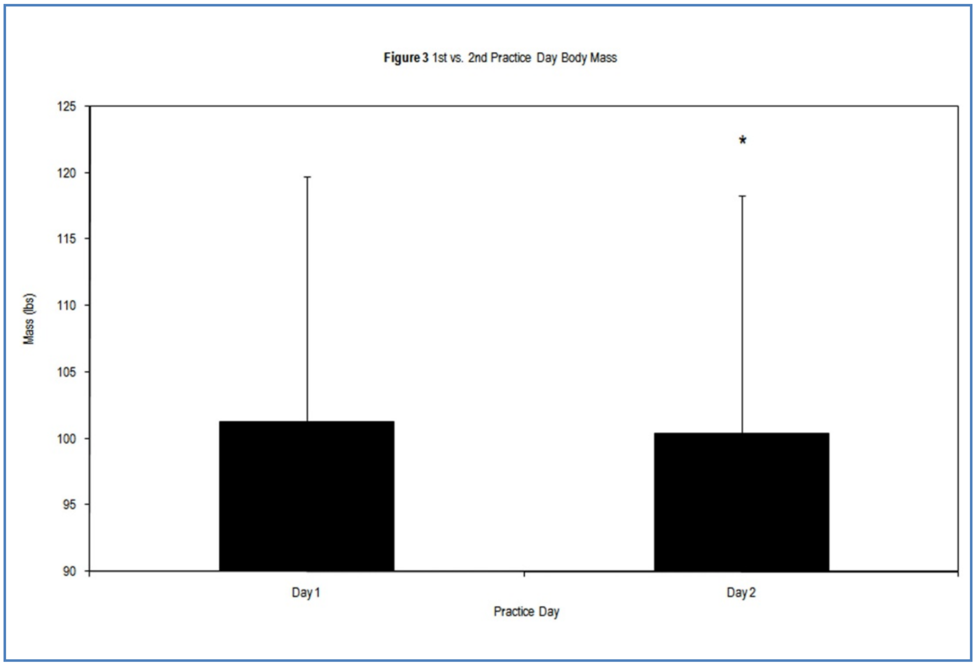

Figure 3. 1st vs 2nd Practice Day Body Mass

Core temperature increased following both types of practice; however, there was no significant difference between D1 and D2 post-practice core temperature (Figure 4). Combined post-practice core temperature was significantly higher than pre-practice (100.5 ± 0.8 ° F vs. 98.6 ± 0.5 ° F, Figure 5).

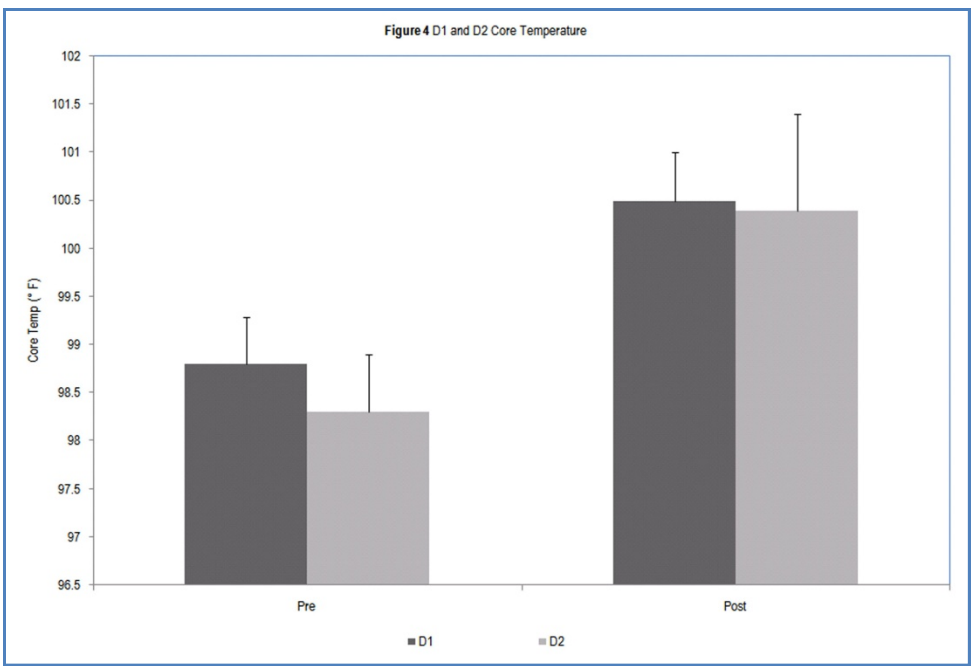

Figure 4. D1 and D2 Core Temperature

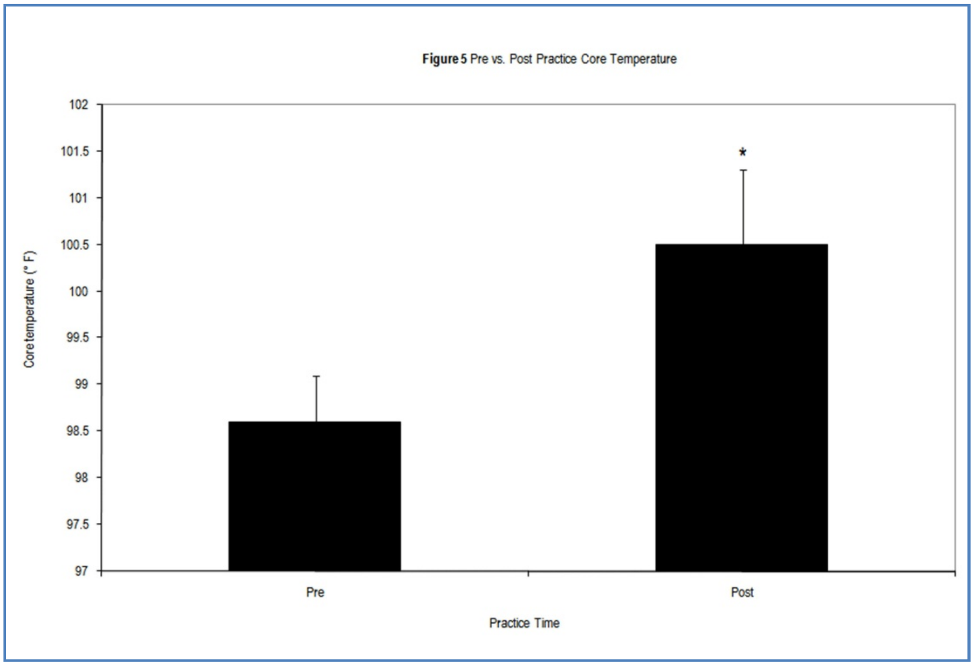

Figure 5. Pre vs Post Practice Core Temperature

Plasma volume increased following both types of practice (Figure 6). Combined post-practice PV was significantly higher than pre-practice (54.6 ± 3.7% vs. 52.4 ± 2.4%, Figure 7). Post-practice PV was 4% higher following D1 compared to D2 practice type (55.7 ± 3.5% vs. 53.5% ± 3.6%, Figure 8). There were no significant differences found in D1, D2, pre- or post- CV or BV.

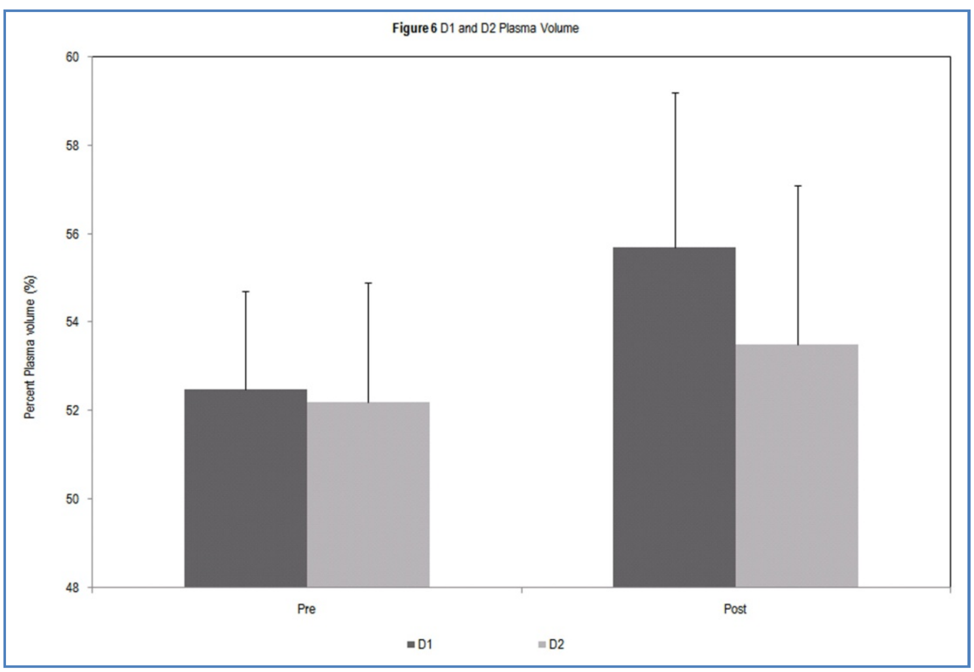

Figure 6. D1 and D2 Plasma Volume

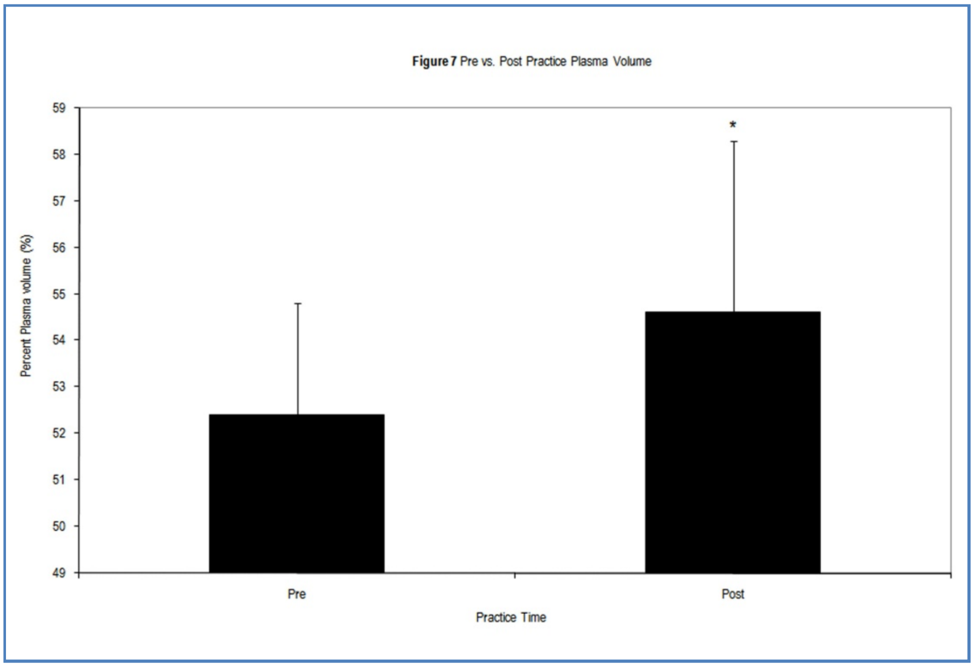

Figure 7. Pre and Post Practice Plasma Volume

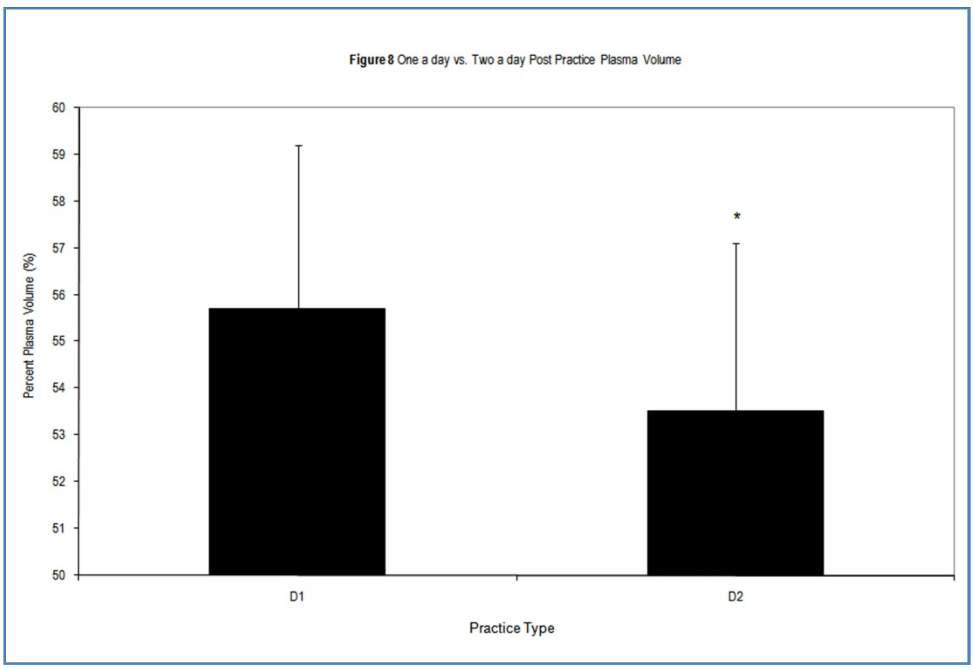

Figure 8. One-a-Day vs Two-a-Day Post Practice Plasma Volume

DISCUSSION

This study demonstrated that these NCAA Division I FCS football players stayed well hydrated during preseason training practices. Common markers of dehydration include attenuated orthostatic blood pressure response, a decrease in plasma volume, and an increase in core temperature.[13] Our findings indicated that the players increased their plasma volume during practice. Even though core temperature increased, it remained lower than levels at which heat illness is indicated, and none of the participants were diagnosed with heat illness.

The increase in plasma volume following practice conflicts with other similar studies which found a decrease in plasma volume.[18,19] Although there was a decrease in body mass, indicating a loss of fluid, it does not appear the fluid was taken from the plasma volume. It is possible that the fluid loss came from intracellular sources and/or from the interstitial fluid, a component of the extracellular fluid.[20] These athletes were allowed unrestricted access to cold water during practice, although ad lib fluid intake in this study was not regulated or monitored. Unrestricted, unmonitored access to water is recommended by the NATA Position Statement on Fluid Replacement.[20] Therefore, no attempt was made to influence water availability and/or intake, which could potentially explain the increase in PV with no change in CV or BV. Additionally, physiochemical equilibrium in blood depends upon body temperature.[17] In our efforts to meet the demands associated with studying a competitive collegiate athletic team, blood samples were taken within 30 to 60 minutes post-practice, possibly resulting in measurement error because the subjects may not have completely cooled down.

An increase in core temperature following practice was expected. The magnitude of the core temperature increase, although significant, was less than expected. The most likely reason for this observation was the lack of extreme environmental heat and humidity during practice. At the time of this study, the average temperature and humidity during practice was very mild for the season. Additionally, most players participated in an on-site summer conditioning program which could explain their tolerance to exercise in the heat. Another contributing factor was the effort of the coaching and athletic training staffs to ensure players were hydrating adequately. It is notable that the primary fluid for hydration during practice was cold water, indicating that it is possible for players to maintain adequate hydration in these conditions without consuming a carbohydrate electrolyte fluid.

It should also be noted that that the ingestible thermometers did not remain within the players' bodies for the full 72 hours, as described by the manufacturer. In fact, some players excreted the thermometers in 7 to 12 hours, which affected the data collection by reducing the number of subjects we could include in the study. We theorized that this was due to the large volume of food and fluids (upwards to 5,000 kcal/day) ingested by the athletes as well as increased physical activity during preseason practices. This information may be useful for teams who consider using the ingestible thermometers as a way to monitor core body temperature as the shorter time period can substantially increase the cost of monitoring (each pill costs approximately $40). Instead of having the athletes ingest one every two days, they may need one every day.

In conclusion, the results of this pilot study suggest that the risk of heat illness in NCAA Division I FCS football players is very low during fall football training practices, in conditions of moderate heat and humidity when unrestricted access to drinking water is available. The type of practice (D1 vs. D2) affected the subjects' plasma volume, but not the body mass or core temperature. We recommend that this study should be replicated in various environments and altitudes, including higher temperatures and/or percent relative humidity where the risk of heat illness may be greater. These studies should also, if possible, monitor fluid consumption and account for differences in player position, i.e. quarterback vs. lineman.

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