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Impact of Hydration on Physiological Parameters in Collegiate Football Athletes

Lauren Woodard Parrish[1], Melinda Wells Valliant[1*], Kathy Knight[1], Martha A. Bass[2],

[1]*Department of Nutrition and Hospitality Management.*
[2]*Department of Health, Exercise Science, and Recreation Management.*

***Corresponding Author:** Melinda Wells Valliant, Center of Health and Sports Performance Department of Nutrition and Hospitality Management, University of Mississippi, USA.*

ABSTRACT

This study investigated the relationship between hydration levels and physiological parameters in collegiate football players. Urine specific gravity and body weight were used to determine hydration levels of athletes, and Pearson correlation coefficient was used to determine relationships between urine specific gravity, body weight, and real-time physiological data .Sixty-seven percent of the football athletes were hypo hydrated based on mean urine specific gravity samples, but no athletes had a mean percent body weight loss greater than 2%. A strong negative correlation was found between increased urine specific gravity and mechanical intensity physiological data (r = -0.885, p = 0.019), but no correlation was found between hydration status and rate of force development, physiological intensity, or average heart rate. No correlations were found between percent change in body weight and any physiological data. Athletes' physiological profiles may not be significantly impacted by short-term hypo hydration.

Keywords: *hydration, athletic performance, training.*

INTRODUCTION

The impact of dehydration (or hypo hydration) on cardiovascular output, central nervous system function, musculoskeletal output, and altered metabolic function; several key physiological parameters that are critical for athletic performance, has been extensively documented (Judelson, et al., 2007). Yet, over 50% of collegiate athletes continue to start practices and games in a dehydrated state(Godek, Godek, & Bartolozzi, 2005; Osterberg, Horswill, & Baker, 2009; Volpe, Poule, & Bland, 2009). Judge et al.(2016) determined that American collegiate football athletes were not aware of proper hydration techniques and identified common misconceptions such as "thirst is the best indicator of dehydration". Volpe et al. (2009) found that 66% of 263 National Collegiate Athletic Association (NCAA) Division I athletes were hypo hydrated (1.020 – 1.029) and 13% were significantly hypo hydrated (≥1.030) during pregame urine specific gravity (USG) screenings. While analyzing pre-game USG samples of professional basketball players, Osterberg et al. (2009) discovered that 52% of the athletes were hypo hydrated going into competition. Godek et al. (2005) found similar findings and concluded that collegiate football players lose an average of 1.5 to 2% of body weight during practices.

While dehydration has been linked to impaired mental and psychomotor ability, many athletes may not be able to perceive any relationship between their hydration status and athletic performance. Nichols et al.(2005) recommended regularly monitoring athletes' fluid consumption, hydration status, inappropriate hydration behaviors, and any consequences of such behaviors. Ultimately, promoting student athlete hydration awareness will allow players to recognize and report hydration related concerns, encouraging behavior change while reducing the risk of injury (Kreider et al., 2010).

Nybo & Nielsen (2001) and Sawka & Coyle (1999)documented the effect of hypo hydration on endurance aerobic exercise, however the influence of hypo hydration on high intensity anaerobic performance is not as concrete (Cheuvront, Carter, Haymes, & Sawka, 2006 and Evetovich et al. 2002). Detailed assessments of high intensity athletic performance remain challenging to obtain as athletic success relies on factors such as cognitive function, postural stability, force development and complex skill technique. American football consists of prolonged periods of exercise with repeated intermittent high intensity bouts of athletic performance resulting in a “start/stop” nature, thus increasing documentation difficulty.

The purpose of this study is to investigate the relationship between hydration levels and physiological profiles that can be used as a proactive approach in monitoring a collegiate athlete’s athletic performance, fatigue, and recovery status. The hypothesis of this study is that insufficient hydration levels will have a negative correlation with physiological profiles of athletes, thus pointing to susceptibility to fatigue and decreased athletic performance. Advancements in high intensity physiological monitoring of collegiate football athletes can facilitate practices that may reduce rates of performance fatigue, stimulate recovery, decrease injury susceptibility, and decrease potential long-term health consequences.

Materials and Methodology

The University of Mississippi Institutional Review Board approved the study protocol as exempt since the data analyzed were collected as routine for athletic sport participation. All researchers completed the Collaborative Institutional Training Initiative Program to conduct human subject research. All technicians were trained in their area of contribution.

Population

A total of six male football players, ages 18 to 23, participated in the current study. Participants were selected based on their minutes played, number of repetitions per practice, history of dehydration or dehydration symptoms. The collegiate athletes were evaluated over three days during pre-season training camp.

Physiological Experimental Design

Participants were fitted with Zephyr Performance Systems Monitor “Bio Harness 3” and wore them during training to collect real time physiological data. The chest strap device contained a high impact triaxial linear accelerometer, which allowed the monitor to examine six degrees of freedom for linear acceleration. The real-time measurements to the nearest millisecond were summarized for each player. These measurements were: rate of force development, acceleration, mechanical intensity, mechanical load, physiological intensity, physiological load, and average heart rate, and are defined as:

Rate of Force Development (N/s)

Measure of explosive strength, speed in which the contractile elements of the muscle can develop force.

Mechanical Intensity (scale 1-10)

Index of musculoskeletal output, related to subject g force activity level, measured in 1/60 minute epochs.

Mechanical Load

Accumulation of mechanical intensities, total sum of mechanical intensities divided by 60.

Physiological Intensity (scale 1-10)

Index of cardiovascular output, related to subject maximum heart rate, measured in 1/60 minute epochs.

Physiological Load

Accumulation of physiological intensities, total sum of physiological intensities divided by 60.

A handheld refractometer was used to determine the USG of football participants. Before each analysis, the refractometer was calibrated using distilled water. Approximately one hour before each practice each participant provided one spontaneously voided urine sample, which was then analyzed for USG within one hour of collection. The corresponding USG was read and recorded by the same researcher. All urine samples were discarded immediately after assessment. According to the National Athletic Trainers’ Association and the American College of Sports Medicine three USG hydration groups are identified (Casa, 2000; Sawka et al., 2007). Athletes that provided a sample with a USG of less than 1.020 were considered euhydrated. Hypo hydrated athletes had a USG between 1.020 and 1.029. Athletes who provided samples with USG values of 1.030 or more were categorized as significantly hypo hydrated.

Body weight was recorded to the nearest 0.1 pound on a portable digital scale (Tanita HD-384 Digital Scale) approximately one hour before practice and immediately following practice. Student athletes were required to towel off excess sweat and wear minimal dry clothing for each weigh-in. Athletes that experienced a 2% or more body mass loss during practice were considered hypo hydrated. Baseline body weights and heights are found in Table 1.

Table1. *Mean baseline weights and heights ofcollegiate football athletes (n = 6)*

	Mean	Std. Deviation
Age	19.50	± 1.22
Weight (kg)	103.76	± 24.34
Height (cm)	188.81	±7.82

Statistical Analysis

Data analysis was conducted using SPSS (version 22.0; SPSS Inc. Chicago, IL). Descriptive statistics were calculated for age, weight, and height. A Pearson correlation coefficient was used to determine the degree and direction of the linear relationship between (1) pre and post practice USG change and Zephyr Performance Systems physiological data, (2) pre and post practice percent change in body weight and Zephyr Performance Systems physiological data. A probability level of $p \leq 0.05$ was used as the criterion for statistical significance.

Results And Discussion

Hydration values are found in Table 1. Pearson correlation coefficient was calculated to determine the relationship between collegiate football athletes' pre- and post-practice change in USG and pre- and post-practice percent change in body weight. No correlation was found ($r = 0.035$, $p = 0.947$) between the hydration status variables.

Table2. *Hydration Status of Collegiate Football Athletes, USG (Mean ± SD)*

Participant	Pre-practice	Post-practice	Change
1	1.0164 ± 1.0164	1.0231 ± 0.0064	+0.0067
2	1.0253 ± 1.0253	1.0235 ± 0.0021	-0.0018
3	1.0093 ± 1.0093	1.0181 ± 0.0019	+0.0088
4	1.0162 ± 1.0162	1.0221 ± 0.0089	+0.0058
5	1.0050 ± 1.0096	1.0156 ± 0.0025	+0.0106
6	1.0210 ± 1.0210	1.0214 ± 0.0047	+0.0033
USG ≥ 1.020	33.3%	66.7%	

Hypo hydration is indicated by a USG≥ 1.020, demonstrated by the ratio of urine density to water density.

The lack of a significant correlation between change in USG and percent change in body weight, may indicate that a single measure of hydration status might not be enough, and that multiple methods of hydration monitoring should be implemented for best results. Previous studies have concluded similar findings in active individuals, therefore a lack of a gold standard remains (Armstrong, 2007; Cheuvront & Sawka, 2005; Oppliger & Bartok, 2002). USG and percent change in body weight are safe, accurate, and inexpensive; therefore they are appropriate techniques to assess hydration status in collegiate athletes.

The collegiate athletes in this study lost between 0.28% and 1.91% of their body weight during preseason practice on average, which is less than previously documented collegiate football players participating in preseason training. During a practice session Godek et al. (2005) reported football players lost between 1.5% and 2.0% of their body weight and Yeargin et al. (2006) concluded a similar finding of 1.2%. Osterberg et al. (2009) revealed the average body weight change following competition of high performance athletes was 1.4%, while athletes in the current study lost an average of 1.09%.

Thirty-three percent of the collegiate athletes provided pre-practice urine samples in which the mean USG was greater than or equal to 1.020, indicating pre-practice hypo hydration. These results are considerably lower compared to Godek et al. (2005) who found that 67% of collegiate football athletes started preseason practice hypo hydrated. Volpe et al. (2009) determined 66% of collegiate athletes and Osterberg et al. (2009) concluded 52% of professional athletes started competition in a hypo hydrated state.

Sixty-seven percent of the football athletes were hypo hydrated based on mean USG samples. However, when percent change in body weight was calculated for each athlete post practice, no athletes had a mean loss greater than 2%, indicating adequate hydration status following practice. On average the athletes lost between 0.28% and 1.91% of their body weight during preseason practice. These results demonstrate maintaining adequate hydration status is difficult when initial dehydrated levels are combined with high intensity training. In adequate fluid levels before, during, and after training increases the risk of detriments to neuromuscular performance, cognitive function, stability, and performance technique. These detriments could lead to overall earlier onset of fatigue, decreased rate of recovery, and declined athletic performance.

Previous research indicates disparities in the critical level of water deficit at which a decrease in aerobic and anaerobic performance occurs. Particularly, it is suggested that aerobic athletic performance is more adversely influenced by hypo hydration than anaerobic strength, power, and muscular endurance (Shirreffs, 2005; Yoshida et al., 2002). However, the topic remains controversial, as studies conclude anaerobic exercise is negatively impacted by hypo hydration when as little as % 2 of body weight is lost (Ftaiti et al., 2001; Hayes & Morse, 2010; Yoshida et al., 2002).

A Pearson correlation was calculated to explore a possible relationship between change in USG and Zephyr Performance Systems physiological data. While no correlation was found with rate of force development ($r=0.768$, $p=0.074$), a strong negative correlation was found between hydration status and mechanical intensity physiological data ($r=-0.885$, $p= 0.019$). No correlation was found between hydration status and physiological intensity ($r=0.363$, $p= 0.479$) or average heart rate ($r= 0.396$, $p= 0.437$). An increased change in USG resulted in a negative influence on mechanical intensity and physiological intensity.

Pearson correlation was used to examine the relationship between percent change in body weight and rate of force development ($r= -0.466$, $p= 0.352$), mechanical intensity ($r= -0.043$, $p= 0.936$), physiological intensity ($r= 0.628$, $p= 0.182$) and average heart rate ($r= 0.505$, $p= 0.307$) however, no correlations were found between percent change in body weight and Zephyr Performance Systems physiological data.

The prevalence of test variables has made research difficult to generalize the impact of dehydration on anaerobic performance. Currently, there is not a criterion standard for measurement of anaerobic work capacity leading to tremendous exercise mode variations. When researching the impact hypo hydration has on anaerobic performance previous physical tests have included vertical jump (Hayes & Morse, 2010; Judelson et al., 2007), 10 to 15 second maximal cycle sprints (Cheuvront et al., 2010; Yoshida et al., 2002), isokinetic force production (Hayes & Morse, 2010), and force production tests to exhaustion (Ftaiti et al., 2001). All of the previously listed exercise test modes utilize anaerobic pathways, however intrinsic differences exist. Interpreting the study results of aerobic and anaerobic performance for sports such as football that includes intermittent high intensity bouts of exercise is further complicated due to the sport not being exclusively aerobic or anaerobic.

There is a substantial lack of evidence identifying the impact of hydration on the rate of force development. The rate of force development is an essential real time measurement complied by the Zephyr Performance Systems Bio Harness and measures the speed in which the contractile elements of the muscle can develop force. Rate of force development is often used by strength and conditioning professionals as a fatigue or state of recovery factor when assessing athletes as it is a major determinant of maximal force and velocity that can be achieved through high intensity performance (Thorlund, Aagaard, & Madsen, 2009). Impaired rates of force development are often detected as an athlete becomes fatigued, has a decreased rate of recovery due to increased muscle damage, or experiences overtraining (Peñailillo, Blazevich, Numazawa, & Nosaka, 2015). The results of the current study reveal a strong negative correlation with hydration status and rate of force development. Even though the results are not significant, the established relationship indicates that as a high-performance athlete becomes more dehydrated their rate of force development is negatively impacted. Mechanical intensity measured by the Zephyr Performance Systems physiological monitor can be described as an index of musculoskeletal output specifically related to g force acceleration activity level. A significant negative correlation of hydration status and mechanical intensity was concluded from the current study. The results show that as an athlete become more dehydrated they have a negatively impacted instantaneous index of effort based on acceleration.

The adverse influence hypo hydration has on rate of force development and mechanical intensity in the current study can be closely related to previous research on dehydration and the impact on athletic performance. Previous research has established the negative impacts induced by hypo hydration on muscular strength and force generation may be caused by detriments in neuromuscular function. Supporting the current findings, when a muscle engages in a maximum concentric action under hypo hydrated conditions muscular strength and overall force is impaired (Ftaiti et al., 2001; Hayes & Morse, 2010; Judelson et al., 2007; Minshull & James, 2013). The hypo hydrated physiological findings of rate of force development and mechanical intensity were similar to (Judelson et al., 2007; Secora et al., 2004; Yoshida et al., 2002) as they concluded the maximal force a muscle group can generate at a velocity is negatively impacted when dehydration levels were reached in athletes.

Conclusion

The present study demonstrates that hypo hydration is a significant occurrence in athletes and as they become more dehydrated their physiological profile may or may not be negatively impacted. A significant correlation did not occur between change in USG and percent change in body weight, indicating that multiple methods of hydration monitoring should be implemented. Prevalence of both pre- and post-practice hypo hydration demonstrate that maintenance of adequate hydration status in collegiate athletes is unfeasible when initial dehydrated levels are combined with high intensity athletic performance. Future research should be conducted with larger sample sizes of collegiate athletes with more detrimental levels of hypo hydration. Specific intervention studies should be conducted to investigate the effectiveness of various training regimes to compare muscle strength and rapid force characteristics outcomes.

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