Hydration status of rugby union players in hot and humid conditions: a comparative team case study of day and night training sessions

Borges, Nattai R.; Doering, Thomas M.; Reaburn, Peter R.; Scanlan, Aaron T.

Published in:
South African Journal for Research in Sport, Physical Education and Recreation

DOI:
10520/EJC-98bcd85ca

Hydration status of rugby union players in hot and humid conditions: A comparative team case study of day and night training sessions

Hidrasie status van Rugby spelers in warm en vogtige toestande : 'n Vergelykende span gevallestudie van dag en nag oefensessies

Running head: Hydration status in rugby players

Abstract

Hydration responses of rugby union players within and between day and night training sessions in hot and humid conditions were monitored. Body mass, fluid ingestion, perceptual thermal stress (TSS), and thirst scores were monitored in ten players (age: 21.9 ± 4.4 yr; body mass: 97.9 ± 15.5 kg; height: 179.5 ± 5.6 cm) across both training sessions. Heat index was higher during the day session compared to the night (44 ºC vs 34 ºC). Significant interaction effects were found for body mass and TSS. Between-group comparisons revealed no significant fluctuations of body mass between sessions. Temporal comparisons showed a significant reduction in body mass across the night session (97.2 ± 15.7; 96.4 ± 15.4 kg), although the mean decrease in body mass did not exceeded >2%. Further, TSS increased significantly across both day (1.2 ± 1.3; 5.2 ± 1.0) and night sessions (1.4 ± 1.0; 3.6 ± 1.6); however, TSS was significantly higher post-training in the day session and players ingested more fluids during the day session (1.4 ± 0.5; 0.9 ± 0.4 $L \cdot hr^{-1}$). Reduced thermal stress scores may compromise self-mediated hydration practices in rugby players when training at night and lead to greater body mass loss.

Keywords: Fluid balance; Thermal stress; Body mass; Diurnal training.

Hydration status of rugby union players in hot and humid conditions: A comparative team case study of day and night training sessions

Introduction

Rugby is a highly intermittent sport with players frequently required to train and compete at high intensities over extended periods (Austin *et al*. 2011; Roberts *et al*. 2008; Quarrie *et al*. 2013). The international appeal of rugby is growing. For example, the New Zealand World Cup held in 2011 hosted teams from 20 countries, and attracted more than 130,000 international visitors (Minsitry of Business, Innovation and Employment, 2012). With increasing popularity and a greater number of global competitions emerging, advances in training approaches are placing rugby players under increasingly higher physical demands. Furthermore, with high participation rates from countries in tropical and sub-tropical climates such as Australia, South Africa, and the Pacific Islands, these demands may be exacerbated when training in hot and humid conditions.

Exercising at high intensities in hot and humid conditions has been shown to alter cardiovascular and nervous system function as core temperature increases (Brotherhood, 2008; Hargreaves, 2008; Cheuvront *et al*. 2010; Racinais *et al*. 2015). However, classifying clear criteria for hot and humid conditions remains difficult due to the individualized nature of accumulated heat stress and as such previous investigations examining exercise during hot and humid conditions have reported temperatures and relative humidity levels ranging from 28-35 ºC and 40-65% (Godek *et al*. 2005; Riveria-Brown *et al.* 2006). The physiological stress resulting from prolonged high intensity exercise and hypohydration in hot and humid conditions can have serious physiological and health-related consequences such as reduced plasma volume, hyponatremia, and increased risk of heat stroke, which may negatively affect sports performance (Aldridge *et al*,. 2005; Cheuvront *et al*. 2010; Cheuvront *et al*. 2013). Maintaining euhydration has been shown to reduce the physiological stress of exercising in hot and humid conditions by maintaining cardiovascular function and reducing core temperature (Cheuvront *et al*. 2010; Racinais *et al*. 2015; Sawka *et al*. 2007). Therefore, maintaining an adequate hydration status during rugby training in hot and humid conditions is important for the performance and health of players.

Existing literature in team sports other than rugby have highlighted the importance of monitoring hydration status throughout training, with evidence suggesting that team sport players are often unable to maintain hydration status throughout training (Arnaoutis *et al*. 2014; Gibson *et al*. 2012; Voitkevica *et al*. 2014; Yeargin *et al*. 2010). However, little is known about the hydration status of rugby players throughout training sessions (Jones *et al*. 2015). Furthermore, no investigation to date has compared the hydration status of training sessions held during the day and at night of rugby players. Comparison of diurnal hydration status is important for both semi-professional athletes that generally train around other occupational commitments either during the day or at night, and professional athletes that are often required to perform multiple training sessions per day. Such empirical information might help coaches, sport scientists, and athletes adequately prepare for day and night training sessions within an annual training plan.

Unfortunately, the monitoring of hydration status is multifaceted and there is no one gold standard field measure for hydration. In the absence of invasive blood and urine monitoring, field-based measures such as body mass fluctuations (Baker *et al*. 2009; Cheuvront *et al*. 2004) and perceptual scales (Armstrong *et al*. 2013; Millard-Stafford *et al*. 2012) have routinely been utilized by coaches and sport scientists. For example, body mass reductions of greater than 2% are suggested to be indicative of hypohydration (Sawka *et al*. 2007) and perceptual scales have been shown to be linearly related to total body water (Armstrong et al. 2013). Although voluntary drinking behavior has been reported to be sufficient to maintain hydration status in most populations (Armstrong *et al*. 2014; Millard-Stafford *et al*. 2012; Wilk *et al*. 2010), no research has investigated the diurnal influences on self-mediated hydration status in rugby players training in hot and humid environments.

Purpose of Research

The aims of this study were to describe and compare the: (i) the body mass fluctuations, (ii) fluid ingestion behavior, and (iii) perceptual thermoregulatory ratings across day and night sessions in rugby players exposed to hot and humid conditions.

Methodology

Subjects

Ten semi-professional Australian male rugby union players from the same club volunteered to participate in the study (age: 21.9 ± 4.4 yr; body mass: 97.9 ± 15.5 kg; height: 179.5 ± 5.6 cm). All players were active in the Central Queensland Australian rugby competition and typically trained four times, and completed one competition match per week. To be eligible for the study all players were required to be free from injury and not taking medication that may have affected their ability to perform exercise or influence hydration status.

Ethical clearance

Prior to inclusion, all players were informed about the study, including the potential risks and benefits, and were required to give a written consent. The study was granted ethical clearance by University Human Research Ethics Committee in accordance with the Helsinki declaration received and the ethics clearance number was H14/11-247.

Experimental approach to the problem

Players were monitored across two separate training sessions separated by 36 hours in the pre-season phase of the annual training plan. Details about the training sessions are shown in Table 1. Temperature and relative humidity were monitored using a portable weather meter (Kestral 3500, AllKestral; Pennsylvania, USA) and heat index was subsequently calculated. The criteria set by the authors to classify the environmental conditions as hot and humid were ambient temperature > 28 ºC and relative humidity > 60%. This classification was based from temperature and humidity ranges in previously published studies (Godek *et al*. 2005; Riveria-Brown *et al.* 2006) and the estimated high risk of heat illness when exercising at temperatures > 28 ºC and relative humidity > 50% (Racinais *et al*. 2015). All testing was conducted around normal training sessions as to not interfere with the training protocols set by the coaching staff. Players were asked to refrain from performing strenuous exercise and consuming alcohol for 24 hours before each training session and maintain normal hydration practices before training.

INSERT TABLE 1 AROUND HERE

Testing protocols

Twenty minutes prior to the scheduled training time players were required to complete a perceived thermal stress scale (TSS) and a 100-mm visual analogue thirst scale (VATS) to determine baseline perceptual levels of thermal stress and thirst prior to training. Body mass and height were then measured to the nearest 0.02 kg using calibrated electronic scales (Masscal; Florida, USA) and 0.1 cm using a stadiometer with players only wearing training shorts. During each training session, each player had a designated water bottle which was weighed to determine the volume of water contained with the same electronic scales mentioned above. Players were instructed to drink *ad libitum* from their designated water bottle only, which was refilled and weighed by the research team as required. The water bottles were only filled with water and supplementary bottles were provided to players for any purpose other than ingestion (e.g. spraying on body, washing mouth-guard, etc.). Immediately at the cessation of each training session adjacent to the field, each player's water bottle was weighed to determine absolute water ingestion (L) and water ingestion corrected for training time ($L\cdot hr^{-1}$). Each player was then instructed to wipe away any excess sweat on their body surface and post-training body mass was obtained. Players then gave perceptual indicators of both thermal stress and thirst using the TSS and VATS. All measures were supervised by the research team.

Physical, physiological and perceptual parameters

Acute changes in body mass (absolute [kg] and relative [%]) were calculated and absolute sweat loss (L) and sweat rate ($L\cdot hr^{-1}$) were determined from changes in body mass corrected for fluid intake. This approach has been shown to provide a valid indication of total sweat loss in hot climates using the following formula (Cheuvront *et al*. 2002):

Sweat loss (L) = Pre-training body mass (kg) – Post-training body mass (kg) + Water ingestion (L)

There was no need to correct for urine loss as players were not required to empty their bladder during either training session.

The TSS was a 0-9 Likert scale where 0 = "Comfortable temperature" and 9 = "Unbearably hot", and the VATS was a 100-mm visual analogue scale where on one side of the 100-mm line, "No thirst" was presented, and on the other end, "Excruciating thirst" was presented (Ely *et al*. 2013, Millard-Stafford *et al*. 2012). Each player was instructed to indicate their perceived thirst on the line which was then measured to the nearest 1 mm to give a numerical score.

Statistical analyses

All data are presented as mean ± standard deviation. Separate 2-way repeated measures ANOVAs were used to detect interactions and main effects between training sessions (day vs. night) and temporally across each session (pre vs. post) for body mass, TSS and VATS. When significant interactions or main effects were found, Tukeys HSD post hoc test was used to identify between-group (day vs. night) and within-group (pre vs. post) differences. Between-group differences for absolute sweat loss, sweat rate, absolute water ingestion and rate of water ingestion were also analyzed using dependent t-tests. When significant differences were observed, effect sizes (ES) were used to characterize the magnitude of difference using the following criteria: *trivial* <0.20; *small* = 0.2-0.59; *moderate* = 0.60-1.19; *large* = 1.20-1.99; *very large* >2.0. If the 90% confidence limits (CL) of the ES crossed the threshold of both ±0.2 the effect would not be considered meaningful and be deemed *unclear* (Hopkins *et al.* 2009). All statistical analyses were conducted using Statistica software package (StatSoft. Inc., Tulsa, USA). Statistical significance was accepted at $P < 0.05$ level.

Results

There was a significant interaction effect ($F_{1, 18} = 7.56$, $P = 0.013$), and within-group ($F_{1, 18} = 15.34$, $P = 0.001$) main effect for body mass comparisons. Post hoc analyses revealed that players were significantly lighter at the cessation of the night session when compared to pre-training values ($P = 0.001$) (Table 2). The magnitude of the difference was found to be *trivial* (ES ± 90%CL = 0.05 ± 0.02). Additionally, changes in body mass across both training sessions were less than the 2% euhydration cut-off (night: 0.8 ± 0.4%; day: 0.1 ± 0.6%) set by the American College of Sports Medicine (ACSM) (Sawka et al. 2007). No other significant differences were found for body mass changes between or within-group ($P > 0.05$).

INSERT TABLE 2 AROUND HERE

Thermal stress scores showed an almost significant interaction effect ($F_{1, 18}$ = 8.10, P = 0.06) and a significant within-group ($F_{1, 18}$ = 49.71, P < 0.001) main effect. Post-hoc analyses revealed significant increases in TSS across both the day (P = 0.002, ES = 2.78 ± 0.73, *very large*) and night sessions (P = 0.012, ES = 2.08 ± 1.15, *very large*). Between-group comparisons revealed significantly higher post-training TSS during the day session compared to the night session (P = 0.043, ES = 1.42 ± 0.84, *large*) (Table 2). There was a significant within-group main effect for VATS ($F_{1, 18}$ = 5.66, P = 0.029) however, post-hoc analysis revealed no significant between- or within-group differences (P > 0.05). Players absolute sweat lost was significantly higher during the night session compared to the day (P = 0.005, ES = 1.50 ± 0.75, *large*), however, when corrected for training duration no significant difference for sweat rate was observed (P = 0.90). Contrastingly, no significant difference was found for absolute water ingestion (P = 0.41), however, when corrected for training duration, players ingested significantly more fluid during the day session compared to the night (P = 0.009 ES = 1.06 ± 0.58, *moderate*) (Table 2).

Discussion

This study aimed to describe and compare the body mass fluctuations, fluid ingestion behavior, and perceptual thermoregulatory ratings across day and night sessions in rugby union players exposed to hot and humid conditions. The major findings showed that players exhibited a: (i) no significant difference between-sessions for pre-training body mass; (ii) Adequate hydration practices throughout both day and night sessions to maintain body mass fluctuations below 2% despite a significant reduction in body mass across the training session held at night; (iii) significantly greater rate of water ingestion during the day session compared to the night session despite similar sweat rates; and (iv) significantly higher thermal stress scores at the cessation of the day session compared to the night session.

This is the first study to compare and contrast day and night variations in body mass and fluid ingestion during training in rugby players. Our findings indicate that the players investigated demonstrated a non-significant 0.68 ± 0.9% reduction in the pre-training body mass between day and night sessions. This value is similar to the acceptable daily variation in body mass previously investigated in men who trained daily in hot conditions (Cheuvront *et al*. 2004). Although inadequate pre-training hydration status has been observed in other team sports such as soccer (Phillips *et al*. 2014; Voitkevica *et al*. 2014) and American football (Yeargin *et al*. 2006), the present study suggests that the pre-training hydration practices were adequate to maintain BM within an acceptable range of day to day variation despite the influences of different occupational requirements and activities prior to training in the day and at night. This result supports existing studies in professional male rugby players (Jones *et al*. 2015) and female rugby league (Jones *et al*. 2016) players who exhibited urine osmolality below the euhydration cutoff used by the authors of 700 $mOsm.kg^{-1}$ at arrival for match play, field, and gym training suggesting that rugby players are able to maintain adequate hydration practices outside of structured training. The present results do, however, contrast another existing study in professional rugby players which reported that 80% of their players started training in a hypohydrated state as measured by urine specific gravity (Cosgrove *et al*. 2014). Although there is contrasting research in regards to pre-training hydration status, it is important to note that the other studies monitored professional rugby or league players and, importantly, the training was not conducted in hot and humid conditions and different measures were utilized to monitor hydration status

The players in the present study also maintained hydration status through-out the training sessions in hot and humid conditions. Although previous literature investigating hydration status during competition gameplay exists (Aragón-Vargas *et al*. 2009; Kurdak *et al*. 2010; Meir *et al*. 2003; Meir and Halliday, 2005; O'Hara *et al*. 2010), little is known about the changes in hydration status of team sports athletes during training in hot and humid conditions. The present findings contrast with those made in other team sports which reported that the professional athletes are not able to maintain hydration status during training in hot and humid conditions (Arnaoutis *et al*. 2014; Godek *et al*. 2005). For example, Arnaoutis *et al*. (2014) reported urine specific gravity values above the 1.020 euhydration cutoff in a cohort of young athletes from a range of sports (basketball, gymnastics, swimming, running, and canoeing) and across training sessions, and concluded that the athletes dehydrated throughout the training sessions, although the study, reported only a 1.1 ± 0.07% decrease in body mass. Additionally, Godek *et al*. (2005) reported that American football players were unable to maintain hydration status when training in hot and humid conditions with urine specific gravity reaching above the 1.020 euhydration cut off on two days of a preseason training camp with players exhibiting ~1.5% drop in body mass across each training session. .

Unfortunately, to date no studies have monitored the hydration status of rugby players during hot and humid conditions rugby union and league players have been shown to maintain hydration status across training sessions although these studies were not held in hot and humid conditions (Jones *et al*. 2016, Jones *et al*. 2015). Jones *et al*. (2015) reported mean body mass fluctuations of 0.3–1 kg across match play, field training and gym training. Interestingly, fluid intake during training was often excessive compared to fluid loss during training in professional male rugby players and that some players were at risk of hyponatremia. This may warrant monitoring of fluid ingestion of rugby players in cooler conditions than those reported in the present study. However, the varied results when training in hot and humid conditions could be due to differing demands of the training sessions or sports examined. Considering the highly technical and tactical nature of rugby, as well as the fact that the training sessions were held during the competitive phase of the season rather than the preseason phase, a greater focus on skill and tactical team development may have led to reduced physical exertion compared to the studies mentioned above, and therefore a possible maintenance of hydration status.

While hydration status as measured by a less than 2% fluctuation in body mass was maintained throughout day and night training sessions in our study, there was a statistically significant reduction in body mass across the night session. Accordingly, the significant reduction in body mass across the night session was likely due to the significantly lower water ingestion rates between sessions (day: 1.4 ± 0.5 $L·hr^{-1}$; night: 0.90 ± 0.40 $L·hr^{-1}$) while maintaining similar sweat rates. Interestingly, this finding aligns with the significant interaction observed for TSS which may suggest that the increased thermal stress while training in conditions of a higher heat index may have led to greater water ingestion and maintenance of body mass across the day session despite similar VATS values. Taken together, these results suggest that, when training in hot and humid conditions, self-mediated hydration practices may be comprised or not sufficient to maintain hydration status during conditions of lower heat index. Indeed, a recent consensus published on training and competing in the heat states that drinking to thirst whilst training in hot environments can still lead to a reduced hydration status (Racinais *et al*. 2015). However, previous studies have not taken into account whether a higher heat index and perceived thermal stress can promote greater water ingestion independent of thirst in athletes training outdoors in hot and humid conditions. This suggests that further research is needed to elucidate the influence of training at lower perceived heat stress responses on thirst and drinking behavior in rugby players.

Finally, the authors profess limitations to this study. Firstly, the limited number of players and field based nature of the outcome measures. Although body mass is an accepted method to monitor acute changes in hydration status, to further understand any diurnal effect on hydration status and water balance, further investigation adopting more invasive methods such as plasma osmolality or urine measures is warranted. Secondly, this investigation was a team-specific case study and might not be representative of other rugby players competing for teams. Lastly, in accordance with previous research (Cheuvront *et al*. 2002) players were weighted with their shorts and absorption of excess sweat or water may have influenced post-session body mass measures.

Practical Applications

Although hydration status was maintained throughout both day and night sessions, the significant reduction in body mass demonstrates the importance of proper hydration practices during training sessions held at night, when heat index may be lower. Therefore, strategies should be put in place by coaches and sport scientists with special consideration when training is held at night in hot and humid environments to ensure adequate hydration practices with players consuming 6 mL of fluid per kilogram of body mass every 2-3 hours before training to ensure they present in a euhydrated state (Racinais *et al*. 2015) and consuming adequate fluids throughout training to replace exercise-induced fluid loss. Furthermore, player education strategies and the development of individualized hydration plans accounting for player occupations in rugby players may be warranted to promote better adherence to these fluid consumption recommendations.

Conclusion

Optimal hydration practices are important in team sports for both optimal sports performance and player safety. The present findings suggest adequate pre-training hydration strategies by rugby players training in hot and humid conditions. Additionally, the current data suggest that the rugby players investigated were able to maintain hydration status throughout day and night sessions with *ad libitum* access to water. Despite the maintenance of hydration status there was a significant reduction in body mass across the night training session due to lower fluid ingestion. The lower fluid ingestion may be related to lower thermal stress scores due to the night session being held in conditions exhibiting a lower heat index. Taken together, these results suggest that players may follow sufficient hydration practices across training during the day, but more care should be taken to educate team athletes about proper hydration habits and tailor individualized hydration plans in preparation for and during night time training sessions.

Acknowledgements

The authors would like to thank Central Queensland Rugby Union for their support and for volunteering their time to complete the current study. There were no conflicts of interest or funding relevant to this study.

References

ALDRIDGE, G., BAKER, J. & DAVIES, B. 2005. Effects of hydration status on aerobic performance for a group of male university rugby players. *Journal of Exercise Physiology Online,* 8**,** 36-42.

ARAGÓN-VARGAS, L. F., MONCADA-JIMÉNEZ, J., HERNÁNDEZ-ELIZONDO, J., BARRENECHEA, A. & MONGE-ALVARADO, M. 2009. Evaluation of pre-game hydration status, heat stress, and fluid balance during professional soccer competition in the heat. *European Journal of Sport Science,* 9**,** 269-276.

ARMSTRONG, L. E., GANIO, M. S., KLAU, J. F., JOHNSON, E. C., CASA, D. J. & MARESH, C. M. 2013. Novel hydration assessment techniques employing thirst and a water intake challenge in healthy men. *Applied Physiology, Nutrition, and Metabolism,* 39**,** 138-144.

ARMSTRONG, L. E., JOHNSON, E. C., KUNCES, L. J., GANIO, M. S., JUDELSON, D. A., KUPCHAK, B. R., VINGREN, J. L., MUNOZ, C. X., HUGGINS, R. A., HYDREN, J. R., MOYEN, N. E. & WILLIAMSON, K. H. 2014. Drinking to Thirst Versus Drinking Ad Libitum During Road Cycling. *Journal of Athletic Training,* 49**,** 624-631.

ARNAOUTIS, G., KAVOURAS, S. A., ANGELOPOULOU, A., SKOULARIKI, C., BISMPIKOU, S., MOURTAKOS, S. & SIDOSSIS, L. S. 2014. Fluid balance during training in elite young athletes of different sports. *The Journal of Strength & Conditioning Research,* Publish Ahead of Print.

AUSTIN, D., GABBETT, T. & JENKINS, D. 2011. The physical demands of Super 14 rugby union. *Journal of Science & Medicine in Sport,* 14**,** 259-263.

BAKER, L., LANG, J. & LARRY KENNEY, W. 2009. Change in body mass accurately and reliably predicts change in body water after endurance exercise. *European Journal of Applied Physiology,* 105**,** 959-967.

BROTHERHOOD, J. R. 2008. Heat stress and strain in exercise and sport. *Journal of Science and Medicine in Sport,* 11**,** 6-19.

CHEUVRONT, S. N., CARTER, R., MONTAIN, S. J. & SAWKA, M. N. 2004. Daily body mass variability and stability in active men undergoing exercise-heat stress. *International journal of sport nutrition and exercise metabolism,* 14**,** 532-540.

CHEUVRONT, S. N., HAYMES, E. M. & SAWKA, M. N. 2002. Comparison of sweat loss estimates for women during prolonged high-intensity running. *Medicine and Science in Sports and Exercise,* 34**,** 1344-50.

CHEUVRONT, S. N., KENEFICK, R. W., CHARKOUDIAN, N. & SAWKA, M. N. 2013. Physiologic basis for understanding quantitative dehydration assessment. *American Journal of Clinical Nutrition,* 97**,** 455-62.

CHEUVRONT, S. N., KENEFICK, R. W., MONTAIN, S. J. & SAWKA, M. N. 2010. Mechanisms of aerobic performance impairment with heat stress and dehydration. *Journal of applied physiology,* 109**,** 1989-1995.

COSGROVE, S. D., LOVE, T. D., BROWN, R. C., BAKER, D. F., HOWE, A. S. & BLACK, K. E. 2014. Fluid and electrolyte balance during two different preseason training sessions in elite rugby union players. *Journal of Strength and Conditioning Research,* 28**,** 520-7.

ELY, B., SOLLANEK, K., CHEUVRONT, S., LIEBERMAN, H. & KENEFICK, R. 2013. Hypohydration and acute thermal stress affect mood state but not cognition or dynamic postural balance. *European Journal of Applied Physiology,* 113**,** 1027-1034.

GIBSON, J. C., STUART-HILL, L. A., PETHICK, W. & GAUL, C. A. 2012. Hydration status and fluid and sodium balance in elite Canadian junior women's soccer players in a cool environment. *Applied Physiology, Nutrition, and Metabolism,* 37**,** 931-937.

GODEK, S. F., BARTOLOZZI, A. R. & GODEK, J. J. 2005. Sweat rate and fluid turnover in American football players compared with runners in a hot and humid environment. *British Journal of Sports Medicine,* 39**,** 205-211.

HARGREAVES, M. 2008. Physiological limits to exercise performance in the heat. *Journal of Science and Medicine in Sport,* 11**,** 66-71.

HOPKINS, W., MARSHALL,S., BATTERHAM, A. & HANIN, J. 2009. Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*; 41(1):3.

JONES, B., TILL, K., KING, R. F., GRAY, M. P. & O'HARA, J. P. 2016. Are Habitual Hydration Strategies of Female Rugby League Players Sufficient to Maintain Fluid Balance and Blood Sodium Concentration during Training and Match-Play? A Research Note from the Field. *Journal of Strength and Conditioning Research*, 30, 875-880.

JONES, B. L., O'HARA, J. P., TILL, K. & KING, R. F. G. J. 2015. Dehydration and Hyponatremia in Professional Rugby Union Players: A Cohort Study Observing English Premiership Rugby Union Players During Match Play, Field, and Gym Training in Cool Environmental Conditions. *Journal of Strength and Conditioning Research,* 29**,** 107-115.

KURDAK, S., SHIRREFFS, S., MAUGHAN, R., OZGÜNEN, K., ZEREN, C., KORKMAZ, S., YAZICI, Z., ERSÖZ, G., BINNET, M. & DVORAK, J. 2010. Hydration and sweating responses to hot-weather football competition. *Scandinavian journal of medicine & science in sports,* 20**,** 133-139.

MEIR, R., BROOKS, L. & SHIELD, T. 2003. Body weight and tympanic temperature change in professional rugby league players during night and day games: a study in the field. *Journal of Strength and Conditioning Research,* 17**,** 566-72.

MEIR, R. A. & HALLIDAY, A. J. 2005. Pre- and post-gaame body mass changes during an internation rugby tournament: a practical perspective. *Journal of Strength and Conditioning Research,* 19**,** 713-716.

MILLARD-STAFFORD, M., WENDLAND, D. M., O'DEA, N. K. & NORMAN, T. L. 2012a. Thirst and hydration status in everyday life. *Nutrition Reviews,* 70**,** S147-S151.

MINISTY OF BUSINESS, INNOVATION AND EMPLOYMENT. 2012. The Stadium of Four 337 Million. Ministry of Business, Innocation and Employment, NZ. Hyperlink: https://www.majorevents.govt.nz/pdf-library/nz-major-events/rugby-world-cup-339 2011/RWC-2011-Host-Nation-Report.pdf. Retrieved on March 15, 2015.

O'HARA, J. P., JONES, B. L., TSAKIRIDES, C., CARROLL, S., COOKE, C. B. & KING, R. F. G. J. 2010. Hydration status of rugby league players during home match play throughout the 2008 Super League season. *Applied Physiology, Nutrition & Metabolism,* 35**,** 790-796.

PHILLIPS, S. M., SYKES, D. & GIBSON, N. 2014. Hydration Status and Fluid Balance of Elite European Youth Soccer Players during Consecutive Training Sessions. *Journal of Sports Science and Medicine,* 13**,** 817-22.

QUARRIE, K. L., HOPKINS, W. G., ANTHONY, M. J. & GILL, N. D. 2013. Positional demands of international rugby union: Evaluation of player actions and movements. *Journal of Science and Medicine in Sport,* 16**,** 353-359.

RACINAIS, S., ALONSO, J. M., COUTTS, A., FLOURIS, A., GIRARD, O., GONZÁLEZ-ALONSO, J., HAUSSWIRTH, C., JAY, O., LEE, J. W., MITCHELL, N., NASSIS, G., NYBO, L., PLUIM, B., ROELANDS, B., SAWKA, M., WINGO, J. & PÉRIARD, J. 2015. Consensus Recommendations on Training and Competing in the Heat. *Sports Medicine***,** 1-14.

RIVERIA-BROWN, A. M., ROWLAND, T. W., RAMIREZ-MARRERO, F. A., SANTACANA, G., & VANN, A. 2006. Exercise tolerance in a hot and humid climate in heat-acclimatized girls and women. *International Journal of Sports Medicine*, 27, 943-950.

ROBERTS, S. P., TREWARTHA, G., HIGGITT, R. J., EL-ABD, J. & STOKES, K. A. 2008. The physical demands of elite English rugby union. *Journal of Sports Sciences,* 26**,** 825-833.

SAWKA, M. N., BURKE, L. M., EICHNER, E. R., MAUGHAN, R. J., MONTAIN, S. J. & STACHENFELD, N. S. 2007. American College of Sports Medicine position stand. Exercise and fluid replacement. *Medicine and Science in Sports and Exercise,* 39**,** 377-90.

TORRES-MCGEHEE, T. M., PRITCHETT, K. L., ZIPPEL, D., MINTON, D. M., CELLAMARE, A. & SIBILIA, M. 2012. Sports Nutrition Knowledge Among Collegiate Athletes, Coaches, Athletic Trainers, and Strength and Conditioning Specialists. *Journal of Athletic Training,* 47**,** 205-211.

VOITKEVICA, L., PONTAGA, I., TIMPMANN, S. & ÖÖPIK, V. 2014. Pre-training hydration status of well-trained soccer players in moderate temperature autumn and cool winter. *Education Physical Training Sport,* 95**,** 57-63.

WILK, B., TIMMONS, B. W. & BAR-OR, O. 2010. Voluntary fluid intake, hydration status, and aerobic performance of adolescent athletes in the heat. *Applied Physiology, Nutrition, and Metabolism,* 35**,** 834-841.

YEARGIN, S. W., CASA, D. J., ARMSTRONG, L. E., WATSON, G., JUDELSON, D. A., PSATHAS, E. & SPARROW, S. L. 2006. Heat acclimatization and hydration status of American football players during initial summer workouts. *Journal of Strength and Conditioning Research,* 20**,** 463-470.

YEARGIN, S. W., CASA, D. J., JUDELSON, D. A., MCDERMOTT, B. P., GANIO, M. S., LEE, E. C., LOPEZ, R. M., STEARNS, R. L., ANDERSON, J. M., ARMSTRONG, L. E., KRAEMER, W. J. & MARESH, C. M. 2010. Thermoregulatory Responses and Hydration Practices in Heat-Acclimatized Adolescents During Preseason High School Football. *Journal of Athletic Training,* 45**,** 136-146.

Table and Figure Legend

Table 1. Training session details and environmental conditions for the day and night training sessions (*n* = 10).

Table 2. Physical, physiological and perceptual indicators of hydration status, thermal stress, and thirst during day and night training sessions in rugby union players (*n* = 10).

Table 1. Training session details and environmental conditions for the day and night training sessions (*n* = 10).

Training Session Time	**Duration (min)**	**Temperature (°C)**	**Relative Humidity (%)**	**Heat Index (°C)**	**Training Activities**
Day (08:00)	55	33.8	66	44	Warm up, specific ball handling work, contact drills, water break, team runs
Night (18:30)	75	29.2	74	34	Warm up, shuttle runs, water break, specific ball handling work, contact drills, water break, back line running, forward line out drills, team runs

Table 2. Physical, physiological and perceptual indicators of hydration status, thermal stress, and thirst during day and night training sessions in rugby union players (*n* = 10).

Measure	Day Session (08:00)		Night Session (18:30)	
	Pre-training	Post- training	Pre-training	Post-training
Mass (kg)	97.9 ± 15.7	97.8 ± 15.5	97.2 ± 15.7	96.4 ± 15.4*
ΔMass (%)		0.1 ± 0.6		0.8 ± 0.4
Sweat loss (L)		1.4 ± 0.3†		1.9 ± 0.3†
Sweat loss ($L·hr^{-1}$)		1.5 ± 0.4		1.5 ± 0.3
Water ingestion (L)		1.3 ± 0.4		1.1 ± 0.5
Water ingestion ($L·hr^{-1}$)		1.4 ± 0.5†		0.9 ± 0.4†
TSS	1.2 ± 1.3	5.2 ± 1.0*	1.4 ± 1.0	3.6 ± 1.6*†
VATS	31.2 ± 15.9	42.8 ± 20.6	28.5 ± 19.8	45.4 ± 21.2

Δ = change across session; TSS = thermal stress; VATS = visual analogue thirst scale. † = significant difference between sessions ($P < 0.05$); * = significant difference across sessions