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**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**

Jones, B., Till, K., King, R.F.G.J., Gray, M.P., O'Hara, J.P.

Running Title: Hydration Strategies of Female Rugby Players

Research Institute Sport, Physical Activity and Leisure, Leeds Beckett University, Leeds, West
Yorkshire, United Kingdom

Dr Ben Jones – B.Jones@LeedsBeckett.ac.uk

Dr Kevin Till – K.Till@LeedsBeckett.ac.uk

Prof. Roderick King – R.King@LeedsBeckett.ac.uk

Michael Gray – M.Gray@LeedsBeckett.ac.uk

Dr John O'Hara – J.OHara@LeedsBeckett.ac.uk

Corresponding Author:

Dr. Ben Jones

Room 112, Fairfax Hall

Research Institute for Sport, Physical Activity and Leisure

Centre for Sports Performance

Headingley Campus, Leeds Beckett University

W.Yorkshire, LS6 3QS

Phone: (044-11) 01132-832600 Ext: 24009

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

ABSTRACT

Limited data exists on the hydration status of female athletes, with no data available on female rugby players. The objective of this study was to investigate the habitual hydration status on arrival, sweat loss, fluid intake, sweat Na^+ loss and blood $[\text{Na}^+]$ during field training and match-play in ten international female rugby league players. Urine osmolality on arrival to match-play ($382 \pm 302 \text{ mOsmol} \cdot \text{kg}^{-1}$) and training ($667 \pm 260 \text{ mOsmol} \cdot \text{kg}^{-1}$) was indicative of euhydration. Players experienced a body mass loss of 0.50 ± 0.45 and $0.56 \pm 0.53\%$ during match-play and training respectively. During match-play players consumed $1.21 \pm 0.43 \text{ kg}$ of fluid and had a sweat loss of $1.54 \pm 0.48 \text{ kg}$. During training players consumed $1.07 \pm 0.90 \text{ kg}$ of fluid, in comparison to $1.25 \pm 0.83 \text{ kg}$ of sweat loss. Blood $[\text{Na}^+]$ was well regulated ($\Delta -0.7 \pm 3.4$ and $\Delta -0.4 \pm 2.6 \text{ mmol} \cdot \text{L}^{-1}$) despite sweat $[\text{Na}^+]$ of 47.8 ± 5.7 and $47.2 \pm 6.3 \text{ mmol} \cdot \text{L}^{-1}$ during match-play and training. The findings of this study show mean blood $[\text{Na}^+]$ appears to be well regulated despite losses of Na^+ in sweat and electrolyte free fluid consumption. For the duration of the study players did not experience a body mass loss (dehydration $>2\%$) indicative of a reduction in exercise performance, thus habitual hydration strategies appear adequate. Practitioners should evaluation the habitual hydration status of athletes to determine if interventions above habitual strategies are warranted.

Key words: Hydration, Electrolyte, Nutrition, Performance

INTRODUCTION

Understanding the habitual hydration strategies of athletes, encompassing sweat loss and fluid consumption is important for strength and conditioning coaches to either optimize hydration strategies or acknowledge habitual behaviours are adequate (6). To date within rugby, hydration strategies (i.e., fluid intake and sweat loss) have only been reported for male rugby league (17) and rugby union (11, 15) players; and male rugby league referees (10). To date no data are available on the hydration strategies of female rugby league players, therefore strength and conditioning coaches do not have an evidence base for which to either intervene or allow habitual practices to continue. There may be differences in fluid homeostasis, due to a biological sex effect (i.e., differences in thermoregulation (9) and metabolic heat production (1)), or behavioural differences (i.e., females are more compliant with fluid intake advice during endurance exercise (5)) between sexes.

Rugby league players are regularly involved in match-play and field based training sessions, thus understanding any differences between the respective session types may allow developments in the preparatory practice (i.e., how players arrive), and habits during training and match-play. In addition to hydration assessments (i.e., body mass change, fluid intake, sweat loss), investigating blood $[Na^+]$ changes in rugby players is also insightful for strength and conditioning coaches. For example, a recent study showed that on some occasions rugby union players consumed excessive fluid and became hyponatremic (blood $[Na^+] < 135 \text{ mmol} \cdot \text{L}^{-1}$) (11). Hyponatremia can lead to sub-optimal muscle function (16) and previous observations of a female tennis player have shown severe implications for health (21). Female athletes have been shown to have a greater prevalence of hyponatremia in comparison to males (24). To the author's knowledge, no study has investigated the hydration habits and change in blood $[Na^+]$ in female rugby players, thus practitioners are unaware of what level of intervention or prescription is required for this population. Therefore, the purpose of this study was to establish the habitual

hydration status on arrival, determine sweat loss, fluid intake, sweat $[\text{Na}^+]$ and $\Delta\text{blood } [\text{Na}^+]$ during field training and international match-play in female rugby league players.

METHODS

Experimental Approach to the Problem

The design of the study was observational in nature, to provide data on the players' habitual hydration status on arrival, sweat loss, fluid intake, sweat $[\text{Na}^+]$, $\Delta\text{blood } [\text{Na}^+]$ and establish post-exercise hydration status during one international match and four field training sessions. Players were advised that observations were to establish sweat loss, in addition to blood and sweat $[\text{Na}^+]$, as to not encourage excessive or abnormal drinking habits. All training sessions lasted approximately 90 minutes and the match lasted 80 minutes. Training sessions started at 1300 hrs and kick off time on the day of the match was 1500 hrs. Although no pre-observation controls were employed, the data collected on arrival to match-play and training explored the habitual arrival status of international female rugby league players.

Subjects

Ten international female rugby league players (age; 24.7 ± 5.8 years and body mass; 73.8 ± 16.0 kg) volunteered to participate in the study. The cohort consisted of 5 positional backs and 5 positional forwards. All players were observed during training and match play. Despite the limited sample size, given the small population group of international female rugby league players in the UK (i.e., the squad; $n = 25$), the sample recruited was deemed appropriate to represent this specific population. All protocols received institutional ethics approval with written consent provided.

Procedures

On arrival, 60 minutes prior to kick off for match-play and 30 minutes prior to training, a urine sample was provided and analysed for osmolality. Players were required to towel dry, to remove any sweat prior to body mass assessment, wearing underwear, determined to the nearest 100 g using calibrated digital scales (Seca, 700 1321008, Germany). Fingertip blood samples were taken for the analysis of $[Na^+]$ while players assumed a semi-recumbent position for 5 minutes. Absorbent sweat patches (Tagaderm +Pad, 3M, Loughborough, UK) were applied to the forearm, scapula, chest and thigh (20).

Individually labelled, pre-weighed commercially available sports drinks (≈ 500 mL) and pre-weighed drinks bottles (≈ 1000 mL) containing water were provided for *ad libitum* consumption during training and match-play (i.e., pre-match and at half-time). The fluid available during actual match-play was water. The commercially available sports drink was Na^+ free and the choice of the coaching staff not researchers. For match observations, all fluid containers were labelled with; pre-match (consumed between pre-match body mass assessment and kick off), half-time and during match-play, which indicated when that specific fluid should be consumed *ad libitum*. This was not required for training as players used their individual fluid containers for the duration of training. A researcher acted as the water carrier during match-play to ensure compliance with individual bottles. Players were advised not to spit out any fluid or use their fluid for anything other than fluid intake, which was adhered to.

A pre-weighed individually labelled jerry can and a Shewee (Shewee Ltd. Tadworth UK) was provided post body mass assessment, to collect any urine output at any time (aggregated for pre-match and during half-time for match-play and for the duration of the training session) to allow calculations of sweat loss. No food was consumed between body mass assessments.

Post match-play and training, prior to any food or fluid intake, sweat patches were removed and players were encouraged to provide a urine sample to ensure an empty bladder prior to post-exercise body mass determination. Following this, a fingertip blood sample was

taken in the same manner as pre-exercise. Percentage body mass change was calculated from the arrival and post-exercise body mass assessments.

All pre-weighed fluid containers were reweighed post-exercise via triplicate analysis independently, using bench top scales (resolution 0.001 kg; CS-2000, Ohaus, USA). Differences in mass from pre to post match-play or training determined fluid intake and urine output. Sweat loss was calculated (body mass pre – body mass post + fluid intake – urine output), although it is acknowledged other mass determinants exist (13).

Urine samples were analysed for osmolality using a calibrated freezing point osmometer (Genotec Osmomat 030-D, 040906, Germany), which had a co-efficient of variation (CV) of 1.4, 1.3, 0.6%, determined against stock solutions of 100, 300 and 850 mOsmol·kg⁻¹, respectively. Urine osmolality was interpreted as euhydration (≤ 700 mOsmol·kg⁻¹), moderate hypohydration (701 – 899 mOsmol·kg⁻¹) and severe hypohydration (≥ 900 mOsmol·kg⁻¹) (22).

Sweat patches worn during exercise were analysed for [Na⁺] as previously described (11), using a flame photometer (Jenway, PFP7 Flame Photometer, Essex, UK). Data were adjusted by 35% to account for the ~30-40% over-estimation of sweat [electrolyte] using the closed-pouch method (19).

Fingertip blood samples were analysed immediately with a GEM[®] Premier TM 4000 containing a 30-day disposable cartridge (GEM[®] Premier TM 4000 PAK) to determine blood [Na⁺]. Within-day CV is reported as 0.5% and between-day CV is reported as 0.5% (2). Blood [Na⁺] was interpreted as hyponatremia (<135 mmol·L⁻¹), normonatremia (135 – 145 mmol·L⁻¹) and hypernatremia (>145 mmol·L⁻¹) (11).

Ambient temperature and relative humidity were measured using a digital weather station (Oregon Scientific, UK). The weather station was placed out of direct sunlight, temperature and relative humidity was recorded 60 minutes prior to kick-off, at kick-off, half-

time and post-match for match-play, with the mean reported. The temperature was measured at the start and end of training, again the mean was reported.

Data Analysis

Data are presented as mean \pm standard deviation. Preliminary analyses were conducted to check for normality with Kolmogorov-Smirnov tests performed on the data set to check for normality. A repeated-measures analysis of variance (ANOVA) was used to determine any significant differences between match-play and mean training data for urine osmolality, fluid intake, sweat loss, sweat loss rate, percentage body mass change, blood $[\text{Na}^+]$ change and sweat $[\text{Na}^+]$. A two-way (activity [match-play vs. training] and time [pre vs. post]) repeated-measures ANOVA was used to determine any significant differences for blood $[\text{Na}^+]$. A repeated-measures ANOVA was used to determine differences between fluid intake time points (i.e., pre-match, first-half, half-time, second-half) with Bonferroni corrections for multiple comparisons. Cohen's d effect sizes with 95% confidence intervals (CI) were calculated, and interpreted using a modified effect size scale of 0 – 0.2 considered to be a trivial effect, 0.2 – 0.6 a small effect, 0.6 – 1.2 a moderate effect, 1.2 – 2.0 a large effect, and >2.0 a very large effect (7). Where the confidence interval crossed 0, the effect was interpreted as unclear. Pearson product moment correlations were calculated to determine correlations for pre, post and Δ blood $[\text{Na}^+]$ against percentage body mass change, total fluid intake, sweat loss and arrival urine osmolality. Thresholds for correlations were interpreted as <0.1 (trivial), 0.1 – 0.3 (small), 0.3 – 0.5 (moderate), 0.5 – 0.7 (large), 0.7 – 0.9 (very large) and >0.9 (extremely large) (8). SPSS version 20.0 was used to conduct analysis with all statistical significance set at $P<0.05$.

RESULTS

The ambient temperature and relative humidity during match-play and training was 24°C and 44% and 17.4 ± 6.5°C, and 47 ± 4%, respectively.

There was a significant difference in arrival urine osmolality between match-play and training (382 ± 302 vs. 667 ± 260 mOsmol·kg⁻¹, $P < 0.001$; moderate $d = -1.01$ [CI -0.04 – -1.90]). Percentage body mass change, fluid intake, urine output and sweat loss are presented in table 1. The difference between match-play and training were all unclear and not significant for; percentage body mass change, sweat loss, urine output and total fluid intake. Sweat loss rate was significantly greater and moderate during training than match-play ($d = 0.85$).

insert table 1 near here

During match-play observations, there was a significant difference ($P = 0.001$) between time points for fluid intake. Fluid intake was significantly lower pre-match (0.135 ± 0.169 kg) than half-time (0.441 ± 0.234 kg, $P < 0.001$; $d = 1.50$ [CI 0.45 – 2.42]), and during match-play (aggregated first and second half; 0.629 ± 0.329 kg, $P = 0.035$; $d = 1.89$ [CI 0.77 – 2.85]).

Sweat [Na⁺] and blood [Na⁺] are presented in table 2. There was no significant effect of activity (match-play vs. training), time (pre vs. post exercise) or activity * time on blood [Na⁺]. The difference between match-play and training for sweat [Na⁺] and Δblood [Na⁺] were all unclear and not significant.

insert table 2 near here

The relationship between blood [Na⁺] and fluid balance measures are presented in table 3, of which no significant relationships were observed. Small relationships were observed for pre-exercise blood [Na⁺] against arrival urine osmolality and fluid intake, post-exercise blood

[Na⁺] against arrival urine osmolality, and change in blood [Na⁺] against fluid intake. All other relationships were trivial.

insert table 3 near here

DISCUSSION

The present study is the first to explore habitual hydration status on arrival, sweat loss, fluid intake, sweat [Na⁺] and Δ blood [Na⁺] in female rugby league players. The study shows that on average (based on urine osmolality) players habitually arrived euhydrated to match-play and training. During match-play and training, players experienced a modest change in body mass (due to a lower fluid intake in comparison to sweat loss), and blood [Na⁺] appeared well regulated pre to post-exercise, despite losses of Na⁺ in sweat and electrolyte-free fluid consumption.

Hydration status prior to match-play appears comparable to their male rugby league counterparts (396 ± 252 mOsmol·kg⁻¹; (17)). Despite a significant difference for mean arrival urine osmolality between match-play and training, this does not precisely indicate that players were either more or less hydrated *per se*, as values were indicative of euhydration (<700 mOsmol·kg⁻¹; (22)). Practitioners should be aware that a more dilute urine sample is not indicative of being more hydrated. The precision of urine osmolality to accurately determine hydration status, when fluid is available, is also questionable (18), however an alternative practical field measure does not exist.

This study provided sweat loss data for female rugby league players, which was less than male rugby league players (reported as 32.64 ± 13.0 mL·min⁻¹ (17); calculated as 1.958 kg·hr⁻¹). This may be due to differences in exercise intensity, although to the author's knowledge, no data are available to support this. Alternatively, the findings of this study supports previous

observations demonstrating larger sweat losses in males than females, although when expressed relative to body mass, the magnitude of difference between female (in this study) and male rugby league players is small (0.29 ± 0.09 vs. 0.34 ± 0.10 mL \cdot min $^{-1}\cdot$ kg $^{-1}$; (17)). Another confounding variable when making comparisons between the findings of this study and that by O'Hara et al., (17) is environmental temperature ($12.1 \pm 5.3^{\circ}\text{C}$ and $70.5 \pm 11.4\%$ relative humidity), which was greater in this study. It would be anticipated that if environmental conditions were the same, a greater magnitude of difference would be observed between male and female rugby league players due to the association of sweat rates and environmental conditions.

On average, during match-play, female rugby league players consumed less fluid than male rugby league players (1.56 ± 0.57 L; (17)), which appears to reconcile with sweat loss data, (i.e., if players sweat less they need to consume less fluid). The body mass change during match-play was modest in comparison to male rugby league players (-1.32% (17)), and similar to female soccer players (12). At no point during this study, did body mass loss exceed 2% for any player. To the authors knowledge, no study has shown that a body mass loss of $<2\%$ has been associated with a decrease in exercise performance, whereas a loss $>2\%$ has (3). Observations of this cohort suggest that severe dehydration *per se* during match-play or training does not appear to be of concern for international female rugby league players, when habitual hydration strategies are adopted.

Mean sweat $[\text{Na}^+]$ was similar between match-play and training, and also similar to data reported for international female soccer players during two training sessions (43.9 ± 13.8 and 46.2 ± 7.9 mmol \cdot L $^{-1}$; (12)). Despite female rugby league players losing Na^+ in sweat and consuming Na^+ free sports drink or water, mean blood $[\text{Na}^+]$ was well regulated, thus it would be assumed that overall Na^+ supplementation would not be required. The small-trivial negative correlation between change in blood $[\text{Na}^+]$ against total fluid intake and sweat loss would also

suggest that neither the ingestion of electrolyte free solution nor sweat loss directly disturbed tightly regulated blood $[\text{Na}^+]$ in this cohort.

The findings of this study show that sweat loss for international female rugby league players during match-play and training is variable; ranging from 0.988 – 2.448 kg and 0.002 – 3.014 kg, respectively. Despite the large observed range in sweat loss, the limited change in body mass (ranging from -1.3 – 0.0% for match-play and -1.7 – 0.6% for training) is due to the habitual adjustments in fluid intake (0.502 – 1.801 kg for match-play and 0.064 – 3.786 kg for training). The findings of this study suggest that fluid intake during match-play and training was sufficient to offset sweat loss, without intervention or prescription, thus during exercise thirst may be the most suitable individualising hydration strategy. It should be acknowledged that some inter-player variability may be due to the fact the phase of menstrual cycle was not acknowledged or recorded. During the luteal phase of the menstrual cycle females have a higher rate of water turnover (4). Contrary, it has previously been reported that this may have a minimal effect on fluid balance *per se* (23) or renal water and electrolyte retention with fluid replacement after exercise (14).

In conclusion, international female rugby league players appear to habitually arrive adequately hydrated to match-play and training, and consume adequate fluid in comparison to their sweat loss, causing a modest change in body mass, less than previously reported in male rugby league players (17). Mean blood $[\text{Na}^+]$ appears well regulated despite losses of Na^+ in sweat and electrolyte free fluid consumption. For the duration of the study players did not experience a body mass loss (dehydration >2%) indicative of a reduction in exercise performance.

PRACTICAL APPLICATION

The findings of the study show that overall female rugby league players arrive to training and match-play hydrated. Further, they remained hydrated during training and match-play, despite varying sweat loss rates. Therefore, strength and conditioning coaches may not need to intervene above the habitual hydration strategies when working with female rugby players. The consumption of only water (with the absence of sodium; i.e., sports drink) is sufficient at maintaining blood $[Na^+]$, thus players do not appear to be at risk of developing hypo- or hypernatremia. Practitioners should first evaluate the individual habitual hydration status of an athlete to determine if interventions above habitual strategies are warranted. This study showed that *overall* habitual hydration strategies were adequate, although one player arrived hypohydrated (urine osmolality $>900 \text{ mOsmol}\cdot\text{kg}^{-1}$) to training and match-play, while one player arrived to training hyponatremic (blood sodium $<135 \text{ mmol}\cdot\text{L}^{-1}$), which may suggest hyperhydration. At no point during exercise did body mass loss exceed 2%, nor was hypo- or hypernatremia observed post exercise. As such, in practice the hydration strategies of players should be determined on a case-by-case basis, with an emphasis on their arrival state. Further, the findings of this study should be applied to mild environmental conditions, as training or matches played in more challenging environmental conditioning (i.e., $>30^\circ\text{C}$) may require specific intervention.

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Table 1. Percentage change in body mass (BM), fluid intake, urine output, sweat loss and sweat loss rate during match-play and training

Percentage Δ BM (%)	Fluid Intake (kg)	Urine Output (kg)	Sweat Loss (kg)	Calculated Sweat Loss (kg·hr ⁻¹)
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Match-play	-0.50 ± 0.45	1.205 ± 0.431	0.087 ± 0.077	1.541 ± 0.480	$1.330 \pm 0.622^*$
Training	-0.56 ± 0.53	1.070 ± 0.903	0.226 ± 0.305	1.246 ± 0.834	0.831 ± 0.556
$d=$	0.12	0.19	-0.62	0.43	0.85
(CI 95%)	(-0.76 – 0.99)	(-0.70 – 1.06)	(-1.49 – 0.30)	(-0.47 – 1.30)	(0.02 – 1.62)

* Denotes a significant difference between match-play and training; $P=0.008$. Percentage Δ BM is from arrival to post-exercise.

Table 2. Pre, post and Δ blood $[\text{Na}^+]$, and sweat $[\text{Na}^+]$ during match-play and training

	Pre-Exercise Blood $[\text{Na}^+]$	Post-Exercise Blood $[\text{Na}^+]$	Δ Blood $[\text{Na}^+]$	Sweat $[\text{Na}^+]$
			(mmol·L ⁻¹)	
Match-play	138.1 ± 2.6	137.4 ± 2.5	-0.7 ± 3.4	47.8 ± 5.7
Training	138.8 ± 2.0	138.4 ± 2.2	-0.4 ± 2.6	47.2 ± 6.3
$d=$	-0.30	-0.42	-0.10	0.10
(CI 95%)	(-1.17 – 0.59)	(-1.29 – 0.48)	(-0.97 – 0.78)	(-0.78 – 0.97)

Table 3. The relationship between arrival urine osmolality, percentage change in body mass, fluid intake and sweat loss with pre, post and Δ blood $[\text{Na}^+]$ during match-play and training.

	Pre-Exercise Blood $[\text{Na}^+]$	Post-Exercise Blood $[\text{Na}^+]$	Δ Blood $[\text{Na}^+]$
Arrival Urine Osmolality	$r=0.231$ ($P=0.115$)	$r=0.231$ ($P=0.115$)	$r=-0.021$ ($P=0.886$)
Percentage Body Mass Change	$r=0.089$ ($P=0.547$)	$r=-0.008$ ($P=0.959$)	$r=-0.063$ ($P=0.673$)
Fluid Intake	$r=0.101$ ($P=0.493$)	$r=-0.063$ ($P=0.672$)	$r=-0.130$ ($P=0.379$)
Sweat loss	$r=0.023$ ($P=0.877$)	$r=-0.093$ ($P=0.527$)	$r=-0.095$ ($P=0.523$)