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Fluid and electrolyte balance during two different pre-season training sessions in elite rugby union players.

Running Title: Blood sodium concentrations during two types of rugby training

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ABSTRACT

The purpose of this study was to compare fluid balance between a resistance and aerobic training session, in elite rugby players. It is hypothesised that resistance exercise will result in a higher prevalence of over-drinking whereas during the aerobic session under-drinking will be more prevalent.

As with previous fluid balance studies, this was an observational study. Twenty-six players completed the resistance training session and twenty players completed the aerobic training session. All players were members of an elite rugby union squad competing in the southern hemisphere's premier competition. For both sessions players provided a pre-exercise urine sample to determine hydration status, pre- and post-exercise measures of body mass and blood sodium concentration were taken and the weight of drinks bottles were recorded to calculate sweat rates and fluid intake rates. Sweat patches were positioned on the shoulder of the players and these remained in place throughout each training session,and were later analysed for sodium concentration.

The percentage of sweat loss replaced was higher in the resistance (196 ± 130%) than the aerobic training session (56 ± 17%; P=0.002). Despite this, no cases of hyponatremia were detected. The results also indicated that over 80% of players started training in a hypohydrated state.

Fluid intake appears to differ depending on the nature of the exercise session. In this group of athletes, players did not match their fluid intakes with their sweat loss,

resulting in over-drinking during resistance training and under-drinking in aerobic training. Therefore, hydration strategies and education need to be tailored to the exercise session. Furthermore, given the large number of players arriving at training hypohydrated, improved hydration strategies away from the training venue are required.

Key words: hydration, sweat rate, sweat sodium, blood sodium

INTRODUCTION

Fluid and sodium balance are important for athletes. Under-drinking which leads to dehydration (body mass losses >2 % of initial body mass) can result in performance impairments which are well documented in laboratory settings (1, 25). The reduction in plasma volume results in a number of consequences for the athlete, including impaired thermoregulation, elevated heart rate, increased muscle glycogen utilisation and reduced central nervous system function. Over-drinking (ingesting a volume of fluid greater than fluid loss) resulting in body mass gain, can lead to a dilution of blood sodium and a risk of developing exercise associated hyponatremia. Exercise associated hyponatremia is defined as a plasma sodium concentration below 135mmol/L (16), and has similar symptoms to dehydration. Mild symptoms include nausea, headaches, and lethargy, whilst more severe symptoms include oedema, seizures, and loss of consciousness (19). Over-drinking has been well studied in endurance sports (>4 hours) (16, 28) with reported prevalence rates between 8-50%. In contrast under-drinking is extensively reported in team sports (7, 21, 32).

However, many team sports players train for long periods over multiple sessions throughout the day, and in some training sessions access to fluid is plentiful and unrestricted. Whilst the majority of studies report team sports athletes drink at rates below sweat rate (7, 21, 32) some studies do report athletes drink at a rate greater than sweat rate and consequently gain weight (14). Horswill et al. (2009) reported a decrease in plasma sodium concentrations amongst cramp prone American footballers during a single training session of 2.2 hours (17). In this study half of the cramp prone players had blood sodium concentrations at the end of the training session below 135 mmol/L. Blood sodium concentrations below 135 mmol/L have also been seen amongst rugby union players during a one hour training session (23).

It appears that some team sports players are prone to over-drinking and a concomitant decline in blood sodium concentration. It is possible that this may be influenced by the type of training that is undertaken. However, it is difficult for a practitioner to determine blood sodium concentrations in the field, as the analysis requires specialist equipment. The weighing of players before and after each training session would provide an indication of those who have consumed fluids in excess of sweat losses or conversely those who have become dehydrated, but in reality this can be time consuming for the practitioner and given the multi-faceted aetiology of sodium balance (including both water and sodium gains and losses) body mass data may not provide an accurate reflection of blood sodium concentrations. Therefore it is of interest to determine whether the type of training session can predict whether rugby players are more at risk of hyponatremia or dehydration and to what extent do fluid intake practices influence blood sodium concentration?

Sweat rates are likely to be higher in aerobic based training compared to resistance training (35), but fluid intake rates may not be reflective of this difference in sweat rate resulting in over- and under-drinking. Indeed this was seen amongst American footballers where the prevalence of over-drinking was higher during resistance training (50%) in comparison to an aerobic (11%) based training session (35). However, at present no study has investigated the blood and sweat sodium concentrations of rugby union players during training or how they differ depending on the type of training. If differences exsist in the prevalance of over- and under-drinking between training type (resistant versus aerobic) then this will have implications for hydration education surrounding each of these sessions.

Therefore the aim of this study was to determine the prevalence of over-drinking and hyponatremia amongst elite rugby union players. We hypothesise that fluid balance and thus risk of hyponatremia will differ between a resistance and an aerobic based training session.

METHODS

Experimental Approach to the Problem

The protocol for determining fluid and electrolyte balance in a field setting have commonly used the methods previously described by Maughan et al. (22), Shirreffs et al. (32). However, due to time constraints the shoulder was the only site used for sweat collection. Previous research (3) has shown that sweat obtained from the shoulder correlates well with whole body sweat electrolyte concentration. Blood sodium changes were measured using protocols previously described by Horswill et al. (17). In order to observe the players' usual habits, measures which caused minimal distraction from the players usual routines were obtained, thus allowing for the determination of differences in habitual fluid intakes between the two different training sessions and the effects these have on blood sodium concentration. Therefore this study is an observational study during two different training sessions over one day of pre-season training, with the dependant variables, body mass change, sweat loss, fluid intake and blood sodium change. The aim of the study was not disclosed to the participants prior to testing. Any player who enquired, was informed that the purpose of the session was to measure sweat electrolyte losses, and was advised to carry out their training routine as normal. As this study was undertaken early in pre-season no education regarding hydration had been undertaken.

Subjects

The sample comprised of elite male Super 15 rugby players based in New Zealand, aged between 18 and 35 years with a mean pre-exercise body mass of 103.8 ± 10.2 kg, height of 186.8 ± 6.9 cm and sum of 8 skinfolds (triceps, subscapular, biceps, illiac crest, supraspinale, abdominal, thigh and calf) 70.9 ± 25.7 mm. Skinfolds were obtained by an ISAK level 1-trained (International Society of Anthropometry and Kinesiology) team dietitian as part of pre-season assesment. Testing was undertaken on one day during two pre-season training sessions in 2010. These were the only exercise sessions for the day and the day prior to testing had been a full day of training. A total of 26 people participated in the morning and 20 in the afternoon session, of these 15 participated in both sessions. This research was conducted in accordance with the Helsinki Declaration 1975 and was approved by the University of Otago Human Ethics Committee prior to testing. Subjects were informed of the experimental procedures and risks. Volunteers then signed an informed consent document before the investigation. No subject under the age of 18 years took part in the study.

Procedure

Upon arrival at the training ground, players were asked to provide a urine sample which was subsequently analysed for urine specific gravity (ATAGO Urincon N, Tokyo, Japan) to determine pre-training hydration status. This measure had a co-efficient of variation of 0.6%. Players were then weighed to the nearest 0.1 g (Tanita

Innerscan BC-568, Kowloon, Hong Kong) in only their shorts to determine pre-training body mass.

A finger prick blood sample was collected before and after the morning and afternoon training sessions into a plain capillary tube. This was then transferred into a single-use disposable cartridge sample well (CG8+, Abbott Point of Care, New Jersey, USA) and immediately analysed for serum sodium, potassium, haemoglobin and haematocrit using a hand-held portable i-STAT analyser (i-STAT, Abbott Point of Care, New Jersey, USA). The i-STAT analyser has previously been used in sports settings and provides a valid measure of serum sodium concentration (8). Plasma volume was subsequently determined using the equations of Dill & Costill (1974) (6). The morning resistance training session (09:30) consisted of 40 minutes of weight training and stretching in an indoor gym (21°C), where each player followed an individual training plan based on their training status and goals. The afternoon aerobic training session (14:00) consisted of running and maximal 100 m sprinting. This session lasted 75 minutes and took place outdoors in sunny conditions (27°C). Both of these training sessions were planned by the coaches and were typical of pre-season training. All players trained in shirts and shorts. Players consumed fluid ad libitum during both training sessions from individually named 750 mL drinks bottles. Players were allowed to choose tap water and/or Powerade™ (Coca-Cola™, Frucor, Auckland, New Zealand; 7.6 % carbohydrate and 28 mg sodium per 100 mL) during the morning session, but for the afternoon session only tap water was available. Players were instructed to drink only from the drink bottle allocated to them and not to spit out any of the beverage. All bottles were weighed using electronic scales (Model 1017, SALTER scale, Victoria, Australia) before and after each training sessions to determine the amount fluid consumed.. Although players were informed that should they need to urinate they were free to do so, no player passed urine during each training session or consumed any food. Players were observed during this time to ensure compliance. Following each training session, players towelled dry and were re-weighed in order to determine sweat loss. Water loss and gain via respiration and substrate oxidation was assumed to be negligible and was not accounted for in subsequent calculations (18, 24). In the time that elapsed between the two training sessions, players were free to consume food and fluid, but this was not measured.

Sweat composition was determined during both the morning and afternoon training sessions. The skin of the right shoulder blade was cleaned with distilled, de-ionised water and dried with sterile gauze wipes before a sweat patch (Tegaderm+ Pad, 3M, Loughborough, UK) was positioned on the right hand shoulder of each participant. Upon the completion of training, the sweat patch was removed with sterile tweezers and immediately placed in a sterile, sealed container for subsequent analysis. Samples were then stored at 4^{o}C until analysis (within 5 days) for sodium via absorbance photometry (Cobas C111 analyser, Roche, AG Basel Switzerland). During the morning session an insufficient volume of sweat was collected in the sweat patch and subsequently sweat composition could not be obtained.

Sample Analysis

Urine samples were analysed for urine specific gravity (USG) using a hand-held optical refractometer (ATAGO urincon N, Tokyo, Japan). Euhydration was assumed when USG was <1.020g/ml (ACSM, 2007). Sweat sodium concentration was determined via absorbance photometry (Cobas C111 analyser, Roche, AG Basel Switzerland). All samples were measured with standardised controls and in duplicate. If the variability exceeded the error of the machine they were re-analysed. All values obtained were within the acceptable physiological range. As sweat potassium has been shown to be elevated as a result of skin leaching rather than sweat loss, all samples were tested for sweat potassium to ensure the values obtained were from sweat samples rather than skin leaching.

Calculations

Sweat rate (L/h) = [Body mass change (kg) + fluid intake (kg) – urinary losses (kg)] / time (hours)

- Sweat sodium loss (mmol) = sweat sodium concentration (mmol/L) * sweat loss (L)
- Sodium intake (mmol) = volume of Powerade (L) * Sodium content of Powerade (mmol/L)
- Carbohydrate intake = volume of Powerade (L) * carbohydrate content (L)
- To convert mmol of sodium to g = (mmol/1000) * 22.99

Statistical analysis

Results were analysed using STATA version 11.0 IC for Mac, with statistical significance set at $P \leq 0.05$ and power of 90 % to detect a difference in fluid balance of 0.5 % between the sessions, 20 participants would be required. Shapiro-Wilk's tests were performed to investigate normality. To test the hypothesis that differences in fluid balance and plasma sodium change would differ between the two training sessions an paired t-test was performed. Correlation analysis was performed by pearsons correlation unless data was non-parametric and subsequently a spearmans rank correlation was performed. Data are reported as mean ± SD.

The retest reliability (ICC) for sweat rates was 0.452 and for fluid intake rates was 0.306 and for blood sodium is 0.590.

The test-retest reliability for sweat sodium concentrations in a similar population was r=0.602.

RESULTS

Fluid balance (loss and gain) between the sessions

As hypothesised the percentage of sweat loss replaced was higher in the morning resistance (196 ± 130%) than the afternoon aerobic training session (56 ± 17%; P=0.002) (Table 1), but there was substantial variation between individuals in both the morning resistance (range 58 – 532%) and afternoon aerobic (range 24 – 92%) training sessions. As a result, on average, players gained body mass in the morning resistance session (+0.43 ± 0.49kg) compared to the afternoon aerobic session (-0.76 ± 0.34kg). Twenty out of 26 players gained weight, with one individual gaining 1.9kg or 1.67% BM during the morning resistance session, whereas all subjects lost weight during the afternoon aerobic training session. No player lost >2% of pre-training body mass in either the morning resistance or afternoon aerobic sessions (Figure 3).

The amount of sweat lost in the morning resistance training session (0.66 ± 0.38 L) was lower than that lost during the afternoon aerobic training session (1.72 ± 0.64 L; P<0.01) (Figure 2) and this difference remained when expressed as sweat rate (0.99 ± 0.57 L/h and 1.38 ± 0.51 L/h, respectively). There was no statistically significant correlation between sweat rate and pre-training body mass for either the morning resistance (r=0.237, P=0.240) or the afternoon aerobic session (r=0.371, P=0.118).

FIGURE 2 about here

During the morning resistance session, players ingested 1.09 ± 0.57L, of fluid of which a greater proportion of intake was obtained from water (0.78 ± 0.68L) than a CHO-E sports drink (0.31 ± 0.42L; P=0.038). This resulted in a mean carbohydrate intake of 16 ± 25 g during the training session. The total amount of fluid consumed during the afternoon aerobic session (0.97 ± 0.51L) was similar to that consumed during the morning resistance session (P=0.930; Figure 2), but when expressed as fluid intake per hour, players ingested fluid at a higher rate in the morning (1.63 ± 0.86L/h) than the afternoon aerobic session (0.77 ± 0.41L/h; P <0.01).

FIGURE 3 about here

Electrolyte balance

Mean blood sodium concentration fell during the morning resistance training session from 139 ± 1 to 138 ±1 mmol/L (P=0.006), but no cases of hyponatremia were observed. The lowest blood sodium concentration observed was 137mmol/L. During the afternoon aerobic training session blood sodium remained stable from pre 140 ± 2 mmol/L to post training 141 ± 3 mmol/L (P=0.126).

There was no significant association between fluid intake rate and the absolute change in blood sodium during the morning resistance session (r=-0.29, P=0.183) but the change in blood sodium was significantly associated with the change in body mass (r= -0.41,P=0.040).

During the afternoon aerobic training session the change in blood sodium concentration was not associated with the rate of fluid intake (r= -0.23, P=0.270), percent body mass change (r=0.440, P=0.175) nor sweat sodium concentration (r= 0.287, P=0.248). Blood potassium concentration remained similar during both the morning resistance (pre 4.6 ± 0.6 mmol/L and post 4.4 ± 0.4 mmol/L) and afternoon aerobic (pre 4.5 ± 0.5 mmol/L and post 4.5 ± 1.2 mmol/L) training sessions. There was a similar change in plasma volume during the morning resistance (1.4 ± 6.7%) and afternoon aerobic (-0.4 ± 7.3%) training sessions (P=0.422).

Pre-training

Mean urine specific gravity before the resistance training session was 1.026 ± 0.006g/ml (Table 1). The results indicated that 89% of players started training in a hypohydrated state. Similarly, 82% of players who took part in the aerobic session began training in a hypohydrated state (1.024 ± 0.008 g/ml) (Figure 1). There was no difference in pre-exercise urine specific gravity between the resistance and aerobic training sessions (P=0.114).

TABLE 1 about here

FIGURE 1 about here

The volume of fluid ingested was not significantly correlated with pre-training urine specific gravity in the resistance ($r = -0.27$; $P = 0.187$) or aerobic training session ($r = -0.14$; $P = 0.594$), but fluid intake was significantly correlated with sweat loss during both the resistance ($r = 0.51$; $P < 0.01$) and aerobic ($r = 0.55$; $P = 0.013$) training sessions.

DISCUSSION

This is the first study to investigate fluid and electrolyte intake and loss in combination with blood sodium concentrations among rugby players during training. In line with the hypothesis the results showed that during aerobic training, players are more likely to under-drink. In contrast, during resistance training players are more likely to over-drink which may lead to a dilution of blood sodium concentration.

In line with previous research a higher prevalence of over-drinking was seen during resistance exercise in comparison to a more aerobic based exercise training session (35). However, unlike the research by Horswill et al. (2009) (17) who reported three cases of hyponatremia, no player in the current study presented with a blood sodium concentration <135mmol/L. Despite this some players did experience large decreases in blood sodium concentration (-4 to +1 mmol/L) during the bout of resistance exercise which was accompanied by the consumption of fluids at rates greater than sweat loss. However with a few other exceptions (5,20) there is very little information on serum sodium concentrations during field studies in elite team sport athletes. This is most likely attributed to the prevalence of voluntary dehydration rather than a perceived risk of over-drinking and hyponatremia during these activities. As little research exists it is difficult to determine the reasons for over-drinking.

Exercise-associated hyponatremia has been described as having three main mechanisms to its aetiology, 1) excessive fluid consumption, 2) inappropriate ADH secretion and 3) an inability to mobilise osmotically inactive sodium stores (26). Although the change in blood sodium was not related to total fluid intake, it was related to be related to the change in body mass, as has been reported in other studies in ironman triathlons (34) and marathons (26, 30) suggesting that the relationship between sweat loss and fluid intake is important in the aetiology of exercise associated hyponatremia. Indeed the resistance training session in the current study was characterised by lower sweat rates and improved access to fluids compared to the aerobic training session, however, these sweat rates were not unusually high or low when compared to those in the literature (36). However, the rates of fluid intake were higher in the present study compared to those reported by Stofan et al (39).

These results suggest that during resistance exercise sweat losses are low but, access to fluid is plentiful therefore despite players not requiring large volumes of fluid they are able to consume vast quantities. This level of intake could be due to access to fluid both in the frequency of rest periods, habit, and potentially inappropriate hydration knowledge (19).

One other explanation could be due to the fact that 82% of players arrived at training hypohydrated (USG >1.020g/ml) (29). This is suggested to correspond to a level of hypohydration that would be sufficient to stimulate sensations of thirst (4,12) and could therefore subsequently influence the amount of fluid consumed. Unfortunately players perception of thirst was not measured in this study as the experimenters did not want to draw attention to the interest in fluid intake behaviour of the players, but the lack of association between pre-exercise hydration status and fluid intake (r=-0.27) would not support this argument. In fact this correlation, albeit weak, indicates that those players who presented with the lowest urine specific gravity ingested the greatest volume of fluid during this exercise session. Female athletes have been reported to be more aware of fluid needs than males in endurance events and are therefore more at risk of over-drinking (17). Perhaps those players most aware of the importance of hydration may be more prone to over-drinking and may require individualised advice (24). It is also possible that despite not being informed of the aims of the study by the researchers or being told how much to drink that the mere presence of the researchers led to some players modifying their behaviour.

The prevalence of hypohydration prior to exercise is consistent with a large number of studies from a variety of sports (27, 33). These studies have also reported a lack of correlation between USG and fluid intake, although some have reported the contrary (22). The presence of hypohydration was also evident prior to the afternoon training session despite the prevalence of drinking in excess during the first session of the day and access to food and fluids during the intervening time period between training sessions. Previous studies have also reported evidence of hypohydration in the second of two-a-day sessions, although this was attributed to a failure to replace losses from the first session of the day rather than the evidence of chronic dehydration seen in the current study (10).

The detrimental effects of pre-exercise hypohydration have been demonstrated on physical (2) and cognitive performance (11). The effects of dehydration on muscular strength and high intensity exercise has been studied to a lesser degree, however it does appear that hypohydration (2-3 %) negatively affects muscular strength and one rep max performance (15).

The replenishment of fluid losses is reported to be achievable when 24h elapses between training sessions through the daily intake of food and fluid (4), but when the gap is shorter, specific rehydration strategies may need to be adopted. Interestingly runners have been reported to replace daily losses during two-a-day sessions, but not so in American Footballers (9). Whilst this may be due to the amount of sweat lost, it has also brought into question the appropriateness of USG as a marker of hydration in individuals with large muscle mass (13). This has been attributed to the increased amount of protein metabolites in the urine and subsequent elevation of urine specific gravity that is not paralleled by the same magnitude of increase in osmolality. Consequently this may explain the high number of players who were classified as hypohydrated before both training sessions. However, USG is a simple and inexpensive measure of hydration status and is commonly used by practitioners.

This is the first study to report sweat electrolyte concentrations in rugby players during rugby-specific training. Sweat sodium concentration was related to the decline in blood sodium concentration during the morning resistance and aerobic afternoon session, assuming a similar sweat sodium concentration during the morning session. This would result in total sweat sodium loss of 2.1 g over the two training sessions with one player losing more than 6 g of sodium. The recommended upper limit for sodium intake in the general population of New Zealand is 2.3g and therefore the sodium loss that occurred during these two training sessions indicates a greater need for an alternate sodium intake recommendation in this athletic population.

Players appeared to be hypohydrated prior to the morning session. Fluid intake during a resistance training session was greater than sweat loss leading to a gain in BM among 20 of the 26 players (up to 1.9kg). Despite the large increase in BM, hypnoatremia was not evident. The reason for over-drinking during resistance training may have been due to high fluid availability, in combination with low sweat rates, and the prevailing level of hypohydration or hydration knowledge, as those who presented with the lowest USG, drank the most during training. Therefore, access to fluid during resistance training sessions may need to be limited because at present those who start closest to euhydration consume the most fluid. Thirst was not measured in this study, so it is unclear whether individuals drank to thirst or in excess. Future studies should address the underlying cause.

LIMITATIONS

Although this study showed differences in the proportion of sweat losses replaced during each training session, we cannot determine the reasons for drinking during these sessions or the impact of drinking strategy on performance from the measures taken.

Further, the use of sweat patches to determine sweat electrolyte losses may have resulted in some overestimation of sweat sodium loss. It has previously been reported that this method of sweat collection can result in overestimations of 35 % for sweat sodium (31). Although, all sodium losses and intakes were measured during the training sessions no measures were taken between the training sessions meaning the sodium balance during the training day could not be calculated.

FUTURE DIRECTIONS

Future research is required to address some of these limitations, in particular the effects of over- and under-drinking on performance during resistance exercise training amongst well-trained individuals. Secondly given the high prevalence of hypohydration at the start of both training sessions research into more aggressive rehydration strategies between training sessions is required in particular, rather than the traditional 4 to 5 hour recovery period which is used in the majority of rehydration studies. Investigating the effects of rehydration strategies overnight is required to prevent athletes arriving at training in a hypohydrated state.

PRACTICAL APPLICATIONS

This study indicates that fluid replacement during exercise sessions differ depending on the type of exercise (resistance or aerobic), with wide variations between players. Measuring and monitoring of body mass change during training sessions and player education on hydration may attenuate the occurrence of under- and over-drinking. This suggests that education of players around drinking needs to be specific to the type of training session.

Secondly, given the high prevalence of hypohydration at the start of both training sessions and the known effects of hypohydration on performance, this study indicates that trainers and athletes need to focus on rehydration between training sessions. If players begin a training session in a euhydrated state, the impact of subsequent dehydration should be minimised. If this is combined with a fluid intake strategy based specifically on the type of session (ie less fluids in resistance training and fluid intakes promoted during aerobic type activities), an athlete should be able to maintain levels of euhydration throughout the training day. Thus they are more likely to begin the subsequent day's training sessions in a euhydrated state. This could have important implications for the quality of training.

As sweat sodium losses were almost equivalent to the recommended upper level in New Zealand sodium intakes in the rehydration foods and fluids should also be considered.

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TABLE CAPTIONS

Table 1: Mean±SD (range) hydration and electrolyte changes during both training sessions and between the resistance AM (n=26) and aerobic PM (n=20) training sessions

Figure Captions

Figure 1. Urine specific gravity (g/ml) of urine samples collected before the resistance AM (●) (n=26) and aerobic PM (o) (n=20) training sessions. Hypohydration was classified as ≥1.020 (ACSM, 2007)

Figure 2. Sweat loss (L), Fluid Intake (L) and Δ BM (kg) during the resistance (AM) (n=26) and aerobic (PM) (n=20) training session

Figure 3. Dehydration (%BM) during the resistance (AM) (n=26) and aerobic (PM) (n=20) training sessions for each player

Figure 4. The relationship between the change in body mass (%) and the change in serum sodium concentration (%) during the resistance (AM) (n=26) training session.

	Resistance (AM) (n=26)			Aerobic (PM) (n=20)		
	Pre	Post	Pre-Post AM P-value	Pre	Post	Pre-Post PM p-value
Urine SG	1.026 ± 0.006 (1.009 – 1.035)	----	----	1.024 ± 0.008 (1.004 – 1.033)	----	----
% Dehydrated[a]	24/27 = 89	----	----	14/17 = 82	----	----
Serum [Na] (mmol/L)	139 ± 1 (138 – 141)	138 ± 1 (137 – 141)	0.007	140 ± 2 (138 – 146)	141 ± 3 (138 – 148)	0.107
Serum [K] (mmol/L)	4.6 ± 0.6 (3.8 – 6.7)	4.4 ± 0.4 (3.7 – 5.1)	0196	4.5 ± 0.5 (4.1 – 6.3)	4.5 ± 1.2) (3.7 – 8.7)	0.198
Sweat Rate (L/hr)	0.99 ± 0.57 (0.21 – 2.05)	----	----	1.38 ± 0.51 (0.81 – 3.27)	----	----
Fluid Intake Rate (L/hr)	1.63 ± 0.86 (0.21 – 3.61)	----	----	0.77 ± 0.41 (0.26 – 2.15)	----	----
% Sweat Replaced	196 ± 130 (58 – 532)	----	----	56 ± 17 (24 – 92)	----	----
BM Loss (%)	+0.42 ± 0.47 (-0.27 to +1.67)	----	----	-0.74 ± 0.30 (-0.11 to -1.25)	----	----

[a] % Dehydration = [[body mass (pre)- Body mass (post)]/ Body mass (pre)] *100.

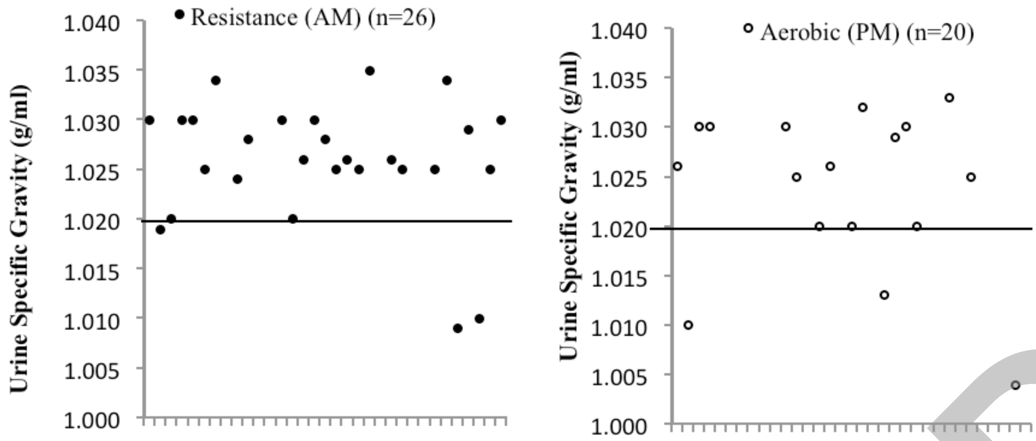

Figure 1. Urine specific gravity (g/ml) of urine samples collected before the resistance (AM) (●) (n=26) and aerobic PM (o) (n=20) training sessions. Hypohydration was classified as ≥1.020 (ACSM, 2007)

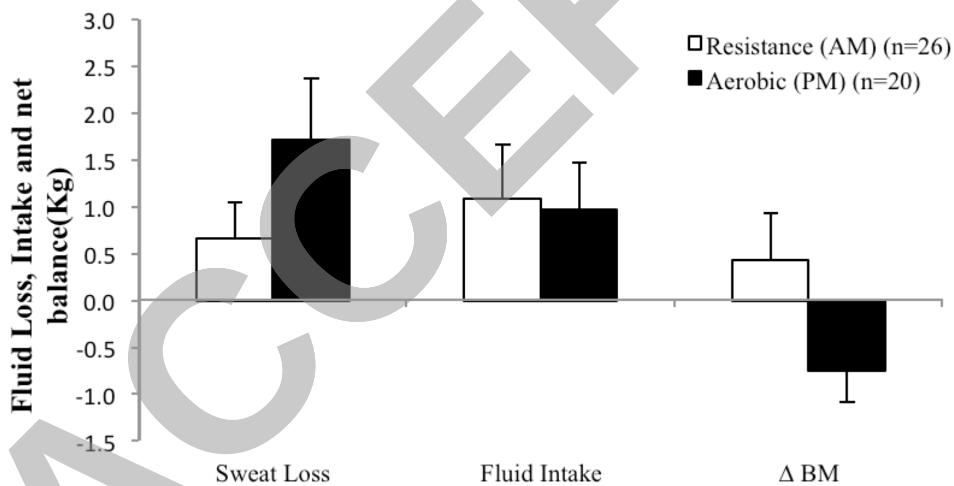

Figure 2. Sweat loss (L), Fluid Intake (L) and Δ BM (kg) during the resistance (AM) (n=26) and aerobic (PM) (n=20) training session

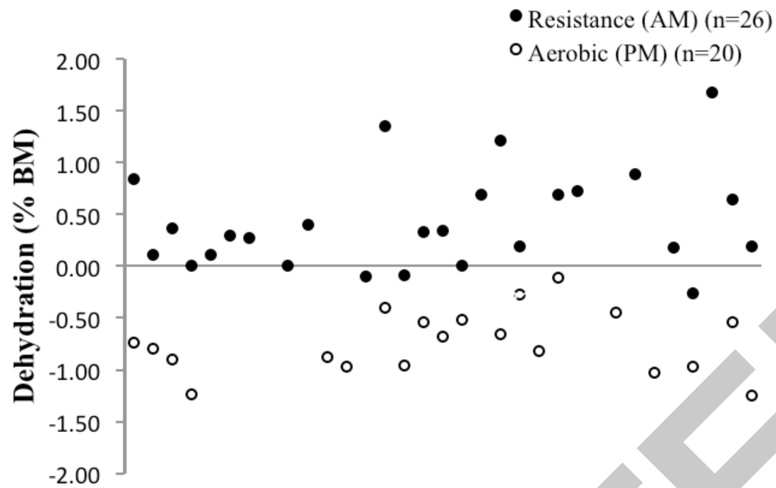

Figure 3. Hydration (%BM) during the resistance (AM) (n=26) and aerobic (PM) (n=20) training sessions for each player

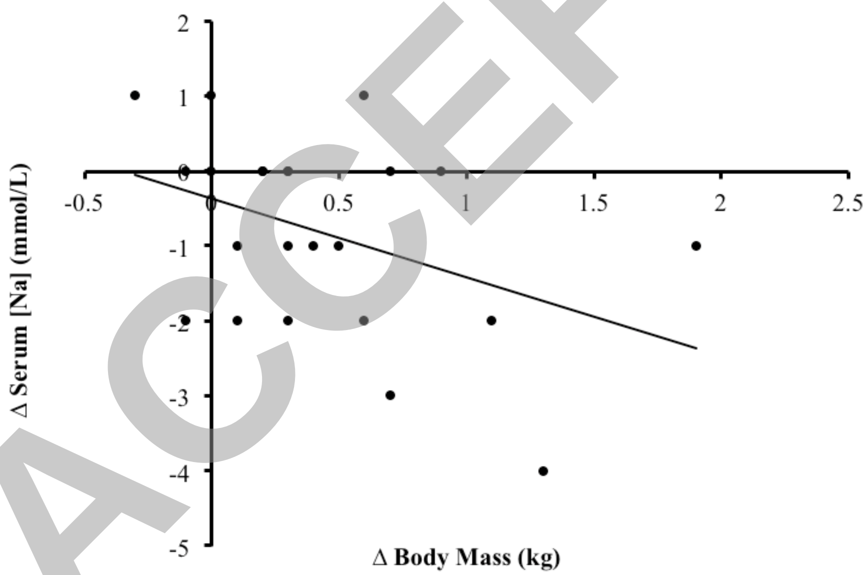

Figure 4. The relationship between the change in body mass and the change in serum sodium concentration during the Resistance (AM) (n=26) training session.