Fluid and Sodium Balance of Elite Wheelchair Rugby Players

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Blood sodium concentration of tetraplegics during exercise has not been investigated. This study aimed to measure blood sodium changes in relation to fluid intakes and thermal comfort in tetraplegics during wheelchair rugby training. Twelve international male wheelchair rugby players volunteered, and measures were taken during 2 training sessions. Body mass, blood sodium concentration, and subjective thermal comfort using a 10-point scale were recorded before and after both training sessions. Fluid intake and the distance covered were measured during both sessions. The mean (SD) percentage changes in body mass during the morning and afternoon training sessions were +0.4% (0.65%) and +0.69% (1.24%), respectively. There was a tendency for fluid intake rate to be correlated with the percentage change in blood sodium concentration ($p = .072, r^2 = .642$) during the morning training session; this correlation reached significance during the afternoon session ($p = .004, r^2 = .717$). Fluid intake was significantly correlated to change in thermal comfort in the morning session ($p = .018, r^2 = .533$), with this correlation showing a tendency in the afternoon session ($p = .066, r^2 = .151$). This is the first study to investigate blood sodium concentrations in a group of tetraplegics. Over the day, blood sodium concentrations significantly declined; 2 players recorded blood sodium concentrations of 135 mmol/L, and 5 recorded blood sodium concentrations of 136 mmol/L. Excessive fluid intake as a means of attenuating thermal discomfort seems to be the primary cause of low blood sodium concentrations in tetraplegic athletes. Findings from this study could aid in the design of fluid-intake strategies for tetraplegics.

Keywords: hyponatremia, blood sodium concentration, hydration and thermal comfort

Wheelchair rugby is a sport designed and played by tetraplegics. Tetraplegia is the impairment or loss of motor and/or function in cervical spinal-cord segments resulting in some impairment in the arms, trunk, pelvis, and legs. One important observation among tetraplegic athletes is their very high fluid intakes (Price & Campbell, 2003), which may increase the risk of fluid and electrolyte imbalance during exercise. The reason for high fluid intakes among tetraplegic athletes are at present unknown, although it may be an attempt to attenuate the perceived heat stress of exercise (Price & Campbell, 2003). There is currently very little information regarding the fluid balance of tetraplegics undertaking sporting activities in field-based settings.

Fluid balance is important for optimal performance of the cardiovascular system and contributes to maintenance of internal homeostasis (Hew-Butler et al., 2005; Kay & Marino, 2000; Sawka & Montain, 2000). However, after a spinal-cord injury there is a disruption of the body's ability to maintain this homeostasis. This disruption results in an inability to produce sweat and vasodilate below the lesion (Randall, Wurster, & Lewin, 1966). As the sweat response and the ability to redistribute blood to the skin surface for cooling are impaired, tetraplegics have limited mechanisms to cool themselves. It has been theorized that those with tetraplegia try to promote thermal comfort by drinking (Price & Campbell, 2003). Alternatively, the large fluid intakes observed among these athletes may be due to adherence to hydration guidelines that may be applicable for able-bodied endurance athletes (Sawka et al., 2007). Although these guidelines to adjust fluid intakes to sweat losses allow for individualization and minimize the possibility of hyponatremia and dehydration in able-bodied populations, and the theory should apply to those with a spinal-cord injury, in practice they are not easily applied to wheelchair athletes due to the problems associated with weighing an athlete in a wheelchair. At present, there are no fluid-intake guidelines that can be easily implemented for wheelchair athletes. Therefore, athletes with spinal-cord injuries may look to the lay media, for example, the Internet, for information. The recommendation to consume 400–800 ml of fluid per hour is cited on many sports and sports-nutrition-related Web sites; however, this figure is likely to be too large for individuals with spinal-cord injuries due to their impaired sweat response (Horleys, 2012; Millennium Institute of Sport and Health, 2009). Although these underlying mechanisms are speculative, the combination of reduced sweat rates and high fluid intakes increases the risk of hyponatremia among...
tetraplegic athletes. This risk is possibly even greater when the complications of a high-level spinal-cord injury are also considered. In the general tetraplegic population, the incidence of hyponatremia is far greater than that of the able-bodied population (Son, Vaidyanathan, Watt, & Krishnan, 1994), with speculation that the increased risk is due to impaired renal function, a reset osmostat, and ineffective blood volume (Son et al., 1994).

Hyponatremia is defined as a serum sodium concentration less than 135 mmol/L (Hew-Butler et al., 2005). This electrolyte imbalance can result in cerebral edema, heart failure, and death (Kipps, Sharma, & Pedoe, 2011). Further compounding the risk of hyponatremia among tetraplegics are impaired renal function and thus an inability to excrete dilute urine (Frisbie, 2007; Sved, McDowell, & Blessing, 1985).

To date, the blood sodium concentrations in tetraplegics in response to exercise have not been investigated. Therefore, the aim of this study was to investigate relationships between blood sodium concentrations, fluid intake, and ratings of thermal comfort among those with tetraplegia during typical wheelchair rugby training sessions.

**Methods**

**Recruitment of Participants**

Twelve international male wheelchair rugby players were recruited to participate in the study. The spinal-cord injury level was classified by the American Spinal Injury Association with both complete lesions and incomplete injuries of the cervical (C) spinal cord. Injuries ranged from complete C5–6 to incomplete C7–8. All players were classified by the International Wheelchair Rugby Association with player points ranging from 0.5 to 3.5. Mean (SD) body mass was 76.75 (18.22) kg and age 31.25 (5.23) years.

Approval for this study was sought and granted by the University of Otago human ethics committee. Participants were informed of the study requirements and provided with opportunities to discuss the study before giving written informed consent.

**Training Session**

All measurements were performed on a single day during a weekend training camp in preparation for regional competitions and the 2010 Rugby Wheelchair World Cup. The training day from which the data were obtained consisted of two indoor training sessions that were typical of training days undertaken by elite wheelchair rugby squads. The first training session took place in the morning, commencing at 10 a.m., and lasted 157 min in total. It comprised a 21-min warm-up and a five-on-five game. The second training session took place in the afternoon, commencing at 1:30 p.m., and consisted of a 9-min warm-up followed with a five-on-five game of 106 min duration. To mimic a real-life setting, no restrictions were placed on the participants between the training sessions. Atmospheric temperature was recorded throughout the training sessions using a thermometer (Exact Temp Fisher Scientific, Loughborough, UK). Mean (SD) ambient temperatures during the morning and afternoon training sessions were 23.0 (1.4) °C and 27.5 (0.7) °C, respectively. We monitored both training sessions to gain information on hydration status over of a usual training camp day, which typically involves two training sessions.

**Protocol**

On arrival at the training center, participants were instructed to empty their bladders or clear their catheter bags and collect a urine sample. This was performed in private, and the preexercise urine sample was collected into a sterile universal tube. The sample was used to assess pretraining hydration status. Pretraining urine samples were analyzed for urine specific gravity (USG) using a handheld optical refractometer (Atago, Tokyo, Japan).

Body mass was measured pre- and posttraining, using a specially made wheelchair-capable digital electronic scale readable to 0.05 kg (Dolphin XK3101, 2010 Auckland, New Zealand). Participants were weighed in their wheelchairs; the wheelchair was then weighed, and from these two readings, body mass was calculated. All participants were weighed in their day wheelchair in minimal clothing (shorts) pre- and posttraining. As the majority of individuals with spinal-cord injuries are unable to sweat below the level of their lesion, it is unlikely that sweat would be trapped in the clothing worn. Catheterized participants were weighed with their bag pre- and posttraining.

Participants provided their own drink bottles and were advised they could drink ad libitum throughout the training sessions. Drink bottles were weighed using electronic scales (Salter model 1017, Tonbridge, England) before and after training. All participants were advised to consume their usual fluid of choice, which was water in all cases except for 1 participant who drank Powerade (Coca-Cola Co., Atlanta, GA) in the morning and afternoon sessions and 2 participants who consumed a V energy drink (Frucor Beverages Ltd., Auckland, New Zealand) during the afternoon session. These drinks contain 225 mg/L and 470 mg/L of sodium, respectively. If a participant required extra fluid during the training session, his drink bottle was weighed and then refilled and weighed again. Participants were advised not to use the weighed drink bottle to pour water over their heads or to spit out any ingested water. Any participant who left the training session to urinate was asked to collect the urine in a container that was then weighed by the investigators on a set of Salter scales (Salter model 1017, Tonbridge, England) to the nearest 1 g.

A wireless cycle computer (BCP-12W, BBB, Leiden, Holland) was attached to the back wheels of the players’ wheelchairs and was reset before the training session commenced. At the end of each training session, these...
were removed and the distance covered and average speed was recorded.

**Sample Handling**

Blood samples were collected and analyzed pre- and posttraining using a handheld portable i-Stat analyzer (i-Stat, Abbott Point of Care, Princeton, NJ) for blood sodium concentration. The site of puncture was cleaned appropriately before a 23-gauge safety lancet was used to puncture the skin site (Unistik 3, Oxford, UK). Whole-blood samples were collected from either the finger or the ear (this was kept consistent for each participant at each testing point) into a plain capillary tube and transferred into the single-use disposable-cartridge sample well (CG8+, Abbott Point of Care). The i-STAT analyzer has previously been used with success in sports settings (Erickson & Wilding, 1993; Hsieh, Roth, Davis, Larrabee, & Callaway, 2002). It has also been shown to be a valid measure of sodium concentration, [Na⁺], when compared with simultaneous laboratory analyzer measurements (Erickson & Wilding, 1993). The measurement of blood sodium via the i-STAT CG8+ cartridges has a coefficient of variation of 0.59%.

Subjective thermal comfort was assessed using a 10-point scale where zero is the coldest you have ever been; 5 is neutral, neither cold nor warm; and 10 is the hottest you have ever been (Gagge, Stolwijk, & Saltin, 1969). Participants were asked by the researcher pre- and posttraining sessions to rate their level of thermal comfort.

**Estimations of Fluid and Sodium Loss**

Sweat loss was calculated from change in body mass pre- to posttraining after correcting for urinary loss and total fluid intake:

\[
\text{Sweat loss (L)} = [\text{body mass pretraining (kg)} - \text{body mass posttraining (kg)}] + [\text{fluid intake (L)} - \text{urinary losses (kg)}]
\]

Percentage change in body mass was based on the percent change in body mass from pretraining values:

\[
\text{Change in body mass (%) = } \left[\frac{[\text{body mass pretraining (kg)} - \text{body mass posttraining (kg)}]}{\text{body mass pretraining (kg)}}\right] \times 100
\]

Sweat rate was calculated as follows:

\[
\text{Rate of sweat loss (L/hr)} = \left[\frac{\text{fluid loss (L)}}{\text{training time (min)}}\right] \times 60
\]

Although sweat loss has been described, it should be noted that mass losses due to substrate oxidation, metabolic water gain, and respiratory water loss would have also occurred but were not measured. Although these are important factors in the accurate calculation of sweat loss, their effect would have been minimal (Maughan, Shirreffs, & Leiper, 2007).

The rate of fluid intake was calculated in a similar manner:

\[
\text{Rate of fluid intake (L/hr)} = \left[\frac{\text{fluid intake (L)}}{\text{training time (min)}}\right] \times 60
\]

**Statistical Analysis**

All data were tested for normality of distribution (Kolmogorov–Smirnov test) and are presented as \( M (SD) \). Differences in physical characteristics between the two training sessions were determined using a paired-sample \( t \) test. Pearson’s product–moment correlation was used to investigate the association between USG and rate of fluid intake, rate of fluid intake and blood sodium, and rate of fluid intake and rate of fluid loss. Correlations between thermal comfort and the rate of fluid intake were determined using Spearman’s rho. An ANOVA was performed to determine differences between blood sodium and USG between the sessions. Statistical significance was set at an alpha level of .05. Analysis was undertaken using SPSS 16.0 software (SPSS Inc., Chicago, IL).

**Results**

**Training Session**

During the training sessions the mean (SD) distance covered by the players was 2.87 (0.87) km in the morning session and 3.40 (1.52) km in afternoon training session. Mean distance covered was not significantly different between the two training sessions (\( p = .191 \)). The mean (SD) moving speeds were 6.7 (1.5) km/hr and 6.1 (0.3) km/hr in the morning and afternoon sessions, respectively.

**Fluid Balance, Hydration, and Thermal Comfort**

The mean (SD) percent change in body mass was +0.41% (0.65%) during the morning training session and +0.69% (1.24%) during the afternoon training session (Table 1). Nine of the 12 players gained body mass during the morning training session, whereas 8 gained body mass during the afternoon session.

A USG value below 1.020 g/ml represents a state of euhydration as suggested by the National Athletic Trainers’ Association (Casa et al., 2000). The mean (SD) USG measured before the morning session was 1.011 (0.006) g/ml, with 10 of the 12 players having a USG value below 1.020 g/ml. Before the afternoon training session, the mean USG was 1.011 (0.005) g/ml, and again 10 of the 12 players had a USG value below 1.020 g/ml (Table 1).

The mean (SD) rates of fluid intake for the morning and afternoon sessions were 0.255 (0.111) L/hr and 0.515 (0.299) L/hr, respectively (\( p = .486 \)). When fluid intake was expressed with respect to distance covered in each training session, mean (SD) fluid intakes were 0.315 (0.458) and 0.286 (0.270) L/km in the morning.
### Table 1  Markers of Hydration Status, Δ Thermal Comfort, and Distance Covered During the 2 Training Sessions

<table>
<thead>
<tr>
<th></th>
<th>Morning</th>
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<th>Afternoon</th>
<th></th>
<th>p</th>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>Range</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Δ body mass (%)</td>
<td>0.41</td>
<td>0.65</td>
<td>-0.59 to 1.37</td>
<td>0.69</td>
<td>1.24</td>
</tr>
<tr>
<td>Urine specific gravity</td>
<td>1.011</td>
<td>0.006</td>
<td>1.005–1.022</td>
<td>1.011</td>
<td>0.005</td>
</tr>
<tr>
<td>Fluid intake rate (L/hr)</td>
<td>0.25</td>
<td>0.11</td>
<td>0.09–0.41</td>
<td>0.52</td>
<td>0.30</td>
</tr>
<tr>
<td>Sweat rate (L/hr)</td>
<td>0.17</td>
<td>0.21</td>
<td>0.00–0.41</td>
<td>0.16</td>
<td>0.34</td>
</tr>
<tr>
<td>Pretraining blood sodium (mmol/L)</td>
<td>140.7</td>
<td>2.2</td>
<td>136.0–143.0</td>
<td>139.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Posttraining blood sodium (mmol/L)</td>
<td>139.2</td>
<td>2.7</td>
<td>136.0–144.0</td>
<td>137.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Δ thermal comfort</td>
<td>2.0</td>
<td>0.7</td>
<td>1.0–3.0</td>
<td>1.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Distance covered (km)</td>
<td>2.87</td>
<td>0.87</td>
<td>1.36–4.51</td>
<td>3.40</td>
<td>1.52</td>
</tr>
</tbody>
</table>
and afternoon training sessions, respectively ($p = .446$). There was a tendency for fluid intake rate to be correlated with the percent change in blood sodium concentration ($p = .072, r^2 = -.642$). When expressed in absolute terms, this correlation was significant ($p = .035, r^2 = -.636$) in the morning session. During the afternoon training session, fluid intake rate was significantly correlated with both percent change in blood sodium concentration ($p = .004, r^2 = -.717$) and absolute change in blood sodium concentration ($p = .007, r^2 = -.852$; Figure 1).

During the morning training session, mean ($SD$) thermal comfort increased significantly from 5.4 (0.9) pretraining to 7.4 (1.1) immediately posttraining ($p < .001$). During the afternoon training session there was a significant increase in mean ($SD$) thermal-comfort scores from 5.9 (0.7) pretraining to 7.8 (1.1) posttraining ($p < .001$). This difference corresponds to a 38.7% (17.8%) and a 31.0% (11.4%) increase in thermal comfort during the morning and afternoon sessions, respectively. In the morning training session fluid intake and the change in thermal comfort were significantly correlated ($p = .018, r^2 = .533$). However, in the afternoon session there was only a tendency for a correlation between fluid intake and the change in thermal comfort ($p = .066, r^2 = .151$; Figure 2).

Mean ($SD$) rate of sweat loss during the morning training session was 0.17 (0.21) L/hr, and during the afternoon training session this was 0.16 (0.34) L/hr ($p = .101$). Sweat rate and rate of fluid intake were not correlated during either the morning ($p = .637, r^2 = -.201$) or the afternoon session ($p = .975, r^2 = .002$; Figure 3).

Blood Sodium

Blood sodium values were obtained from 10 players in the morning training session and 8 players in the afternoon session, due to limited time between players arriving at training and the start of training. Mean ($SD$) blood sodium before the morning training session was 140.7 (2.2) mmol/L and fell to 139.2 (2.7) mmol/L at the end of the morning training session. At the start of the afternoon session, blood sodium concentrations were 139.2 (2.7) mmol/L, decreasing to 137.5 (1.9) mmol/L at the end of the afternoon training session. The mean ($SD$) percentage change during the morning training session was $-1.1\%$ ($1.3\%; p = .06$) and during the afternoon training session was $-3.0\%$ ($2.2\%; p = .135$). There was a significant decline in blood sodium concentrations over the entire training day—from pretraining in the morning (140.7 [2.2] mmol/L) until the posttraining blood sample at the end of the afternoon session (137.5 [1.9] mmol/L)—of 1.9% (2.0%; $p = .032$). There was no correlation between blood sodium concentrations and sweat rate in either the morning ($p = .352, r^2 = .102$) or the afternoon session ($p = .920, r^2 = -.152$). One of the participants who consumed a V energy drink recorded a blood sodium concentration of 135 mmol/L at the end of the second training session.

Discussion

Spinal-cord-injured (SCI) individuals are at increased risk of hyponatremia. Laboratory-based research has shown that tetraplegics consume fluids in excess of sweat losses
Figure 2 — Correlation between rate of fluid intake and change in thermal comfort during the morning and afternoon training sessions.

Figure 3 — Correlation between sweat rate and rate of fluid intake during the morning and afternoon training sessions.
hyponatremia, the results warrant further investigation. Times per day, and the potential issues associated with period. However, given the vigorous training regimens impairments. It is therefore important that they carefully This may be due to altered gastric emptying and renal blood sodium after the exercise session has finished. As no increase in blood sodium concentration was seen after the consumption of lunch (about an hour before the afternoon session), it is possible that individuals with spinal-cord injuries are at risk for further dilution of their blood sodium after the exercise session has finished. This may be due to altered gastric emptying and renal impairments. It is therefore important that they carefully monitor their food and fluid intakes in the postexercise period. However, given the vigorous training regimens of elite wheelchair athletes, who may exercise several times per day, and the potential issues associated with hyponatremia, the results warrant further investigation.

The mechanism for blood sodium dilution is an imbalance between water and sodium intake and loss. Excessive fluid consumption is generally considered the main cause of hyponatremia among ultraendurance athletes (Speedy et al., 1999). Given the low sweat rates and the gains in body mass observed in this group of wheelchair athletes, it would appear that excessive fluid intake of beverages low in sodium could be a cause of low blood sodium concentrations in tetraplegic athletes. This theory is further supported by the fact that the degree of change in blood sodium concentrations was positively associated with the volume of fluid consumed. As most of the participants consumed water, this study cannot determine the effects of other beverages on blood sodium. The dilution of blood sodium could be compounded by impaired renal function in response to a fluid load, but it is beyond the scope of this study to determine this. In addition, there was no correlation between sweat rate and change in blood sodium concentration in either of the training sessions. The rates of sweat loss in this group of athletes averaged 0.17 L/hr, which is similar to those reported previously in SCI athletes (Burnham, 1998). Although quite variable, sweat rates reported in previous work conducted on able-bodied athletes during football training have ranged from 1.67 to 3.14 L/hr (Shirreffs et al., 2005) and 1.06–2.65 L/hr. (Maughan, Shirreffs, Merson, & Horswill, 2005). This substantial difference in sweat losses between able-bodied and SCI athletes has been explained by Randall et al. (1966), who reported that only 25–30% of the sweat glands could be activated in people with a high-level (cervical-region) spinal-cord injury. Thus, high losses of sodium through sweat are unlikely to contribute to the hyponatremia often reported in SCI athletes.

The obvious problem with such low sweat rates in athletes with tetraplegia is that even small amounts of fluid will increase the risk of low blood sodium concentrations, especially if the drinks are low in sodium. It is therefore important to determine why these athletes drink to the extent they do. Our study suggests that fluid intake may be related to attempts to reduce perception of thermal discomfort. There was a positive association between increased thermal discomfort, from neutral toward excessively hot, and fluid intake. This finding supports the suggestions of Price and Campbell (2003), who theorized that SCI individuals consume fluid during exercise in an attempt to attenuate increased thermal strain. It is noted that our study was unable to measure core temperature and that this measure may have aided with the assertion that tetraplegic athletes drink to attenuate the thermal strain of exercise. This could mean that alternative measures to decrease the thermal strain need to be used, for example, ice vests.

Furthermore, SCI individuals may drink more because of the high prevalence of urinary tract infections and kidney and bladder stones reported in this population (Shekelle, Morton, Clark, Pathak, & Vickrey, 1999). The higher incidence of urinary tract infections has led to advice to increase fluid intakes and promote euhydration among the SCI population (Chen, Roseman, Funkhouser, & DeVivo, 2001). However, currently there is no definitive research showing an association between USG and the risk of bladder or kidney stones for those with a spinal-cord injury (Chen et al., 2001). Despite the lack of concrete evidence, it is possible the players in the current study regularly ingested fluid throughout the day in an attempt to attenuate the risk of urinary tract infections. Data obtained from the USG analysis supports this theory. Results suggest that on commencement of exercise most able-bodied athletes tested have some degree of dehydration, with mean USG of 1.018–1.022 g/ml commonly being reported (Stover, Zachwieja, Stefan, Murray, & Horswill, 2006). This is in contrast to the samples provided by the wheelchair rugby players in the current study, who had a mean (SD) USG of 1.012 (0.005) g/ml. Only 2 of the 26 samples collected from the players had a USG equal to or above 1.020 g/ml, the National Athletic Trainers’ Association criterion for euhydration/hyphydration among athletes, (Casa et al., 2000), suggesting that most of the athletes began training in a hyperhydrated state. If players are starting training in a well-hydrated state they may be at greater risk of developing hyponatremia and therefore possibly do not need to consume fluid during the training session.

Regardless of the mechanism determining why these athletes consume fluid in excess of their losses, it is imperative that recommendations specific to this athletic
population be designed to reduce the risk of hyponatremia and hypothermia. This study provides the first field-based data that, when combined with laboratory-based literature, can form the basis of these recommendations. Mean sweat losses of 0.17 L/hr were observed and ranged from 0.00 to 0.85 L/hr, so recommendations would need to consider the low sweat rates of the majority of these athletes. In addition, given the association between fluid intake and ratings of thermal discomfort observed in this study, strategies other than ingesting fluid to reduce thermal discomfort may need to be considered.

There is some evidence that these guidelines may need some degree of individualization, given the heterogeneity of this population. Individualized fluid guidelines are also encouraged for able-bodied athletes but will differ for the athletic tetraplegic population, where a greater emphasis should be placed on preventing hyperhydration, rather than hypohydration, and attenuating thermal strain by other methods. In general, fluid losses are influenced by many factors including environmental temperature, relative humidity, and clothing being worn (Maughan, 2001); exercise intensity (Greenhaff & Clough, 1989); fitness level (Baum, Bruck, & Schwennicke, 1976); and acclimatization status (Maughan & Shirreffs, 2004). Further factors that could affect the sweat rate of wheelchair athletes include the severity and type of disability. Even among those with the same disability, differences in the amount of sweat produced have been observed (Price, 2006). In our study, sweat loss ranged from 0.00 to 0.85 L/hr. These factors must be kept in mind when designing recommendations for SCI athletes.

The amount of work performed by the athletes is also important when designing hydration and dietary strategies. This is the first study that has attempted to objectively quantify the activity performed in a typical training session undertaken by elite wheelchair rugby players. The method employed in this study, which used a cycle computer mounted on the wheelchair, allowed us to measure distance covered and speed during training. Given the inappropriateness of using of heart-rate monitors for athletes with a complete spinal-cord injury above the thoracic sixth vertebra, this simple tool for measuring distance covered provided a measure of individual training volume. This could be used in future studies to provide greater individualized information regarding each player’s activity in relation to other parameters such as energy requirements.

In conclusion, the data suggest that athletes with tetraplegia ingest fluid in excess of their requirements, largely in an attempt to reduce thermal discomfort. Given the low blood sodium concentrations observed in this study, such behavior may increase the risk of hyponatremia. Therefore, specific recommendations for individuals with tetraplegia are required, with more emphasis on the risk of hyponatremia. These recommendations may include the provision of drinks with added sodium or for drinks to be served at cold temperatures. The findings of this study could help form the basis of these recommendations.

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References


