Original Article

Dehydration Rates and Rehydration Efficacy of Water and Sports Drink During One Hour of Moderate Intensity Exercise in Well-trained Flatwater Kayakers

Jeremy MF Sun,[1]*MBBS*, Jason KK Chia,[1]*MBBS, MSpMed (Aust)*, Abdul Rashid Aziz,[2]*BPE (Sport Studies)*, Benedict Tan,[1]*MBBS, DFD (CAW), MSpMed (Aust)*

Abstract

Introduction: The aim of this study is to investigate the amount of water loss and percentage dehydration experienced during 1 hour of paddling on the kayak ergometer so as to help coaches and athletes tailor a suitable and adequate rehydration regime. Also, rehydration efficacy between water and a well established, commercially available sports drink (Gatorade, Quaker Oats company, USA) was investigated in this cross-over study. Materials and Methods: Ten national flatwater kayakers were monitored in a controlled setting while paddling the kayak ergometer for 1 hour at an intensity sustainable for long distance marathon. They rehydrated themselves *ad libitum* with provided beverage. Post-void towel-dried body mass was measured before and after the exercise with percentage dehydration calculated. Body core temperature (tympanic temperatures), ratings of perceived exertion and thirst index were monitored every 15 minutes. The amount of fluid consumed, urine output and urine specific gravity were obtained after exercise. Results: The results [mean ± standard deviation (SD)] showed that kayakers underwent 1.10 ± 0.52% dehydration while rehydrating with water as compared to 0.72 ± 0.38% while rehydrating with Gatorade. Also, athletes on water rehydration had higher rating of perceived exertion (RPE) at the 30th and 60th minute mark of the exercise. Overall, athletes undergoing water rehydration lost significantly more body mass (0.70 ± 0.39 kg) as compared to rehydrating with Gatorade (0.46 ± 0.27). Conclusion: Although the hydration efficacy of Gatorade proved superior to that of water, the athletes' hydration habits with either fluids did not provide adequate hydration. It is recommended that specific strategies be developed to address dehydration and rehydration issues of kayakers in Singapore.

Ann Acad Med Singapore 2008;37:261-5

Key words: Canoe, Gatorade, Fluid replacement, Marathon

Introduction

Flatwater kayaking has been gaining popularity in the world and steep growth has been observed in the Asian region. Long distance paddling is often necessary training for competitive kayakers competing in either the sprint or marathon disciplines. However, racing long distances up to 36 km is peculiar to the marathon discipline. Hence, dehydration is a significant problem in such races and is often the cause of what is described by athletes as "hitting a wall". Studies have shown that a fluid deficit of greater than 2% of an individual's body mass results in decreased exercise tolerance and is likely to have a negative impact on the sporting performance.[1,2] To minimise such occurrences and to enable efficient rehydration of the athlete while minimising disruption of training or racing, it is crucial to determine the degree of dehydration suffered during paddling.

Marathon boats are very light. Single kayaks weigh about 8 kg while doubles can weigh a mere 12 kg. Limited space on board the craft makes carrying a whole races' supply of consumables inconvenient. Therefore, to maximise the weight advantage, the rehydration system has to be kept to a minimum while ensuring adequate rehydration of the athlete. This can be facilitated by land support crews that can replenish rehydration supplies of the athlete during the portage.

Currently, there is little published data on dehydration in flatwater kayakers and hence there are 2 aims of this study. Firstly, to investigate the amount of dehydration a kayaker experiences while undergoing 1 hour of

[1] Changi Sports Medicine Centre, Changi General Hospital, Singapore
[2] Exercise Physiology Department, Singapore Sports Council, Singapore
Address for Correspondence: Dr Jeremy MF Sun, Changi General Hospital, Changi Sports Medicine Centre, 2 Simei Street 3, Singapore 529889.
Email: jermie@singnet.com.sg

paddling on an ergometer. Secondly, whether water or a commercially available sports drink (Gatorade) gives better rehydration.

Materials and Methods

Ten members of the Singapore National flatwater kayaking team (5 male and 5 female) volunteered to participate in the study. They were competitive athletes who were training for an upcoming international marathon event. Subjects had been residing in the country for at least 10 years and were therefore acclimatised to the native hot and humid weather. All subjects were informed of the risks and benefits involved in this study and informed consent to participate in this study was obtained. The study protocol was approved by the institutional review board. The subject's characteristics are summarised in Table 1.

Table 1. Subject Characteristics (n = 10)

	Male	Female	Total
Age (y)	22.8 ± 1.1	21.0 ± 2.7	21.9 ± 2.2
Body stature (cm)	173.4 ± 3.2	159.6 ± 4.7	166.5 ± 8.2
Body mass (kg)	70.8 ± 5.0	52.2 ± 7.3	61.5 ± 11.5
Experience in sport (y)	5.8 ± 1.1	4.4 ± 2.2	5.1 ± 1.8

This is a crossover design study with each subject serving as his own control. Each subject was required to make 2 visits to the study site. A familiarisation trial was not done as the athletes have previously trained on the ergometers before. The study was conducted on 2 Sundays a week apart. The paddling exercise was conducted in the middle of a roofed squash court that was well ventilated. This enabled a constant and controllable environment. High wall fans were switched on so that some air movement was present. Paddling was performed on a kayak ergometer (Kayakpro Speedstroke, USA) which has been shown to simulate actual open water paddling closely.[3] On the first visit, athletes rehydrated with a commercially available sports drink (GH) while they rehydrated with water (WH) on the second visit. The commercially available sports drink was Gatorade lemon-lime flavour. Subjects were not blinded to the identity of the 2 fluids as we were interested to investigate how their rehydration habits differed between the 2 drinks provided. The mentioned sports drink contained 6 g 100 mL^{-1} of glucose, 41 mg 100 mL^{-1} of sodium and 11.7 mg 100mL^{-1} of potassium. There was no carbonation, and osmolality was not assessed. The fluid was consumed *ad libitum* and was delivered via a waterbag system connected to a tubing with a bite valve at the end. Some athletes kept the bite valve in their mouth throughout the whole study while some called on for assistance to place the bite valve in the mouth so that paddling will not be disrupted. Environmental temperature and humidity were recorded hourly via a whirling psychrometer. All athletes were told to wear loose fitting tanktops.

Pre-exercise, the athletes had their post-void towel-dried body mass in minimal clothing measured digitally (kg ± 0.1, Model 708, Seca, Hamburg, Germany). This was done 20 minutes before commencement of the exercise. Full waterbag mass was also measured at the start and end of the exercise (Mettler Toledo). During the exercise, tympanic temperature (±0.1°C Braun Thermoscan, USA), rating of perceived exertion (RPE) and thirst index were measured at 15 minutes intervals (0, 15, 30, 45, 60 minutes). After exercise, post-void towel-dried body mass in minimal clothing was measured digitally again. Excreted urine volume was measured to be included as part of body mass lost. Specific gravity of the urine was also measured via manual refractometer. In addition, their waterbags were weighed to determine the amount of fluid consumed. Lastly, athletes were asked whether they suffered any gastrointestinal complaints such as nausea, vomitting, abdominal pain or bloatedness.

Intensity of Exercise

Before the actual 1 hour of paddling begins, each paddler was required to perform an all out sprint effort to achieve his maximum speed as shown by the speedometer attached to the kayak ergometer. This was done by asking the athlete to paddle at his fastest speed possible for 15 seconds. The highest value on the speedometer registered was taken as his maximum achievable speed. The athlete was then required to paddle at 65% ± 5% of his maximum speed during the 1 hour paddle. This was achieved by the athlete themselves who constantly monitored his or her own speed via the clearly visible speedometer. The mean speed for the male and female athletes was (11.3 ± 1.7 km/h) and (9.1 ± 1.2 km/h) respectively. This procedure was repeated for each of the 2 visits.

Determination of Tympanic Temperature

Tympanic temperatures were recorded just prior to the start of the 1 hour paddle (at min 0^{th}) and every 15 minutes of the exercise. Core temperature was represented with the temperature taken from a digital tympanic infrared scanner (±0.1°C Braun Thermoscan, USA).

Determination of RPE and Thirst Index

Borg's rating of perceived exertion of 6 to 20 was used,[4] while the thirst index used a number rating from 1 to 5 ("Not at all" to "Very much").[5] These readings were taken just prior to exercise and subsequently every 15 minutes interval of exercise. Paddling was not disrupted during measurement taking.

Determination of Urine Volume and Specific Gravity

Urine was collected in sterile containers immediately after exercise and its mass was measured (g ± 0.01, Mettler Toledo, USA). The mass of the container was subtracted from this measurement to determine the amount of urine. Urine specific gravity was assessed with a manual refractometer (± 0.001, URICONNE, Japan).

Determination of Environmental Conditions

Humidity and temperature were monitored and recorded every hour using a whirling psychrometer (°C ± 0.1, Lambrecht, Germany). Due to the nature of the venue, humidity and temperature values remained constant throughout the testing.

Determination of Time of Maximal Exertion

After the 60th minute of paddling, the athletes were required to paddle and maintain at their maximum attainable speed for as long as they could. When the speed fell below 1.0 km/h of the maximum speed, the athletes were asked to stop and the time which he or she maintained at maximum speed was recorded.

Statistical Analysis

The SPSS for Windows version 13.0 was used for all statistical analyses and data were presented as mean ± standard deviation (SD). Differences in various variables between water and Gatorade rehydration were analysed using the paired *t*-test. $P < 0.05$ was considered statistically significant.

Results

Environmental Conditions

Due to the nature of the venue where the study was conducted, environmental conditions such as the environmental humidity and the environmental temperature remained relatively constant. The ambient temperature and humidity on the Sunday when athletes consumed Gatorade for rehydration was 30°C and 76% respectively. The ambient temperature and humidity on the Sunday when athletes consumed water for rehydration was 29.5°C and 69% respectively

RPE

Mean RPE (GH) was lower overall at all times after the 0th minute. There were significant differences observed between RPE (WH) and the RPE (GH) during the 30th and 60th minute of exercise as shown in Figure 1.

Thirst Index

Ratings of thirst showed a general increase as time progressed. However, there was no significant difference in subjective ratings between the water and Gatorade rehydration groups (Fig. 2).

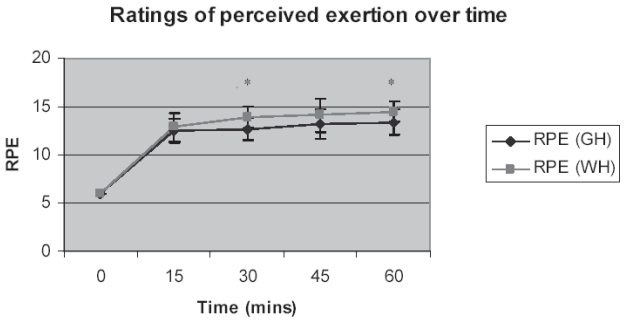


Fig 1. Subject's rating of perceived exertion (RPE) during the 60 minutes of paddling

* RPE with water intervention significantly higher than RPE with Gatorade intervention, $P < 0.05$

Mean Tympanic Temperature

Both water and Gatorade rehydration demonstrated an increase in tympanic temperature during the first 15 minutes. From the 15th minute to the 30th minute, a decrease in tympanic temperature was seen during both GH and WH. However, in the WH group, this cooling effect stopped at the 30th minute after which a slight increase in mean tympanic temperatures was observed. In the GH group, the cooling effect was more prolonged, lasting from the 15th minute to the 45th minute before a slight increase in tympanic temperature occurred. Overall, mean tympanic temperature in the GH group was significantly lower than in the WH group during the 45th minute and 60th minute (Fig. 3).

Volume of Fluid Consumed, Urine Volume and Urine Specific Gravity

Mean urine volume and mean urine specific gravity was not statistically different between GH and WH (Table 2). Volume of Gatorade consumed was only slightly higher than water. This difference was not statistically significant despite studies showing athletes consuming more sports drinks than water during exercise due to a taste preference.[6] Out of the 10 athletes who took part in the study, 6 athletes consumed more Gatorade than water.

Mean Body Mass Loss, Mean Estimated Water Loss and Mean Percentage Dehydration

Mean body mass loss was calculated by the equation: (mean pre-exercise voided body mass) – (mean post-exercise voided body mass). Mean estimated water loss was calculated as: (mean body mass loss) + (mean volume of fluid consumed). Mean percentage dehydration was calculated as follows:[(mean body mass loss) / (mean pre-exercise voided body mass)] x 100. Mean body mass loss and mean percentage dehydration was higher in WH than in GH. This difference was statistically significant ($P < 0.05$). A similar trend was also seen in mean estimated water loss; however, the difference was not statistically significant.

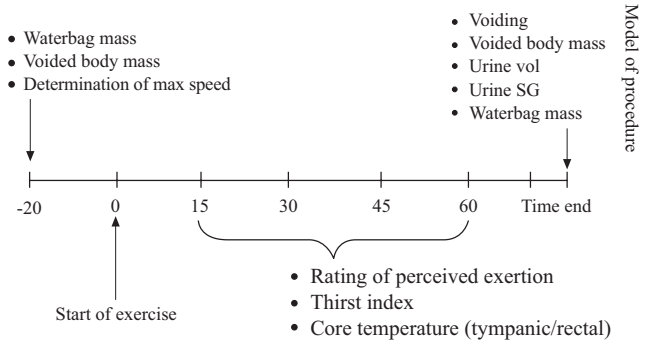
Table 2. Volume of Fluid (Water and Gatorade Sports Drink) Consumed, Urine Output, Urine Specific Gravity and Mean Loss in Body Mass during the Interventions

	Water	Gatorade
Volume of fluid consumed (mL)	519 ± 269	578 ± 240
Urine output (mL)	104 ± 142	120 ± 71
Urine specific gravity	1.02 ± 0.012	1.018 ± 0.008
Mean loss in body mass (kg)	0.70 ± 0.39*	0.46 ± 0.27*
Mean estimated water loss (L)	1.22 ± 0.59	1.04 ± 0.32
Mean percentage dehydration (%)	1.10 ± 0.52†	0.72 ± 0.38†
Mean time of maximal exertion (s)	31.7 ± 8.5‡	37.7 ± 10.3‡

* Body mass loss in water intervention significantly higher than body mass loss in Gatorade intervention (P <0.05)

† Mean percentage dehydration in water intervention significantly higher than mean percentage dehydration in Gatorade intervention (P <0.05).

‡ Mean time of maximal exertion is significantly longer in individuals consuming Gatorade compared to individuals consuming water [P <0.05 (one-tailed)].



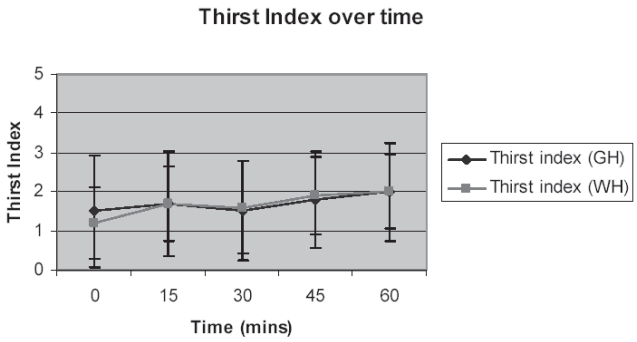


Fig 2. Subject's rating of thirst during the 60 minutes of paddling.

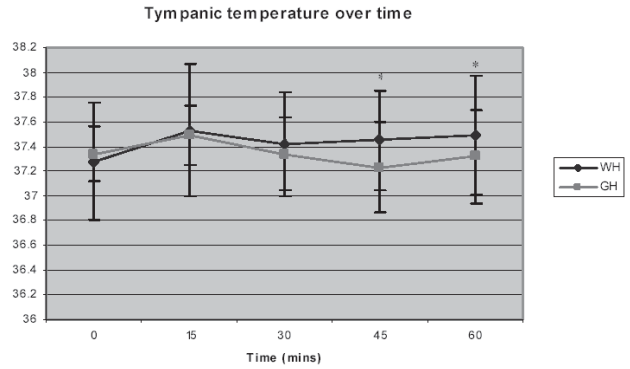


Fig 3. Subject's tympanic temperature during 60 minutes of paddling

* Tympanic temperature with water intervention significantly higher than tympanic temperature with Gatorade intervention (P <0.05).

Time of Maximal Exertion

The mean time of maximal exertion for paddlers consuming Gatorade (37.7 ± 10.3 s) was significantly longer than when they consumed water (31.7 ± 8.5 s).

Gastrointestinal Complaints

Athletes from both the GH and WH groups did not complain of any gastrointestinal symptoms.

Discussion

Dehydration in various endurance activities has been generally well investigated. Slater and Tan[7] observed in sailing that a day of club racing resulted in percentage dehydration averaging 1.59%. In soccer, players can experience 1.59% of dehydration during 90 minutes of training on the field.[8] However, little research has been reported for flatwater kayaking particularly on this form of exercise in the tropical environment where heat and humidity is significantly higher. The major finding of the study is that percentage dehydration occurring during 1 hour of kayak ergometer paddling is comparable to those found in other sports such as swimming.[9] Our kayakers experienced a mean percentage dehydration of 1.10 ± 0.52% while rehydrating with water and a mean percentage dehydration of 0.72 ± 0.38% while rehydrating with Gatorade. Furthermore, to test the difference between the amount of dehydration experienced within the 2 interventions, we made the paddlers perform a time to maximal exertion which showed a significantly longer duration for those on Gatorade (37.7 ± 10.3 s) as compared to those on water (31.7 ± 8.5 s). These findings suggest that Gatorade may result in better rehydration compared to water and this may translate to a slightly better performance. However, these values only represent an hour of paddling exercise. During an actual marathon race which may last for 3 hours, dehydration will likely be significantly more and this will result in performance inhibition if the current fluid rehydration regime was maintained. Since an athlete may paddle for around 35 minutes non-stop before being able to replenish his drinks by land support crew during the portage, it is recommended that kayakers in a marathon event carry at least 0.61 L of sports drink such as Gatorade between each portage and consume all of it during the paddling. This value is obtained by getting the fraction of water loss experienced when paddling for 35 out of 60 minutes.

Rehydration habits were shown to be different for the 2 fluids provided in this study. Kayakers had an estimated water loss averaging 1.22 L of water in the WH group and 1.04 L in the GH group. However, kayakers only drank an average of 519 mL of water compared to 578 mL of Gatorade thereby replacing only 43% of water loss when consuming water and 56% of water loss when consuming Gatorade. Although rehydration fluid volume was not controlled and allowed to be consumed *ad libitum*, this allowed us to evaluate certain aspects of Gatorade rehydration as compared to water rehydration. There have been suggestions that the superior rehydration efficacy of Gatorade as compared to water may be partly due to the athletes preferral consumption of flavoured drinks.[12] However in this study, the volume of Gatorade ingested was not significantly greater than that of water. Perhaps, the presence of glucose in Gatorade assisted in the absorption of water in the gastrointestinal tract.

Wilk et al[10] showed that voluntary dehydration could be prevented altogether in boys (9 to 12 years) exercising in the heat if they had ready access to a sports drink consisting of flavoured water with 6% carbohydrate and 18 mmol/L NaCl, while hypohydration of 0.65% was observed with plain water and 0.32% with flavoured water. While our kayakers did experience a significant degree of dehydration even on sports drinks, it was lesser than that experienced when they consumed water only. This was further supported by the lower mean tympanic temperature and lower mean RPE observed for the kayakers. Hence, we recommend our kayakers carry sports drinks during long trainings rather than just plain water. This will help athletes train effectively and reduce risk of developing dehydration.

Limitations

In this study, the small number of subjects as well as the large inter-individual variability would reduce the statistical significance of some of the variables measured. In addition, kayakers were assumed to be euhydrated prior to the exercise. However, they were advised the day before to hydrate themselves well in preparation for the study. Food intake prior to the study may also affect the efficacy of hydration with a certain fluid and hence the study can be better improved by standardising the food taken and the time between consuming the food and the start of the exercise. Although there was no statistically significant volumetric difference between the mean consumption of the 2 beverages, randomisation of the rehydration fluid should have been performed to prevent athletes from being habituated to the test procedure. Another limitation is that the kayaking ergometer can never replicate actual paddling conditions totally and in actual marathon events, "wash-riding" which is similar to drafting in cycling can actually reduce the intensity at which a kayaker requires to paddle at to maintain a given speed.[11] Ideally, core temperature should be assessed via rectal thermometer.

Conclusion

Consumption of Gatorade had better hydration efficacy for the kayakers with reduced loss of body mass and lesser percentage dehydration. This is also supported by lower perceived ratings of exertion and lower tympanic temperatures towards the end of the 1 hour paddling exercise. According to the dehydration rates in this study, paddlers should carry approximately 1.04 L of Gatorade or an equivalent sports drink for every hour of exercise to minimise risk of dehydration and to maximise training efficiency. In addition, optimal hydration habits of kayakers should be encouraged. Coaches can help by emphasising the importance of hydration to the athletes and making hydration an integral part of the training regime.

Acknowledgement: *This study was supported by the Singapore Sports Council and the Singapore Canoe Federation. The equipment for this study was supplied by the Singapore Sports Council and the Changi Sports Medicine Centre. Kayakpro Ergometer was kindly provided by the Sports Recreation Centre, National University of Singapore. The authors would like to acknowledge the expert technical assistance of Lee Hong Choo and Amanda Nio Qing Xia.*

REFERENCES

1. Sawka MN, Pandolf KB. Effects of body water loss on physiological function and exercise heat performance. In: Gisolfi CV, Lamb DR, Murray R, editors. Perspective in Exercise Science and Sport Medicine: Fluid Homeostasis During Exercise. Vol 3. Carmel: Benchmark Press, 1990:1-38
2. Yoshida T, Takanishi T, Nakai S, Yorimoto A, Morimoto T. The critical level of water deficit causing a decrease in human exercise performance: a practical field study. Eur J Appl Physiol 2002;87:529-34.
3. van Someren KA, Phillips GR, Palmer GS. Comparison of physiological responses to open water kayaking and kayak ergometry. Int J Sports Med 2000;21:2004.
4. Noble BJ, Borg GA, Jacobs I, Ceci R, Kaiser P. A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. Med Sci in Sports Exer 1983;15:523-8.
5. Saat M, Singh R, Sirisinghe RG, Nawawai M. Rehdyration after exercise with fresh cocnut water, carbohydrate-electrolyte beverage and plain water. J Physiol Anthropol Appl Human Sci 2002;21:93-104
6. Wilmore JH, Morton AR, Gilbey HJ, Wood RJ. Role of taste preference on fluid intake during and after 90 min of running at 60% of VO2max in the heat. Med Sci Sports Exerc 1998;30:587-95.
7. Slater G, Tan B. An assessment of dietary practices among Laser class sailors. In: Legg SJ, Mackie H, Cochrane D, editors. Human Performance in Sailing Conference Proceeding. Auckland: UNITEC School of Sport, 2003:2-4.
8. Shirreffs SM, Aragon-Vargas LF, Chamorro M, Maughan RJ, Serratosa L, Zachwieja JJ. The sweating response of elite professional soccer players to training in the heat. Int J Sports Med 2005;26:90-5.
9. Cox GR, Broad EM, Riley MD, Burke LM. Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. J Sci Med Sport 2002;5:183-93
10. Wilk B, Bar-Or O. Effect of drink flavour and NaCl on voluntary drinking and hydration in boys exercising in the heat. J Appl Physiol 1996;80:1112-7
11. Pérez-Landaluce J, Rodríguez-Alonso M, Fernandez-Garcia B, Bustillo-Fernandez E, Terrados N. Importance of washing riding in kayaking training and competition. Med Sci Sports Exerc 1998;30:1721-4.
12. Minehan MR, Riley MD, Burke LM. Effect of flavor and awareness of kilojoule content of drinks on preference and fluid balance in team sports. Int J Sport Nutr Exerc Metab 2002;12:81-92.