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FLUID INTAKE AND CHANGES IN BLOOD BIOCHEMISTRY, RUNNING SPEED AND BODY MASS DURING AN 80 KM MOUNTAIN TRAIL RACE

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Abstract

Introduction: To measure changes in body mass, total body water, running performance, fluid intake and blood biochemical variables in an ultra-marathon mountain race.

Methods: 9 subjects (44.0 ± 9.2 years; 72.2 ± 9.0 kg) were measured 2-days before the race, immediately pre-race and post-race for body mass (BM), total body water (TBW), plasma osmolality, plasma sodium ([Na^+]), plasma potassium ([K^+]) and plasma total protein concentrations. Fluid intake and rating of perceived exertion (RPE) were also measured over the entire race.

Results: Significant BM loss occurred from 2-days pre-race to post-race (-3.1 ± 1.2 kg; $P<0.05$) and pre-race to post-race (-3.7 ± 2.7 kg; $P<0.01$). A positive linear relationship was found between fluid intake and changes in BM during the race (r = 0.7; $P<0.05$). Rates of fluid intake (321-628 ml/hr) and total body mass loss varied substantially between individuals. Plasma osmolality and [Na^+] concentrations were well regulated and did not change significantly. There was a non- significant correlation between changes in body mass and race performance.

Conclusion: We conclude that drinking rates vary substantially in athletes drinking *ad libitum* during an 80 km mountain race whereas plasma osmolality and [Na^+] are well regulated despite large changes in BM. Therefore, drinking *ad libitum* during prolonged endurance running seems to be an appropriate method to maintain fluid homeostasis during ultra-marathon mountain races.

Key words: *fluid balance, plasma sodium, plasma osmolality, exercise*

Introduction

Current fluid replacement guidelines advise athletes to consume enough fluid in order to prevent a >2% decrease in body mass during exercise (1). These guidelines are usually applied to athletes participating in events such as road running, triathlons, tennis, soccer and American football. There is less information about rates of fluid intake and body mass losses in ultra-distance events like the Ironman triathlon or ultra-marathon races, in which some successful athletes can incur body mass losses > 6-8% without apparent detriment to their health or performance (2-4). It is usually difficult to measure fluid intakes in these races since competitors cover large geographical distances and the events last for prolonged periods making careful observation impractical.

A local 80km trail race provided an opportunity to carefully monitor rates of fluid intake in athletes during exercise. At the same time we were able to measure changes in body mass, running speed, rating of perceived exertion and various blood biochemical measures.

We hypothesized that rates of fluid intake amongst the competitors would vary as would the extent to which they lost body mass during the race. In contrast blood electrolyte measures especially plasma sodium concentrations and plasma osmolality would vary less since these are the biological variables that are homeostatically regulated during exercise (5). Finally we seek to re-enforce the observation that athletes losing the most body mass during the race will exhibit the best performance whilst drinking and eating ad libitum during an 80km off-road running race.

Materials and Methods

Subjects: All entrants of the 2007 Peninsula Ultra Fun Run (PUFfeR) 80km trail race were invited to participate in this study. Approval for this study was obtained from the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape

Town and was carried out according to the Declaration of Helsinki (Seoul, 2008). Ten athletes (Table 1) gave written informed consent to participate in this project from a field limited to 125 runners (8% of the entire field). All food and fluid were consumed *ad libitum* during the race.

Setting: The PUFfeR is an 80km trail race starting at Cape Point (Cape Town, South Africa) which traverses the Cape Peninsula for 80km (highest elevation of 1080m) over the Table Mountain National Park with 13 checkpoints dotted at intervals of 6 km (Figure 2). Ambient temperature (dry bulb) fluctuated between 8-20°C on race day (South African National Weather Bureau) on a clear and calm day.

Measurement of Body Mass(BM): Subjects were weighed in racing attire without shoes after emptying their bladder on an electronic digital scale (Beurer GS32) (to the nearest 0.1 kg) on three occasions: 1. race briefing (2-days pre-race), 2. 60 minutes prior to race start (pre-race) and 3. immediately upon completion of the race (post-race).

Blood Biochemical Analyses: 10 ml venous blood samples were collected on the three occasions described, into lithium- heparin Vacutainer (Becton Dickinson, Rutherford, NJ) tubes. During the blood drawing subjects were seated following measurements of their body mass. Samples were stored on ice until centrifugation. Blood samples were centrifuged at 3000g for 10 minutes at 4°C. Plasma was extracted and stored at -20°C until analysed for: plasma sodium ($[Na^+]$) and potassium ($[K^+]$) (EasyLyte PLUS Na/K/Cl analyzer, Medica Corporation) concentrations; plasma osmolality (POsm) (Osmomat 030 Cryoscopic osmometer, Gonotec) (CV- 2.86%); and plasma protein concentrations (Roche P-Module, Biuret) (CV- 2.1%) (Table 2).

Fluid Intake: Fluid intakes were measured and recorded by researchers stationed at 13 mandatory checkpoints throughout the 80 km route. Researchers recorded the number and size of cups (175 ml or 350 ml) consumed by the athletes at the checkpoints. They also questioned each athlete about the volume of fluid consumed between checkpoints with a fluid recall method. As a result subjects needed to recall only the additional volumes of fluid consumed during the previous ~6 km. The data from the 13 checkpoints was then summed to calculate the total volume (L) and rates of fluid intake (ml/hr) for the individual athletes (Table 3).

The exploratory measurement of total body water took place 2-days before; immediately before and after the race with the use of deuterium oxide dosage.

Measurement of Total Body Water (TBW): TBW was calculated with the diluted isotope method using deuterium oxide. A ~1.5 ml saliva sample was used to calculate natural deuterium abundance (as well as increased deuterium abundance due to prior doses) and after a 2-hour equilibration period to determine TBW on three separate occasions: race briefing (2-days pre-race), race morning (pre-race) and immediately after race completion (post-race). Saliva was collected by placing a sterile cotton wool swab into each subject's mouth with sterile tweezers. Each subject then was asked to moisten the cotton swab with saliva by rolling the swab around the mouth until the swab was fully saturated. The cotton swab was then removed with tweezers and immediately placed into the barrel of a 10 ml sterile syringe. All saliva was then extracted by compressing the cotton swab against the head of the syringe and which allowed all collected fluid to flow directly into a cryotube. Samples were immediately sealed and frozen (-20°C) until further analysis could be performed. Food and fluids consumption was prohibited during the 2-hour equilibration. During the post-race setting fluid ingestion was restricted. However some subjects required to drink. In which case the volume ingested was measured (to the nearest 0.001g) and corrected for during the first hour of equilibration. No further ingestion was allowed during the final hour during the 2-hour equilibration period which followed baseline saliva sampling. A 2-hour equilibration period following deuterium administration has been seen to be appropriate (6-17). All urine produced during this equilibration period was collected to account for any isotope loss. The deuterium enrichment and volume of these urine samples were accounted for in subsequent TBW calculations.

The dose of deuterium used for total body water measurement was administered as individualized doses immediately following baseline saliva sampling. Each deuterium dose was dispensed from a 4% weight-to-weight stock solution that was created by mixing required amounts of 99% Deuterium Oxide (Cambridge Isotope Laboratories Inc., MA.) and distilled water. The premixed deuterium stock solution was poured into an airtight container and sealed with duct tape to prevent fractionation during storage. Each participant received a dose of approximately 0.05 g/kg body weight with each dosage pre-weighed to the nearest 0.001g. After each dosage had been consumed, the dose bottle was immediately re-weighed to quantify the exact amount that had been ingested. TBW determination was obtained through measurement of deuterium enrichment in saliva samples, as measured by continuous flow isotope ratio mass spectrometry (Europa Scientific ANCA-GSL and Geo 20-20 IRMS, Iso-Analytical Inc, UK)(relative standard deviation <2%). Total body water was calculated utilizing the Halliday and Miller method (18) with a modified correction factor for non-aqueous hydrogen exchange at 1.04 (4 %)(12;18).

Calculations:

Equation 1:

The Davies method was used to calculate the total body water (TBW) in kilograms (kg)(19):

$$\textbf{TBW (kg)} = [(((T^*A)/a) \times ((Ea-Et)/(Es-Ep)))/1000] / 1.04$$

Whereas: **A** = amount of dose solution drunk (g); **a** = amount of dose solution diluted in T (g); **T** = amount of tap water '**a**' was diluted in; **Ea** = enrichment of diluted dose; **Et** = enrichment of tap water used to dilute the dose; **Ep** = enrichment of baseline sample; **Es** = enrichment of post dose sample; **1.04** = correction factor for over estimation of TBW by the use of deuterium (20).

Equation 2:

Total body water (kg) was attained and percentages of total body water (TBW) were calculated as:

$$\%\Delta \text{ TBW} = [\text{TBW (post-race)} - \text{TBW (pre-race)}] / \text{TBW (post-race)} \times 100$$

Equation 3:

Percent of body mass (%Δ BM) lost or gained during the race was calculated as the difference between the starting weight (either 2-day pre-race or pre-race) and the finishing weight (post-race) divided by the start weight and multiplied by 100.

Equation 4:

Change in plasma volume (PV) was calculated (21):

$$\Delta \text{ PV (\%)} = [\text{total protein (post)} - \text{total protein (pre)}] / \text{total protein (pre)}$$

Equation 5:

Performance Analysis: Running speed (km/hr) was calculated as an average over the entire race and over each leg between twelve checkpoints:

$$\text{Running Speed (km/hr)} = \text{Distance (km)} / \text{Race Time (hrs)}$$

Rating of Perceived Exertion (RPE): RPE was noted using the Borg (6-20) category ratio scale(22). RPE was noted at each checkpoint, it was mandatory for subjects to stop and check in.

Statistical analysis

Data were analyzed using the STATISTICA version 8 (StatSoft Tulsa, OK) statistical program using correlations, repeated measures ANOVAs and post-hoc analysis with Tukeys HSD. Pearson's correlations were calculated through the use of Prism 3 (GraphPad Software, Inc). Where applicable, all data are presented as means ± standard deviations (SD) including the range of values. Statistical significance was accepted when $p< 0.05$.

Results

Eight of the runners (seven males and one female) successfully completed the 80 km mountain race with a mean finishing time of 691.4 ± 51.8 minutes (range: 583.5 – 769.2) (Table 1). One female runner withdrew prior to race start and all her baseline data collected were excluded entirely from the subsequent analysis. One male runner dropped out at ~60 km, but completed bodymass measurements after being transported to the finish line. Thus his data were included in the study since he did complete ultra-distance. The mean age of the cohort was 44.0 ± 9.2 years (range: 33 - 61) with a mean baseline weight (2-days pre) of 72.2 ± 9.0 kg (range: 61.3 - 88.6) (Table 1).

The individual data for body mass measurements including the relative and absolute changes during the course of the experiment are detailed in Table 1. Body mass increased ~1.05 kg (±1.99) from 2-days pre-race to immediately pre-race but decreased ~4 kg (±2.55) (5% BM) during the course of the race ($P<0.05$).

Plasma potassium (K^+), sodium (Na^+) and protein concentrations did not change significantly during the race, nor did the plasma osmolality (Table 2). Furthermore, no significant correlations existed between percent change in body mass with either post-race plasma sodium concentrations or plasma osmolality (Figure 1). The dotted lines indicate the normal range of plasma osmolality (280–296 mOsm/kgH_2O) while the solid lines denote the normal range of plasma sodium (135–145 mmol/L) (23). Only one plasma sodium concentration fell outside the normal range whereas three plasma osmolalities were above the normal range.

Table 3 provides a breakdown of the fluid intakes of the subjects denoted as water intake and the intake of 3 different carbohydrate containing drinks (CHO A, B and C). The column noted as "other" is the sum of different fluid types other than those already described. Total volumes of fluid ingested during the race varied from 2.11–6.11 liters (mean 4.50 liters). The rates of fluid intake varied from 327 to 628 ml/hr (mean 422 ml/hr).

The data obtained resulted in only two complete sets of data for all three TBW measurements (Table 4). However we did acquire 3 data sets of changes in the period between 2-days pre-race to immediately pre-race (A-B); 5 data sets of changes from 2-days pre-race to post-race (A-C) and 4 data sets from immediately pre-race to post-race (B-C).

Table 1. *Body mass changes in runners participating in an 80km ultra endurance trail race*

Subject	Sex	RT (hrs)	BM (kg)			Δ BM (kg)			%Δ BM (kg)		
			A	B	C	A-B	A-C	B-C	A-B	A-C	B-C
1	M	12.2	75.0	76.4	71.4	1.4	-3.6	-5.0	1.9	-4.8	-6.5
2	M	12.82	61.3	60.7	59.9	-0.6	-1.4	-0.8	-1.0	-2.3	-1.3
3	M	10.98	78.1	80.7	74.1	2.6	-4.0	-6.6	3.3	-5.1	-8.2
4	M	9.72	74.5	74.8	72.1	0.3	-2.4	-2.7	0.4	-3.2	-3.6
5	M	10.92	70.2	67.2	67.4	-3.0	-2.8	0.2	-4.3	-4.0	0.3
6	M	12.2	88.6	89.9	83.6	1.3	-5.0	-6.3	1.5	-5.6	-7.0
7	M	11.77	-	74.2	73.3	-	-	-0.9	-	-	-1.2
8	M	-	68.7	71.7	65.4	3.0	-3.3	-6.3	4.4	-4.8	-8.8
9	F	11.57	61.3	64.7	59.4	3.4	-1.9	-5.3	5.5	-3.1	-8.2
mean		***11.5***	***72.2***	***73.4***	***69.6**** #	***1.1***	***-3.1***	***-3.7***	***1.5***	***-4.1***$	***-5.0***$
±SD		***1.0***	***9.0***	***8.8***	***7.6***	***2.1***	***1.2***	***2.7***	***3.1***	***1.2***	***3.5***

RT- Race Time; BM- Body mass; %Δ- Percentage change; A- 2 Days Pre-race; B- Pre-race; C- Post-race
*P<0.05 when compared to A; #P<0.001 when compared to B; $$P$<0.05 when compared to A-B; (-) - Unavailable data.

Table 2. *Haematological measures of runners participating in an 80km ultra endurance trail race (Mean ± SD)*

	2-Days Pre-race	Pre-race	Post-race
Plasma [K+] (mmol/L)	5.0 ± 0.5 (n= 8)	4.9 ± 0.6 (n= 9)	5.1 ± 0.7 (n= 8)
Plasma [Na+] (mmol/L)	140.0 ± 2.0 (n= 8)	137.3 ± 2.2 (n= 9)	138.5 ± 4.3 (n= 8)
Plasma Osmolality (mosm/kgH_2O)	286.1 ± 9.7 (n= 8)	298.2 ± 7.4 (n= 9)	292.9 ± 8.5 (n= 8)
Plasma Protein (g/L)	71.0 ± 3.3 (n= 8)	73.0 ± 2.8 (n= 8)	75.0 ± 5.1 (n= 8)

Table 3. *Fluid intake of runners participating in an 80km ultra endurance trail race*

Subject	Fluid Intake (ml)							
	Fluid	CHO A	CHO B	Cola	CHO C	Other	Total (L)	Rate (ml/hr)
1	965	690	350	1980	-	-	3.99	327
2	1050	2500	1025	300	-	170	5.05	394
3	800	200	175	2160	-	200	3.54	322
4	2720	1800	700	885	-	-	6.11	628
5	2290	1050	850	875	-	200	5.27	482
6	2610	375	1025	835	-	300	5.15	422
7	2500	650	1400	-	500	385	5.44	462
8	910	125	175	350	-	550	2.11	-
9	1430	125	450	1325	-	575	3.91	338
mean	**1697**	**835**	**683**	**1089**	**500**	**340**	**4.50**	**422**
±SD	***816***	***823***	***427***	***688***		***169***	***1.23***	***103***

Subject 8 = did not complete the race, retired at 60 km. L – Liter; CHO A contains 7g/100ml carbohydrates & 30mg/100ml sodium; CHO B contains 7.5g/100ml carbohydrate & 21mg/100ml sodium; CHO C contains 20g/100ml carbohydrates & 47.5mg/100ml sodium

Table 4. *Total body water changes of participants in an 80km ultra-endurance trail race*

Subject	TBW (kg)			Δ TBW (kg)			% TBW relative to BM			%ΔTBW relative to BM		
	A	B	C	A-B	A-C	B-C	A	B	C	A-B	A-C	B-C
1	44.3	-	-	-	-	-	59.1	-	-	-	-	-
2	37.7	37.8	35.1	-0.1	-2.6	-2.7	61.5	62.3	58.6	1.4	-4.7	-6.0
3	-	40.6	37.5	-	-	-3.2	-	50.4	50.6	-	-	0.4
4	43.6	-	41.9	-	-1.6	-	58.5	-	58.2	-	-0.6	-
5	40.1	39.4	-	-0.7	-	-	57.1	58.6	-	2.6	-	-
6	53.8	51.5	50.2	-2.3	-3.6	-1.4	60.7	57.3	60.0	-5.6	-1.2	4.7
7	-	48.6	45.8	-	-	-2.8	-	65.5	62.5	-	-	-4.7
8	40.7	-	37.6	-	-3.0	-	59.2	-	57.6	-	-2.8	-
9	39.7	-	38.2	-	-1.5	-	64.7	-	64.3	-	-0.7	-
mean	***42.8***	***43.6***	***40.9***	***-1.0***	***-2.5***	***-2.5***	***60.1***	***58.8***	***58.8***	***-0.6***	***-2.0***	***-1.4***
±SD	***5.35***	***6.09***	***5.40***	***1.11***	***0.91***	***0.80***	***2.48***	***5.72***	***4.37***	***4.44***	***1.76***	***4.92***

TBW- Total body water; A- 2 Days Pre-race; B- Pre-race; C- Post-race; Δ-change; (-) – data unavailable

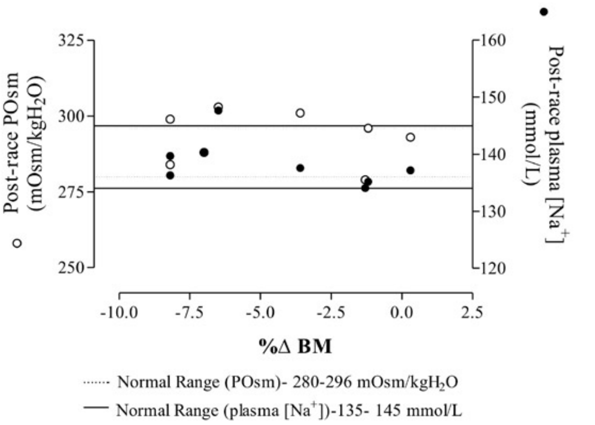

Fig. 1. *Percentage change (%Δ) in body mass (BM) in relation to post-race plasma osmolality (POsm) and sodium concentrations ([Na⁺])*

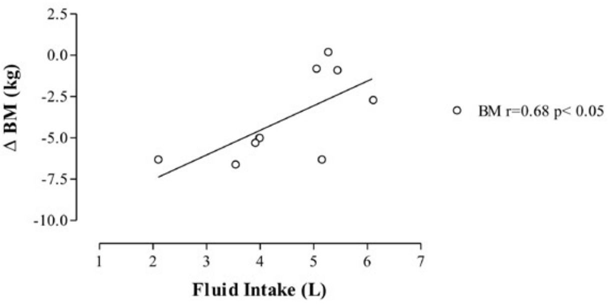

Fig. 3. *Changes (Δ) in body mass (B-C) (BM) in relation to total fluid intake (liters)*

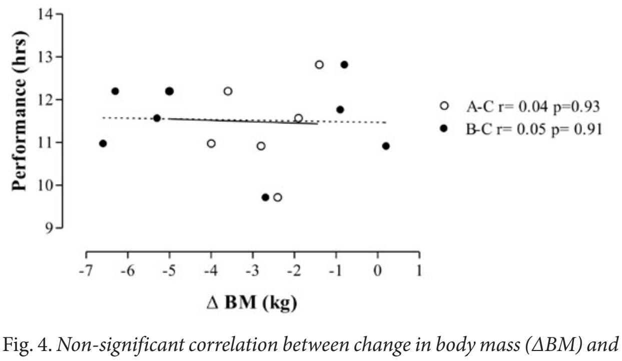

Fig. 4. *Non-significant correlation between change in body mass (ΔBM) and performance (race time) (hours) for both 2-days pre-race minus post-race (A-C) and immediately pre-race minus post-race (B-C) (n = 8)*

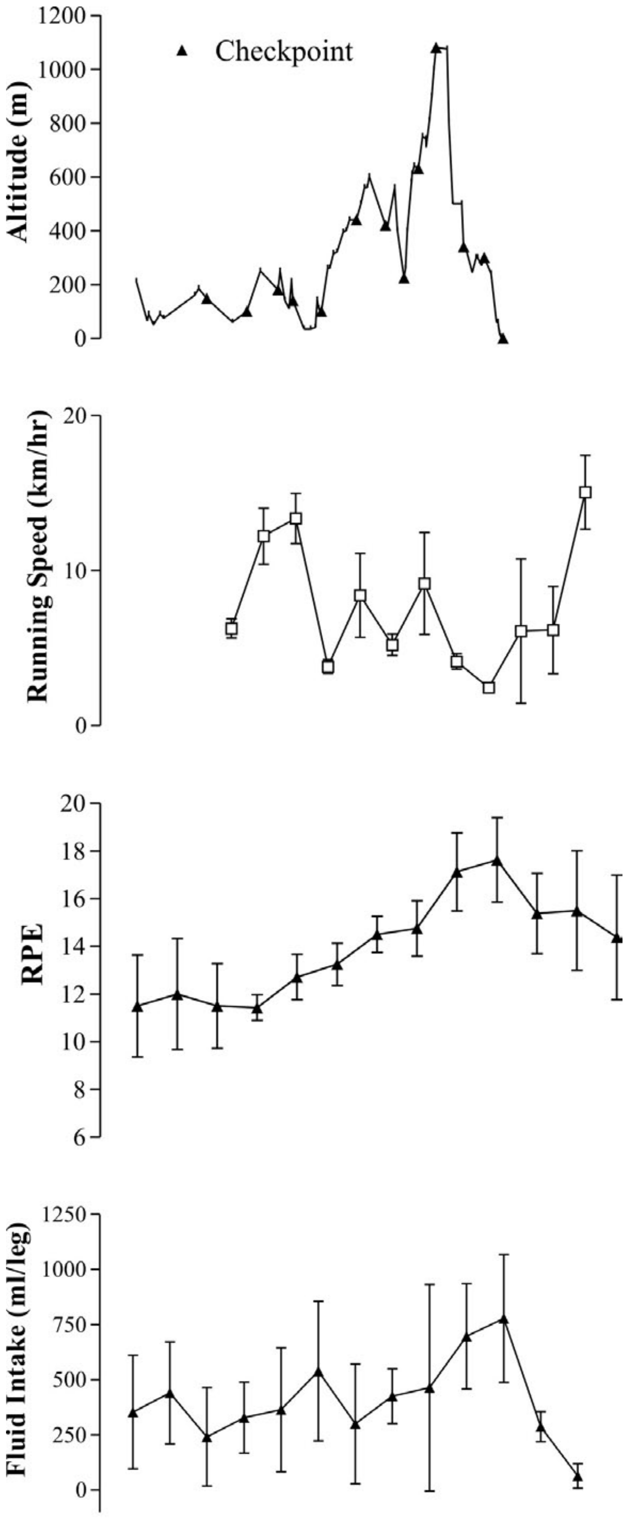

Fig. 2. *The race profile in distance (checkpoints) set against change altitude (m); subject's running speed (km/hr); their ratings of perceived exertion (RPE) and fluid intake from the last checkpoint to the specified checkpoint (ml/leg)*

Figure 2 illustrates the race profile and elevation (altitude - meters); average running speed of the group between checkpoints (km/hrs); average RPE and average fluid intake of the group at each checkpoint with bars indicating standard deviation.

There was a significant correlation between percentage change in body mass and fluid intake so that those athletes who ingested the most fluid had the smallest reductions in body mass during the race and vice versa (Figure 3).

There was also no correlation between performance and change in body mass from 2-days pre-race to post-race and immediately pre-race to post-race (Figure 4).

Discussion

The first relevant finding of this study was that despite quite large individual differences in body mass loss, subjects completed the race without significant changes in plasma sodium or potassium concentrations or in plasma osmolality. Although there were certain biochemical markers out of the normal ranges, Kratz et al. noted in a group of athletes that there was an increase in range of biochemical values in those who finished a marathon without any clinical complications (24). Ad libitum rates of fluid intake were relatively similar between subjects and were at the lower range of the current American College of Sports Medicine (1) and USA Track and Field/International Marathon Medical Directors Association guidelines (25).

These data therefore confirm that moderate drinking according to the dictates of thirst appropriately protects the homeostasis of plasma electrolyte concentrations and plasma osmolality (26). Importantly no athlete drank to excess, thereby avoiding a significant gain in body mass and developing exercise- associated hyponatremic encephalopathy as can occur when athletes are encouraged to drink to "stay ahead of thirst" or "as much as tolerable" and demonstrates that fluid restriction is not necessary to prevent exercise- associated hyponatremia (27). It seems suggestive that overdrinking is seems to be associative with that of the inexperienced runner, this rationalized since any athlete entering this race need to demonstrate some pedigree in both ultra-distance running on both trail and the road (qualify with a ultra-distance race run within in the year and have showed some sort of trail running history). Hence it seems these seasoned athletes indeed are in touch with their bodily needs in regards to both fluid and nutrition and thus have consumed enough to finish in good health.

The second important finding was that plasma sodium concentrations and plasma osmolality were regulated within the adjusted normal range (established by Kratz et al.) even in subjects who lost > 2% of body mass during the race (Figure 1; Table 2). As previously shown by us (27) these variables are homeostatically regulated within the normal range despite quite large differences in percentage body mass loss (26,28). This suggests that athletes are able to regulate their plasma osmolality even when they lose greater than 2% of their body mass during prolonged exercise (5).

All finishers were asymptomatic despite body mass losses greater than 2% in six subjects and > 6% in five subjects. This again confirms our previous findings that athletes may complete ultra-distance races with a body mass loss > 6%, yet be completely asymptomatic (3,4,29). This conflicts with the theory that any body mass loss greater than 2% is inevitably injurious to health or performance during exercise (1). The recent study of Kao et al. (4) reported that athletes completing 12- and 24-hour ultra-marathons can finish without adverse effects on their health even when the body mass loss in some exceeded 7%. Furthermore there was a significant relationship between percentage body mass loss and performance so that athletes who lost the greatest mass completed the greatest distance in the 24 hour race. This is the opposite of the expected outcome if a body mass loss >2% causes a progressive impairment in running performance (1). In contrast we found no such relationship although we noted that regardless of >2% body mass loss that subjects were able to complete the race without experiencing severe dehydration. However the 2 fastest runners lost between 2-3% of their body mass which again exceeds the recommended optimum weight loss according to currently accepted blanket drinking guidelines (Figure 4).

This suggests that the body's hydration state is not regulated solely by the volume of fluid ingested during exercise and that this regulation is highly individualized. While changes in body mass may be useful to predict fluid homeostasis in certain clinical scenarios at rest and over short episodes of exercise (<2 hours) (30), during exercise the protection of plasma osmolality and the plasma sodium concentrations may in some cases require a concomitant decrease in body water content and hence in body mass without causing any apparent disruption of bodily function or athletic performance.

Limited data obtained from total body water measurement by deuterium analysis revealed a small but highly variable (range 1.5L – 3.6L) decrease in TBW content from 2-days pre-race to post-race (Table 4). This is interesting to note because a majority of the athletes finished adequately hydrated (best indicated by plasma osmolality) and the athletes concerned in the data set did not complete the race with significant clinical signs of dehydration. The same could be noted with the data set obtained from immediately pre-race to post-race (B-C).

These small observations lead us to believe that TBW is more appropriately physiologically regulated rather than body mass, which encourages us to further assess the relationship between body mass and TBW loss during ultra-endurance exercise and exercise of a short duration (<3 hours). This brief data set was not in agreement with findings of Baker et al. (31) who ran subjects intermittently for a period of 2 hours in total for each running session. Although we do not feel 2 hours of intermittent exercise is sufficient in length and structure (exercising to certain body mass loss percentages) to observe such findings as we have found with some our subjects data sets but do feel it would comparable in the exercise of a short duration (e.g. half-marathon, football matches etc.). Further investigation into the discrepancy in this respect to field versus laboratory setting.

In summary, this study found that ad libitum drinking rates between 300–650 ml/hr were associated with protection of plasma osmolality and plasma electrolyte homeostasis despite a range of body mass losses. The maintenance of water and solute homeostasis was likely regulated by fluid regulatory hormones arginine vasopressin and aldosterone although these hormones were not measured in this study. This data set also reveals the "reality" of drinking behavior in the field rather than the unrealistic forced drinking and eventual skewed data from laboratory studies on which many fluid intake guidelines are set. The mean change in body mass loss during the race was 5%. Despite changes in body mass exceeding 2%, no subject developed medical complications such as severe dehydration or fluid balance associated disorders. Finally these data support the adoption of ad libitum drinking guidelines during exercise since performance is not negatively affected (25,32).

Strengths and weaknesses of the study

The strengths of this study include the use of deuterium to quantify changes in total body water. Furthermore, our ability to accurately measure and quantify fluid intake is an improvement over the commonly utilised – but less exact - fluid recall method. The weaknesses of this study include our very limited small sample size (8% participation out of the entire field) with further loss of deuterium data due to methodological difficulties pre-race. Furthermore, only one woman finished the study which may have biased our limited results, since sex-hormones may influence fluid balance parameters particularly during the luteal phase of the menstrual cycle. However, the numbers of individuals – male or female - who are capable of finishing gruelling mountain ultra-endurance races provide a very limited subject pool to draw upon.

Future directions

A larger cohort of ultra-endurance athletes will be investigated in future, to make these preliminary findings more robust. Furthermore, to better understand fluid balance despite body masss loss in athletes participating in ultra-endurance exercise, fluid regulatory hormones such as arginine vasopressin, aldosterone and natriuretic peptides will be evaluated along with measurement of total body water using the deuterium dilution method. Hopefully with a bigger cohort, we can document associations between changes in total body water versus the maintenance of plasma osmolality and sodium concentrations.

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