Appendix 2

Hydration Status Tracking Report: March 2013

Overview:

Extreme environmental heat stress experienced by fire-fighters as part of their training or live call-out experiences provide situations that severely challenge the normal limits of physiological functioning in terms of fluid balance, temperature regulation and physical and mental performance (1).

It is commonly suggested that becoming dehydrated by as little as 2% from an optimally recommended hydrated level can contribute to impaired performance in terms of aerobic work capacity, strength, power and cognitive decision making. As levels of dehydration increase away from this optimal, recommended level it is reported that heightened feelings of lethargy, headaches, nausea and general ill-feeling are commonplace (2). Clearly in a career field such as fire-fighting when the wellbeing of the fire-fighter and the lives of others are potentially at risk it is therefore not surprising that remaining suitably but effectively hydrated before, during and after extreme heat exposure should be the aim of any fire-fighter.

Pre-Heat Exposure Hydration:

Achieving an optimal hydrated status prior to the demands of extreme heat exposure sets the stage for optimising physiological and mental performance. Therefore it is important for fire-fighters to understand how to accurately measure their hydration status prior to heat exposure situations.

This can be achieved inexpensively through monitoring the combination of a urine sample's colour alongside how close to their habitual body-mass the fire-fighter is. For the purpose of this case study, pre-heat exposure hydration was measured through urine specific gravity (USG) instead of urine colour using a refractometer as the equipment was available and provides a more objective result than self-assessing hydration status from a colour chart.

Baseline hydration measures were also evaluated through assessing the plasma percentage (haematocrit) within a sample of blood taken from a finger-prick sample.

Normative values suggest that around 55% of a whole blood sample should be watery plasma content in an optimally hydrated individual.

A blood sample that is around this 55% marker would be more dilute and flow more readily throughout the body compared to a more dehydrated sample with a lower percentage of plasma. In these instances, the blood would be more viscous and thicker, wouldn't flow throughout the arteries and veins as readily and would place greater stress on the cardiovascular system leading to increases in heart rate and blood pressure responses.

Table 1: Indices of Hydration Status:

Condition	% Body Mass Change from Normal Value	Urine Colour	Urine Specific Gravity
Well-Hydrated (Optimal)	+1% to -1%	Clear / Very Light Yellow Tint	Less than 1.010
Minimal Dehydration	-1% to -3%	Light Yellow - Yellow	1.010 – 1.020
Significant Dehydration	-3% to -5%	Dark Yellow - Orange - Tan	1.021 – 1.030
Serious Dehydration	Greater than 5%	Dark Orange – Brown	Greater than 1.030

Table 2: Pre-Heat Exposure Hydration Measures:

Instructor Name	**Clothed Body Mass (kg)**	**Urine Specific Gravity**	**Blood Plasma (%)**
M H	95.9	1.024	53
G R	83.3	1.011	53
C T	81.3	1.007	55
P O	96.0	1.028	49

Analysing these baseline measurements as shown in Table 2 above would suggest that CT was in an optimally hydrated state before beginning the morning's first heat-exposure session, GR was minimally dehydrated and that both MH and PO were starting the session in a classified significantly dehydrated state.

For future practices this provides an adequate baseline for CT, GR to follow whilst it is recommended that GR, MH and PO are made aware of their actual clothed body mass at around 10:00 am when they were both suitably hydrated to provide a clear / very light yellow tinted urine sample.

Pre-Heat Exposure Fluid Guidelines:

Current hydration guidelines suggest that between 400 – 600 ml of fluid should be consumed within 2-3 hours of beginning the morning heat exposure session with an additional 200 – 300 ml of fluid in the 10 – 20 minutes prior to beginning the session. Although water alone is considered appropriate as a choice of fluid to promote baseline hydration, it is acknowledged that the individual tolerances and preferences should also be considered when deciding the actual choice of fluid to be consumed. As an example, it would be more advantageous for someone to drink a tall glass of water alongside their morning tea or coffee instead of totally cutting out their habitual practices and risking the potential negative effects of caffeine withdrawal such as headaches, lethargy and lack of concentration (3).

Once this optimal starting hydration status becomes achieved and habitual through appropriate fluid intake practices, it should then the fire-fighter's primary aim to remain optimally hydrated throughout the day or at the very worst to only realise levels of minimal dehydration as outlined in Table 1 above.

Environmental Conditions and Variations in Heat Exposure Stresses:

The sweat rates of individuals are subject to variations in ambient environmental temperature and humidity as well as heat exposure temperature and physical demands of the task during the duration of heat exposure. The data was collated for this case-study during early March when ambient temperature was recorded at 5°C and the heat exposure demands for the instructors was to run an 75 minute heat exposure session (approximately) in the containers in the morning and to repeat an identical session in the afternoon. During the 2nd afternoon session the average temperatures recorded from the containers were 507°C from Probe 2, 222°C from Probe 3 and 165°C from Probe 4.

The rehydration requirements for the instructors at different times of the year, such as summer and / or when they are running different heat exposure sessions, such as "hot-house" training and casualty recoveries may and probably will elicit different rates of dehydration. Therefore, it would be beneficial to collate further data at another opportunity to allow comparison of environmental / heat / work intensities upon rates of dehydration.

Hydration Status Tracking Report:

All four instructors were continually weighed, recording their fluid and food intake and providing further urinary and blood plasma samples throughout the duration of the day which enabled us to assess how successful each instructor was in achieving an optimal level of hydration as the day progressed from baseline and after both the first and second heat exposure sessions. Each instructor's individual responses are detailed on pages 5 – 9.

Actual Sweat Rates

The plan was to measure how much actual sweat each instructor lost during each heat exposure session in order to calculate individual sweat rates. Unfortunately on this occasion as each instructor was weighed in full protective kit before and after each heat exposure session, the data proved inconclusive as the sweat lost during the actual heat exposure was potentially still within the protective clothing and tunics.

It is therefore recommended that for future occasions the instructors are weighed in immediately before changing into the protective clothing and once again immediately after showering and redressing into their normal clothing in order to ascertain individual sweat rates.

Electrolyte Replacement Requirements:

It is also important to consider that during extreme conditions where sweat losses are high that key electrolytes such as sodium and potassium are also lost as well. These electrolytes are not only responsible for assisting fluid balance and muscle functioning but also are vitally important in offsetting the risks of hyponatemia, a potentially fatal conditon experienced through ingesting large volumes of water when sodium levels are insufficient to enable the water to be uptaken at cellular level which can lead to feels of nausea, disorientation and as the condition worsens without sufficient sodium intake, can lead to collapse, coma and death.

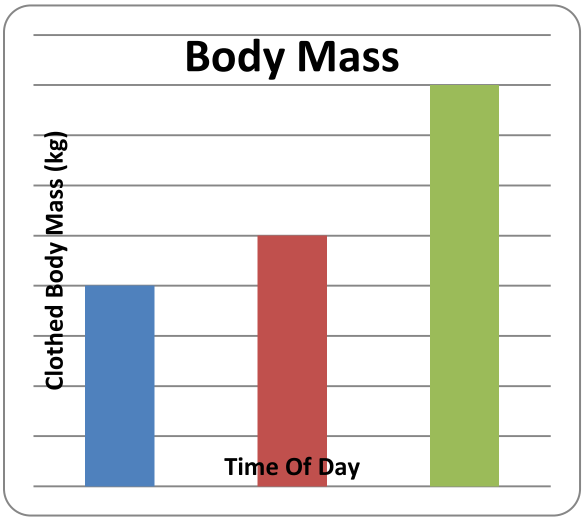
During this case-study, over 85% of all sweat losses were replaced by the instructors drinking water alone. The nature of the lunchtime routine with food types being voluntarily chosen by the instructors provided opportunities to gain some sodium through their food intake which was apparent. However, if an instructor voluntarily chose to eat a low sodium lunch on a similar day of intensive work; this could potentially create a situation where electrolyte losses and in particular sodium deficiences could become more problematic.

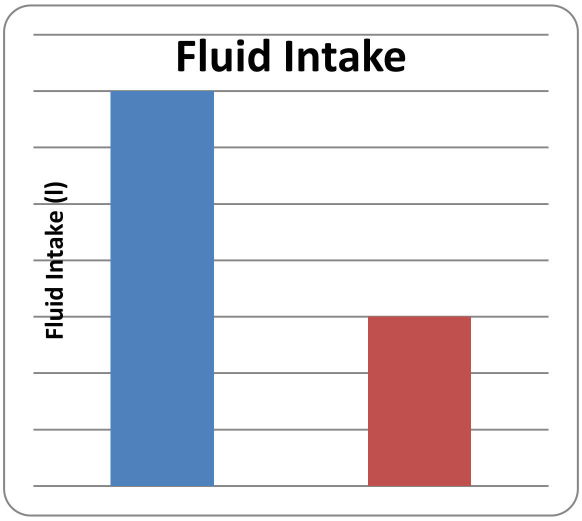
Ensuring that the instructors drink a sports drink with higher levels of sodium such as as Lucozade Sport or Powerade at the end of the 1st and / or 2nd session would provide an opportunity to aid rehydration guaranteeing a contribution to replacing electrolyte losses.

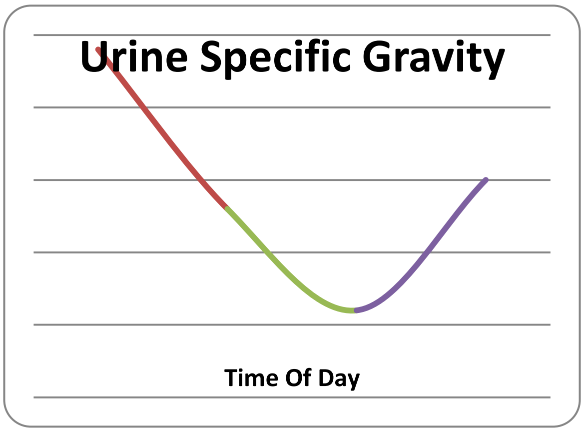
Drinking a 500ml sports drink after the 1st session would also providing sugars through the carbohydrate content of the drink assisting in increasing energy levels and alertness for the afternoon session ahead and latterly, if ingested post-instruction after the 2nd session could improve rehydration, alertness and energy levels before the instructor’s drive home.

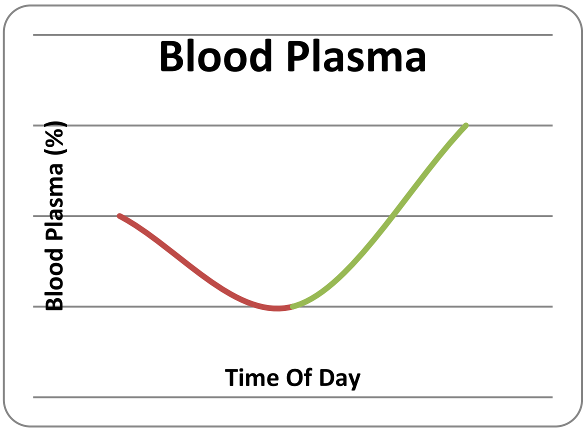
Case Study Hydration Tracking Report Data:

Instructor 1: M H:









Key Observations:

i) By the end of the day after both heat exposure sessions, MH body mass had increased by 0.5% (0.4kg) factoring in fluid drank, urinary losses and food ingested which suggests that he was better hydrated at the end of the day compared to when the baseline measures were taken in the morning in terms of body mass analysis.

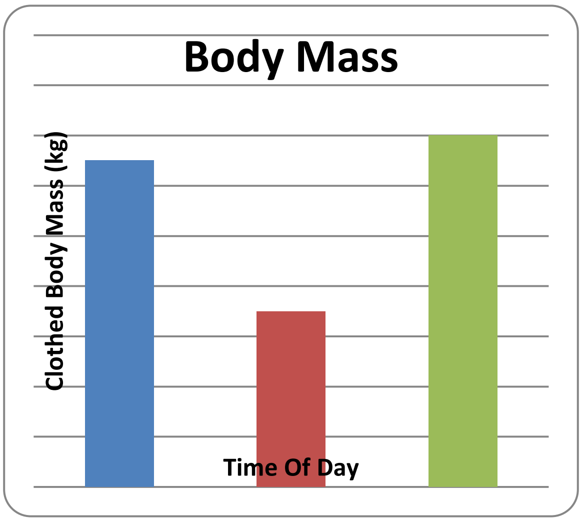
ii) By the end of the day after both heat exposure sessions, MH blood plasma had actually expanded from 54% to 55% which suggests that his blood was better hydrated at the end of the day compared to when the baseline measures were taken in the morning.

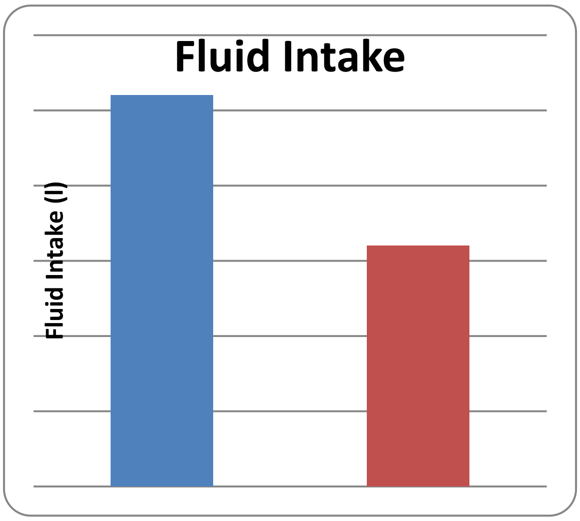
iii) MH drank 1.75 litres of fluid during the morning session which was sufficient to replace sweat losses as well as to move to an optimal level of hydration when analysed through USG analysis by lunchtime. Despite this, it would appear that the 0.75 litres of fluid drank between lunchtime and during the afternoon session was not quite enough to maintain the same optimal level of hydration as the USG marker had slipped to a level of minimal dehydration.

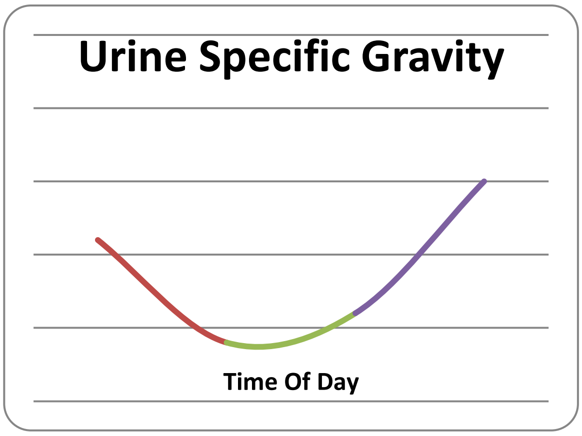
iv) However, in all cases MH hydration status improved from baseline measures despite being subjected to heat exposure conditions twice ending the day classified as minimally dehydrated when factoring in USG markers.

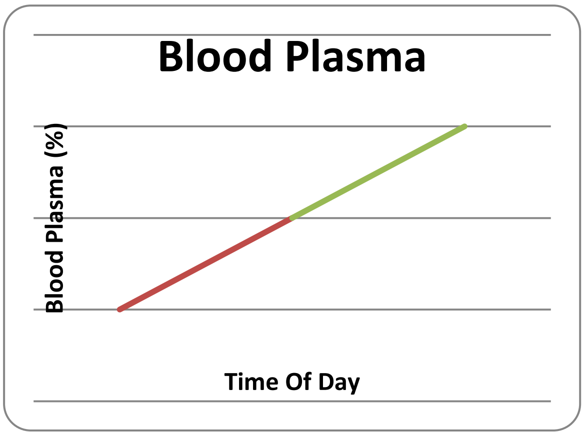
v) MH food intake during the day would have provided a certain level of sodium which would have been required to offset the risks of hyponatremia and assist water uptake into the cells. However, whether sufficient levels of lost electrolytes throughout the day would have been provided within the food ingested is questionable.

Instructor 2: G R









Key Observations:

i) By the end of the day after both heat exposure sessions, GR body mass had increased by 0.1% (0.1kg) factoring in fluid drank, urinary losses and food ingested which suggests that he was able to replace all sweat losses and remain equally hydrated at the end of the day compared to when the baseline measures were taken in terms of body mass analysis.

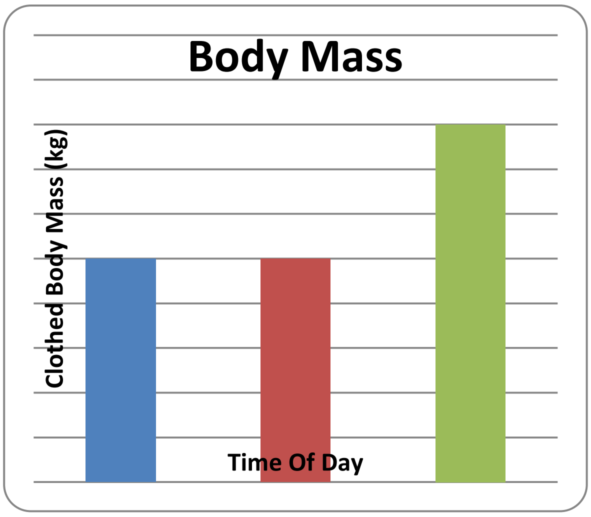
ii) By the end of the day after both heat exposure sessions, GR blood plasma had actually expanded from 53% to 55% which suggests that his blood was better hydrated at the end of the day compared to when the baseline measures were taken.

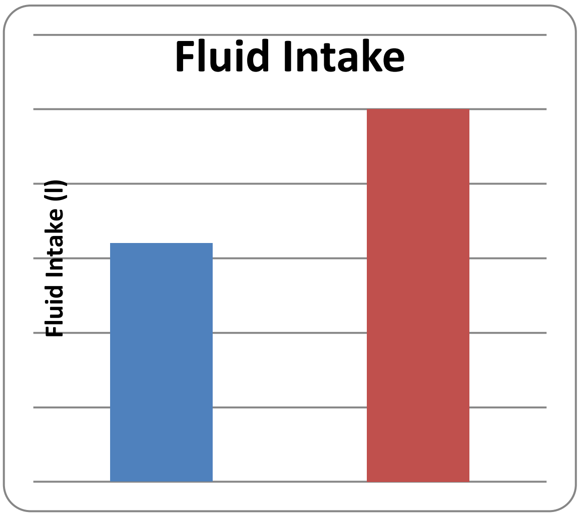
iii) GR drank 1.25 litres of fluid during the morning session which was sufficient to become optimally hydrated when analysed through USG analysis at lunchtime. However, it would appear that the 0.75 litres of fluid drank between lunchtime and during the afternoon session was not quite enough to maintain the same optimal level of hydration as the USG marker had slipped to a level of minimal dehydration at the end of the day.

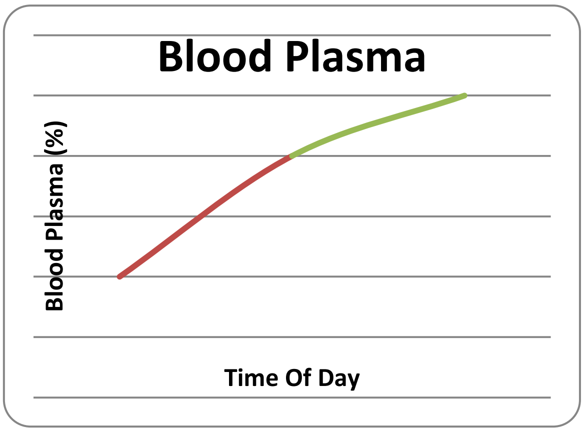
iv) Overall, in two out of three markers (Body Mass & Blood Plasma), GR hydration status became better hydrated than the baseline measures at the end of the day after both heat exposure sessions and only would be classified as minimally dehydrated when factoring in the third marker of urine specific gravity.

v) GR food intake during the day would have provided a certain level of sodium which would have been required to offset the risks of hyponatremia and assist water uptake into the cells. However, whether sufficient levels of lost electrolytes throughout the day would have been provided within the food ingested is questionable.

Instructor 3: P O:







Key Observations:

i) By the end of the day after both heat exposure sessions, PO body mass had increased by 0.6% (0.6kg) factoring in fluid drank, urinary losses and food ingested which suggests that he was better hydrated at the end of the day compared to when the baseline measures were taken in terms of body mass analysis.

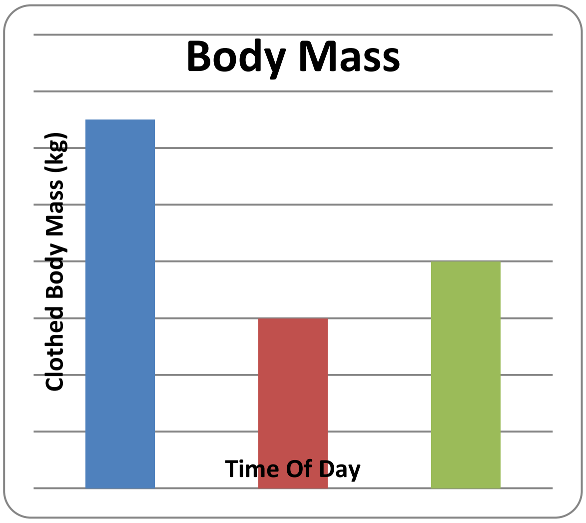
ii) By the end of the day after both heat exposure sessions, PO blood plasma had actually expanded from 49% to 52% which suggests that his blood was better hydrated at the end of the day compared to when the baseline measures were taken; but still around 3% away from an optimally hydrated measure.

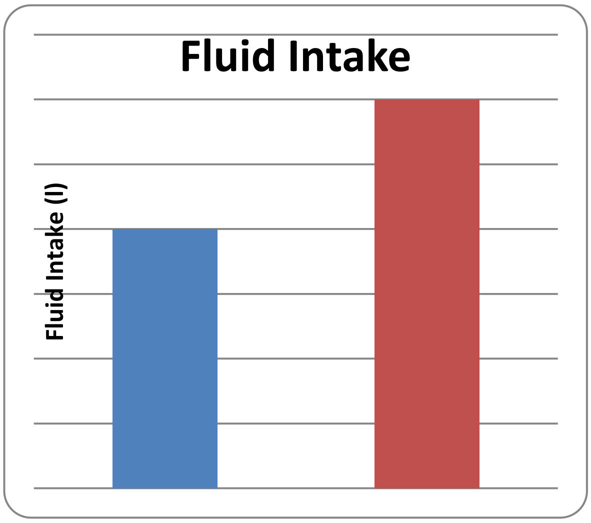
iii) PO drank 0.75 litres of fluid during the morning session which was sufficient to replace the sweat losses endured during the morning heat exposure session. Similarly, it would appear that the 1.25 litres of fluid drank between lunchtime and the end of the day was also sufficient to replace sweat losses endured during the afternoon heat exposure session.

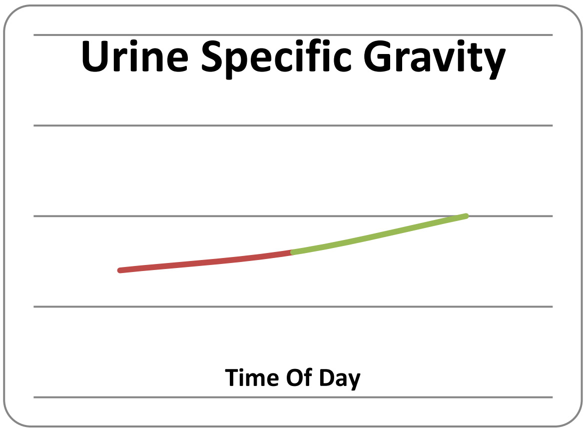
iv) Despite drinking sufficient fluids to replace sweat losses throughout the day and becoming slightly better hydrated in terms of body mass, blood plasma and urine specific gravity markers; PO remained in a classification of significant dehydration at the end of the day similar to his baseline measures. Therefore the fluids ingested throughout just consistently maintained his level of significant dehydration and prevented him from becoming further dehydrated than he already was.

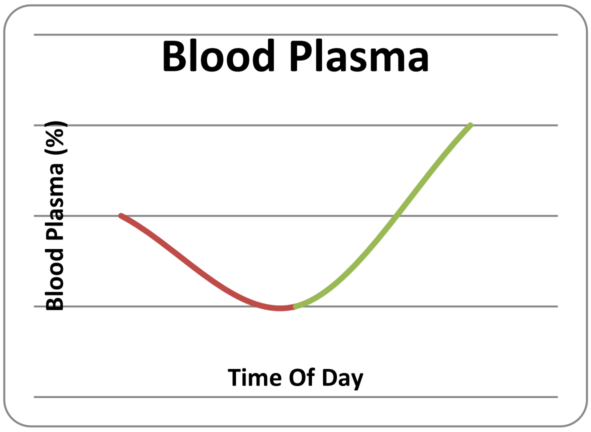
v) PO food intake during the day would have provided a certain level of sodium which would have been required to offset the risks of hyponatremia and assist water uptake into the cells. However, whether sufficient levels of lost electrolytes throughout the day would have been provided within the food ingested is questionable

<u>Condition Setting Instructor: C T:</u>









<u>Key Observations:</u>

i) By the end of the day after both heat exposure sessions, CT body mass had decreased by 0.6% (0.5kg) factoring in fluid drank, urinary losses and food ingested which suggests that he was just about able to remain optimally hydrated at the end of the day compared to when the baseline measures were taken in terms of body mass analysis preventing body mass losses greater than 1%.

ii) By the end of the day after both heat exposure sessions, CT blood plasma had actually expanded from 55% to 56% which suggests that his blood was better hydrated at the end of the day compared to when the baseline measures were taken, remaining optimally hydrated.

CT drank 1 litre of fluid during the morning session which was actually insufficient to replace the sweat losses endured during the morning heat exposure session. However, as CT began the day optimally hydrated, the negative losses experienced in body mass, blood plasma and USG measures by lunchtime still enabled CT to be classified as optimally hydrated. Furthermore, it would appear that the greater amount of 1.5 litres of fluid drank between lunchtime and the end of the day was more sufficient to replace sweat losses endured during the afternoon heat exposure session. This amount allowed him to regain some of his earlier body mass and blood plasma losses whilst ensuring that his USG marker, and his hydration classification status overall remained as optimally hydrated.

iii) Even though CT was acting as the condition setter for both sessions and was therefore subjected to greater heat exposure and physiological stresses over longer durations than the other three instructors on this particular day, overall in all three hydration markers CT hydration status remained as optimally hydrated as the baseline measures by the end of the day after completing both heat exposure sessions.

iv) CT food intake during the day would have provided a certain level of sodium which would have been required to offset the risks of hyponatremia and assist water uptake into the cells. However, whether sufficient levels of lost electrolytes throughout the day would have been provided within the food ingested is questionable.

Concluding Summary Points:

The data analysed from this case study enables us to draw a few relevant conclusions:

i) The ability for instructors to habitually be able to self-assess their hydration status prior to heat exposure sessions as optimally hydrated through body mass readings and urine colour assessment should be encouraged.

ii) The above point should be considered even more important for the instructor that takes on the role of the condition setter who will be subjected to more prolonged heat exposure and greater levels of physiological stress compared to their fellow instructors. All four instructors drank between 2 – 2.5 litres of fluid throughout the day, yet it was only the condition setter who actually still lost weight.

iii) Analysing the data from both “container” heat exposure sessions suggests that no instructor was drinking insufficient levels of fluid to become significantly dehydrated by the end of the day.

iv) However, the importance of starting the day optimally hydrated was apparent and as in PO’s case the fluids ingested throughout the day just enabled him to remain significantly dehydrated and prevent him from become further dehydrated.

v) There was no evidence witnessed during this case study of any dangerous levels of over drinking practices by any of the instructors.

vi) However, it should be reinforced that electrolytes such as sodium and potassium need to be replaced throughout the day to offset the potential threat of symptoms associated with hyponatremia if only water is ingested by the instructors. Currently the ability for instructors to gain sodium through their voluntarily chosen lunches is available, although there is no guarantee that instructors may on occasion opt for a low / no sodium lunch choice.

vii) Providing the instructors with a sports recovery drink such as Lucozade Sport or Powerade after each heat exposure session would create an opportunity for instructors to promote rehydration whilst simultaneously contributing to replacing electrolyte and glycogen losses. This could be achieved if these types of drink were provided to the instructors in addition to just water alone.

viii) Alternatively, providing the canteen were able to stock sports recovery drinks such as Lucozade Sport or Powerade, instructors could be advised to ensure that one of the items they chose on their lunch menu was one of these types of drink.

ix) Finally, it should be reminded that the provided data and analysis remains valid for ambient temperatures for early March (5°C) and for the type of heat exposure training the instructors were subjected to during this case study. To gain comparisons for dehydration rates experienced during different times of year or different training intensities, it is strongly advised that further case study assessment days are arranged.

References:

1: Cheuvront, S.N. et al. (2010) “Mechanisms of aerobic performance impairment with heat stress and dehydration” *in Journal of Applied Physiology*; Vol. 109; **Pp. 1985 – 1995.**

2: Maughan, R.J. (2003) “Impact of mild dehydration on wellness and exercise performance” *in European Journal of Clinical Nutrition*; Vol. 53; (**S2**); **Pp. S19 – S23**.

3. Fink, H.H. et al. (2006) *Practical Applications in Sports Nutrition*; Jones and Bartlett; Sudbury; MA.