The Use of Bioelectrical Impedance Analysis (BIA) in Assessing Hydration Status of Runners Competing in a Multi-Stage Ultra-Marathon Conducted in a Hot Ambient Environment

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Multi-Stage Ultra Marathon Competition

Increased in popularity over the past 10 year amongst amateur sports population

Varied Distances
≥200km over 5-8 days

Temperature Extremes
Heat: ≥30 °C
Cold: ≤0 °C

Sustenance
Self sufficient:
≥2400Kcal/day (10-15kg pack)
~12L/day water ration.

Semi-Self sufficient:
2-5kg pack weight + water \textit{ad libitum}

Race environment
“Strong encouragement & promotion for fluid (water) & electrolyte intake”
Euhydration in Ultra-Marathon Competition

• Maintaining euhydration is essential for optimal exercise performance during consecutive days of exercise.

• Exercise induced dehydration (water deficit of >2-3% BM) is associated with metabolic alterations, thermoregulatory and CV strain.

Multi-factorial contribution to decrements in exercise performance

• Anecdotal evidence suggests ultra-marathon runners may not be adequately maintaining hydration during consecutive days of competition-warrants investigation (2009 Al Andalus Ultra-Marathon).

• Argued runners (esp. slower runners) may be at risk of hyponatremia due to over-drinking.

(Sawka et al., 2007; Hew-Butler et al., 2006; Sawka & Noakes, 2007; Kleiner, 1999; Costa et al., 2010; Noakes, 2007)
Measuring Hydration Status During Ultra-Marathon Competition

- Multi-frequency bioelectric impedance analysis:
  
  - Improvements in technology - measurement of TBW and ECW through 5-500kHz electrical current (Deurenberg et al., 1993; 1995; Ward et al., 2000).
  
  - Predominantly used in Clinical settings. Not commonly used in applied Sports & Exercise Sciences.
  
  - Validation: highly correlated with isotope dilutions (e.g. bromide & deuterium oxide; \( r=0.91-0.96; P<0.001 \). Patel et al., 1994; DeLorenzo et al., 1997; Johnson et al., 1992; Khaled et al., 1997; Ellis & Wong 1998).
  
  - Reliable method in determine prolonged and acute changes in hypohydration and hyperhydration (\( r=0.97-0.99; P<0.001 \)) status in males and females (\( r=0.96-0.98; P<0.001 \). Shanholtzer & Patterson, 2003a; 2003b)
Aim & Hypothesis

**Aim:** To monitor hydration status of ultra-marathon runners using BIA during a multi-stage ultra-marathon competition conducted in a hot ambient environment.

**Hypotheses:**

1. Ultra-marathon runners are not maintaining euhydration during consecutive days of exercise during ultra-marathon competition in the heat.

2. The degree of sub-optimal hydration status prolongs and deepens as competition days progress.
**Methods**

Participants ($n=37$; M=24, F=13): age 42 ± 7y; height 1.71 ± 0.10m; BM 69.1 ± 12.6kg; training load 71 ± 36km·week$^{-1}$; previous ultras 0-40.

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
</tr>
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<tbody>
<tr>
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<td>BM + BIA</td>
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<td>~09:00</td>
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<tr>
<td>37km</td>
<td>42km</td>
<td>42km</td>
<td>61km</td>
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<tr>
<td>Total: 37km</td>
<td>Total: 79km</td>
<td>Total: 121km</td>
<td>Total: 182km</td>
<td>Total: 219km</td>
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<tr>
<td>BM + BIA</td>
<td>BM + BIA</td>
<td>BM + BIA</td>
<td>BM + BIA</td>
<td>BM + BIA</td>
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<tr>
<td>21:00-22:00</td>
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<td>21:00-22:00</td>
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<tr>
<td>Food + fluid recall interview</td>
<td>Food + fluid recall interview</td>
<td>Food + fluid recall interview</td>
<td>Food + fluid recall interview</td>
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</tr>
</tbody>
</table>

- **Tmax:** 32-37°C
- **Fast**
  - M=17; F=1
  - 9.2 ± 1.1km·h$^{-1}$
- **Slow**
  - M=7; F=12
  - 7.0 ± 0.7km·h$^{-1}$

27h07min ± 4h34min
8.3 ± 1.5 km·h$^{-1}$
Analytical Methods: Field Based


• BIA (TBW, ECW, ICW): QuadScan 4000 multi-frequency bioelectric impedance analyser (Bodystat Ltd., Douglas, UK).

• Food & fluid intake: Interview form (ARG Sport, Coventry University).

• Dietary assessment: Dietplan 6 Dietary analysis software (Forestfield, Horsham, UK).

• Statistical analysis: One-way ANOVA with post hoc & Paired T-test.
Results: Total Daily fluid Intake

Fast: 8.8 ± 1.1 L·day\(^{-1}\) * 119 ± 22 ml·kgbw·day\(^{-1}\) *
Slow: 7.9 ± 1.8 L·day\(^{-1}\) 126 ± 22 ml·kgbw·day\(^{-1}\)

30% CHO Rich Fluids
- Soft drink
- Sports drinks
- Fruit juice
- CHO+PRO drinks
- Milk
- Protein drinks

# P< 0.01 vs. Stage 4; * P< 0.01 Fast vs. Slow.
Fluid Intake During Exercise

Fast: 4.3 ± 0.8 L *
Slow: 4.7 ± 1.4 L

Fast 848 ± 155 ml·h⁻¹ *
Slow 667 ± 167 ml·h⁻¹

58 ± 15 ml·kgbw⁻¹ *
71 ± 17 ml·kgbw⁻¹

28% CHO Rich Fluids
Sports drinks
Soft drink
Fruit juice
CHO+PRO drinks

# P< 0.01 vs. Stage 4; * P< 0.01 Fast vs. Slow

98% urinated; 18% ↑ thirst; 8% ↓ thirst; 61% GI discomfort.
Total Body Water (TBW)

Fast: Pre 67% (48 L) *
Slow: Pre 65% (41 L)
Post 71% (50 L)
Post 70% (43 L)

Ψ P< 0.01 vs. Pre; Φ P< 0.01 vs. Stage 1 pre; Δ P< 0.01 vs. Stage 1 post; * P< 0.01 Fast vs. Slow
Extra (ECW) & Intra (ICW) Cellular Water

Ψ $P<0.01$ vs. Pre; Φ $P<0.01$ vs. Stage 1 pre; * $P<0.01$ Fast vs. Slow
Exercise Induced Body Weight Change

Exercise-Induced Weight Loss (%)

- Fast: * 3.2%
- Slow: 2.2%

# $P<0.01$ vs. Stage 1; * $P<0.01$ Fast vs. Slow
### Daily Electrolyte Intakes

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<th>Na</th>
<th>Salt equ.</th>
<th>Cl</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Ph</th>
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<tr>
<td></td>
<td>3633mg</td>
<td>9.1g</td>
<td>4901mg</td>
<td>4018mg</td>
<td>1117mg</td>
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<td>1899mg</td>
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### Sodium Intakes During Exercise

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<tr>
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<th>Na</th>
<th>Salt equ.</th>
<th>Na mg/L</th>
<th>Salt equ. g/L</th>
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<tbody>
<tr>
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<td>909mg</td>
<td>2.3g</td>
<td>216mg</td>
<td>0.5g</td>
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</table>

### Sodium Intakes Post Exercise

<table>
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<th>Na</th>
<th>Salt equ.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>408mg</td>
<td>1.0g</td>
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</table>
Discussion & Conclusion

• Current fluid intake practices of runners during a multi-stage ultra-marathon competition are sufficient to maintain fluid balance whilst competing in a hot ambient environment in accordance with BIA (Hew-Butler et al., 2006; Shanholzer & Patterson, 2003; Noakes, 2007).

• Weight loss observed post-exercise appears not to be caused by a reduction in hydration status, and is likely attributed to energy substrate loss and urination during competition (Jeukendrup & Jentjens, 2000; Rehrer, 2001; Mitchell et al., 1972; Pugh et al., 1967; Pivarnik et al., 1984).

• “Current fluid intake habits observed during multi-stage ultra-marathon competition may possibly suggest runners are more susceptible to hyponatremia than dehydration” (Noakes, 2007; Hew-Butler et al., 2008).

• Dietary electrolyte intakes appear to be sufficient to meet runners daily requirements (ACMS, 2009).
Further Developments

• The role of pre-race nutritional education on dietary practices (nutritional and hydration balance).

• Plasma osmolality and BIA measurements during ultra-marathon competition in the heat.

• Self-sufficient Ultra-marathon (12 L·day⁻¹ water ration).

• Do electrolyte solutions have a role to play in hydration during ultra-marathon competition (appropriate laboratory controlled studies)? Are dietary electrolytes sufficient?

• Reassess exercise-induced weight loss & the contribution of energy substrate losses.
Thank you.

Dr. Andrew Murray, Vera Costa, Dr. Ricardo Costa, Ben Lee, Abigail Swancott, Dr. Volker Sheer, Lisa Hardy.
References


**Daily carbohydrate Intake**

- Total CHO intake (g·kgbw·day$^{-1}$)
  - Stage 1: 8.0 g·kgbw·day$^{-1}$
  - Stage 2: 8.2 g·kgbw·day$^{-1}$
  - Stage 3: 7.7 g·kgbw·day$^{-1}$
  - Overall Mean: 8.0 g·kgbw·day$^{-1}$

- Daily carbohydrate intake:
  - Fast: 598 g·day$^{-1}$
  - Slow: 480 g·day$^{-1}$
  - Overall Mean: 524 g·day$^{-1}$

* $P < 0.01$ Fast vs. Slow; NSDiff between stages.
Urine Osmolality

- **Fast:** Pre 650 mOsmol·kg⁻¹, Post 846 mOsmol·kg⁻¹
- **Slow:** Pre 675 mOsmol·kg⁻¹, Post 930 mOsmol·kg⁻¹

Ψ P< 0.01 vs. Pre; Φ P< 0.01 vs. Stage 1 pre; NSDiff between speeds.