Heat Illness Prevention in Athletics

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Athletes exercising in the heat lose tremendous amounts of fluid and salt


Crampers seem to lose more salt than non-crampers


Schedules, uniforms, hydration protocols, monitoring, and emergency response systems must be tailored to your environment

Hypohydration

- Sweat output exceeds water intake
- **Net loss of body fluid**, typically from the extracellular compartment
- Compromised thermoregulation, even in acclimated individuals
- With greater degrees of dehydration, increased losses from intracellular compartment
- Seen with exercise in the heat, febrile illness, gastrointestinal disorders
- Result of losses due to
  - evaporation, nausea and vomiting, diarrhea, urination, sputum, insensible losses

Pathophysiology

- Exercise generates metabolic heat from substrate metabolism
- Increase in body core temperature via convective conduction
Pathophysiology - Hypohydration

- Once “set point” exceeded, thermoregulatory mechanisms activate
- Anterior hypothalamus controls heat dissipation
  “warm receptors” trigger cutaneous vasodilation
- Hypothalamic “osmoreceptors” sense increase in osmolality
Epidemiology - Team Sports

• Football
  – Collegiate
    • 4.0 to 3.5 L during a typical 2.5 hr two a day practice
  – Professional
    • 2.14 L/hr
    • 4.83L am practice
    • 4.8L pm practice
    • 9.4L Daily sweat losses
    • 12.2L Necessary daily fluid consumption (130%)
Pathophysiology - Hypohydration

- Vasodilation, shunting of blood to periphery, sweat gland activation
- Sweat rate increases with work intensity
- Increases with environmental heat
- Sweat rates 1-3 L/hr, variable
- Eliminate 2.7 kJ heat/ml sweat
- Efficiency of heat loss through evaporation decreases with increases in ambient temperature and humidity, and with dehydration (>3%)
Pathophysiology - Hypohydration

• Osmolality of blood increases
• Hypothalamus triggers vasopressin release via pituitary, renin release via kidneys
• Increase water and sodium retention in kidneys, increased thirst drive
• Thirst drive ~ 5% dehydration
• Fluid absorption .8-1L/hr optimal
• Maximal fluid intake 300-500 ml/hr runners (600-800 ml/hr cyclists) in reality
• Sweat is hypotonic, but does contain Na, K, Cl, Mg
• Increased electrolyte loss with increased sweat rate
• Also burn carbohydrate with muscle activity, leading to hypoglycemia and fatigue
• Average sweat sodium loss for 2.5 hr collegiate football practice 5.1 g +/- 2.3g
  
Electrolyte Losses

- Sweat rate 2.5 L/hr
- Sweat sodium concentration 83meq/L
- Total sweat loss (2.5L/hr x 4 hours) 10L sweat loss
- Total meq sodium in sweat (10L x 83meq/L) 830meq/L
- Total NaCl in sweat needing replacement
  - 830meq/L x 23 mg Na/1meq Na x 1 g NaCl/393mg Na =

  - **48.6 g NaCl**
    - 8-10 cans soup
    - 12.6 servings of tomato juice
    - 40-128 L of sports drink

- Average daily intake = 8-13 g NaCl

Pathophysiology - Team Sports

- Work rate difficult to predict
- Multiple work bouts at near maximal effort
- Intervals of rest/low intensity exercise
- High degree of individual variability
  - position, size, style of play
- Sport variability
  - protective gear, uniforms, season, indoor/outdoor
- Significant loss of body water
- Psychomotor demands
So What?
Metabolic Consequences

- Decreased blood volume
- Impaired heat dissipation
- Reduced oxygen carrying capacity to muscle
- Decreased stroke volume, cutaneous blood flow
- Impaired gastric emptying, splanchnic and renal blood flow
- Performance
Increased HR, Temp, Perceived effort
Increased osmolality
Increased catecholamines
Increased core temperature at given intensity
Enhanced muscle glycogen breakdown
Hyperthermia, death
Wallace 2004, Medicine and Science in Sports and Exercise

- WBGT not only from day of disease increased risk of EHI
- 11% per degree F
- (OR = 1.1 °F, 95% CI, 1.10-1.30)
- WBGT of day prior to disease increased risk
- (OR = 1.03 °F, 95% CI, 1.02-1.05)
Performance consequences of hypohydration

- 2% dehydration led to increased times and decreased running velocity in 1500-10000m distances. Armstrong, Medicine and Science in Sports and Exercise, 1985.

- > 2% fluid deficits associated with significantly decreased performance on psychomotor tests, progressive with degree of dehydration. Gopinathan PM, Archives of Environmental Medicine, 1988.

- Cyclists exercising in heat, inc HR, perceived exertion, and core body temp, as well as dec. stroke volume, decreased cardiac output directly proportional to degree of dehydration. Coyle et. al., Medicine and Science in Sports and Exercise, 1992.
Performance consequences of hypohydration


• 2% fluid deficits trend towards decrease in 30 second jump test, inaccuracy with free throw shooting, inc. HR. Hoffman et al., International Journal of Sports Medicine, 1995.
Clinical Syndromes

- Heat Cramps
- Heat Syncope
- Heat Exhaustion
- Exertional Heat Stroke
- Hyponatremia
Core temperature

Offensive lineman

*Mid practice breaks

Core temp over time

two a day practice

Examining Work Output in NCAA Division I Football Players During Pre-season Training in the Heat
University of Connecticut, Storrs, CT; University of South Florida, Tampa, FL; University of Tennessee Chattanooga, Chattanooga, TN; University of South Carolina, Columbia, SC; University of Ottawa, Ontario, Canada

Purpose: To evaluate the work output that occurs during a preseason football practice in the heat. Furthermore, to compare how these data differ between positions and skill level.

Methods: Observational field study in hot conditions in the Southeast United States (WBGT: 28.75 ± 2.11°C) involving 49 male NCAA Division I football players (21±2 yrs, 187±7 cm, 110.3 ± 23.4 kg). Subjects exercised for 9 practice sessions (142 ± 16 min) over 8 days. Body mass was recorded pre and post-practice to determine percent body mass loss (% DHY), while heart rate and GPS data were recorded throughout the entirety of each practice session to determine intensity (HR), distance covered (DC), and velocity (V). The 49 subjects were divided into 2 groups: linemen (L) (N=25; 22 + 1 yrs, 126 ± 16 kg, 190 + 4 cm,) vs. non-linemen (NL) (N=24; 21 + 1 yrs, 91 + 11 kg, 183 + 8 cm); and starters (S) (N=17; 21 + 1 yrs, 118 + 22 kg, 190 + 7 cm) vs. non-starters (NS) (N=32; 20 + 1 yrs, 105 + 22 kg, 185 + 7 cm) for statistical analysis. Comparisons of intensity, distance covered, percentage of total distance covered spent at a velocity greater than 2 m·s, and % body mass loss were made using an independent samples t-test.

Results: DC was significantly greater (p=0.001) in NL compared to L (3532 ± 943 m vs. 2573 ± 489 m). HR (135 ± 12 bpm vs. 136 ± 8 bpm; p=0.617), V (29.5 ± 5.75% vs. 26.08 ± 6.42%; p=0.504), and %DHY (-1.76 ± 0.95% vs. -1.63 ± 0.82%; p=0.609) were similar between NL and L, respectively. No significant differences were observed between S and NS for DC (3072 ± 761 m vs. 3027 ± 953 m; p=0.867), V (28.29 ± 6.28% vs. 27.16 ± 6.27%; p=0.763), HR (136 ± 10 bpm vs. 135 ± 10 bpm; 0.750), or %DHY (-1.56 ± 0.98% vs. -1.82 ± 0.78%; p=0.316).

Conclusions: Non-linemen are subjected to covering a greater absolute distance during a preseason practice session, while maintaining a similar intensity, velocity, and hydration status (when permitted to drink ad libitum) as linemen. In addition, players exposed to similar practice demands provide similar work output during a preseason practice session regardless of their skill level.
Soccer Core Temperature Elevations

File Name
ms008_081510_1927.cvt

Graph showing temperature and heart rate over time.
Soccer Core Temperature Elevations

File Name
ms008_081510_1927.cvt

Graph showing core temperature and heart rate elevations over time.
<table>
<thead>
<tr>
<th>AM Practices</th>
<th>P = &lt; 0.05 Significant</th>
<th>PM Practices</th>
<th>P = &lt; 0.05 Significant</th>
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<tr>
<td>OL vs. OB</td>
<td>P = &lt;0.01*</td>
<td>OL vs. OB</td>
<td>P = &lt;0.01*</td>
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<tr>
<td>OL vs. DL</td>
<td>P = &lt;0.01*</td>
<td>OL vs. DL</td>
<td>P = &lt;0.01*</td>
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<td>OB vs. DB + WR</td>
<td>P = &lt;0.01*</td>
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<td>P = 0.012</td>
<td>DB + WR vs. OB</td>
<td>P = 0.02</td>
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N=66
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<th>Control Variables</th>
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<th>Pr &gt; F</th>
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<td>Group</td>
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<td>6.33</td>
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<td>Previous Practice Heat Stress</td>
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<tr>
<td>Heat Stress</td>
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<td>13.88</td>
<td>&lt;.0001*</td>
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<tr>
<td>Overall</td>
<td>3</td>
<td>11.47</td>
<td>&lt;.0001*</td>
</tr>
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</table>
Self Generated Air velocity affects cooling

Figure 2. A comparison of self-generated air velocities (vself) between non-linemen (gray) and linemen (white) during the 4 key drill classifications. Comparisons between linemen and non-linemen are given for average vself values (solid line) and the average vself values within the upper quartile of movement (dotted line). *Significant difference between non-linemen and linemen (p ≤ 0.05). NS indicates no significant difference. Error bars indicate standard error.

What do we do about it?
Preventative Cooling?

- 21 D-I football offensive lineman
- Core temp monitoring via ingestible thermistors
- Traditional break vs “Polar Pod” break during normal practice breaks
- Temps recorded throughout practice and before/after breaks
- Environmental conditions via WBGT0
- Heat Illness Symptom Questionnaire to assess subjective symptoms (3)
More than willing participants...

Ambient:  WBGTo 94.2,  
Heat Index 103,  
Humidity 65%

Polar Pod:  WBGTi  
52.3, Humidity 50%
Results

• Cooling rate
  – Polar pod: 0.035 +/- 0.55 deg F/min
  – Traditional: 0.016 +/- 0.52 deg F/min
  – P = 0.308 (no significant difference)

• Max temperatures
  – Polar Pod: 101.73 +/- 0.61 deg F
  – Traditional: 101.76 +/- 0.67 deg F
  – P= 0.905 (no significant difference)
Results

- Subjective symptoms assessment via HISI
  - Polar pod: 2.4
  - Traditional: 2.6
- Subjective feedback:
  - “Refreshed”
  - “Improved energy”
  - “I died and the polar pod brought me back to life”
USF Sports Medicine Soccer
Heat Physiology Study
Twelve Division-I female soccer players volunteered for this randomized, crossover study.

Participants were assigned to either their traditional shade break (CON) or a cold trailer (POD) cooled to 4-10 °C.

Environmental conditions were recorded for both conditions.

Core temperature ($T_{gi}$) was monitored via ingestible thermistors.

Heart rates (HR) were monitored using wearable sensors.

Percent loss of body weight (% BML) and urine specific gravity ($U_{sg}$) were measured to determine hydration status.

Repeated measures ANOVA were used to assess differences between conditions.
Results

- Mean wet bulb globe temperature was similar across days ($31.3\pm 2.1^\circ C; P=.095$)

- Percent of time in various aerobic intensity zones was similar ($P>0.05$)
USF Sports Medicine Soccer
Heat Physiology Study : Field

Study Results

• There were no differences in overall practice $T_{gi}$ between POD (38.2±0.4°C) and CON (38.2±0.3°F; $P>0.05$)

• No differences realized in $T_{gi}$ over time, condition, pre to post-break $T_{gi}$ or cooling rates ($P>0.05$)

• Both conditions saw decreased HR over time ($P=0.000$) but post-break POD HR (98.6±11.6 bpm) was significantly lower than CON HR (123.8±19 bpm; $P=0.005$)

• Mean % BML was similar for POD (-0.76±.48%) and CON (-0.53±.56%; $P=.218$)

• There was an overall time effect for $U_{SG}$ ($P=0.001$) and pre-to-post differences between conditions in $U_{SG}$ (POD: -0.010±0.007, CON: -0.005±0.006; $P=0.035$).
TGI and HR Pre and Post Polar Pod

<table>
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<tr>
<th></th>
<th>TGI</th>
<th>HR</th>
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<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>POD</td>
<td>38.4 ± 0.40</td>
<td>38.25 ± 0.44</td>
</tr>
<tr>
<td>Control</td>
<td>38.51 ± 0.41</td>
<td>38.45 ± 0.46</td>
</tr>
</tbody>
</table>

TGI = gastrointestinal temperature; HR = heart rate
Polar Pod Perceptuals

* Indicates post break POD < CON (p≤0.05)
Core Temperature and Intensity vs. Hydration

- Twenty-nine male football players (age = 21 ± 1 year, height = 187 ± 9 cm, mass = 110.1 ± 23.5 kg, body mass index [BMI] = 31.3 ± 5.0, and body surface area [BSA] = 2.34 ± 0.27 m²)

- 8 days of practice in a warm environment (wet bulb globe temperature: 29.6 ± 1.6° C).

- Starters (S; n = 12), nonstarters (n = 17) and linemen (L; n = 14) or nonlinemen (NL; n = 15).

- Core body temperature (T), hydration status, physical performance characteristics (GPS)

Core Temperature, Intensity and Hydration

- Low-velocity movement, high-velocity movement, average velocity, BMI, and BSA were significantly different ($p = 0.002$, $p < 0.001$, $p = 0.02$, $p < 0.001$, $p < 0.001$, respectively) between L vs. NL.

- Intensity measures of average heart rate ($138 \pm 9$ bpm), low-velocity movement ($4.2 \pm 1.7\%$), high-velocity movement ($0.6 \pm 0.6\%$), and average velocity ($0.36 \pm 0.10$ m·s$^{-1}$) accounted for 42% of the variability observed in $T$ ($38.32 \pm 0.34^\circ$ C, $r = 0.65$, $p = 0.01$).
Core Temperature, Intensity and Hydration

- Hydration measures (percent body mass loss = $-1.56 \pm 0.80\%$, urine specific gravity $[U_{sg}] = 1.025 \pm 0.006$, and urine color $[U_{col}] = 6 \pm 1$) did not add to the prediction of $T$ ($p = 0.83$). Metrics of exercise intensity accounted for 39% of the variability observed in maximum $T$ ($38.83 \pm 0.42^\circ C$, $r = 0.62$, $p = 0.02$). Hydration measures did not add to this prediction ($p = 0.40$).

- Heart rate and $T$ were not different between L and NL ($p > 0.05$). Exercise intensity primarily accounted for the rise in core body temperature. Although L spent less time at higher velocities, $T$ was similar to NL, suggesting that differences in BMI and BSA added to thermoregulatory strain.
## Prediction of Tgi

<table>
<thead>
<tr>
<th>Model factors</th>
<th>Temperature</th>
<th>Variability in temperature explained by model</th>
<th>Pearson product-moment correlation ($r$)</th>
<th>$p$</th>
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<tbody>
<tr>
<td>Intensity*</td>
<td>$T_{avg}$</td>
<td>42%</td>
<td>0.65</td>
<td>0.01†</td>
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<td></td>
<td>$T_{max}$</td>
<td>43%</td>
<td>0.66</td>
<td>0.02†</td>
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<tr>
<td>Intensity, hydration†</td>
<td>$T_{avg}$</td>
<td>44%</td>
<td>0.66</td>
<td>0.40</td>
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<td>$T_{max}$</td>
<td>39%</td>
<td>0.62</td>
<td>0.83</td>
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<tr>
<td>Intensity, hydration, individual characteristics§</td>
<td>$T_{avg}$</td>
<td>60%</td>
<td>0.78</td>
<td>0.09</td>
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<tr>
<td></td>
<td>$T_{max}$</td>
<td>53%</td>
<td>0.73</td>
<td>0.33</td>
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</table>

*Intensity variables are the following: heart rate, $V_{2-4}$, $V_{4-6}$, $V_{avg}$.
†$p \leq 0.05$.
‡Hydration variables are the following: % body mass loss and posturine specific gravity.
§Individual Characteristics variables are the following: position, body mass index, and body surface area.
Variance in Temperature and Local Sweat Rates

Regional sweating differs between elite American football linemen and backs independently of metabolic heat production

Tomasz M. Deren1, Anthony R. Bain1, Eric E. Coris2, Steve M. Walz2 and Ollie Jay1

1University of Ottawa, Ottawa, ON, Canada; 2University of South Florida, Tampa, FL, USA

Evaporative heat loss via sweating is the primary heat dissipation avenue during exercise, particularly in the heat. In typical summer football training camps, linemen have significantly greater elevations in core temperature than backs. However, it is unclear if differences in sweating are responsible for these higher core temperatures. **PURPOSE**: To investigate whether differences in local and whole-body sweat rates between football linemen and backs exist independently of differences in metabolic heat production. **METHODS**: 12 NCAA Division 1 American football players (6 linemen [mass: 141.6±6.5 kg; BSA: 2.67±0.08 m²] and 6 backs [mass: 88.1±13.4 kg; BSA: 2.11±0.19 m²]) at a fixed metabolic heat production of 350 W/m² for 60-min in a climatic chamber (Tdb: 32.4±1.0ºC; Twb: 26.3±0.6ºC; Vair: 0.9±0.1 m/s). Core temperature (Tcore) and mean skin temperature (Tsk) were measured throughout exercise. Local sweat rates (LSR) on the head, arm, upper back, lower back and chest were measured after 10, 30 and 50 min of exercise using a technical absorbent method, and whole-body sweat loss was measured using changes in pre and postexercise body weight. **RESULTS**: Whole-body sweat rate was identical in linemen (8.6±1.8 g/m²/min) and backs (8.6±1.4 g/m²/min); however, LSR was significantly greater (P<0.05) in linemen at 4 of 5 sites (head, arm, upper back and chest) after 10-min; at 2 of 5 sites (arm and chest) after 30-min; but no differences were observed for LSR between linemen and backs after 50-min. Core temperature at the end of the trial was significantly greater (P=0.025) in linemen (38.48±0.39ºC) relative to backs (38.01±0.24ºC). Mean Tsk was similar in linemen (35.34±0.48ºC) compared to backs (35.21±0.25ºC); however, when accounting for differences in starting Tsk, linemen (1.71±0.23ºC) had a greater change (P<0.001) in Tsk than backs (0.82±0.26ºC). **CONCLUSION**: Despite identical whole-body sweating at a fixed heat production per unit surface area, upper body LSR in linemen is greater during the early stages of exercise and presumably lower elsewhere. More profuse upper body sweating in linemen is attributed to a greater change in skin temperature. This potentially leads to a greater amount of non-evaporated sweat dripping off the body, a lower whole-body evaporative efficiency and greater elevations in core temperature.

Monitoring

- Predisposing illness/medication?
- Environmental conditions
- Athletic trainers critical
- Be conscious of excessive reps at any given position
- Watchful eye for mild and more severe heat illness
- Core temp, heart rate monitoring
- Heat illness symptom index
- Weight changes post practice
- Replacing fluid/electrolyte losses – oral or I.V. ??
- Immediate cooling for even mild heat illness
- Mental confusion – Heat stroke until proven otherwise
- ABCs – rectal temperature
- Activate emergency plan
- Immediate cooling – Ice water immersion
- IVF?
- Cool to 101, avoid shivering
- Watch for cardiac arrhythmia, seizure, multiorgan failure, DIC,


*Consensus Statement- Prehospital Care of Exertional Heat Stroke.*

Summary

Get conditioned and acclimatized

- Pre season risk assessment
- Drink fluids – sports drink
  - At least 20 ounces (2 to 3 cups) before practice
  - 10 ounces (one cup) every 10-15 min
  - One liter per hour
  - Weigh in and out - Don’t lose weight during practice
  - 24 ounces (3 cups) per pound of body weight lost
- Let us know if having trouble
- Symptom questionairres
- Heat pills
Thank you!
References

- Deren, Tomasz M.¹; Coris, Eric E.²; Casa, Douglas J.³; DeMartini, Julie K.³; Bain, Anthony R.¹; Walz, Steve M.²; Jay, Ollie¹,⁴ Maximum Heat Loss Potential Is Lower in Football Linemen During an NCAA Summer Training Camp Because of Lower Self-Generated Air Flow, Journal of Strength and Conditioning Research: June 2014 - Volume 28 - Issue 6 - p 1656–1663
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- Speedy DB, Rogers IR, Diagnosis and Prevention of Hyponatremia at an Ultradiatance triathlon, Clinical Journal of Sports Medicine, vol. 10, no. 1, 2000, pp. 52-58.
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