The Difference in Core Temperature and Heart Rate Between Collegiate American Football Backs and Linemen During Pre-Season

Beth P. Ward, LAT, ATC
Graduate Assistant
West Chester University
Objectives

1. Introduction
   a. Exertional heat illness (EHI)

2. Overview of Related Literature
   a. Thermoregulation – body size, aerobic fitness, acclimatization
   b. EHI and American Football

3. Purpose

4. Methods

5. Results

6. Discussion

7. Conclusions
Introduction

• Exertional heat illness (EHI) and exertional heat stroke (EHS) have been documented issues in certain occupations and sports.¹,²
**Exertional Heat Illness**

- **EHI**: A condition that couples heat production and insufficient heat dissipation
  - Results in hyperthermic body core temperature ($T_c$) (38°C – 39.5°C)

- **EHS**: A condition associated with a $T_c$ of 40°C or higher and central nervous system (CNS) abnormalities
  - Considered the most fatal of EHI

3, 4, 5
Exertional Heat Illness

- EHI is more prominent during exercise in hot/humid environments

- This can result in *uncompensable heat stress*

**Uncompensable heat stress:**
- Occurs when evaporative sweating for cooling does not match heat production
- Can result in decreased thermoregulation and an increased $T_c$ ➔ Increased EHS risk
Thermoregulation

• Thermoregulation occurs when heat production and heat dissipation are balanced

• **DURING EXERCISE:**
  • The body must adjust for an increase in the amount of heat generated by the muscles
  
  • Increase in metabolic heat production
  
  • Generated heat must move to the periphery to maintain normal $T_c$
Thermoregulation

- Factors that affect thermoregulation:
  - Hot/humid environments
  - Clothing and equipment
  - Higher Body mass
  - Lower BSA/mass
  - Lower Aerobic fitness level
  - Slower acclimatization rates
- Each of these can contribute to one’s risk for EHI

8,9,10
Body size

- Body surface area (BSA) (m$^2$): the amount of skin and tissue covering the body.

- BSA/mass: the ratio of skin to mass of the body.
  - A high BSA + a high mass = a low BSA/mass ratio.

- Both of these characteristics affect heat dissipation via dry and wet methods.
Body Size

- Those with a higher mass exercising in hot/humid environments:
  - Rely heavily on evaporation for heat dissipation
  - Can’t dissipate heat as quickly
    - Due to high humidity reducing evaporation capability
  - Store more heat $\rightarrow$ Increased $T_c$
Aerobic Fitness

During exercise:

- $T_c$ and HR increase
- Reach steady state – heat production and heat loss are balanced

- This steady state, known as cardiovascular stability, is more efficient and reached more quickly in those that have higher aerobic fitness
Aerobic Fitness

• Those that are aerobically fit:
  • Have increased recovery from exercise
  • Are able to maintain cardiovascular stability
    • Decreases risk for EHI
Acclimatization

- Physiological adaptations that occur due to regular exposure to an extreme environment, such as hot environments

- Decrease the hindering effects of exercising in the heat

- Can take **7-14 days** of repeated exposure to acclimatize

4, 15, 16, 17
Acclimatization

• **Physiological changes include:**
  • Increased plasma volume
  • Increased sweat rate
  • Decreased sodium losses in sweat and urine
  • Decreased HR during exercise
  • Decreased $T_c$ at rest
  • Decreased rate of $T_c$ increase during exercise

• The rate of acclimatization has been associated with:
  • **Aerobic fitness**
    • Due to initial cardiovascular improvements

4, 15,16,17
EHI and American Football

• American football players are at risk for developing EHI due to the nature of the sport and the individual characteristics of each player.
EHI and American Football

- From 1995-present: 54 heat-related deaths have occurred in American football

- 90% of these occurred in practice

- From 2010-2014: average of 2.6 heat stroke deaths per year
American football requires a significant level of aerobic fitness to adjust to varying exercise intensities, the addition of padding, and the potential for increased body mass.

- However, it is common for positional players to not be aerobically fit.

- Less fit individuals can have higher heart rates and core temperatures at lower exercise intensities that will continue to rise at high intensity intervals.

- Players with a higher BMI (low BSA/mass) tend to be less conditioned and may not thermoregulate effectively.
Problem Statement

• The direct influence of BSA/mass and aerobic fitness levels on maximal $T_c$ and HR values during athletic participation has not been widely examined.

• Specifically, not in the American Football population
Purpose
Purpose

• The purpose of this study was to evaluate the effects of HR, VO$_{2peak}$ (aerobic fitness), and BSA/mass on $T_c$ in American Football players during pre-season.
Hypotheses

1. Linemen (LM) will be significantly less fit and larger than backs (BKs).

2. Subjects with lower BSA/mass and \( VO_{2\text{peak}} \) values will have higher \( T_c \) values and \( T_c \) variability throughout pre-season.

3. Similarly, subjects with lower BSA/mass and \( VO_{2\text{peak}} \) values will have higher HR values and HR variability throughout pre-season.

4. All subjects will demonstrate acclimatization via reduced \( T_c \) and HR variables after 10 days of pre-season.

5. \( T_c \) and HR variables will have a direct relationship throughout pre-season.
Methods
Participants

• 20 volunteer NCAA Division III football players
• Ages 18-22
• 9 LM, 11 BKs
Experimental Design

- Field study
- Observational cohort
Independent and Dependent Variables

- **Independent variables:**
  - $HR_{\text{max}}$
    - (maximum HR reached that day)
  - $\Delta HR$ (max-min)
  - $VO_{\text{peak}}$
  - BSA/mass
  - Group (LM vs. BKs)

- **Dependent Variables:**
  - $T_{\text{cmax}}$
    - (maximum $T_c$ reached that day)
  - $\Delta T_c$ (max-min)
Baseline Data Collection

- August 10-12
- Height, weight, BSA/mass, resting HR
- $\text{VO}_2\text{peak}$ test (Bruce Protocol)
Data Collection Dates

- Day 2 (D1)
- Day 3 (D2)
- Day 4 (D3)
- Day 5 (D4)
- Day 10 (D5)
Core Temperature

• $T_c$ measured via ingestible temperature pill (Ingestible CorTemp® (HQ Inc., Pametto FL)).

• Subjects ingested thermistors ~5 hrs prior to practice.

• $T_c$ was received and stored using a CorTemp® hand-held recorder (HQ Inc., Pametto FL).

• Thermistors were excreted within 12-24 hrs
Heart Rate

- The Ingestible CorTemp® (HQ Inc., Pametto FL) sensors also measured HR in conjunction with Polar® (Polar Electro Oy., Kempele, Finland) T31 heart rate straps.

- The emitted HR for each player was received and stored using CorTemp® hand-held recorders (Hq Inc., Pametto FL).
Wet Bulb Globe Temperature

- A Wet Bulb Globe Temperature (WBGT) Index Calculator (Sigma Product & MFG Inc., Fort Mill, SC) was used to measure WBGT on the designated days.
Data Collection On The Field

• Subjects swallowed The Ingestible CorTemp® sensors ~5 hrs prior to practice.

• Subjects reported to receive HR strap

• Baseline $T_c$ and HR were recorded.

• Every 10 minutes throughout practice, $T_c$ and HR were recorded using CorTemp® hand-held recorder.

• WBGT measurements were recorded 3-4 times during practice.
Data Collection

• **Post practice:** Subjects returned HR strap

• $T_{cmax}$ and $HR_{max}$, were recorded
Statistical Analysis

- Statistical analysis was performed using the Statistical Package of Social Sciences (v.22; SPSS, Chicago, IL).

- **Unpaired t-tests:**
  - To compare between group differences

- **Separate group by day repeated measures ANOVA:**
  - To compare variables across days between groups

- **Paired t-tests:**
  - To compare variables with groups combined across days
Results
<table>
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<tr>
<th>Subject</th>
<th>Position</th>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BSA/mass (cm²)</th>
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• BSA/mass (cm²) was higher in BKs (233.9 ± 10.8) vs. LM (209.95 ± 12.99), (P<0.005).

• VO₂peak (ml/kg•min) was higher in BKs (48.9 ± 1.5) vs. LM (42.4 ± 5.4), (P=0.012).
Results - Between Groups

• A significant group by day (D1-5) interaction in $\Delta T_c$
  $F(3.09,3.11)=3.63, (P=0.017)$.

• Post-hoc analysis revealed that BKs had significantly
  (P=0.02) higher $\Delta T_c (D1)$ (3.47 ± 1.23°C) vs. LM (2.34 ±
  0.69°C).

• On D4, the $\Delta T_c$ was lower in the BKs (2.59 ± 0.71°C) vs.
  LM (3.24 ± 0.79°C) but was not significant (P=0.11).
$\Delta T_c$ across days between BKs vs. LM
Results – Between Groups

- Overall $T_{c_{\text{max}}} (D1-5)$ was significantly higher in LM ($39.1 \pm 0.19^\circ C$) vs. BKs ($38.8 \pm 0.36$)
Acclimatization Results: Paired t-tests

- With groups combined, $T_{c_{\text{max}}} (D1-4) (38.92 \pm 0.205°C)$ was significantly higher than $T_{c_{\text{max}}} (D5) (38.32 \pm 0.362°C)$, ($P<0.05$).

- $\Delta T_c (D1-4) (3.89 \pm 0.78°C)$ was significantly higher than $\Delta T_c (D5) (2.11 \pm 0.76°C)$, ($P<0.05$).
Tcmax (D1-4) vs. Tcmax (D5)
$\Delta T_c$ Across Days in All Subjects.
Acclimatization Results – Paired t-tests

- $HR_{\text{max}} (D1-4) (168.62 \pm 10.94 \text{ bpm})$ was significantly higher than $HR_{\text{max}} (D5) (152.06 \pm 14.43 \text{ bpm})$, ($P=0.003$).

- Similarly, $\Delta HR (D1-4) (92.31 \pm 16.4 \text{ bpm})$ was significantly higher than $\Delta HR (D5) (70.61 \pm 12.98 \text{ bpm})$, ($P=0.001$).
HR_{max} (D1-4) vs. HR_{max} (D5)
ΔHR Across Days in All Subjects
Discussion
Discussion

• We were able to show that these groups differed in terms of body size (BSA/mass) and fitness level (VO_{2peak}).

• The LM were bigger and less fit when compared to the BKs.\textsuperscript{19-21}

• This resulted in higher overall $T_{c_{\text{max}}}$ (D1-5) values compared to BKs.\textsuperscript{19-21}

  • The variable of $T_{c_{\text{max}}}$ between LM and BKs has only been reported in 3 previous studies in the literature.\textsuperscript{19-21}

• LM showed greater variability ($\Delta T_c$) vs. the BKs
  • $T_c$ variability has never been reported
Discussion

- We were able to show that all subjects showed signs of acclimatization within 10 days of pre-season

- $T_{cmax}$ and $HR_{max}$ values were lower on D5 of pre-season vs. D1-4

- $\Delta T_c$ and $\Delta HR$ showed less variability on D5 vs. D1-4
Conclusions

• LM can be at a higher risk of suffering from EHI longer throughout pre-season due to:
  
  • Lower BSA/mass vales,
  • Lower $VO_{2peak}$ values,
  • The result of higher $T_{cmax}$ values.

• The results of this study provide pertinent information for the identification of individuals at risk for EHI.
Conclusions

• **EHI Prevention:**
  • Follow proper acclimatization guidelines (10-14 days)
    • Gradual addition of padding and equipment
    • Single day practices for the first initial days

• Identify possibly at-risk athletes
  • Larger, less aerobically fit

• Emphasize Aerobic exercise in off-season conditioning
  • Not just lifting!
References


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