Original Article

Gastrointestinal Temperature Trends in Football Linemen During Physical Exertion Under Heat Stress

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Context: Exertional heat stroke is the third leading cause of death in US athletes. Elevations in core temperature in the digestive tract (T_{GI}) have correlated with core temperature and are possible indicators of those at increased risk of heat stroke.

Objective: The primary objective was to compare a.m. vs. p.m. T_{GI} variation in collegiate football linemen during intense "two-a-day" preseason practice. A secondary objective was to compare longitudinal T_{GI} in offensive and defensive linemen.

Design: Cross-sectional observational study.

Setting: Division I Intercollegiate Athletics Football Program.

Interventions: T_{GI} was monitored during consecutive preseason sessions.

Main Outcome Measurements: T_{GI}, heat illness, weight changes, environmental stress, and subjective symptoms.

Results: Mean T_{GI} were 37.8°C and 38.3°C during a.m. and p.m. practices, respectively. The a.m. practices revealed higher T_{GI} gain (1.8°C) compared to p.m. (1.4°C). The p.m. practices had higher maximum T_{GI} than a.m. practices (39.1°C versus 38.8, P=0.0001). Mean time to maximum temperature (T_{max}) was 1 hr and 30 min for a.m. and 1 hr and 22 min for p.m. practices. Offensive linemen trended toward higher mean T_{GI} than defensive players (38.0°C vs. 36.7°C, P = 0.069). The rate of rise in T_{GI} was significantly greater in a.m. practices. A decrease in rate of T_{GI} rise was seen from the first to last a.m. practices of the week (P = 0.004).

Conclusion: Significant T_{GI} elevations in asymptomatic athletes are common in extreme heat during football practice. Intense a.m. practices in full gear result in higher net temperature gain and rate of temperature gain than p.m. practices. Offensive linemen trended toward higher T_{GI} than defensive linemen. As players acclimatized, a decrease in the rate of T_{GI} increase was appreciable, particularly in a.m. practices. Appreciating cumulative heat stress and variations in heat stress related to scheduling of practice is critical.

Key Words: athletes, heat exhaustion, heat illness, heat stroke, thermoregulation

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Exertional heat illness contributed to at least 21 deaths from 1995 to 2001 in youth football[1] and 5,246 hospitalizations and 37 deaths in operational military personnel between 1980 and 2002.[2] In healthy persons, exercise is generally well tolerated as metabolic heat generated by exertion is dissipated by the thermoregulatory systems of the body.[3,4] In some cases, however, ambient temperature, humidity, subject dehydration, equipment, medications, and other factors lead to failure of the thermoregulatory system and massive gains in core temperature (T_C) resulting in multiorgan fail-

Key Points

- Even in asymptomatic athletes exercising in the heat, significant core temperature elevations are common.
- Offensive and defensive linemen seem to be at particular risk of elevated core temperature elevations.
- Core temperature rises fastest during more intense practices in full pads.
- Initial core temperature at the beginning of practice is higher for afternoon practices following a previous morning practice, suggesting the possibility of accumulated "heat stress." For athletes exercising in the heat of "two-a-day" drills, this may be particularly concerning.

ure.[3,5–14] Given sheer size and muscle mass, football linemen pushing the limits of thermoregulation with intense exercise in the heat may be at highest risk.[15,16] The purpose of this study was to compare a.m. vs. p.m. core temperature in the digestive tract (T_{GI}) variations in Division I collegiate football linemen during "two-a-day" practices in a hot and humid environment. Additionally, the authors sought to assess the comparative risk of elevated T_{GI} between offensive and defensive linemen, and the variation of T_{GI} over time.

Methods

To assess T_{GI} changes during intense physical exertion in heat stress, 11 National Collegiate Athletic Association Division I football athletes (7 offensive linemen [OL], 4 defensive linemen [DL]) were monitored through a week of "two-a-day" practices during preseason training in the August heat of the southeastern United States. This study was designed to have 80% power to detect a 0.2°C mean temperature difference (alpha = 0.05, SD = 1.1 °C) between a.m. and p.m. practices. This study also had 80% power to detect the 0.3°C mean temperature difference (alpha = 0.05, SD = 1.2°C) between offensive and defensive players. The study was approved by the USF Institutional Review Board.

Athletes were given ingestible T_{GI} thermistors (CorTemp, HQ Inc., Palmetto, Fl.) at least 4 hours prior to practice.[17] The sensors were capable of transmitting accurate T_{GI} readings (±0.1°C) to a handheld recorder (CorTemp, HQ Inc., Palmetto FL.) positioned within 1 meter of the athletes' flank or abdomen.[17] Frequent T_{GI} measurements were taken by the athletic trainers throughout practice. Athletes were removed from practice for any clinical heat illness or for a T_{GI} greater than 39.4°C. Rapid cooling measures were undertaken once T_{GI} exceeded 39.2°C.

Basic demographic information, pre- and postpractice weight (Tanita Corp., BWB-800A, NTEP approved, Class III, range 98.2–200 kg), pre- and postpractice wet bulb globe temperature (WBGT) (Bacharach, Inc., Pittsburgh, PA, 12–7022, accuracy to ±5% relative humidity), and postpractice Heat Illness Symptom Index questionnaires were obtained on each athlete.[18] For percent body fat, three-fold skin caliper testing was performed using Lange skin calipers (Betatech Inc., Cambridge Maryland).

A total of 1,328 T_{GI} data points were obtained for 11 players in 9 practices (mean, 16 observations/player/ practice). Data were analyzed using SAS® (SAS®, Inc., Ver. 9.2., 2005). Procedure (Proc in SAS®) was used to tabulate demographics and calculate mean for minimum and maximum temperatures for each athlete during a.m. and p.m. practices. The SAS Proc Regression procedure was used to analyze the overall change in temperature over time for all players during a.m. and p.m. practices. Mean T_{GI} from the first practice was compared to mean T_{GI} for the last practice using ANOVA in a generalized linear model design, adjusting for missing values.

Results

Demographics

The demographic profile for the 11 players is given in the Table. Mean age was 21.6 years (min = 20.0 yrs., max = 24.0 yrs.). Mean height was 190.5 cm (min = 180.3 cm, max = 203.2 cm). Mean weight was 129.5 kg (min = 100.5 kg, max = 147.3 kg). Mean body fat was 14.1%. The mean wet bulb globe temperature (WBGT) was 26.5°C (SD = 1.7) for a.m. practices and 26.3°C (SD = 1.7) for p.m. practices. Figures 1 and 2 represent the T_{GI} profile for each athlete over a.m. and p.m. practices.

In a.m. practices, mean T_{GI} was 38.0°C (37.0–39.1°C), with significant individual variability in T_{GI} (SD = 1.1°C). The mean maximum temperature (T_{max}) was 38.8°C (range = 37.4–40.0°C, SD = 1.4°C). For a.m. practices, OL had a higher mean T_{GI} than DL overall (38.0°C vs. 36.7°C respectively), but this was not statistically significant. Mean time to T_{max} was 1.5 hours (range = 0.40–2.40 hr) and was more rapid in DL vs. OL (1.23 vs.1.30 hrs, P=0.12), but this was not statistically significant during a.m. practices. Overall mean a.m.T_{GI} gain was 1.8°C.

For p.m. practices, mean T_{GI} was 38.5°C (37.6–39.0°C), which was higher than the mean a.m. practices. There was significant individual variability in T_{GI} similar to a.m. practice (SD = 0.8°C). Average T_{max} was 39.1°C (38.0–39.6°C and SD = 0.9°C). For p.m. practices, OL had similar mean T_{GI} to DL (38.3°C vs. 38.4°C, respectively). Average time to T_{max} was 1.25 hours (range = 0.39–2.37 hrs, SD = 0.63 hrs) and elevated more rapidly in DL than in OL (1.31 hrs, SD = 0.51 hrs vs. 1.42 hrs SD = 0.69 hrs, P = 0.06), but this was not quite statistically significant.

The T_{GI} profile for one typical offensive lineman during a.m. and p.m. practice is given in Figure 3. ΔT1 is the initial change in T_{GI} for practice 1, which was an a.m. practice, while ΔT2 is the change in T_{GI} for practice 2, which was a p.m. practice. This T_{GI} profile was characterized by a rapid initial rise in temperature due to active and intense practice, ΔT1 to $T_{max}{}^1$. $T_{max}{}^1$ (40.0°C) is the

Table. Demographic Of the Players (N = 11)

Variable	Mean	Median	Minimum	Maximum
Age (in years)	21.6	22.0	20.0	24.0
Height (in cm)	190.5	190.5	180.3	203.2
Weight (in kgs)	129.5	130.5	100.5	147.3
Body Fat (in percent)	14.1%	15.1%	2.2%	23.2%
BMI	35.3	37.2	26.2	41.3
Weight Loss/ Player/ Practice (in lbs)	4.4	6.9	−2.0	14.7

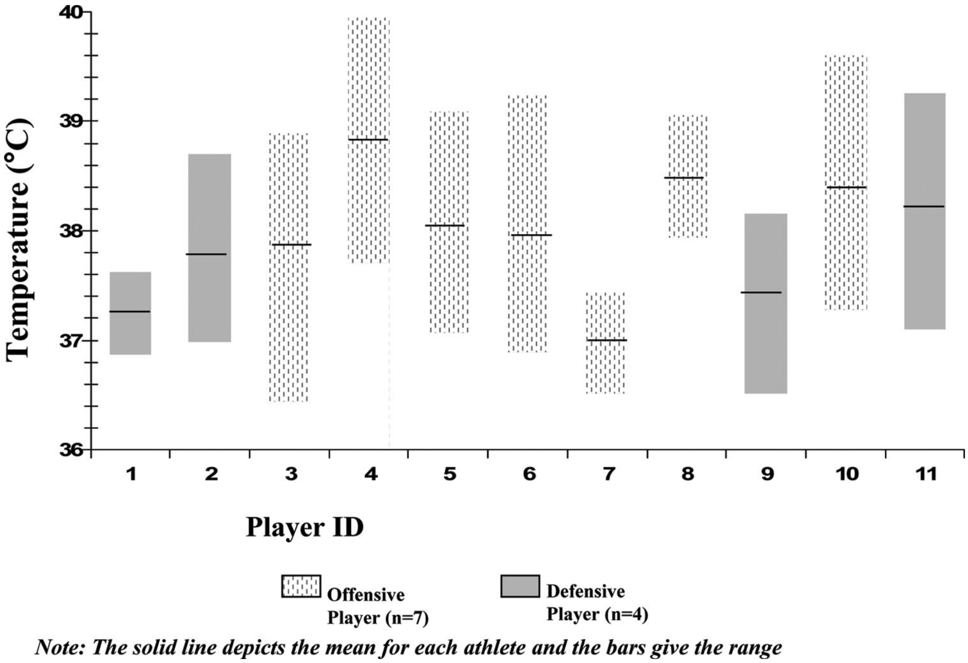

Fig. 1 **Mean temperature (T_{GI}) a.m. practices.**

first peak in ΔT1, at which point the athlete was asymptomatic. $T_{max}{}^1$ was achieved within 50 minutes of initiating activity. The trough reflected a typical practice break when athletes were required to cool and hydrate. Once resumed, the T_{GI} again demonstrated a rapid climb and peaked at $T_{max}{}^2$(>39.4°C). The athlete remained asymptomatic throughout practice. In the p.m. practice, the athlete demonstrated an initial elevated T_{GI} relative to the a.m. practice, but had a significantly slower rise in T_{GI}. The drop in temperature mid p.m. was again indicative of the rest break, followed by a repeat rise in T_{GI}, apparently interrupted only by the end of practice.

The regression model for change in temperature over time for all players is given in Figure 4. Mean initial T_{GI} of players during a.m. practices was significantly lower than p.m. practices ($P < 0.0001$). However, the rise in a.m. T_{GI} was 28% higher than that of the afternoon practices (1.8°C vs 1.4°C; $P = 0.0045$). There was a statistically significant mean T_{GI} decrease from the first to the last a.m. practice of the week. (38.6°C vs. 37.5°C; $P = 0.004$).

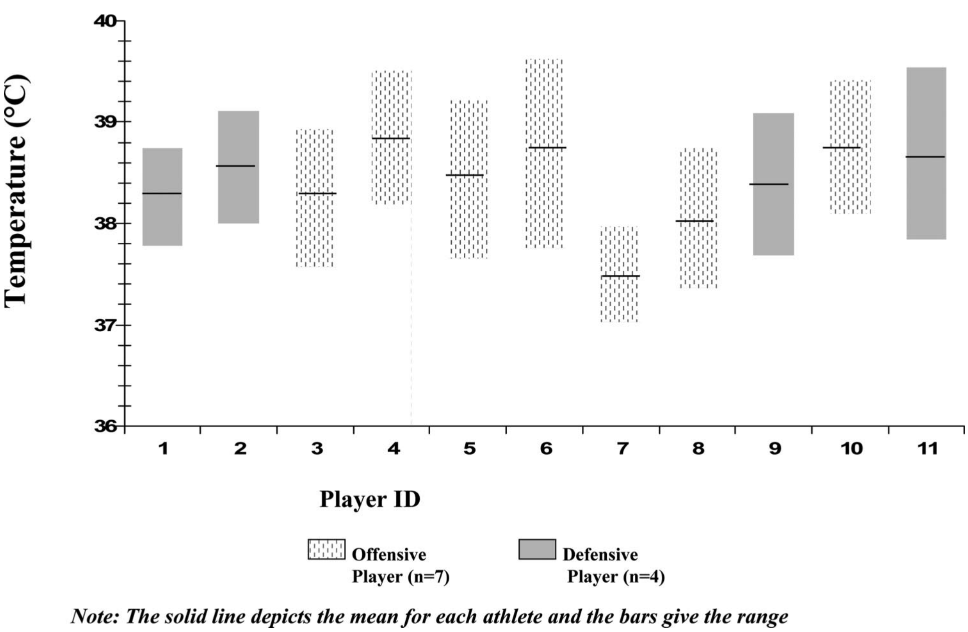

Fig. 2 **Mean temperature (T_{GI}) p.m. practices.**

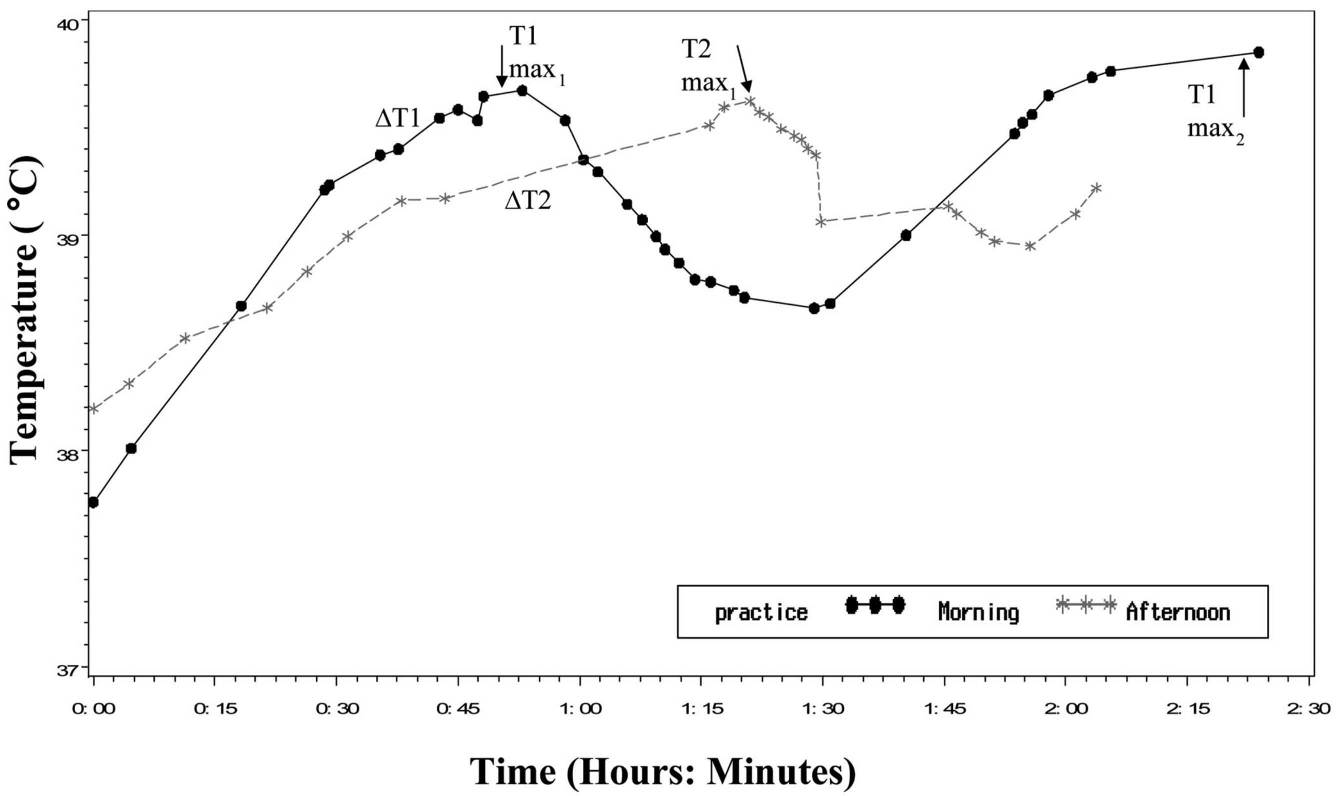

Fig. 3 Individual T_{GI} profile of offensive lineman during two-a-day practices.

Discussion

We successfully documented T_{GI} in collegiate football linemen during the first week of "two-a-day" practices in hot, humid environmental conditions. Many athletes reached a T_{GI} of at least 38.9°C.

When evaluating the overall mean T_{GI} (Figs. 1 and 2) for a.m. vs. p.m. practices, several interesting observations were made. The initial mean T_{GI} for p.m. practice was elevated compared to a.m. practice, possibly reflecting retained heat stores from the earlier practice. Retained heat stores may account for the increase in T_{max} observed in the p.m. practices when compared with the a.m. Previously, it has been demonstrated that it is this cumulative heat stress that often leads to severe exertional heat illness.[13] Inter-

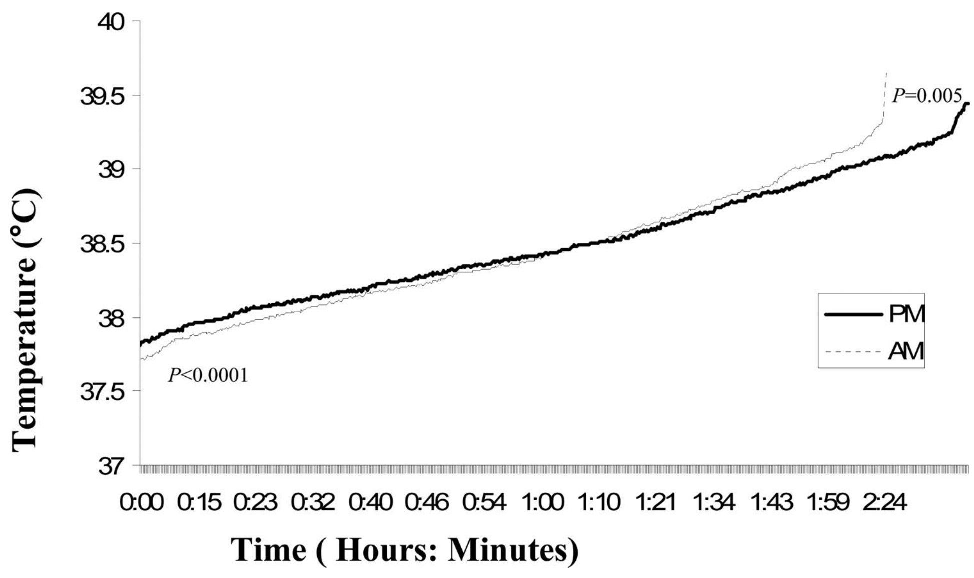

Fig. 4 Regression curve for T_{GI} during a.m. and p.m. practices.

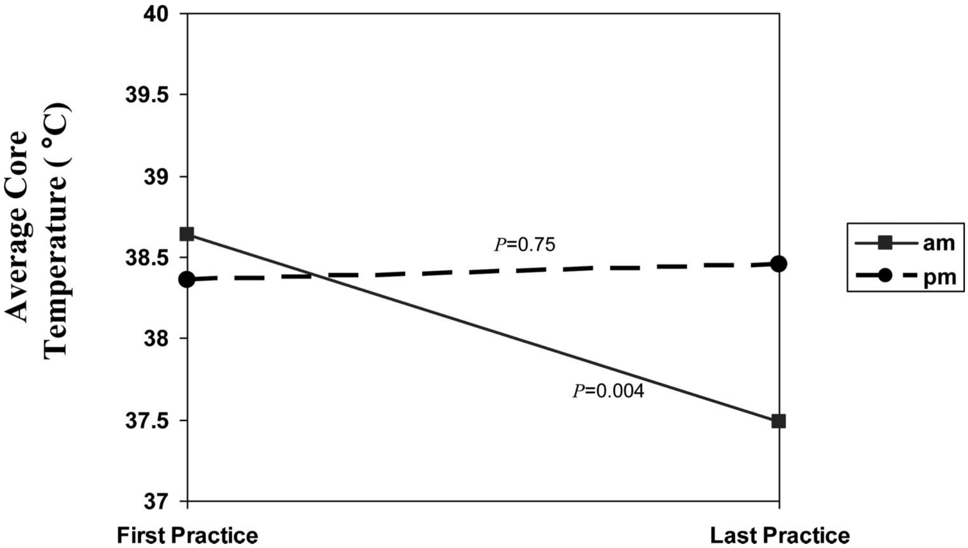

Fig. 5 Regression curve for T_{GI} from first practice to last practice, 12 days later.

estingly, the overall change in T_{GI} was greater for a.m. practices (1.8°C) than p.m. practices (1.4°C).

Additionally, the slope of the rise in temperature, ΔT, was significantly greater for a.m. practices than that for the p.m. practices ($P = 0.004$). This may be related to the intensity of practice, as a.m. practices tend to be more rigorous. Likely an even greater factor, full pads were worn for all a.m. practices. The lighter attire (helmet and shoulder pads) worn during p.m. practices typically allowed for more efficient heat dissipation, possibly accounting for the lesser T_{GI} rise observed. Both intensity of exercise and equipment worn appear to be major factors in increased T_{GI} in football players.[15,19]

A statistically significant decrease in mean T_{GI} was seen for a.m. practices from the first practice to the last (Fig. 5). Likely a result of acclimatization, and possibly greater conditioning of the athletes by the end of the sessions, this further emphasizes the need for practice schedules allowing for acclimatization early in training.

The rapid rise in T_{GI} seen in the individual example (Fig. 3) to greater than 39.4°C within 50 minutes of routine practice is indicative of significant T_{GI} elevations of a degree typically unexpected in asymptomatic athletes. The point at which these elevated temperatures progress to complete thermoregulatory failure remains unknown. Efforts to limit this heat stress accumulation are of the utmost importance in the athletic arena. The rapid response to cooling efforts during practice further emphasizes the need for rest periods, hydration, cooling, and recognition of heat-related signs and symptoms during practice.

Limitations

The data collection was limited to frequent, intermittent monitoring by graduate assistant athletic trainers who recorded T_{GI} during "athlete accessible" times so as not to interfere with normal practice. As a result, readings from the athletes are occasionally sparse and not at preset, uniform intervals. Ideally, this monitoring would be done continually during practice by having participating athletes wear data recorders incorporated into their shoulder pads.

During the study, occasional difficulty was encountered with optimum thermistor administration. Athletes would occasionally not take their thermistor on schedule, resulting in esophageal or gastric monitoring and falsely low temperatures after liquid ingestion. Pill administration error was minimized when investigators had the athletes ingest pills at bedtime the night before practice.

This is also a small sample size, leading to limited ability for subgroup analysis. The data recorders ($2500/recorder) and ingestible thermistors ($40/pill) required are costly and necessitate larger grant funding to perform on a large population. The current approach reflects what many smaller institutions may be able to accomplish on a relatively limited budget to monitor the highest risk athletes. Larger studies for more subgroup analysis are planned.

Conclusion

Exertional heatstroke (EHS) and lesser forms of heat illness continue to be a concern in athletes participating strenuously in hot, humid conditions. Lower initial mean T_{GI}, a greater rate of T_{GI} increase, and higher overall mean T_{GI} gain were noted in the a.m. practices. The greater mean T_{max} observed in p.m. practices is most likely attributed to retained heat stores from the previous a.m. practice. The major finding of this work is the further description of T_{GI} trends in collegiate football linemen in preseason workouts under intense environmental heat stress. Those linemen at highest risk of elevated T_{max} appear to be offensive linemen. The patterns of these changes, particularly the effectiveness of the rest period in reducing core temperature, and the persistent elevated temperature seen on commencement of the second practice of the day, should influence practice scheduling and rest period planning. Magnitude of T_{GI} elevation suggests the necessity to further elucidate the point at which uncompensated heat stress and thermoregulatory failure occurs in football players.

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Please see Dr. Randell Wexler's editorial on page 557 of this issue.

"Have you ever observed a humming-bird moving about in an aerial dance among the flowers - a living prismatic gem.... it is a creature of such fairy-like loveliness as to mock all description."

—W.H. Hudson