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Original Research

The American Football Uniform: Uncompensable Heat Stress and Hyperthermic Exhaustion

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Abstract

Context: In hot environments, the American football uniform predisposes athletes to exertional heat exhaustion or exercise-induced hyperthermia at the threshold for heat stroke (rectal temperature [T_{re}] > 39°C).

Objective: To evaluate the differential effects of 2 American football uniform configurations on exercise, thermal, cardiovascular, hematologic, and perceptual responses in a hot, humid environment.

Design: Randomized controlled trial.

Setting: Human Performance Laboratory.

Patients or Other Participants: Ten men with more than 3 years of competitive experience as football linemen (age = 23.8 ± 4.3 years, height = 183.9 ± 6.3 cm, mass = 117.41 ± 12.59 kg, body fat = 30.1% ± 5.5%).

Intervention(s): Participants completed 3 controlled exercise protocols consisting of repetitive box lifting (lifting, carrying, and depositing a 20.4-kg box at a rate of 10 lifts per minute for 10 minutes), seated recovery (10 minutes), and up to 60 minutes of treadmill walking. They wore one of the following: a partial uniform (PART) that included the National Football League (NFL) uniform without a helmet and shoulder pads; a full uniform (FULL) that included the full NFL uniform; or control clothing (CON) that included socks, sneakers, and shorts. Exercise, meals, and hydration status were controlled.

Main Outcome Measure(s): We assessed sweat rate, T_{re}, heart rate, blood pressure, treadmill exercise time, perceptual measurements, plasma volume,

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plasma lactate, plasma glucose, plasma osmolality, body mass, and fat mass.

Results: During 19 of 30 experiments, participants halted exercise as a result of volitional exhaustion. Mean sweat rate, T_{re}, heart rate, and treadmill exercise time during the CON condition were different from those measures during the PART (*P* range, .04–.001; d range, 0.42–0.92) and FULL (*P* range, .04–.003; d range, 1.04–1.17) conditions; no differences were detected for perceptual measurements, plasma volume, plasma lactate, plasma glucose, or plasma osmolality. Exhaustion occurred during the FULL and PART conditions at the same T_{re} (39.2° C). Systolic and diastolic blood pressures (n = 9) indicated that hypotension developed throughout exercise (all treatments). Compared with the PART condition, the FULL condition resulted in a faster rate of T_{re} increase ($P < .001$, d = 0.79), decreased treadmill exercise time ($P = .005$, d = 0.48), and fewer completed exercise bouts. Interestingly, T_{re} increase was correlated with lean body mass during the FULL condition ($R^2 = 0.71$, $P = .005$), and treadmill exercise time was correlated with total fat mass during the CON ($R^2 = 0.90$, $P < .001$) and PART ($R^2 = 0.69$, $P = .005$) conditions.

Conclusions: The FULL and PART conditions resulted in greater physiologic strain than the CON condition. These findings indicated that critical internal temperature and hypotension were concurrent with exhaustion during uncompensable (FULL) or nearly uncompensable (PART) heat stress and that anthropomorphic characteristics influenced heat storage and exercise time to exhaustion.

Keywords: heat tolerance, rectal temperature, heart rate, sweat rate, blood pressure

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