HYPOHYDRATION: EFFECTS ON BODY FLUID REDISTRIBUTION, TEMPERATURE REGULATION & EXERCISE-HEAT TOLERANCE

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INTRODUCTION

Depending on climatic conditions the relative contributions of evaporative and dry (radiative and conductive) heat exchange to the total heat loss will vary (1). The hotter the climate the greater dependence on evaporative heat loss, and thus sweating. Persons in the desert often have sweating rates of 0.3 to 1.2 $L \cdot h^{-1}$ while performing occupational activities. Persons wearing protective clothing often have sweating rates of 1 to 2 $L \cdot h^{-1}$ while performing light intensity exercise. Likewise, athletes performing high intensity exercise in the heat commonly have sweating rates of 1 to 2.5 $L \cdot h^{-1}$.

During situations of high sweating rate, a principal problem is to avoid **a** reduction in total body water (hypohydration) by matching fluid consumption to sweat loss. Frequently, persons will hypohydrate by 2% to **8%** of their body weight during situations of prolonged high sweat loss. If hypohydrated persons exercise in the heat, they will incur significant adverse effects. This paper reviews hypohydration effects on temperature regulation and exercise-heat performance.

BODY WATER LOSS

Sweat induced hypohydration will decrease plasma volume and increase plasma osmotic pressure in proportion to the level of fluid loss (2). Plasma volume decreases because it provides the precursor fluid for sweat, and osmolality increases because sweat is ordinarily hypotonic relative to plasma. Sodium and chloride are primarily responsible for the elevated plasma osmolality. It is the plasma hyperosmolality which mobilizes fluid from the intracellular to the extracellular space to enable plasma volume defense in hypohydrated subjects. Hypohydration mediated by sweating will influence each fluid space as a consequence of free fluid exchange, Water redistributes largely from the intra- and extracellular spaces of muscle and skin in order to maintain blood volume, however, neither brain nor liver loose significant water content (3).

TEMPERATURE REGULATION

Hypohydration increases core temperature responses during exercise in temperate and hot climates (4,5). **A** critical deficit of 1% of body weight elevates core temperature during exercise. **As** the magnitude of water deficit increases, there is a concomitant graded elevation of core temperature during exercise heat stress (6,7). The magnitude of core temperature elevation ranges fiom 0.1 to 0.23° C for every percent body weight lost **(2).** In addition, data suggests that the core temperature elevation, for a given water deficit, may become greater with increased exercise intensity **(2).**

Hypohydration not only elevates core temperature responses, but it negates the core temperature advantages conferred by high aerobic fitness and heat acclimation. Figure 1 illustrates the effects of hypohydration *(5%* body weight loss) on core temperature responses in the same persons when unacclimated and when heat acclimated persons (8). Heat acclimation lowered core temperature responses when euhydrated; however, when hypohydrated similar core temperature responses were observed regardless of acclimation state. Therefore, the core temperature penalty induced by hypohydration was greater in heat acclimated than unacclimated persons.

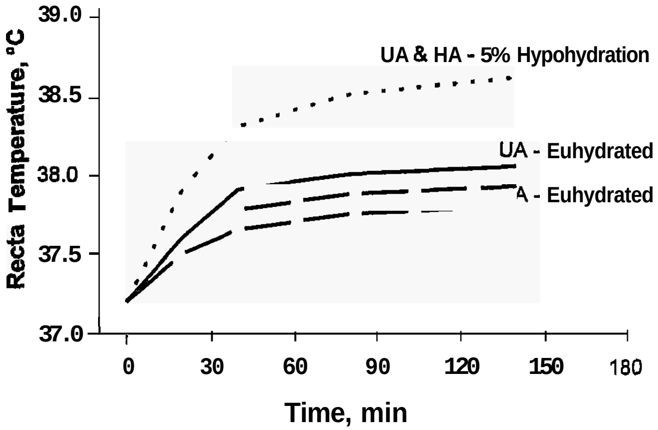

Figure 1 Influence of hypohydration *(5%* of body weight) and heat acclimation on rectal temperature during exercise-heat stress. **UA** is unacclimated and HA is heat acclimated.

Hypohydration impairs both *dry* and evaporative heat loss (or, if the air is warmer than the skin, dehydration aggravates *dry* heat gain) *(5).* Hypohydration delays sweating onset (9,11) and skin vasodilitation *(5).* It also reduces sweating sensitivity (10). Hypohydration maybe associated with either reduced (9,10) or unchanged sweating rates (4) at a given metabolic rate in the heat. The physiological mechanisms mediating the reduced *dry* and evaporative heat loss fiom hypohydration include both the separate and combined effects of plasma hyperosmolality and reduced blood volume (11).

EXERCISE-HEAT TOLERANCE

Few investigators have documented the effects of hypohydration on human tolerance to submaximal exercise in the heat. Adolph & associates (12) had subjects attempt endurance (2 to 23 hours) walks in the desert and either allowed them to drink water ad libitum or had them not drink. They reported that one of fifty-nine (2%) and eleven of seventy soldiers (16%) suffered exhaustion from heat strain when they did or did not drink, respectively. In subsequent experiments, they reported that one of fifty-nine subjects (2%) and fifteen of seventy subjects (21%) suffered exhaustion from heat strain during an attempted eight-hour desert walk when they did and did not drink, respectively.

Ladell (13) had subjects attempt 140-min walks in a hot climate while ingesting different combinations of salt and water. They reported that exhaustion from heat strain occurred in 9 of 12 *(75%)* experiments when receiving neither water or salt, and 3 of 41 *(7%)* experiments when receiving only water. Sawka and colleagues *(7)* had subjects attempt 140 min walks in a desert climate when euhydrated and when hypohydrated by 3%, *5%,* and 7% of their body weight. All eight subjects completed the euhydration and 3% hypohydration experiments, and seven subjects completed the *5%* hypohydration experiments, For the *7%* hypohydration experiments, six subjects discontinued after completing only (mean) 64 minutes.

To determine whether hypohydration alters heat strain tolerance, Sawka and colleagues (14) had subjects walk to exhaustion when either euhydrated or hypohydrated (8% of TBW). The experiments were designed so that the combined environment (T_a = 49° C, rh = 20%) and exercise intensity (47% $\dot{V}O_2max$) would not allow thermal equilibrium and heat exhaustion would eventually occur. Hypohydration reduced tolerance time (121 to 55 min), but more importantly, hypohydration reduced the core temperature that a person could tolerate. Heat exhaustion occurred at a core temperature –0.4° C lower when hypohydrated than when euhydrated. These findings suggest that hypohydration not only impairs exercise performance, but also reduces tolerance to heat strain.

CONCLUSION

Hypohydration increases heat strain, reduces heat tolerance and exercise performance and increases risk for heat injury. Hydration level is the most important factor influencing exercise-heat performance since hypohydration negates the thermoregulatory advantages of high physical fitness and heat acclimatization.

DISCLAIMER

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