



SPORTS SCIENCE EXCHANGE

THE OLDER ATHLETE: EXERCISE IN HOT ENVIRONMENTS

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Key Points

1. Epidemiological accounts of heat wave statistics and some laboratory studies have indicated that individuals over the age of 60 are less heat tolerant than younger individuals. It has also been suggested that older men and women are limited in their ability to exercise in hot conditions.
2. The above conclusions are not supported by research performed on older athletes. When healthy regular exercisers 55-70 years old are compared with young adults of similar aerobic fitness, acclimation state, body size, and body composition, both groups respond with similar rates of heat storage and similar body core temperatures during exercise in the heat. Likewise, older athletes and young adults are equally capable of acclimating to exercise in the heat.
3. Primarily because of age-related changes in control of blood flow to the skin, there are subtle differences in the way older athletes and young adults respond to exercise in the heat.
4. While fluid consumption is important for people of all ages before, during, and after exercise in hot conditions, adequate fluid intake should be particularly emphasized for older exercisers.
5. Aerobic fitness, acclimation, and hydration state are far more important in determining successful ability to exercise in hot environments than is age.

INTRODUCTION

Aging is often associated with decreased physiologic function, including a decreased ability to regulate body temperature effectively during heat stress. Proponents of this belief point to epidemiological studies which consistently show a relationship between age and morbidity and mortality during climatic heat waves. Furthermore, many laboratory studies have demonstrated that older individuals respond to an imposed heat challenge with higher core temperatures and heart rates, lower sweating rates, and a greater loss of body fluid compared to younger individuals. What is not clear, however, is whether chronologic age *per se* causes poor heat tolerance or whether other factors which change concomitantly with advancing age play a larger role than age itself. A partial list of such factors is shown in Table 1.

Table 1. Selected variables that change with age and could affect heat tolerance independent of chronological age.

1. Decreased aerobic capacity (VO_2max) and associated variables
2. Sedentary lifestyle
3. Altered anthropometric characteristics and body composition (e.g., decreased lean body mass)
4. Chronic hypohydration resulting from reduced fluid intake and/or increased fluid excretion by the kidneys
5. Increased prevalence of chronic diseases (hypertension, diabetes, heart disease, etc.)
6. Increased use of prescription medications (diuretics, adrenergic blockers, vasodilators, anticholinergics, etc.)

When dealing with exercise and heat tolerance in older individuals, it is important to understand clearly the questions being posed. Whether the "average" 65-year-old is at greater risk of heat illness during sustained activity than the "average" 25-year-old is a distinctly different question than "Is the fit, healthy, older athlete at greater risk of heat illness than an average 25-year-old?" This latter question relates directly to a basic physiological question, "Are there inevitable or irreversible age-related changes that diminish heat tolerance?"

EXPERIMENTAL APPROACHES

Approach one — There are no comprehensive longitudinal studies of aging and heat tolerance. Our limited understanding of this topic comes from 1) a few notable longitudinal case study reports (Robinson et al., 1965), 2) cross-sectional comparisons of older and younger subjects selected randomly or selected as “representative” of their respective age groups, and 3) cross-sectional comparisons that attempt to match older and younger subject groups in various ways. While the first approach provides a glimpse of true aging changes, the low subject numbers (one to a few) limit the generalizability of the results. The second and third approaches — true cross-sectional comparisons — also have merit, but each asks a distinctly different question.

The second approach typically attempts to answer the question, “Do average older and younger adults respond differently when exposed to heat stress?” The advantage of this approach is that results are more applicable to the general population, e.g., for making policy decisions. The disadvantage is trying to delineate true age-related changes from those more closely related to the variables in Table 1. For example, if a lower sweating rate occurs in older persons during a particular study, is that reduced sweating due to aging, or does it reflect a lower aerobic fitness in the older subjects? This approach is further flawed when exercise is introduced, because it is different for older and younger subjects who differ in $\dot{V}O_{2\max}$ to exercise at similar intensities.

Approach three — matching groups of older and younger subjects with respect to as many characteristics as possible — comes closer to answering the question of whether age per se alters the physiological response to heat stress. Perhaps more importantly for the purposes of this review, it also yields data specific to the subgroup of healthy older adults who are highly fit, and who exercise on a regular basis. We have used such a cross-sectional approach over the past several years and continue to study various aspects of human temperature regulation in our subjects during passive (rest) and active (exercise) heat exposures (Havenith et al., 1992; Kenney et al., 1990, 1991; Kenney & Havenith 1991). In this series of studies we recruited healthy men and women aged 55–70 who regularly engaged in aerobic exercise, some at an elite competitive level. These men and women were medically screened for overt disease and did not take prescription medications that would influence the responses

we were measuring. We also recruited young (20–30 year-old) subjects with similar physiologic characteristics, most notably $\dot{V}O_{2\max}$, body size, and adiposity. Careful attention was paid to equalizing hydration and acclimation status. When subjects are matched in this way, exercising subjects can generate similar absolute metabolic heat production (a function of absolute $\dot{V}O_2$) while also exercising at a similar % $\dot{V}O_{2\max}$. The underlying hypothesis of this approach is as follows: if the healthiest and fittest members of the “older” population exhibit responses significantly different from their matched younger counterparts, such differences can be attributed to chronologic age. The results from such studies are applicable only to this select subgroup of older athletes.

HEAT LOSS RESPONSES DURING EXERCISE IN WARM ENVIRONMENTS

Skin Blood Flow. When aerobic exercise is performed, a large amount of metabolic heat is produced by the contracting muscles. In fact, less than 25% of all the energy produced by the contracting muscles is used to produce work, with the remaining 75% appearing as heat in the muscles. Were it not for the well-developed ability of humans to dissipate this heat load, exercise could be sustained for only a short period of time. The two basic mechanisms by which humans eliminate the excess heat of exercise are by 1) dramatically increasing skin blood flow (SkBF) and 2) producing (and subsequently evaporating) sweat. The former allows heat to be moved (by convection) from the body core to the skin, whereas the latter provides the major avenue for dissipation of that heat to the environment.

In several studies (Kenney, 1988; Kenney et al., 1990, 1991; Kenney & Anderson, 1988; Kenney & Havenith 1991) using various methods to estimate SkBF, we have consistently observed a significantly lower (25–40%) SkBF in older athletes. The most likely reason for the reduced flow appears to be structural changes within the cutaneous vessels; these changes attenuate active vasodilation. Put in simple terms, maintaining a high degree of fitness does not prevent the skin from aging. While it is difficult to test this hypothesis directly, we have ruled out several other possibilities, including sympathetic nervous system influences and hydration effects (Kenney et al., 1990; Kenney & Havenith 1991).

Sweating Responses. Much attention has been paid to the question of whether

older men and women sweat less than younger individuals, yet studies have yielded decidedly contradictory answers (Drinkwater & Horvath, 1983; Lind et al., 1970; Pandolf et al., 1988; Robinson et al., 1965; Smolander et al., 1990; Wagner et al., 1972). This controversy has developed largely because of the study design issues raised above, i.e., $\dot{V}O_{2\max}$, acclimation, and hydration all have profound effects on sweating rate. For a given pharmacologic stimulus (e.g., injecting a sweat-inducing substance into the skin), heat-acclimated athletes over the age of 60 activate the same number of sweat glands in a given skin area as do young adults, but each gland has a significantly lower sweat output (Kenney & Fowler, 1988). However, whether or not older athletes will sweat less during exercise in a specific hot environment is less clear and depends on several factors, including environmental conditions and exercise intensity (Kenney & Hodgson, 1987). Genetics plays a large role in determining sweating rate, and wide interindividual variability exists in the sweating responses of older athletes. While most older subjects have lower sweating rates than do their fitness-matched young counterparts, a few of our older subjects have exhibited very high sweating rates. Those with a diminished maximal ability to sweat will manifest that deficit more commonly in hot, dry environments (Kenney & Hodgson, 1987).

CAN OLDER ATHLETES IMPROVE HEAT LOSS RESPONSES?

Since healthy, fit middle-aged and older men and women exhibit a diminished SkBF response during heat stress, the question arises as to whether the older athlete can improve his or her thermoregulatory responses. In younger people, for example, aerobic training and heat acclimation increase both sweating rate and SkBF at a given core temperature (Nadel et al., 1974; Roberts et al., 1977). Unfortunately, few training and/or acclimation studies have been conducted on older subjects, with fewer yet reporting changes in thermoregulatory function.

Training. Tankersley et al., (1991) divided a group of older subjects into two distinct groups— seven athletes who regularly engaged in distance running (HO) and six healthy but less-active older men (NO). Seven “normally fit” young (Y) men with $\dot{V}O_{2\max}$ values similar to those of the HO group and exercise habits similar to those of the NO group also were tested. Each subject performed a 20-min exercise bout in a warm environment, with sweating responses and SkBF measured. SkBF and chest

sweating rate at a given core temperature were always highest in the young men and lowest in the NO group; the HO group was intermediate. The HO group, either through rigorous training or via genetic predisposition, showed less of an age-related decline in SkBF and sweating rate than did the NO group. Similar results have been reported for pharmacologically-induced sweating on the forearm (Buono et al., 1991). These investigators reported that "...participation in lifelong aerobic exercise may retard the decrease of peripheral sweat production usually associated with aging. Further work is needed, however, to determine if such changes can improve overall thermoregulatory function in elderly people". Cross-sectional comparisons are useful, but they cannot distinguish between exercise training effects and genetically-endowed attributes. This research question deserves further attention.

Heat Acclimation. Perhaps nowhere is the interaction between age and fitness more evident than in studies of heat acclimation. Because both daily (or frequent) exercise and warm ambient temperatures are integral components of heat acclimation, it is almost impossible to separate training effects from those specific to acclimation. The beneficial effects of heat acclimation on heat tolerance and athletic performance are well known — lower core temperatures and heart rates, higher sweating rates, an expanded blood volume, and production of a more dilute sweat. Research clearly supports the hypothesis that older athletes are capable of acclimating to the heat. Sid Robinson and his colleagues (1965) reported that a group of four fit men were able to acclimate to exercise in a hot climate "about as well" as they had 21 years earlier. Pandolf et al., (1988) heat acclimated a group of middle-aged (46 ± 5 y) exercisers, and matched them closely for VO_2max with a group of 20-year-olds. Because the older men were regular exercisers (averaging 24 miles per week compared to five miles per week for the young men), they actually performed better during the first 2-3 heat exposures. Over the next 7-8 days, there were no age-related differences, except for lower heart rates in the trained middle-aged group.

HEAT STORAGE AND CHANGES IN CORE TEMPERATURE

Despite the existence of nonthermal factors (including such influences as age and fitness) that influence control of SkBF, Nadel (1986) suggested that these influences have relatively little importance to body temperature regulation during exer-

cise. For example, when exercise is performed in a hypohydrated state, body core temperature increases to a greater extent; therefore, the core-to-skin temperature gradient increases. Because overall core-to-skin heat transfer is a product of SkBF, the core-to-skin gradient, and the specific heat of the blood, lower SkBF is offset by the larger thermal gradient. In hypovolemic subjects, a 30% lower SkBF creates a difference in heat transfer of less than 10%.

Therefore, it is interesting to note that a relatively lower SkBF in healthy older athletes (when compared to young adults) likewise does not typically translate into greater heat storage or poorer heat tolerance. Rather, because the maintenance of lower mean skin temperatures by the older subjects increases the core-to-skin thermal gradient, their rates of convective heat transfer from core-to-skin are similar to those of young adults (Kenney et al., 1991). Smolander et al., (1990) reported similar findings. The point raised by this observation is that older athletes are able to thermoregulate adequately, albeit via slightly different mechanisms, during exercise in warm environments. However, the costs of maintaining a high VO_2 , a high level of hydration, etc., may be decidedly greater in older people.

Another way to examine this issue is to test a large sample of individuals of widely varied age, VO_2max , body size, fitness, etc., in a standardized exercise/heat challenge. Using multiple regression analyses, the relative influence of each of these individual characteristics in determining the thermoregulatory response can be assessed. We recently tested a group of individuals in a standard protocol utilizing a warm, humid (35°C , 80% rh) environment. These subjects will serve as a longitudinal data base for future testing. A preliminary analysis of data from a sample of 56 individuals ranging in age from 20-73 years revealed that once VO_2max had been factored out of the equation, there was no significant effect of age on heat storage or body core temperature (Havenith et al., 1992).

HYDRATION AND BODY FLUIDS

Some have suggested that aging is accompanied by reduced thirst and increased excretion of water by the kidney, which ultimately lead to a state of hyperosmolar hypohydration (Phillips et al., 1984; Rolls & Phillips, 1990). Independently or combined, hypovolemia (low blood volume) and hypertonicity (high serum osmolality) can lead to reduced heat tolerance. When "average fit" older (60's) and

younger (20's) men were systematically dehydrated during heat exposure for three hours, the older men reduced their blood volume and increased their plasma osmolality to a greater extent, even though their weight loss was similar to that of the younger men (Meischer & Fortney, 1989). Perhaps more importantly, the older men rated themselves as less thirsty. Our studies have shown a similar inability in older male and female athletes to maintain plasma volume during a thermal challenge (Kenney et al., 1990; Kenney & Anderson, 1988). Because maintenance of plasma volume during exercise affects performance, it seems wise to pay close attention to hydration issues when advising older athletes.

SUMMARY

Physiological effector responses (e.g., SkBF and sweat gland output) to thermal stimuli typically diminish with advancing age, a result probably attributable to the inevitability of age-related changes in the skin. However, criterion measures of heat tolerance (changes in core temperature and heat storage) often show minimal age-related alterations if healthy men and women maintain a high degree of aerobic fitness. From numerous studies over the past five years, the following conclusions can be drawn: 1) even when homogenous groups of older athletes are compared with younger individuals of the same gender, size, body composition, VO_2max , acclimation state, and hydration level, some age-related differences in sweating and SkBF responses exist; 2) these differences typically do not translate into "poorer" heat tolerance during exercise; older athletes can tolerate and acclimate to heat stress; and 3) there is an increased degree of variability in thermoregulatory responses with increasing age. The ability to exercise in hot climates is less a function of chronological age than of functional capacity (especially VO_2max and associated variables) and physiological health status. Implicit in this conclusion is the notion that thermal tolerance, at any age, is a modifiable individual characteristic.

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TIPS FOR THE OLDER ATHLETE

More and more senior-level athletes are competing in aerobic activities, some of which are held in hot climates or during periods of hot weather. Additionally, many men and women over the age of 60 have become regular exercisers, taking up (or continuing to engage in) running, cycling, and even triathlons. While the notion still exists that older individuals do not tolerate heat stress as well as when they were young, that conclusion is not supported by research performed on older athletes. When healthy regular exercisers 55-70 years old are compared with young adults of similar VO_2max , acclimation state, and body size and composition, they respond with similar rates of heat storage and similar body core temperatures during exercise in the heat, and they are equally capable of acclimating to exercise in the heat. Aerobic fitness, acclimation, and hydration state are far more important in determining successful ability to exercise in hot environments than is age. However, there are subtle age-related differences in the control of blood flow to the skin and in body fluid balance during exercise in the heat. While fluid consumption is important for people of all ages before, during, and after exercise in hot conditions, adequate fluid intake should be particularly emphasized for older exercisers.

Tips for the Older Athlete

1. **Acclimate.** Most heat-related illnesses occur during the first few exercise sessions in the heat. On the first hot days, shorten exercise duration in half and use your normal target heart rate as a guide to intensity.
2. **Hydrate.** Pay attention to fluid intake when exercising in hot weather. Drink as much fluid as tolerable 30 to 45 minutes prior to exercise, and a cupful every 15 minutes during exercise if possible. After exercise, drink more than the amount of fluid that quenches thirst by continuing to drink periodically over the subsequent 2 h. Eat meals high in water content (fruits and vegetables). To best restore the sodium, as well as the water, lost during exercise in the heat, a sports drink is recommended for rehydration.
3. **Use common sense.** If one is concerned that it may be too hot to exercise at a certain time of day, it probably is. Exercise early in the morning or late in the evening, or choose an alternative exercise mode, such as swimming, on that day.
4. **Maintain a high fitness level.** The best single predictor of heat intolerance in older individuals exercising at a given pace is maximal aerobic capacity (VO_2max). Those with a low VO_2max are often heat intolerant.
5. **Learn about exercise in the heat.** Learn the signs and symptoms of heat exhaustion and heat stroke and learn emergency treatments for heat illness (see box).
6. **Pay attention to changes in health status or use of prescription drugs.** Many illnesses or diseases (diabetes, hypertension, etc.) can lower the ability to exercise in the heat. Also, prescription medications can often profoundly affect thermoregulation in hot environments. Before exercising, ask a physician about the effects of any newly prescribed medications and whether exercise is appropriate for your current health status.

	Heat Exhaustion	Heat Stroke
Cause	primarily dehydration (less often salt depletion)	sudden failure of thermoregulatory system
Symptoms	chills, light-headedness, dizziness, headache, nausea	similar to heat exhaustion but progressing to neurological impairment (disorientation, loss of consciousness, seizures)
Body Temperature	typically 100-102°F	>104-105°F
Sweating	profuse	often absent, but skin may still be wet from earlier sweating
Treatment	<ul style="list-style-type: none">• get to shaded cool area• administer fluids (orally if conscious, otherwise intravenously.	<ul style="list-style-type: none">• immediate cooling by whatever means are available• always get rapid medical care