Fluid balance of elderly people in hot environments

The control of fluid balance in elderly people has an important influence on morbidity and mortality in high environmental temperatures. Body-fluid regulation in heat is critically affected by age-related changes in the function of sweat glands and the kidneys, and in the sensation of thirst. Different problems arise in younger active elderly people compared with older sedentary individuals or those with comorbidity. We discuss water-deficiency and salt-deficiency heat exhaustion disorders together with the assessment and management of heat-induced dehydration.

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Experience with the effects of urban heat-waves on mortality over the past 40 years has confirmed that elderly people are among the most vulnerable. The increased risk is due not only to greater frailty and disease load in older people, but also to reduced efficiency of adaptive processes such as control of fluid balance.

In anticipation of the future threat of more severe and lengthy heat-waves, greater consideration needs to be given to the causes of morbidity in hot conditions and the management of elderly patients both in the community and in hospital. Recent reports suggest that poor standards of practice and training exist in the management of fluid and electrolyte balance, particularly for elderly patients.[1]

Ageing and fluid balance

Increasing age results in a decline in lean body mass; the percentage of water in the body of an elderly person is lower than that of a young adult; and the decrease in intracellular volume is more marked than is extracellular volume (figure). The loss of 1 litre of water, for example by sweating, will therefore be a proportionally greater strain for elderly people.

No marked trends are seen for serum levels of sodium, chloride, or bicarbonate with age in normal healthy individuals, although elderly patients in hospital tend to show somewhat lower levels of sodium compared with age-matched controls.[2] Apart from overall modulation by cardiovascular, neural, and endocrine systems, regulation of body fluids under heat stress is particularly affected by age-related changes in the function of the kidneys and sweat glands and in the sensation of thirst.

Renal regulation of homeostasis

Many anatomical and functional changes that affect homeostasis occur in the ageing kidney. Both intrinsic and extrarenal control mechanisms are implicated. Renal mass is lost, mainly due to progressive atrophy of the renal cortex and also a decrease in renal blood flow. An almost linear decline in glomerular filtration rate occuring with age in most healthy people is well documented. Elderly people are more sensitive to water depletion or repletion than are young adults.

Human antidiuretic hormone plays a crucial role in regulating water balance, and the arginine vasopressin response to osmotic stress (ie, dehydration) is usually enhanced in older people. However, the renal response to arginine vasopressin is impaired even in healthy elderly individuals through attenuation of renal tubular activity.

Older people are also less responsive in the renin-angiotensin-aldosterone axis and have reduced plasma renin and aldosterone activity, which predisposes them to natriuresis and salt depletion. The decline in renal function with age also indicates that older people are less able to excrete a salt load or to adjust to salt deficiency.

Even in the absence of renal disease, older people are at increased risk of hyperkalaemia because of reduced renal function[3] and a blunted ability of the aged kidney to correct an acid load. Hyperkalaemia may occur with pre-renal failure in dehydrated frail elderly individuals.

Effect of sweating on fluid balance

To most investigators, the overriding fact concerning human thermogenic sweat composition is that it is hypotonic to plasma. Sodium chloride is the main constituent accounting for about 90% of the osmotic activity and present at 1–4 g/l, with higher values associated with increased sweating. Many factors modify the salt concentration of sweat. Some of the variation is accounted for by differences in dietary salt intake.

The process of heat acclimatisation is generally accompanied by a reduction in the concentration of salt in the sweat starting after 1 or 2 days of significant sweating. In effect, even allowing for increased sweating, this adaptation eventually reduces the need for major salt supplementation in acclimatised people. However, total salt loss from sweating can be large, and with physical activity in environmental heat in unacclimatised individuals, it may exceed renal loss and lead to a negative salt balance.

No uniform trend in sweat sodium or chloride concentration is seen from 20 to 70 years of age. Active elderly people and those who exercise regularly are capable of secreting significant amounts, thus influencing fluid balance. Sedentary elderly people sweat much less than younger adults or active seniors in the heat because of a marked atrophy of the sweat glands and reduced peripheral neurohumoral control.[4] Diminished sweating capacity is an important component of thermoregulatory failure in old age, which is compounded by impaired vasodilatation.

Thirst sensation

Older adults living independently in the community normally drink adequate volumes of fluid on a daily basis. But with the challenge of fluid deprivation or exercise in a hot climate, healthy elderly people show a reduced sensation of thirst. Complete fluid balance is attained eventually, but full restoration is slowed. With the ageing process, control systems associated with thirst and satiety are attenuated. One determinant of the drinking response and a strong stimulus of thirst is the endogenous level of angiotensin II. A separate central renin-angiotensin axis might independently modulate thirst and vasopressin release.[5] Healthy elderly people are less responsive to angiotensin II, and on average plasma angiotensin-II concentrations fall moderately with increasing age. Other evidence suggests that older men and women have a higher osmotic operating point for thirst sensation and a diminished response to unloading of baroreceptors by hypovolaemia.[6] Whatever the underlying effects of ageing, clearly many elderly patients do not possess a normal thirst sensation and are consequently at higher risk of dehydration.

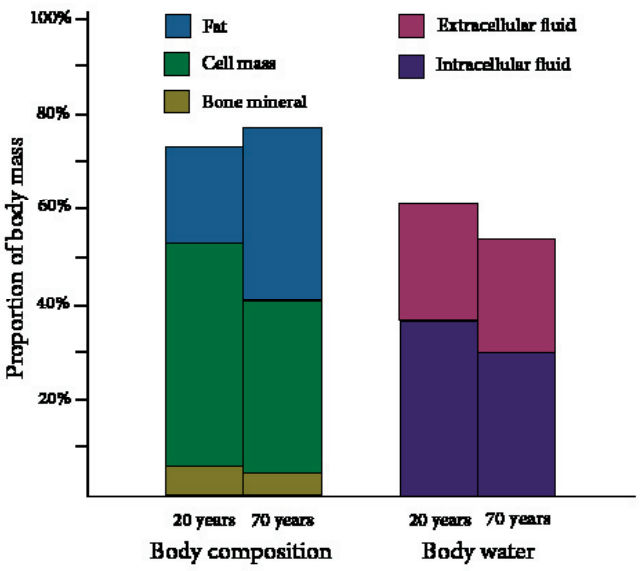

Figure: Change in body composition and location of body water in young and old healthy male adults

Water and electrolyte balance

Water-deficiency and salt-deficiency heat exhaustion are serious disorders often associated with high levels of physical activity in young adults, and can be a precursor to heat-stroke.[7] Elderly people are less likely to work to exhaustion in hot temperatures, but the two disorders are often recognised in elderly casualties of heat. The table shows the main clinical differences between the two conditions; although the two may sometimes coexist.

Classic symptoms of water depletion include intense thirst, fatigue, and giddiness—and in salt depletion include fatigue, nausea, vomiting, giddiness, and muscle cramps. Precise diagnosis is predominantly by laboratory testing, with important support from clinical observations. In elderly patients, the reduced efficiency of the kidneys,

sweating, and thirst mechanisms may further obscure the differential diagnosis.

Fluid replacement in water deficiency requires encouragement to regularly take cool and flavoured drinks. If you have serious doubts about whether the patient is primarily water or salt depleted, using isotonic saline when starting parenteral treatment is best. Otherwise, the intravenous fluid of choice is 5% glucose. For patients with salt depletion, salted drinks in a strict dosage should be given up to a concentration of 0·5% salt in flavoured fluids. For salt depleted patients who are comatose or vomiting or who refuse to drink, intravenous isotonic saline is the fluid of choice.

Active elders

Active elderly people of 60–70 years may show little cardiovascular or thermoregulatory differences from younger adults (20–30 years) during exercise and heat stress. Some subtle differences in body fluid balance have, however, been observed. For example, plasma volume appears to be preserved during exercise dehydration in heat in older men at the expense of losing more fluid from the intracellular space and less from interstitial space. An inverse relationship exists between sodium concentration in sweat and the volume of fluid mobilised from intracellular fluid and in older men the sodium concentration of sweat is less than in younger individuals.[8] These findings have been confirmed in similar studies by other authors.[9]

Sedentary elderly

Elderly people who are isolated in their homes need particular care and attention in heat-wave conditions, especially if cooling facilities are poor. Although sweat losses may be comparatively small, insensible cutaneous water loss will increase as skin temperature rises. Total insensible water loss from the skin together with respiratory loss can then exceed 2 l/day even in the absence of sweating.

Infirmity and immobility may deny access to fluid, which, combined with impairment of the kidney to conserve water and lack of thirst sensation will contribute to dehydration. The situation is similar to absolute water lack associated with acute febrile illness, which is one of the most common causes of hypernatraemia in elderly patients. Haemoconcentration with falling plasma volume can lead to oligaemic shock, and failure of thermoregulation can lead to heat-stroke. Increased episodes of hyperviscosity and thrombosis are seen in susceptible elderly people exposed to heat.[10]

Duration of a heat-wave rather than its intensity increases hospital admissions for disorders of fluid and electrolyte balance, acute renal failure and heat stroke, as well as respiratory disease.[11] Similarly during the 1995 heat-wave in Chicago, increased admissions were recorded as being mainly due to dehydration, heat-stroke, heat exhaustion, and acute renal failure.[12] Many of the older patients who succumbed to heat-waves in Europe in 2003[13] and in California in 2006[14] were described as dehydrated, hypernatraemic, and hyperkalaemic with evidence of renal failure.

Comorbidity

Medical conditions that reduce cardiac and renal reserve obviously affect the capacity of elderly people to respond adequately to heat stress. Chronic renal failure due to hypertension, diabetes mellitus, nephrosclerosis, or obstruction is common in older people and they have a greater critical water and electrolyte balance and a tendency to develop cardiac failure. An examination of susceptibility to

	Predominant salt depletion	Predominant water depletion
Thirst	Not prominent	Prominent
Fatigue	Marked	Less marked
Giddiness	Prominent	Less prominent
Muscle cramps	In most cases	Absent
Vomiting	In most cases	Usually absent
Thermal sweating	Usually unchanged	Diminished
Haemoconcentration	Early and marked	Slight until late
Urine concentration	Moderate	Pronounced
Urine sodium	Below average	Above average
Mode of death	Oligaemic shock	Oligaemic shock Heat stroke

Table: Distinguishing features of water-depletion and salt-depletion heat exhaustion

temperature extremes in people with chronic illnesses has identified those with diabetes mellitus as being most at risk on very hot days.[15] An association with impairment of autonomic nervous control has been suggested as an explanation.

Many drugs can interfere with the ability to excrete free water. In most instances this action is excessive retention of ingested or infused free water. A high incidence of adverse drug effects on fluid balance in older people living in the community has been recorded,[16] emphasising the potential morbidity associated with any type of diuretic.

Dehydration

Dehydration is the most common fluid and electrolyte imbalance in older adults and it is naturally much more frequent in hot conditions. Three categories are usually identified:

1. Isotonic dehydration involving a balanced loss of solutes and water (eg, during complete fasting, vomiting, or diarrhoea);
2. Hypotonic dehydration in which sodium is lost at a greater rate than water resulting in a serum sodium concentration less than 135 mmol/l (eg, water overloading);
3. Hypertonic dehydration in which water losses exceed those of sodium, usually diagnosed by a serum sodium concentration greater than 145 mmol/l (eg, excessive loss of water during fever, decreased water intake). Sweating promotes hypernatraemia because sweat is essentially an hypotonic salt solution. Hypernatraemic dehydration is the most probable form of dehydration associated with elderly people in hot conditions.

Assessment

No simple symptom or sign of dehydration can be regarded as pathognomonic. Axillary skin moisture is sometimes used as an initial test but in comparison with biochemical measurement it is only 50% reliable. The axillary area has both eccrine and apocrine glands, which are thermally and mentally activated. Intraocular pressure measured by tonometer is similarly not well correlated with serum osmolarity.

The most useful clinical signs appear to include dry mouth and tongue, sunken eyes, dry mucous membranes, upper body muscle weakness, difficulty with speech, and confusion.[17] In elderly patients these are, of course, common presentations for many other conditions. Thirst is the main symptom in water deficiency, less so in salt deficiency, but as discussed above it is often diminished in elderly individuals.

Measurement of fluid balance by fluid charts is a primary requirement. The recommended daily intake of fluid is commonly set at 1600 ml for 70 kg bodyweight in 24 hours. In dehydrated patients the volume of urine is low and the urine is concentrated. Biochemical assessment is made by blood urea nitrogen: creatinine ratio, serum sodium concentration, and haematocrit.

Management

In non-ambulatory nursing home residents, the presentation of fluids directly into the hands of residents every 1·5 hours throughout the day significantly improves hydration. Semi-independent residents are often more at risk than immobile ones, who probably have more regular attention. Special care must be taken during fluid treatment of the elderly not to allow underhydration or overhy-

dration to occur. Elderly patients with dehydration account for a substantial number of acute hospital admissions for intravenous fluid therapy. Subcutaneous fluid infusion is a safe alternative for rehydration and maintenance.[18] Salt supplementation would normally be required in physically active older people in hot situations but usually not in sedentary individuals.

General advice on cooling, fluid intake, and other measures required to help prevent heat-related dehydration and illness in heat-waves has been issued by the Department of Health.[19] Additionally, heat-health warning systems are now coming into use to link public-health actions to meteorological forecasts of dangerous weather.[20] The care of elderly people at home and of vulnerable people in institutions remain key areas of concern in reducing morbidity and mortality in excessive environmental heat.

Conclusions

Environmentally associated morbidity and mortality in heat waves or prolonged hot conditions are most pronounced in the elderly population. Deficiency in maintaining fluid balance is an important underlying cause. The extent of mortality in heat-waves in older people has been well documented but less is known of the characteristics of morbidity. Hypernatraemic dehydration has frequently been observed in mortality studies.

Three categories of elderly people need to be considered: younger active people who may be fit enough to incur excess water and electrolyte losses during exercise in the heat, sedentary elderly individuals who through lack of adaptive sweating capacity rely on vasodilatation to dissipate heat, and those with significant morbidity such as cardiac or renal failure who require special treatment. Preventive measures targeting those at risk need to be implemented before the occurrence of predicted heat waves.

Ensuring appropriate fluid intake and reducing insensible fluid loss by behavioural and mechanical cooling procedures are key to maintenance of adequate fluid balance. Adjustments also need to be made in the dosage of medications such as diuretics. Alerting primary health-care services, health visitors, and carers to the dangers of hot environments will help to diminish casualties in temperature extremes.

I have no conflict of interest.

Key points

- Body fluid homeostasis in elderly people in hot conditions is affected by a decline in the efficiency of renal regulation, sweating function, and the sensation of thirst.
- Water-deficiency and salt-deficiency heat exhaustion are disorders that lead to oligaemia and heat stroke in the elderly.
- These syndromes often derive from physical activity in hot conditions; active younger elderly may incur either or both, sedentary older persons are more likely to suffer from water deficiency.
- Patients with cardiac, renal, or metabolic comorbidity are at greatest risk in the heat.
- More training in the assessment and management of fluid balance in elderly people in hot climates is needed to improve outcomes.

References

1. Allison SP, Lobo DN. Fluid and electrolytes in the elderly. *Curr Opin Clin Nutr Metab Care* 2004; **7**: 27–33
2. Lye M. Disturbances of homeostasis. In: Tallis RC, Fillit HM, Brocklehurst JC (Eds). Geriatric medicine and gerontology. 5th Edn. London: Churchill Livingstone, 1998: 925–48
3. Biswas K, Mulkerrin EC. Potassium homoeostasis in the elderly *Q J Med* 1997; **90**: 487–92
4. Abdel-Rahman TA, Collins KJ, Cowen T, Rustin M. Immunohistochemical, morphological and functional changes in the peripheral sudomotor neuro-effector system in elderly people. *J Auton Nerv Syst* 1992; **37**: 187–98
5. McKinley MJ, Johnson AK. The physiological regulation of thirst and fluid intake. *Physiology* 2004; **19**: 1–6
6. Kenney WL, Chiu P. Influence of age on thirst and fluid intake. *Med Sci Sports Exerc* 2001; **33**: 1524–32
7. Collins KJ. Heat stress and associated disorders. In: Cook GC, Zumla AL (Eds). Manson's tropical diseases. 22st edition. London: WB Saunders, 2009: 527–35
8. Morgan AL, Sinning WE, Weldy DL. Age effects on body fluid distribution during exercise in heat. *Aviat Space Environ Med* 2002; **73**: 750–57
9. Nose H, Mack GW, Shi X, Nadel ER. Shift in body fluid compartments after dehydration in humans. *J Appl Physiol* 1998; **65**: 318–24
10. Keatinge WR. Death in heat waves. *BMJ* 2003; **327**: 512–13
11. Mastrangelo G, Fedeli U, Visentin C et al. Pattern and determinants of hospitalization during heat waves : an ecological study. *BMC Public Health* 2007; **7**: 200
12. Semenza JC, McCullough JE, Flanders WD et al. Excess hospital admissions during the July 1995 heat wave in Chicago. *Amer J Prev Med* 1999; **16**: 269–77
13. Flynn A, McGreevy C, Mulkerrin EC. Why do older patients die in a heatwave? *Q J Med* 2005; **98**: 227–29
14. Knowlton K, Rotkin EM, King G, et al. The 2006 California heat wave: impacts on hospitalizations and emergency department visits. *Environ Health Perspect* 2009; **117**: 61–67
15. Schwartz J. Who is sensitive to extremes of temperature? A case-only analysis. *Epidemiology* 2005; **16**: 67–72
16. Gurwitz JH, Field TS, Harrold LR et al. Incidence and preventability of adverse drug events among older persons in the ambulatory setting. *JAMA* 2003; **289**: 1107–16
17. Hodgkinson B, Evans D, Wood J. Maintaining oral hydration in older adults: a systematic review. *Int J Nurs Prac* 2003; **9**: S19–S28
18. Dainty P, Elizabeth J. Subcutaneous fluids—a blast from the past or a rosy future? *Geriatr Med* 2009; **3**: 135–39
19. Department of Health. Heatwave plan for England—protecting health and reducing harm from extreme heat and heatwaves. London: Department of Health. 2005
20. Kovats RS, Ebi KL. Heatwaves and public health in Europe. *Eur J Pub Health* 2006; **16**: 592–99