

Physiological and behavioural responses to thermal stresses in tennis

Background: Tennis is played year-round throughout the world in a wide variety of weather conditions. Often players in the Australian Open, held in the middle of summer, are faced with air temperatures exceeding 40°C. The current Extreme Heat Policy used at the Australian Open postpones play at an absolute air temperature $\geq 35^\circ\text{C}$ and a Wet Bulb Globe Temperature $\geq 28^\circ\text{C}$. This is based on the American College of Sports Medicine's Exertional Heat Illness Policy for distance running. Therefore, this policy may be inappropriate for tennis where activity is interspersed with rest periods which reduce the overall exercise intensity. Furthermore, there has been no known scientific evaluation of this policy. However, a review of its applicability to tennis using the current information base is difficult since there is no objective information about the effects of environmental conditions on players' physiological responses, comfort and behaviour. Tennis players of all levels would benefit from objective and comprehensive information relating to how the thermal environment affects their health and safety, and comfort. Such information enables them to make decisions about whether they choose to play tennis on a given day, the duration and intensity at which they play, the required fluid replacement, strategies to manage thermal comfort (e.g. wetting the skin, moving to the shade or fanning), and tactical modifications. These decisions enable players to minimise the risk of developing heat illness, and maximise comfort in adverse weather conditions.

Research objectives: The aim of this thesis was to obtain comprehensive data on environmental and metabolic heat stress, and body temperature regulation during competitive singles tennis matches over each of the seasons in Sydney, Australia. These data were then be used to determine whether a steady-state core body temperature and thermal comfort are being achieved in tennis, in addition to the mechanisms responsible for their attainment (i.e. autonomic / physiological thermoregulation or behavioural / psychological thermoregulation?). These data were also used for the rational analysis of heat stress, which will enable prediction of all thermal exchanges and thus, tolerable environmental conditions for tennis. Finally, these data enabled an evaluation of the current Extreme Heat Policy and the suggestion of an alternative method for assessing heat stress in tennis (the Belding and Hatch Heat Stress Index).

Hypotheses: There is expected to be a range of environmental conditions (the prescriptive zone) in which thermoregulation is successful and body core temperature is maintained relative to the workload but independent of the environmental stress.

Whilst environmental conditions within the prescriptive zone enable the maintenance of body core temperature, skin temperature is hypothesized to rise with increasing ambient temperature up to approximately 36°C in order to maintain convective heat dissipation. Since the thermal gradient for convective heat loss is reduced as air temperature approaches skin temperature, with heat being gained when skin temperature exceeds air temperature, the evaporation of sweat becomes the major if not sole method of heat dissipation. Therefore, sweat rate would be expected to increase with ambient temperature in order to maintain thermal equilibrium. Whilst core body temperature is maintained within tolerable levels during the prescriptive zone, players may subjectively rate conditions within the prescriptive zone as intolerable due to thermal discomfort that results from high core and skin temperatures and/or skin wettedness. In more stressful environmental conditions, or when players are experiencing physiological or subjective strain, players are expected to modify their behaviour to reduce the workload and heat production. This would be indicated by a reduction in effective playing time, point duration and stroke frequency. Within the prescriptive zone, it is anticipated that thermoregulatory responses will agree with previously published studies including: metabolic heat production of approximately 680 W, heart rate of around 145 beats $\cdot\text{min}^{-1}$; body core (rectal) temperature of around 38.2°C; and sweat rate of approximately 0.93 L $\cdot\text{h}^{-1}$. When conditions exceed the prescriptive zone, core body temperature is expected to be higher in response to the greater heat load that results in thermal equilibrium being achieved at a higher core body temperature. However, it is unknown whether the thermal environment and exercise intensity will represent a stress level above the upper threshold of the prescriptive zone during the experimental tennis matches within this study.

Methods: In the laboratory, the maximum aerobic power ($\text{VO}_{2\text{max}}$) and body composition for each subject was assessed. Experimental tennis matches were completed by men and women of varying standards in a range of thermal environments. Each of the six thermal stresses (air temperature, humidity, solar radiation, air movement, clothing and metabolic heat production) were measured or predicted for each tennis match and player. A whirling psychrometer was used to measure dry bulb (air) temperature and wet bulb temperature (for humidity) at 20 minute intervals throughout each tennis match and player. Mean radiant temperature (for solar radiation) was assessed by a globe thermometer, which recorded globe temperature each minute throughout matches. Air movement was also logged each minute

