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Heat stress incidence and matchplay characteristics in women's Grand Slam tennis

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ABSTRACT

Objectives: To explore the relationship of wet bulb globe temperature (WBGT) on heat-related incidents and alterations in matchplay and behavioural characteristics in women's tennis at the Australian Open.
Design: From 360 main draw Australian Open women's matches (2014-2016), data describing on-court calls for trainers, doctors, cooling devices and water, post match medical consults and matchplay characteristics were collated.
Methods: Data were referenced against estimated WBGT and categorised into standard zones (zone 5: >32.3 °C, zone 4: 30.1–32.2 °C, zone 3: 27.9–30 °C, zone 2: 22.3–27.9 °C, zone 1: <22.2 °C). Generalized linear models assessed the association of WBGT zone on heat-related medical incidences, court call-outs and match characteristics.
Results: With an increased estimated WBGT zone, there was an increase in total trainer calls (+19.5%/zone; $p = 0.019$), total doctor calls (+54.1%; $p < 0.001$), total calls for heat related incidents (+55.9%; $p < 0.001$), and cooling devices (+31.4%; $p < 0.001$) calculated from the regression slope. When match characteristics were adjusted for match quality, significant decreases ($p < 0.001$) in the number of winners and net approaches and increase in double faults were associated with increased estimated WBGT zone.
Conclusions: An association between higher estimated WBGT and medical callouts (heat and non-heat related) was evident, with an increased call rate >32 °C WBGT, despite no heat-related retirements. As estimated WBGT increased, the number of winners and net approaches were reduced, while double faults increased, particularly >30 °C WBGT. Accordingly, the manner in which female players manage and play in the heat during women's Grand Slam tennis appears to change at ≈30 °C WBGT.

1. Introduction

As the Australian Open (AO) is played each year during the Southern Hemisphere summer, tennis matchplay during extreme heat (>35 °C dry bulb) and its potential implications for athlete wellbeing and performance is a constant source of discussion. This scrutiny exists against the backdrop of the American College of Sports Medicine (ACSM) stating that exercise in temperatures >28 °C Wet Bulb Globe Temperature (WBGT) places individuals at high risk for heat illness.[1] In turn, the Women's Tennis Association (WTA) introduced an extreme heat policy that allows players to receive a 10-min rest period between the second and third set (if a third set is to be played) in conditions >28 °C WBGT.[2] Notwithstanding the lack of publicly available evidence surrounding the effect of extreme heat on player wellbeing and performance in women's tennis, the logic was that this rest allows for core temperature reductions.[3] The AO has followed the WTA's lead, providing players with this choice prior to commencing the deciding set.

Heat illness is a multi-factorial occurrence, yet prolonged or high-intensity exercise in hot/humid environments is a significant contributor.[1] In professional women's tennis, the prevalence of heat illness remains poorly reported. Of the limited literature available, the 1994–2009 US Open reported a heat illness rate of 1.42 per 1000 match exposures in women, although no association with ambient temperature was found (26–33 °C).[4] Interestingly, reduced heat illness rates in women were evident compared to men (1.45 vs 2.45/1000 h)[4]; potentially due to the variation in their heat policy compared to the men's, as well as the shorter match durations, reduced number of sets and/or the more baseline oriented playing style of the female game.[5] Heat policy dictated rest

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periods may mitigate the rise in core temperature and reduce the risk of heat illness.[3] Though the gender-based policy difference may have some physiological basis as it has been suggested that women gain heat faster once the environmental temperature rises above that of the skin due to their larger skin surface area to body mass ratio.[6] However, it must be noted that these claims remain contentious owing to a lack of definitive supporting evidence.[6] Regardless, reported heat illness rates do not necessarily capture all player discomfort, which might otherwise be informed by the behavioural responses of players (i.e. cooling and water call outs). These changes in behavioural responses evident during exercise in the heat may also infer that increased core temperature >39.0 °C can affect cognitive function.[7] Hence, thermal comfort, decision making and tennis performance may become compromised.

From a performance perspective the impact of environmental conditions on the characteristics of professional women's tennis matchplay has not been examined. In men's tennis in the heat (33.6 ± 0.9 °C WBGT), an increase in rest periods (+9.6 ± 3.6 s) between points has been reported, while point length, number of points and games, aces and double faults were stable between hot and cool conditions.[8] This increase in rest may explain the maintenance of core temperatures (<40.0 °C) during matchplay even in extreme environmental conditions.[9,10] Further, such an adjustment could also explain the absence of reduced physical performance outcomes, i.e. speed and power, following matchplay in the heat.[11] However, as yet there is no comparable insight describing the effect of higher thermal stress on tennis matchplay characteristics in professional women's tennis.

This study aimed to retrospectively determine the effect of environmental conditions on heat-related trainer and doctor call outs, behavioural responses and match characteristics in women's Grand Slam tennis at the AO. It was hypothesised that with increasing WBGT there would be an increase in heat related medical consults, along with increases in water and cooling device call outs but with minimal changes to match characteristics.

2. Methods

Data were obtained from all 360 matches in the first four rounds of the 2014, 2015 and 2016 AO Women's Main Draw. The participants held a mean Women's Tennis Association rank of 67 ± 72, age 25 ± 4 and were from 45 different countries. Participant consent for the use of data for research purposes was gained upon tournament entry via tournament conditions of entry. Ethical approval was granted by the institutional Human Research Ethics Committee (UTS HREC REF NO. 2015000126).

Descriptive point level data and player rank information were collected from the AO tournament organisers (outlined in Supplementary Table 1). Data from match umpires and match coding professionals were combined to provide real-time point level data. The coding professionals were extensively trained and used a platform that is widely used in professional tennis and has high inter- and intra-tester reliability.[12] Weather data were retrospectively collated from half-hourly recordings from an Australian Bureau of Meteorology weather station located within 100 m of the venue. As this station did not record globe temperature, an estimated WBGT is provided by Australian Bureau of Meteorology, based on the formula;

$$\mathrm{WBGT} = 0.567 \times \mathrm{Ta} + 0.393 \times \mathrm{e} + 3.94,$$

where: Ta = dry bulb temperature (°C) and e = Water vapour pressure (hPa) [humidity].[13,14]

Whilst recognised as a limitation, this formula has previously been used to estimate WBGT without black globe temperature.[15–17] It is also acknowledged that WBGT is only one measure of thermal stress, and has limitations related to air movement, calibration and lack of adjustment for clothing type.[18] Regardless, it is currently the primary measure of heat stress at the AO and throughout international tennis, and as such is the most relevant measure for this study over multiple years and courts.[2]

Records of on-court calls for medical consults made by AO medical doctors and physiotherapists, as well as calls for cooling devices/water were gathered from time stamped tournament communication call logs. Post-match heat related consults were collated from the tournament's medical database, where consults were considered to be heat related if identified by the treating medical practitioner as the result of hot environmental loads or heat illness. Matches with large amounts of missing data were excluded from analyses (i.e., WBGT, on-court calls, or large amounts of match data; n = 12), as were matches suspended for rain or played under a closed roof (i.e., environmental conditions altered or unknown; n = 2). All data were collated into Microsoft Excel and classified into a WBGT zone according to the ASCM classification [1], zone 5: >32.3 °C, zone 4: 30.1–32.2 °C, zone 3: 27.9–30 °C, zone 2: 22.3–27.9 °C, zone 1: <22.2 °C (with ACSM's zones <10 and 10.1–22.2 °C being combined to form zone 1, and zones 22.3–25.6 °C and 25.7–27.8 °C being combined to form zone 2). Thus, a numerical increase in zone indicates a change from more temperate to extreme heat temperatures.

Analyses for the present study were completed in RStudio version 0.99.902 (RStudio: Integrated Development for R. RStudio, Inc., Boston, MA). The association of estimated WBGT zone and study outcomes were assessed through generalised linear models (GLM). Poission distributions were modelled with count outcomes, and continuous outcomes with a Gaussian distribution. Medical and behavioural outcomes were considered per match as well as per 1000 match h; the later rates being determined by dividing the number of medical and behavioural call outs per zone by the total duration of matches for each estimated WBGT zone and reported as rates per 1000 h. The risk of inconsistency in trends owing to rare events was measured with the average relative standard error, with continuity corrections for cases where no events were observed. Odds ratios were also calculated for the likelihood of medical or behavioural call occurring in each estimated WBGT zone compared to zone 5.

Recognising that player quality may influence matchplay outcomes, analysis of match performance was undertaken with (adjusted model) and without (unadjusted model) adjustments for player quality. In the adjusted analyses, players were considered of similar quality when pre-match Elo ratings were within 50 points.[19] Elo ratings are based on the strength of each player's career wins and have been proposed to provide a more accurate sense of player ability than traditional ranking systems.[19] Unadjusted analyses simply compared the performance outcomes of all matches in each zone. To limit the impact of different distributions of player quality, which can confound the assessment of the associations, adjusted analysis matched each player and opponent in an extreme group (5–3) to a moderate zone (1–2). Confidence intervals are reported at the 95% level and statistical significance was defined as an effect of 5% significance or less.

3. Results

With each increase in estimated WBGT zone, there was an increase in total trainer calls (+19.5%/zone; p = 0.019), total doctor calls (+54.1%; p < 0.001), total calls for heat related incidents (+55.9%; p < 0.001), post-match heat related consults (+68.3%; p = 0.010), and calls for cooling devices (+31.4%; p < 0.001). When medical and behavioural events were examined as a rate per 1000 h (Table 1), both heat related call outs and non-heat related call outs

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