HEAT STRESS AND TENNIS PERFORMANCE

– *Written by Julien D. Périard, Qatar*

Extremely hot conditions took over Rod Laver Arena and the rest of the tennis grounds in Melbourne Park during the 2014 Australian Open. After days of sweltering hot weather and temperatures reaching 43°C, play was suspended for several hours when organisers invoked the Extreme Heat Policy. The stoppage in play, however, occurred only after a plastic bottle had reportedly started melting on court, a ball boy and a male player fainted, a female player experienced cramping and vomiting, and several notable players expressed their concerns regarding the safety of continuing to compete in such conditions. Unfortunately, the sequence of events that played out on the international stage in Australia is mirrored worldwide each year in numerous lower-profile events, highlighting the challenges and consequences of competing under severe heat stress. In effect, the development of hyperthermia during exercise in the heat has been shown to impair endurance[1] and intermittent exercise performance (e.g. soccer)[2,3]. These performance impairments occur in conjunction with elevations in physiological and perceptual strain, relative to when exercise is performed in cooler conditions. During the development of hyperthermia, progressive dehydration can also occur if fluids are not sufficiently consumed, which can in turn exacerbate the rise in thermal strain.

Tennis is a high-intensity, long-duration intermittent activity[4] with work periods performed at 60 to 75% of maximal oxygen uptake interspersed with periods of light activity or rest[5]. The cumulative effect of these high-intensity repetitive efforts over several hours has a detrimental influence on performance through the development of fatigue[4,6]. This fatigue, described as a time-dependent exercise-induced decrement in the capacity to produce maximal force or power, has important implications for several performance aspects such as sprinting, jumping and force production. This brief review will examine the role of heat stress and hydration on match-play tennis performance and thermoregulation.

MATCH-PLAY TENNIS, HEAT STRESS AND THERMOREGULATION

The rise in body core temperature during exercise is mediated by relative intensity/workload and the prevailing environmental conditions. In conditions within the prescriptive zone – ambient temperatures in which deep body core temperature remains stable during exercise[7] – core temperature increases safely up to 38.3°C during match-play tennis[8–10]. This suggests that in temperate environments, both autonomic (e.g. sweating) and behavioural (e.g. adjustments in play and recovery) thermoregulation successfully regulate core temperature. However, in hot ambient conditions core temperatures above 39.5°C have been reported during play[8,11–13]. The development of this thermal strain, along with the concomitant increase in physiological and perceptual strain (Figures 1 and 2), is characterised by a

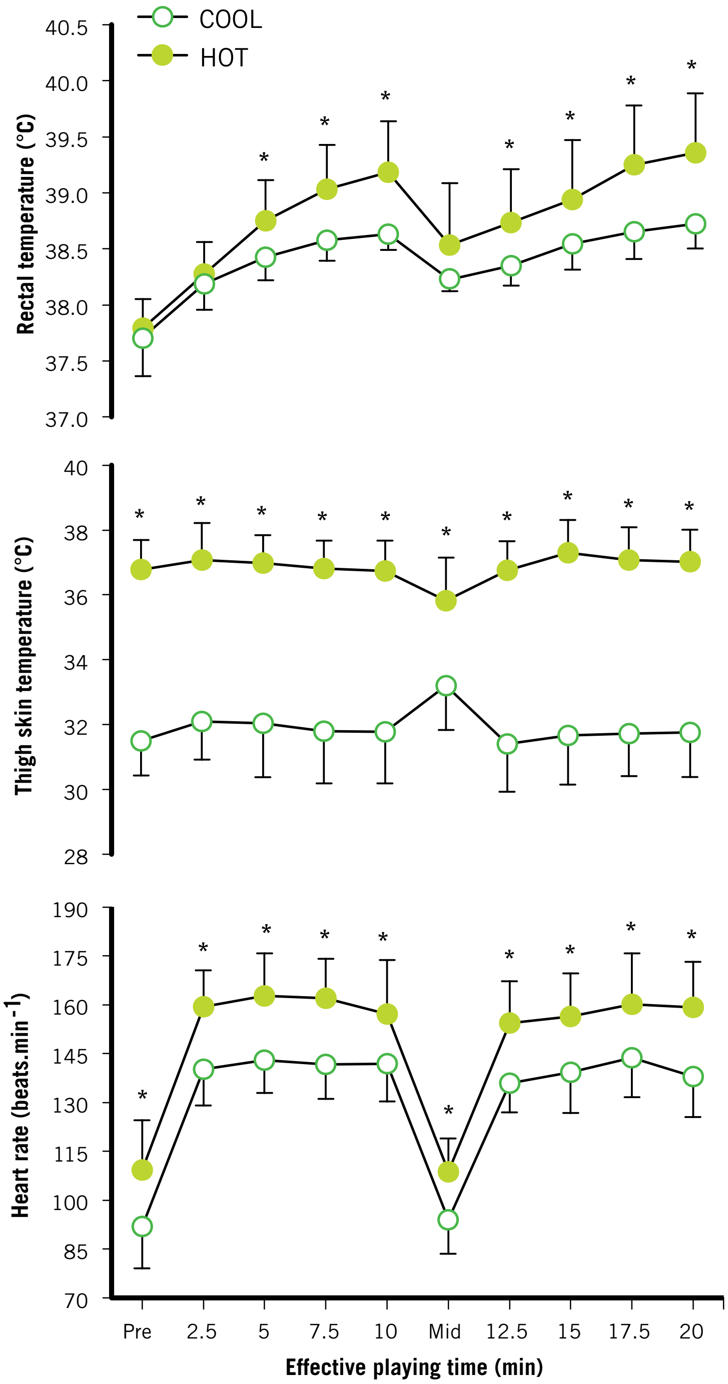

Figure 1: Rectal temperature, thigh skin temperature and heart rate during 20 minutes of effective match-play tennis (2 × 10 minutes) in COOL and HOT conditions. *Significantly different from COOL, $P < 0.05$. Reproduced with permission[13].

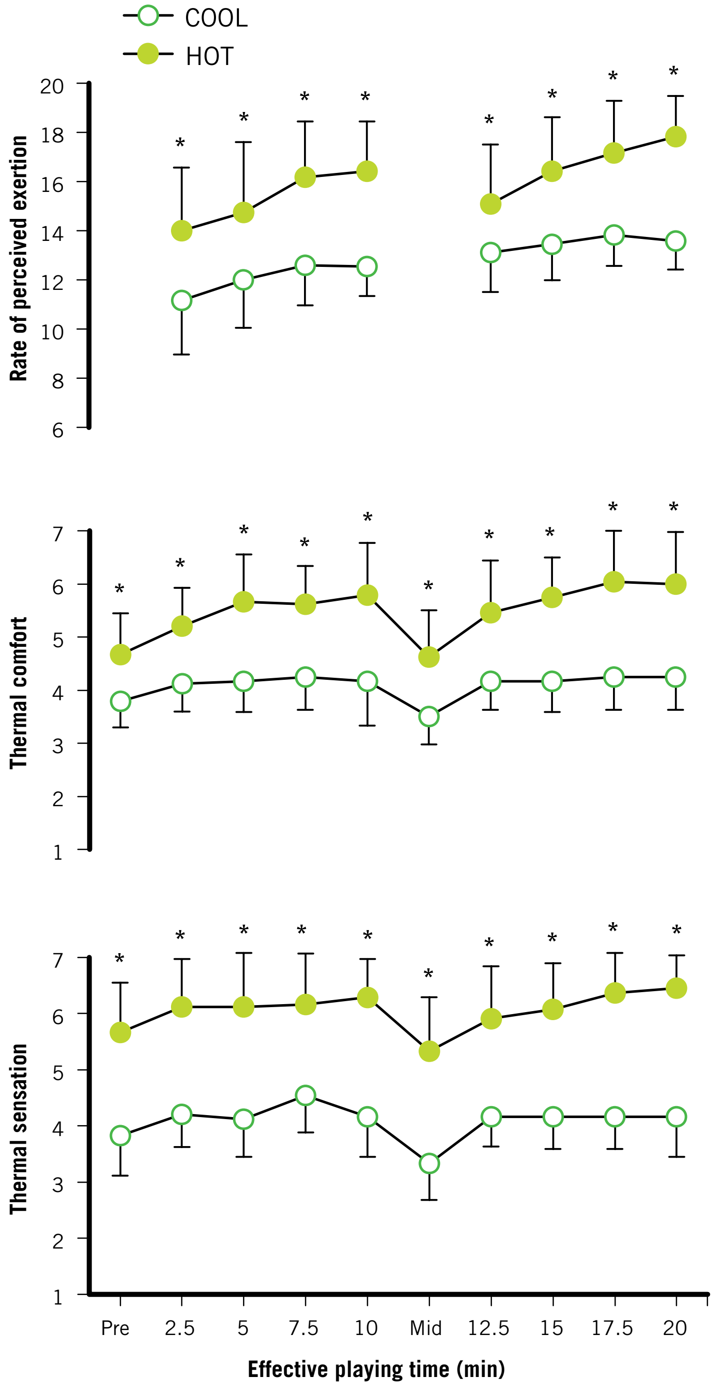

Figure 2: Ratings of perceived exertion (arbitrary units: 6 to 20), thermal comfort (arbitrary units: 1 to 7) and thermal sensation (arbitrary units: 1 to 7) during 20 minutes of effective match-play tennis (2 × 10 minutes) in COOL and HOT conditions. *Significantly different from COOL, $P < 0.01$. Reproduced with permission[13].

reduction in effective playing time[10,13], which is the percentage of total match time spent with the ball in play. This reduction stems from both a decrease in point duration[10] and/or an increase in time between points (e.g. Table 1)[13]. Accordingly, these adjustments in match-play characteristics in hot ambient conditions have been suggested to represent behavioural strategies adopted to minimise or offset the sensation of environmental conditions being rated as difficult. In essence, these adjustments allow players a certain measure of self-regulation with regard to the rate of heat production in environmental conditions that contribute to increased core temperature during exercise.

FATIGUE AND PERFORMANCE IN THE HEAT

Over the course of a tennis match, players repeatedly execute forceful lower-limb actions to produce explosive strokes and rapid on-court movements (e.g. accelerations, decelerations, multi-directional displacements). As the intensity and/or the duration of matches increase,

Table 1

Match characteristic	*Match condition*	*Effective playing time (min)* 0 - 10	10 - 20	*Match mean*
Point duration (s)	COOL	7.1 ± 1.7	6.6 ± 1.2	6.8 ± 1.4
	HOT	7.4 ± 0.8	7.5 ± 1.1	7.4 ± 0.5
Between point duration (s)	COOL	17.3 ± 4.0	18.6 ± 5.0	18.0 ± 4.2
	HOT	27.2 ± 4.2*	27.9 ± 4.0*	27.6 ± 2.8*
Effective playing (%)	COOL	20.9 ± 4.7	19.6 ± 3.5	20.3 ± 4.0
	HOT	17.1 ± 1.4*	16.7± 1.5*	16.9 ± 1.4*

**Significantly different from COOL, P <0.05. Reproduced with permission[13].*

Table 1: Point duration, time between points and effective playing percentage during 20 minutes of effective match-play tennis (2 × 10 minutes) in COOL and HOT conditions.

these movements lead to exercise-induced fatigue. Mechanisms both proximal (i.e. central fatigue) and distal (i.e. peripheral fatigue) to the neuromuscular junction modulate this fatigue, which can lead to alterations in performance. For example, Girard et al[4,6,14] reported that neuromuscular function deteriorated during prolonged (3 hours) match-play tennis in temperate conditions. More specifically, the authors noted that lower limb strength decreased during a maximal voluntary isometric contraction of both the knee extensors and plantar flexors following play, in association with peripheral (i.e. low-frequency fatigue) and central (i.e. a reduction in voluntary activation) fatigue. Recently, it was demonstrated that knee extensor and plantar flexor strength is reduced immediately following match-play tennis in both hot (36°C) and cool (22°C) conditions (Figure 3)[15]. However, after play in the heat, the reduction in strength was exacerbated in the knee extensors only, persisting for 24 hours after match completion. This loss of strength was attributed to a combination of both central and peripheral fatigue factors, whereas fatigue in the plantar flexors was mainly attributed to peripheral fatigue.

Naturally, the development of fatigue at the neuromuscular level has important implications for performance via losses in the efficiency of on-court movements and stroke proficiency, especially during tournament play. Accordingly, fatigue during extended play is manifested by decrements in match-related physical performance (i.e. sprinting and jumping), regardless of the environmental conditions[14,16]. From a tennis perspective, a decrease in sprint ability may reduce the time required to achieve whole body stability in the preparation of stroke execution, which may lead to less accurate or less powerful strokes and/or enhance error rate[17]. Interestingly however, despite the exacerbated loss of strength in the knee extensors following match-play tennis under heat stress, physical performance parameters are similarly impaired in hot and cool conditions, with the impairment occurring primarily after approximately 60 minutes of total playing time, with limited additional reductions thereafter[18]. As such, it appears that the additional increase in body core temperature incurred in hot compared with cool matches does not exacerbate the overall reduction in sprinting and jumping ability.

HYDRATION AND PERFORMANCE IN THE HEAT

Hyperthermia is of particular concern when tennis tournaments are played in hot environmental conditions, such as during the Australian and US Opens, where air temperature can exceed 40°C. In these hot environments, dehydration can occur if fluids losses are not replenished. Although the precise influence a given level of dehydration has on performance remains

> **Match-play tennis in the heat leads to significant levels of thermal, physiological and perceptual strain**

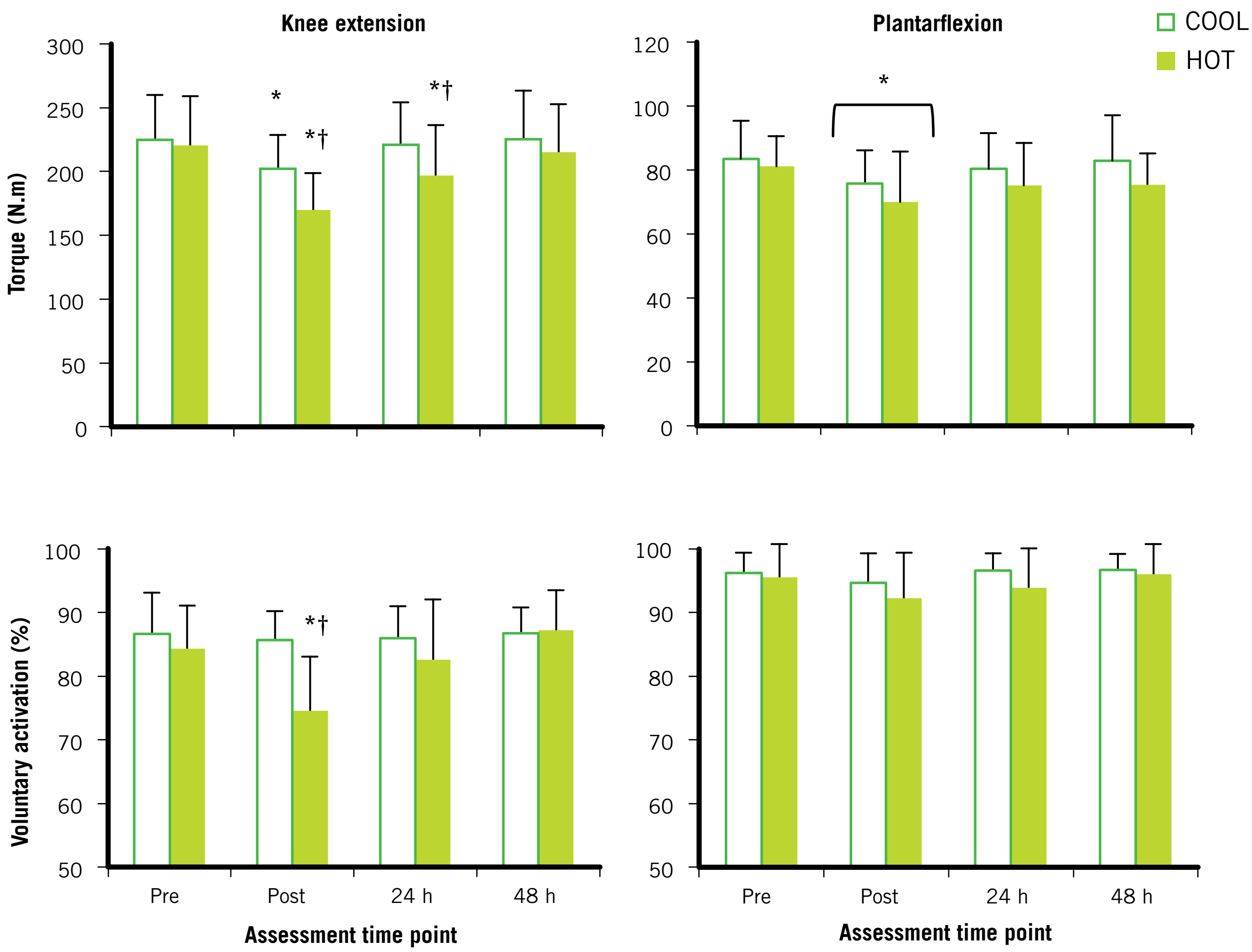

Figure 3: Torque production and voluntary activation during a brief (5 seconds) MVC of the knee extensors (left panels) and plantar flexors (right panels) performed prior to (pre) and following (post, 24 hours and 48 hours) 20 minutes of effective match-play tennis in COOL and HOT conditions.

*Significantly different from Pre, $P<0.05$. †Significantly different from COOL, $P<0.05$. MVC=maximal voluntary contraction. Reproduced with permission[15].

a topic of debate, it has been reported that exercise-induced dehydration amounting to a 2 to 7% deficit in pre-exercise body mass can reduce endurance exercise performance by 7 to 60% (for a review on the topic see Cheuvront et al[19]).

During match-play tennis sweat rates vary based on ambient temperature and humidity, but can reach 2.5 L per hour in certain individuals. Interestingly, thirst is a poor indicator of hydration status and during exercise the sensation of thirst may not be perceived until 1.5 L of body water is lost, or a deficit of 2% body mass is incurred. As such, ad libitum fluid consumption often leads to involuntary dehydration[20]. It is therefore recommended that hydration regimens be individualised based on sweat rate and composition. However, gastric emptying, the process by which fluid leaves the stomach and enters the duodenum, is only around 1.2 L per hour, which may prevent some hydration regimens to fully offset fluid losses when sweating is profuse. Therefore, it is further recommended to replace fluid losses so that dehydration does not exceed 1 to 2% of pre-exercise body mass during prolonged exercise[21,22]. It is also suggested that fluid consumption should not result in a gain in body mass. However, this latter point may be irrelevant if an individual begins exercise in a severely dehydrated state (i.e. acute or chronic hypohydration)[22].

Recently, it was demonstrated that due to the nature of the game (i.e. the regular breaks allowing ample opportunity to rehydrate), ad libitum fluid consumption allowed for less than 1% in body mass loss to occur during match-play in the heat[23]. However, it was also demonstrated that undertaking play in a well-hydrated state by following an individualised hydration regimen attenuated the early rise in thermal, perceptual and physiological strain (Figure 4). Conversely, repeated-sprint ability and maximal voluntary strength in the lower limbs deteriorated similarly following play, regardless of whether competition was undertaken in a euhydrated or slightly dehydrated state, but then recovered within 24 hours[23]. Consequently, it appears that when tennis is played in the heat, undertaking the matches in a euhydrated state, optimising sodium intake and preventing large decrements in body mass may help in minimising thermal, physiological and perceptual strain in the early part of a match, whereas this will have minimal influence on the decrement in physical performance.

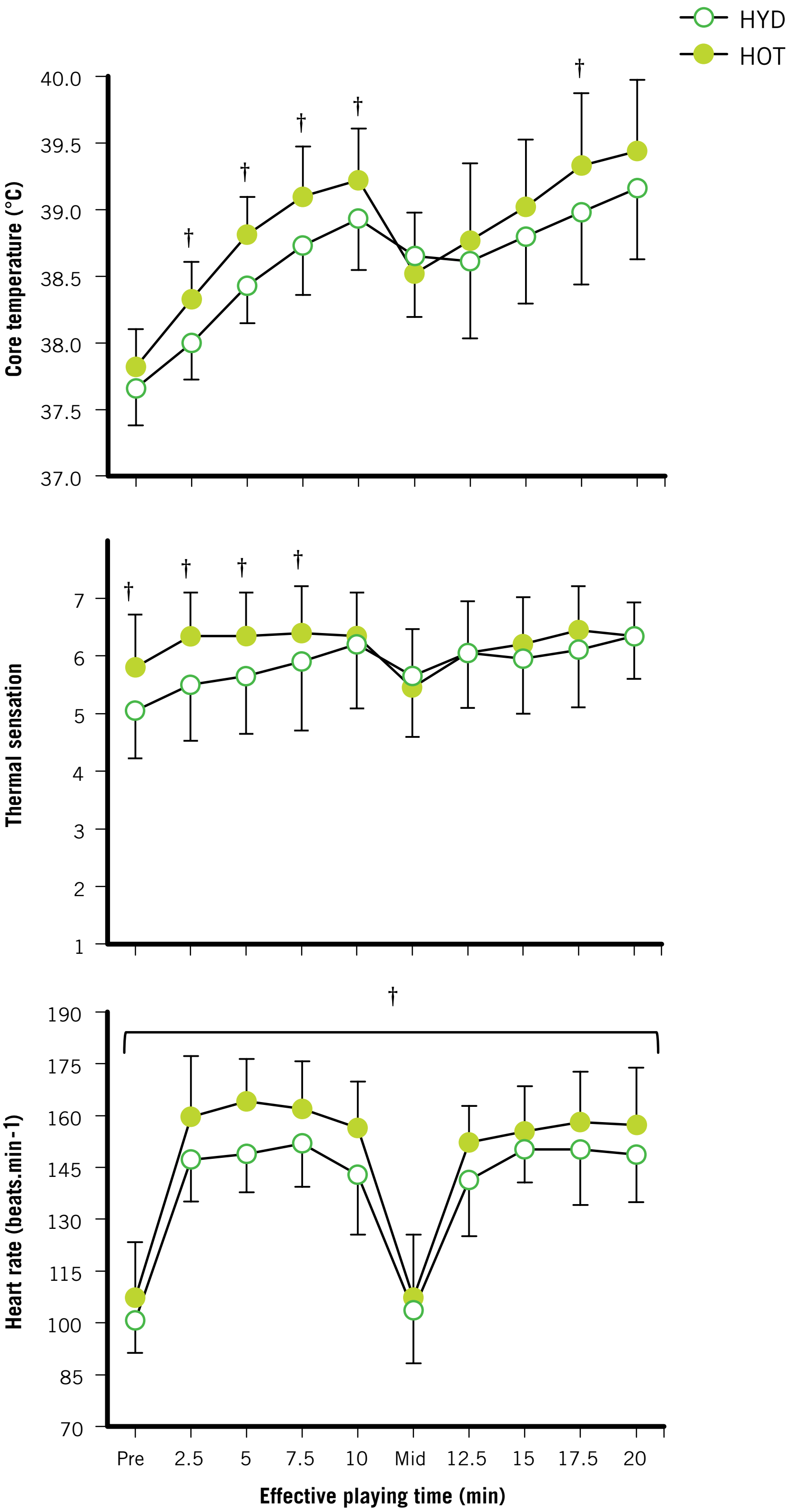

Figure 4: Core temperature, thermal sensation and heart rate, during 20 minutes of effective match-play tennis in HOT and HYD conditions. †Significant difference between HOT and HYD, P <0.05. Reproduced with permission[23], HYD=hydration trial.

SUMMARY

Competitive match-play tennis in the heat leads to significantly greater levels of thermal, physiological and perceptual strain compared to when play is undertaken in temperate or cool conditions. This occurs despite the ability to hydrate adequately and maintain body mass losses under 1%. The increases in strain however, may be attenuated somewhat by strategies and on-court tactics that result in reducing effective playing time (e.g. decreasing point duration and increasing time between points). Indeed, these behavioural strategies appear to minimise or offset the rise in strain, in particular the sensation of environmental conditions being rated as difficult. Along with measurable increases in thermal strain, the development of fatigue can lead to a cascade of alterations in neuromuscular function, which can impact on performance acutely in a match setting and over a longer time course during tournament play. Notwithstanding, physical performance responses such as jumping and sprinting are similarly impaired when competing in hot and cool environments. Ultimately, while recent findings provide novel insight into the influence of heat stress on performance, more specific research into tennis movements and strokes is required to fully elucidate the role of hyperthermia within the sport.

References
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Julien D. Périard Ph.D.
Research Scientist
Athlete Health and Performance Research Centre
Aspetar – Orthopaedic and Sports Medicine Hospital
Doha, Qatar
Contact:julien.periard@aspetar.com