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Review article

Nutrition for Tennis: Practical Recommendations

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Abstract

Tennis is a pan-global sport that is played year-round in both hemispheres. This places notable demands on the physical and psychological preparation of players and included in these demands are nutritional and fluid requirements both of training and match-play. Thus, the purpose of this article is to review nutritional recommendations for tennis. Notably, tennis players do not excel in any particular physiological or anthropometric characteristic but are well adapted in all areas which is probably a result of the varied nature of the training demands of tennis match play. Energy expenditures of 30.9 ± 5.5 and 45.3 ± 7.3 $kJ\cdot min^{-1}$ have been reported in women and men players respectively regardless of court surface. Tennis players should follow a habitually high carbohydrate diet of between 6-10 $g\cdot kg^{-1}\cdot d^{-1}$ to ensure adequate glycogen stores, with women generally requiring slightly less than men. Protein intake guidelines for tennis players training at a high intensity and duration on a daily basis should be ~1.6 $g\cdot kg^{-1}\cdot d^{-1}$ and dietary fat intake should not exceed 2 $g\cdot kg^{-1}\cdot d^{-1}$. Caffeine in doses of 3 $mg\cdot kg^{-1}$ provides ergogenic benefit when taken before and/or during tennis match play. Depending on environmental conditions, sweat rates of 0.5 to and over 5 $L\cdot hr^{-1}$ and sodium losses of 0.5 – 1.8 g have been recorded in men and women players. 200 mL of fluid containing electrolytes should be consumed every change-over in mild to moderate temperatures of < 27°C but in temperatures greater than 27°C players should aim for ≥ 400 mL. 30-60 $g\cdot hr^{-1}$ of carbohydrate should be ingested when match play exceeds 2 hours.

Key words: Caffeine, diet, electrolyte, supplements, carbohydrate, fluid.

Introduction

For occupational, military and leisure-related reasons, interest in the nutritional requirements of activities has a long history (Porter, 1999). Hippocrates (c 460-370BC) advised athletes and propounded health-related aspects of diet. Galen (c AD129-216) was appointed by Roman Emperor Marcus Aurelius to tend to the medical and surgical needs of gladiators. This extended to advising gladiators' trainers and related staff and included those who designed and prepared the combatants' diets. Sometime between AD384-389), Vegetius wrote his treatise *Epitoma rei militaris* (Epitome of military science) (Whipp et al., 1998) that included consideration of the nutritional requirements of marching Roman legionnaires. Some two thousand years later, bodies such as the English Institute of Sport employ nutritionists and dieticians to advise and guide athletes both to support their training and preparation for competition.

This advice is also an important part of modern-day tennis. Tennis is a pan-global sport that is played year-round in both hemispheres. The economic impact of tennis is substantial both in terms of prize money that is available and associated sponsorships of tournaments and coverage by various media. It is big business. This places notable demands on the physical and psychological preparation of players and included in these demands are nutritional and fluid requirements both of training and match-play.

Conducting nutrition research in tennis presents several challenges because of the numerous variables involved but mainly because of the lack of valid, standardised and reliable performance protocols that are sensitive enough to detect meaningful changes in performance before and after an intervention. Nonetheless, there are sufficient studies that have been conducted in tennis and other racket sports with similar demands to provide nutritional recommendations for tennis competitors. The purpose of this article is to provide evidence-based nutritional recommendations for tennis players.

Anthropometric and physiological characteristics of tennis players

Table 1 presents typical anthropometric and physiological characteristics of modern tennis players. Notably tennis players do not excel in any particular characteristic but are well adapted in all areas. This is likely a result of the varied nature of tennis match play and training demands (Reid et al., 2008).

Table 1. Mean (± standard deviation) anthropometric and physiological characteristics of women and men tennis players taken from Christmass et al. (1998); Ferrauti et al. (2001); Smekal et al. (2001); Davey et al. (2003); Kraemer et al. (2003); Novas et al. (2003); Girard et al. (2006); Fernandez-Fernandez et al. (2007); Hornery et al. (2007); Mendez-Villanueva et al. (2007); Murias et al. (2007); Fernandez-Fernandez et al. (2008); Morante et al. (2008).

Gender	Stature (m)	Body mass (kg)	VO_{2max} ($ml\cdot kg^{-1}\cdot min^{-1}$)
Women	1.67 (.05)	59 (6)	48 (3)
Men	1.81 (.09)	77 (7)	53 (3)

Energy expenditures in tennis

Tennis is broadly considered an intermittent sport, that comprises brief periods (4 – 10 s) of activity interspersed with short active recovery durations (10 – 20) and longer passive recovery bouts (60 – 90 s) (Fernandez-Fernandez et al., 2006). However, matches can last for three or more hours although only about 15% of total time is actual match-play. The physiological demands of tennis match-

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play are complex and depend on highly variable interactions between technical, tactical, physical and environmental constraints. Typically, the type of court surface, style of play (serve and volley, baseline player), duration of rally, phase of play (service or return game) and ambient temperature and humidity combine to influence the energy demands and make tailoring match-specific nutritional strategies a major challenge. Moreover, factors such as playing surface influences bounce and ball speed which in turn affects rally duration and consequently the energy expenditure.

As well as court surface, playing style also influences rally duration. Players who play from the baseline are likely to have longer rallies than those who prefer to serve and volley (Smekal et al., 2001). Therefore, players who use baseline tactics on clay courts are more likely to be involved in longer rallies than players who opt for serve-and-volley tactics on grass courts and therefore, expend more energy. Longer rallies on clay courts lead to larger percentage playing times than on hard courts (approx. 25% vs. 21% respectively) (Christmass et al., 1998; Fernandez et al., 2007; 2008; Girard et al., 2006; Martin et al., 2011; Mendez-Villanueva et al., 2007; Smekal et al., 2001) and potentially, longer match durations and greater energy expenditures.

Environmental constraints such as ambient temperature and humidity influence both tennis match play and energy demands through autonomic and/or behavioural mechanisms (Morante and Brotherhood, 2008). The duration of rallies has been found to be positively correlated with rectal temperature and thermal perception as well as skin temperature (Morante and Brotherhood, 2008). However, the intermittent activity profile of tennis means that in most environments (< 35 °C) players are able to regulate body temperature responses within safe-limits.

Energy expenditures of 30.9 ± 5.5 and 45.3 ± 7.3 kJ·min^{-1} have been reported in women and men players respectively regardless of court surface as indicated in Table 2. These data are based upon assumptions of mean body mass, maximum oxygen uptake (table 1) a fractional utilization of 55% VO_{2max}, 1 L of O_2 equivalent to 21 kJ (5 kcal) of energy and a mean RQ of 0.9. Assuming that all fluid lost by sweating must be replaced, fluid requirements in a range of ambient temperatures are estimated from sweat rate using the regression equation of Morante et al. (2007) assuming a mean body mass from Table 1.

Table 2. Estimated energy expenditure (± standard deviation) by sex and match duration. Calculated from: Christmass et al. (1998); O'Donoghue et al. (2001); Smekal et al. (2001); Girard et al. (2006); Fernandez-Fernandez et al. (2007); Hornery et al. (2007); Mendez-Villanueva et al. (2007); Murias et al. (2007); Fernandez-Fernandez et al. (2008); Martin et al. (2011).

	Energy expenditure	
	Women	**Men**
kJ·min^{-1}	30.9 (5.5)	45.3 (7.3)
kcal·min^{-1}	7.4 (1.3)	10.8 (1.8)
kcal·kg^{-1}·hr^{-1}	7.5 (.5)	8.4 (.5)
60 min match (kcal)	443 (79)	649 (105)
90 min match (kcal)	664 (118)	973 (157)
150 min match (kcal)	1107 (196)	1622 (262)
300 min match (kcal)		3244 (524)

Future research should identify energy expenditures of both men and women players using more accurate methods such as doubly labelled water, during different training phases and tournaments in elite-standard (≤ 100 rank) tennis players.

General macronutrient and energy intake recommendations for tennis

The nutritional challenges facing elite-standard tennis players are unique. Year-round competition with a heavy travel programme and unpredictable time spent in competitive match-play make for a complicated nutrition strategy. It might be important to integrate training, and training nutrition, into a competition programme if tournaments dominate the calendar. This requires a carefully planned strategy, allowing for periods of physical training, skill acquisition, competitive performance and sufficient time for recovery and adaptation. Independent of the time of year, adequate energy must be consumed to support the volume, intensity and duration of activity.

Estimated energy expenditure during tennis play for between 1-5+ h for men can range from 2.72 ± 0.44 MJ to 13.58 ± 2.19 MJ (649 kcal ± 105 to ≥ 3244 kcal ± 524) (Table 2). One study that investigated seasonal changes in the diets of four women tennis players (age 19.3 y ± 15.0) reported no differences in energy intake across the seasons, but did report variation in macronutrient intakes (Nutter, 1991). Notably, the diets were lower in carbohydrate during the in-season (49 % and 55 % for in- and post-season respectively) and lower in fat (33 % and 28 % for in- and post-season, respectively). The findings of this study should be interpreted with caution because they are unlikely to be representative of professional tennis players who do not have such clearly defined seasons. Elite-standard tennis players are required to maintain their optimal body mass and composition all year round and thus have to adjust their energy intakes during short periods of rest or travel.

Dietary carbohydrate intake recommendations

Carbohydrate intake during tennis match play will be considered in greater detail in the supplements section, therefore this section will address general carbohydrate recommendations for tennis players. It has been understood for many years that a high carbohydrate diet leads to increased muscle glycogen stores (Bergstrom, 1967), which contributes to optimal performance particularly in endurance-type activities (Hargreaves, 2004). It is also known that a low carbohydrate diet (<15 % of total energy intake) can impair high-intensity exercise and endurance performance, both of which are key aspects of tennis match-play. Although no studies have directly investigated muscle glycogen concentrations during tennis, it is likely that glycogen depletion is a key contributing factor to fatigue during prolonged matches. Furthermore, when out of competition, elite-standard tennis players will train anywhere between 4-6 h per day and take only a brief off-season, thus energy demands are high throughout the year. During the frequent, high-intensity periods of a match (<75 % VO_{2peak}), carbohydrate oxidation will contribute markedly to ATP production. The amount and rate of carbohydrate oxidation during tennis depends on the duration and the intensity of the match or training session. As a general guideline, elite-standard tennis players should have a habitually high carbohydrate diet of between 6-10 $g \cdot kg^{-1} \cdot d^{-1}$ to ensure adequate glycogen stores, with women generally requiring slightly less than men. This recommendation should be tailored to suit daily energy expenditure. During periods of intensified training, high carbohydrate diets are recommended to support immune function and help prevent over-reaching and overtraining from occurring.

Elite-standard tennis players should ensure that they are adequately fuelled and hydrated before each match; however this could be challenging without knowing how long a match will last. Furthermore, a delayed start in a tournament could disrupt rehearsed pre-match meal routines and cause players either to be undernourished and hungry at the onset of a match, or to play on a stomach of undigested food. Either way, this could be detrimental to performance and could create gastrointestinal problems. Other issues could arise when tennis players compete in more than one match per day e.g. if they enter both singles and doubles match-play in tournaments. This situation can leave players with an inadequate or sometimes an unknown duration of recovery which makes post-match refuelling difficult. Recovery may therefore be with carbohydrates only due to their ease of digestion and protein could be sacrificed, thus compromising optimal recovery. In addition, an unexpected result or an early exit from a tournament could mean athletes have overeaten during their preparations. Tennis players should seek guidance from a suitably qualified sports nutrition specialist to address these issues to maximise performance.

Dietary protein intake recommendations

There are limited data on the dietary intakes and requirements for protein in racket sports, with most published guidelines aimed specifically either at solely strength- or endurance-trained athletes. While tennis includes aspects both of strength and endurance performance, it is not directly comparable to either. It is thus more appropriate to estimate the protein requirements of tennis players based either on the volume and intensity of training or competition. One study investigated the dietary intakes of four women collegiate-standard tennis players and reported daily protein intakes of 1.3 $g \cdot kg^{-1} \cdot d^{-1}$ and 1.2 $g \cdot kg^{-1} \cdot d^{-1}$ in season and post-season, respectively (Nutter, 1991). In addition, Gropper et al. (2003) investigated dietary intake of seven women tennis players aged 19 yrs who were training for 4 h/d, 6 d/wk. This study reported low protein intakes of 0.8 $g \cdot kg^{-1} \cdot d^{-1}$. The protein intake guidelines for an elite-standard athlete, training at high intensity and duration on a daily basis are ~1.8 $g \cdot kg^{-1} \cdot d^{-1}$ (Phillips and Van Loon, 2011). This amount of protein is likely to be achieved without supplementation in a diet that has increase energy intake (~12 MJ), such as the diet of an elite-standard athlete. Guidelines for women athletes are typically lower than those for men because of lower total energy intakes. Total energy intakes in the studies referenced here were 7.60 ± 3.83 MJ (1815 kcal ± 916) (Gropper, 2003) and 6.97 ± 2.16 MJ (1664 kcal ± 515) (Nutter, 1991). One study that has investigated the nutritional profiles of adolescent male tennis players (aged 14-18 yrs) reported estimated total energy intake to be 12.42 MJ (2967 kcal) and found that 63 % of the athletes consumed >1.5 $g \cdot kg^{-1} \cdot d^{-1}$ protein, 33 % consumed 1.0-1.5 $g \cdot kg^{-1} \cdot d^{-1}$ and only 4 % consumed <1 $g \cdot kg^{-1} \cdot d^{-1}$ (Juzwiak, 2008). These athletes, although young and not at elite-standard or professional status, are much closer to the recommended dietary protein intakes of ~1.6 $g \cdot kg^{-1} \cdot d^{-1}$.

Because of the lack of nutrition-related research in elite-standard tennis, perhaps it is particularly important to consider the timing, type and amount of protein that is consumed, and it's co-ingestion with other nutrients. Manipulation of these factors will impact the effectiveness of the protein to stimulate protein synthesis and maximise recovery and adaptation.

Dietary fat intake recommendations

Due to the nature of professional tennis and the lack of a clearly defined 'off-season', athletes are required to maintain peak physical shape and body composition throughout the year.

While carbohydrate is the predominant fuel that is used during tennis, fat oxidation will also contribute to energy provision, especially as the duration of the match or training session increases. With matches lasting anywhere between 2-5 h, and one record-breaking match lasting 11 h 5 min at Wimbledon in 2010, endurance is an important element in tennis. Similar to protein requirements, no studies have specifically investigated the daily dietary fat requirements of elite-standard tennis players. Juzwiak's (2008) study is one of the few that have investigated the nutritional profiles of men tennis players. Fat intake, as a percentage of total energy intake was reported, with 70 % of athletes consuming >30 % of total energy per day from fat. The suggested amount of daily fat required to ensure adequate intramuscular triacylglyceride stores for an endurance athlete training for >2 h per day is 2 g/kg (Stellingwerff, 2011). This recommendation should not be directly applied to tennis, where matches involve many high-intensity (<75 % VO_{2peak}) exertions with carbohydrate acting as the main fuel.

While it is understood that moderately low body fat aids speed and agility on court and improves heat tolerance, there is no scientific evidence showing that low body fat levels are required to become a successful tennis player. Instead, the successes of highly lean and muscular tennis players provide the evidence that there may be an advantage to having low body fat. Unfortunately, there has been disturbing coverage of unflattering photographs in the media over the years of professional tennis players (particularly female players) who are reported to look out of condition and 'fat' (Harris, 2000). Clearly, whilst there is no apparent requirement for tennis players to have very low body fat levels, there is equally no benefit in carrying excess body fat, and that high amounts of lean mass will contribute to impulse development and strength during match-play,. Whatever the dietary requirements of the athlete, some sources of fat must be included in the diet to allow for the absorption of fat-soluble vitamins, synthesis of hormones and to support effective function of cell membranes.

Micronutrients

There is no reason to suspect micronutrient deficiencies in healthy elite-standard tennis players with high energy intakes and varied diets. However, in situations where energy intake is restricted, for instance during times of weight loss or body composition manipulation, the risk of inadequate intake of vitamins and minerals becomes greater. During a tournament, at any standard, it is not known exactly how many matches one will play, or indeed, how long each of those matches might last. Furthermore, the exact match start time might be uncertain in a tournament timetable. This makes planning high quality, nutrient-rich pre-match and recovery meals difficult and thus there is often an increased reliance on sports foods and supplements, or fast food options. Sports foods could replace the immediate requirements for certain macronutrients such as carbohydrates and protein, however they do not contain the range of micronutrients found in natural food sources and thus should not become the main component of a player's diet. Micronutrient supplementation might be appropriate to support the athlete during times where nutrition is compromised such as during travel or heavy periods of training and competition.

Gropper et al. (2003) investigated the copper and iron intakes of 70 women collegiate athletes, aged 18-25 yr, of which eight were tennis players. Mean serum copper and ceruloplasmin were within the normal range for all athletes. Mean iron status, assessed by haemoglobin, haematocrit and serum ferritin was adequate. However, 10 of the athletes had serum ferritin concentrations <12 mg/ml which suggests iron depletion was prevalent, in the absence of anaemia. More research is required to assess both the macro- and micronutrient intakes and requirements of tennis players, specifically in those athletes whoes nutritional status might be compromised by low energy intakes.

Dietary practices of tennis players

Although Tennis is the most popular racket sport in the world (Chandler, 2000), little data detail the dietary practices of its players. There are only three accounts of the practices of young players. Juzwiak et al. (2008) examined 44 male adolescent players from 10 - 18 years of age. Mean energy intake was equal to or greater than energy expenditure for 68% of the sample however 32% of participants experienced a negative energy balance. Carbohydrate intake was largely adequate with 8% of the boys consuming values greater than 8 $g·kg^{-1}·day^{-1}$; values between 5-8 $g·kg^{-1}·day^{-1}$ occurred in 50% of the sample and 32% consumed values below 5 $g·kg^{-1}·day^{-1}$. Protein intakes were sufficient: 73% consumed values greater than 1.5 $g·kg^{-1}·day^{-1}$ and 25% consumed values within a 1.0 - 1.5 $g·kg^{-1}·day^{-1}$ range. Mean lipid intake expressed as a % total energy was similarly high as 80% of the sample reporting values greater than 30%. These findings contrast with Gropper et al. (2003) and Nutter (1991) who reported that female US Collegiate-standard players had insufficient energy and carbohydrate intakes ranging from 6.14 - 7.62 $MJ·kg^{-1}·day^{-1}$ for energy and 3.8 - 4.0 $g·kg^{-1}$ for carbohydrate. Of note, calcium intakes were low in all of the studies and could be a concern for these groups. Females are at a greater risk of developing osteoporosis and sufficient calcium is essential for bone mass development during adolescence (Otten et al., 2006). Sex-related differences in energy intake feature commonly and these findings reflect the observation that women athletes generally report lower energy intakes than men. Further studies are needed to corroborate these observations and further work is needed to identify the dietary habits of professional players with the challenging travel and playing commitments that professional sport requires.

Nutrition and travel

Professional tennis players are frequent travellers because of their busy year round competitive schedule. Environmental and climatic conditions, altitude, ambient temperatures and weather, as well as culture, hygiene and time-zone differences can all disrupt a player's preparations. Long travel times can cause fatigue (Reilly et al., 2008). Travel fatigue is affected by the length and conditions of the trip and time spent awake. Circadian variations and the "body clock" are affected by time-zone differences in the night-day cycle (Reilly et al., 2009). Jet lag is a disruption to chronobiological homeostasis caused by long trans-meridian travel times and is a potential problem for frequent travellers.

Jet lag: Jet lag results from asynchronous sleep-wake and light-dark cycles and is a physiological phenomenon characterised by sleep disruption and insomnia, fatigue, disorientation and reduced physical performance (Waterhouse et al., 2007). Daylight is an important signal that synchronizes the body clock to the light/dark cycle -- a zeitgeber-- and promotes wakefulness and alertness. Melatonin is a hormone secreted from the pineal gland at night and works in opposition to daylight to promote drowsiness and prepare the body for forthcoming sleep (Waterhouse et al., 2007). Circadian variations are sensitive to environmental cues and alterations to the light-dark cycle.

Strategies to attenuate Jet lag: Reilly et al. (2007) in their recommendations to travelers describe a host of behavioural, dietary and pharmacological interventions that could help ameliorate some of the symptoms of jet lag and separate the behavioural and dietary modifications into pre, during and post-flight adjustments. Reilly et al. (1997) suggest that meal timing, altering macronutrient intake and following the Argonne diet, which has been described as a pre and post-flight dietary intervention can help athletes cope with the symptoms of jet lag. The Argonne diet consists of intermittent, alternate day fasting, ingesting a high protein breakfast (to provide substrate for catecholamines) and carbohydrate-rich evening meals (to provide substrate for serotonin).

Ensuring adequate hydration during travel is highly recommended; dehydration may enhance the subjective symptoms of jet lag and the circadian rhythm of renal function is also disrupted by trans-meridian travel (Reilly et al., 2007). Reilly et al. (2007) discuss the likelihood of dry air experienced during flights leading to increased respiratory fluid loss, which may potentially lead to dehydration; travelers are advised to increase fluid consumption by 10 – 20 ml per hour of flight duration to compensate for fluid losses. On board food and fluids are often provided by the airline to passengers however these may not be sufficient for athletes with specific dietary and energy requirements. Travelling athletes are advised to communicate their dietary requirements with the airlines prior to travelling and could bring their own food to consume on board if required.

Although training will most likely be reduced upon arrival, exercise can act as a zeitgeber and be beneficial to adjusting to new time zone and so should not be completely eliminated, however this is likely to be more effective when a phase delay is required after westerly travel (Reilly et al., 2007). Exercising in the morning after an easterly time-zone transition of 7-9 hours is not recommended (where a phase advance is needed) until the travelling athlete to new the time zone (Reilly et al., 2007).

Administration of supplemental melatonin can beneficially modify the body-clock phase-response curve; the light-dark cycle initiates the phase advance experienced during the morning hours. During travel, a phase advance is required after an eastward flight and a phase delay is necessary after a westward flight to maintain the body clock's circadian pattern (Reilly et al., 2005). Temperature, physical activity and eating patterns are all important exogenous factors that influence physiological cycles. Performance measures such as strength and other types of maximal-intensity exercise, flexibility and reaction time also display circadian cycles that could be adversely affected by travel (Reilly et al., 2007). Jet leg can also be attenuated with the use of pharmacological and environmental interventions but the applicability of pharmacological chronobiotics such as caffeine and other stimulants, benzodiazepines and supplemental melatonin or the co-ingestion of caffeine and melatonin cannot be recommended because of inconclusive evidence, prohibition and the potential for toxicity and impurity (Reilly et al., 2007; 2008; 2009). Recommendations to deal with jet lag are provided in Table 3.

Heat Exposure: High ambient temperatures tend to increase core temperature and heart rate and predispose an athlete to dehydration (Armstrong, 2006).Tennis is often played in hot and humid conditions and players can sweat approximately 2.5 $L \cdot h^{-1}$ and up to 3.0 $L \cdot h^{-1}$ during match-play (Bergeron et al., 1995a;1995b; Bergeron, 2003). This approached limits of tolerability. Bergeron et al. (1995a; 1995b) reported that during match-play men players had greater fluid losses than women despite both sexes consuming similar fluid amounts but both did not drink sufficient fluid to replace losses. Dehydration exacerbates cardiac strain and increases glycogenolysis. Increased sweat rate also increases mineral loss (Armstrong, 2006). Electrolyte balance is necessary to limit the likelihood of developing fatigue, dehydration and cramping; Na^{+} depletion is linked to heat-related muscle cramps in particular (Bergeron et al., 1995a; 1995b). When competing in hot environments, maintaining appropriate fluid, mineral, muscle and liver glycogen balance should be a priority (Kovacs, 2006a). Fluid intakes should ideally be individualised but general recommendations are that players should consume 200 mL of fluid every 15 minutes during mild conditions (< 27 °C) and up to 400 mL every 15 minutes during hot and humid conditions to help maintain fluid balance during play (Kovacs, 2006a; Bergeron et al., 1995a;1995b). Consuming electrolyte-rich sports drinks during long training sessions and matches in hot environments can accommodate fluid and mineral losses players experience and help delay muscle cramps (Jung et al., 2005; Kovacs, 2006a; 2006b; 2006c).

Table 3. Strategies to cope with jet lag.

Coping with jet lag	
Pre-flight	• Adjust sleep habits to reflect the new time zone in the days before the flight. • If possible, arrive in the new time zone in advance of competition.
On-board	• Extra fluid is required to compensate for on-board dry air and air conditioning, which could lead to dehydration. An additional15-20 ml per hour of extra fluid is required. • Alcoholic beverages cannot be recommended because of possible urine loss. Caffeine-based drinks should be consumed with caution because of their stimulant effects.
Post-flight	• Moderate light exposure during daylight hours during the daytime can promote alertness and light visors and sleeping masks at night can help promote sleep. • If travelling westwards, exercise in the new environment could provide a phase delay. • If travelling eastwards avoid exercise in the morning for 2 - 3 days. • Excessive fluid consumption should be avoided in the evening to prevent unnecessary voiding at night,

Jet lag recommendations adapted from Reilly et al. (2008) and Reilly et al. (2009).

High-altitude environments: Acute exposure to altitude decreases appetite and increases glucose uptake at rest and during exercise (Butterfield, 1996; Roberts et al., 1996). Maintaining adequate carbohydrate intake is necessary when training and competing at altitude but reduced appetite could be problematic for some. Hoyt and Honig (1996) recommended that a high-carbohydrate low-sodium diet should be consumed during the first three days of altitude exposure to promote sodium and fluid loss; sodium and fluid retention is a key factor in acute mountain sickness. Exercise at altitude can also promote sodium and fluid retention and athletes should be advised against exercising in the first three days of exposure (Anand and Chandrashekhar, 1996). After this initial acclimatization period, athletes should resume their typical sea-level diet and training programmes.

Practical challenges: Burke et al. (2007) and Reilly et al. (2007) stated that travel destinations might provide reduced access to foods and food preparation opportunities and that a large part of the athlete's intake might have to be provided by hotels, restaurants and take-away-type outlets, which might not provide adequate nutrition to support players' requirements. Similarly, different cultures and food options can be problematic for players with particular food preferences, and an unfamiliar language could make interpreting food labels and menus troublesome. Differences in food hygiene and water standards also present a risk of exposure to gastrointestinal pathogens and infection. Many of these problems can be ameliorated with careful planning before departure. Dietary requirements can be communicated to agencies and hotels before arrival and in the event that suitably nutritious foods are not available in the host country, the player can bring or send non-perishable foods and goods where customs and quarantine laws allow. Dried foods, breakfast cereals, dried fruits, and nuts, crackers, canned goods, rice, noodles, protein powders, bars and drinks can be useful. Players should educate themselves about the nutritional characteristics and food supply in the host country. In this regard, the internet is a useful resource, and consulting others with experience of the host destination about food customs allows players to make informed choices. Multivitamin and mineral supplements might be beneficial to compensate for dietary inadequacy in the event that nutritious food is not available (Maughan et al., 2007).

Infection and immunity: Travelling poses the risk of infection (Young and Fricker, 2006) and gastrointestinal disturbances are common when travelling abroad. Players are advised to avoid possibly contaminated foods such as raw or unpeeled fruits and vegetables, uncooked meats, fish, eggs and local water and ice cubes (where appropriate) and to make use of bottled water where possible. Special attention should be paid to personal hygiene and travelling players are advised to be fastidious with hand washing. The administration of probiotics four weeks before travel has been advocated as an effective and safe measure for preventing diarrhoea (Sazawal et al., and McFarland, 2007). Probiotics obstruct diarrhoeal pathogens and can boost systemic immunity (Surwaicz, 2003). However the efficacy of supplemental probiotics to prevent G.I disturbance or respiratory tract infections after prolonged exercise has been questioned (Kekkonen et al., 2007). The use of prophylactic probiotics can be beneficial to athletes under conditions of environmental and physical stress however further evidence is required to validate the immune-protective effects of supplementation (West et al., 2009). Anti-diarrhoeal medications are indicated for symptomatic relief, along with adequate rest and the replacement of fluids and electrolytes and short-term fasting (Brukner and Khan, 2001; Reilly et al., 2007). Medical assistance should be sought for more severe infections and might require antibiotics.

Nutrition for tournaments

Tournament-play poses several challenges that could impede a player's recovery and subsequent match performance. Match-length can vary from less than one hour to more than five hours in a five-set match. Matches can contain hundreds of short, irregular explosive bursts of activity and intermittent recovery periods (Kovacs, 2006a; 2006b; 2006c). The irregularity of match and tournament play distinguishes tennis from many sports and tennis tournaments can last up to two weeks. Depending on the time between rounds and duration of the event, match-to-match recovery could range from as little as one and up to a maximum of 48 hours. Ferrauti et al. (2003) investigated blood glucose kinetics during tournament-play in elite-standard players and found that endogenous glycogen stores were sufficient to provide energy for 100 minutes of exercise. If recovery between matches was short, hypoglcyemia and glycogen depletion could affect subsequent performances. In the event of little time between matches, the recovery period might not be sufficient to ensure adequate repletion of muscle and liver glycogen, sufficient fluid and mineral replenishment and adequate repair of damaged muscle and soft tissues. This requires targeted nutritional interventions to address recovery and minimise performance decay.

A structured program of carbohydrate feeding is required to maintain adequate energy and glycogen availability throughout tournaments (Kovacs, 2006a; 2006b; 2006c). Suggested carbohydrate intakes for players are 7 - 10 $g \cdot kg^{-1}$ to be consumed daily; 30 - 60 $g \cdot hr^{-1}$ consumed during matches to maintain glucose homeostasis and replenish muscle glycogen during intermissions and 1.5 g · kg after matches when glycogen synthesis is highest to facilitate repletion (Burke et al., 2001; Kovacs, 2006a; 2006b; 2006c). Commercially available CHO-electrolyte sports drinks offer the advantages of a readily available CHO and electrolyte-rich fluid source and could be the preferable option for CHO supplementation during matches played in hot conditions (Jung et al., 2005). When time for recovery window is short, it is important for CHO to be consumed at the completion of a match. A delay of several hours can lead to a 47% reduction of muscle glycogen storage compared with feeding immediately after exercise (Ivy et al., 1988). The addition of insulinogenic proteins such as whey protein can facilitate muscle glycogen storage and increase muscle protein synthesis by inducing a state of hyperinsulinaemia and hyperaminoacidaemia, this allowing more effective post-exercise recovery (Manninen, 2006; West et al., 2009; Van Loon et al., 2000a; 2000b).

The latter stages of tournaments are when athletes are more susceptible to dehydration, mineral losses and heat-related decline in performance (Kovacs, 2006a). Mean fluid intakes of 1.6 $L \cdot hr^{-1}$ have been reported during match-play with intakes up to 2 $L \cdot hr^{-1}$ (Bergeron, 2003). Bergeron (2003) reported that despite large volumes of fluid being consumed, players still experienced a 1 $L \cdot hr^{-1}$ shortfall in fluid requirements. Magal et al. (2003) reported that 3% dehydration reduced 5- and 10-m sprint performance in tennis players, so adversely affecting performance. CHO-electrolyte solutions promote fluid absorption better than plain water (Murray, 1992) and provide advantages beyond enhanced fluid absorption (Murray, 1992). Vergauwen et al., (1998) reported that CHO supplementation attenuated sprint ability, stroke precision and maximal-intensity exercise compared with a placebo during match conditions and can ameliorate some of the effects of dehydration during match-play. However, it must be noted that data confirming the benefits of CHO supplementation in tennis-specific performance is conflicting (Mitchell et al., 1992). Despite the ambiguity, it is generally recommended that players consume CHO in between back-to-back matches to promote glycogen replenishment (Gisolfi and Duchman, 1992; Kovacs, 2006b).

Nutrition and periodization

Recommendations to periodize nutrition programs to reflect the progressive cycling of training stressors have emerged (Stellingwerf, et al., 2007; Houtkooper et al., 2007). Periodization is the systematic cycling of training phases to ensure optimal adaptation and readiness for key competitive events (Stellingwerf et al., 2007). With traditional periodization models, the training calendar is separated into general and specific preparation, competitive and transition phases. Training goals differ between phases. Preparatory phases develop non-specific and specific physical qualities whereas competition phases maintain and stabilize the newly-developed improvements and transition phases are periods of mental and physical recuperation (Bompa and Carrera, 2005). Typically, the volume and intensity of training are on opposite ends of the spectrum; when volume is high, training intensity is low. The training calendar usually begins with high-volume low-intensity preparation phases and progress to high-intensity low-volume phases as the athlete tapers into competition. Other non-traditional periodization models intersperse phases of high-volume and high-intensity training specifically and concentrate training demands into blocks (Issurin, 2008), or alternate between high-volume and high-intensity training cycles or sessions (Kraemer and Fleck, 2007). Training should be tailored to the requirements of the sport, the competitive calendar and athlete's specific physical requirements (Bompa and Carrera, 2005). With such cyclical variation in stressors and volume, dietary requirements will vary between the training phases.

The intensive competitive calendar, frequent travel and uncertain playing arrangements make structured and progressive training difficult for the professional tennis player (Reid et al., 2009) and there is a lack of evidence that addresses tennis-specific periodized training. The tennis calendar is 11 months long and is interspersed with many competitions, which could preclude the use of traditional periodization models that taper athletes for specific competitions. However Marques, (2005) suggested that players can peak for competitions by training through less important competitions and organizing their calendar to target key events, suggesting that a cyclical approach to training periodization is possible despite the demanding schedule. For specific information about tennis-specific periodization we refer you to the studies of Reid et al. (2009), Marques (2005) and Kraemer et al. (2007).

The oscillation of training volume and intensity affects energy requirements and metabolism. Carbohydrate and total energy requirements should increase during periods of high training volume or high energy expenditure to provide sufficient energy for ATP provision and decrease appropriately during lower volume phases where energy expenditure is generally lower (Stellingwerf et al., 2007; 2011). Dietary fat provides important fuel at low exercise intensities and is essential for lipid-soluble nutrient absorption. Because of its high energy density, excess fat consumption can lead to excessive energy intake and body-mass gain (Burke, 2007). Dietary fat intakes should be highest when energy expenditure is at its greatest during the high-volume preparatory phases and reduced appropriately as the player attempts to taper and peak for a key event when energy expenditure reduces. Protein is essential for effective recovery and energy provision during extended periods of exercise (Tipton and Wolfe, 2004). Protein intakes beyond 1.7 g·kg BW^{-1} might be the upper ceiling of an athlete's protein needs given sufficient total energy intake (Tarnopolsky, 1999) although benefits to higher protein intakes might occur that are not currently identifiable (Tipton and Wolfe, 2004). Protein intakes should remain consistent during the training and competitive calendar to ensure adequate recovery from training and competition. Guidelines for the periodization of energy and macro nutrients are provided in Table 4.

Fluids and electrolytes

It has been well established that fluid and electrolyte balance are important factors for optimal exercise performance (ACSM, 2009), particularly in sports such as tennis where players often compete in hot and humid

Table 4. Macronutrient guidelines based on training phase.

	Training Phases			
	General Preparation	**Specific Preparation**	**Competition / 'In-season'**	**Transition**
Training goals and characteristics:	Basic strength and aerobic 'base' development	Tennis-specific energy system and strength / maximal-intensity exercise development.	Maintenance / stabilization of technique, strength and speed	Physiological and psychological recovery and restoration
	High-volume, low-intensity activities	Higher intensity, reduced volume	'undulating' low- and high-intensity activities	Volume and intensity is lowest
Dietary goals and specifics:	Provide sufficient energy and macro micronutrients to support high-volume training and muscular adaptations.	Energy intake might be reduced as volume lowers but still provides sufficient nutrients and fluids to support adaptation.	Provide sufficient nutrition and hydration to optimise recovery and performance. Energy might be reduced further	Reduce energy and carbohydrate intake to its lowest, approaching those of inactive /sedentary individuals.
CHO (g·kg^{-1}·day^{-1})	6-7	7-8	8-10	4-5
Protein (g·kg^{-1}·day^{-1})	1.5 - 1.7	1.5 - 1.7	1.5 - 1.7	1.5 - 1.7
Fat (g·kg^{-1}·day^{-1})	1.1 - 1.5	1.1 - 1.5	1.0	1.0

Dietary guideline adapted from Tipton and Wolfe, (2004).

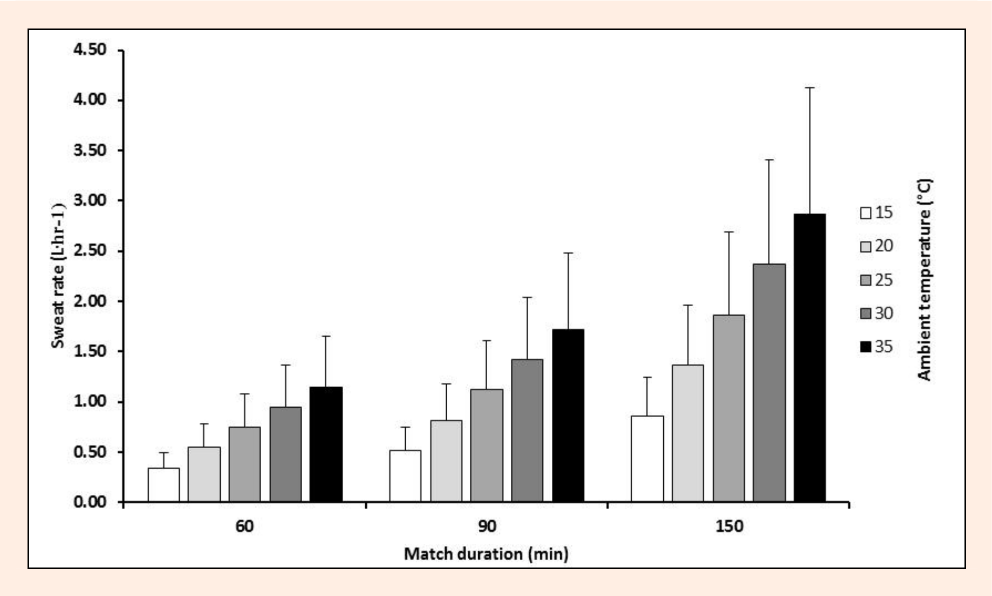

Figure 1. **Women sweat rate over a range of ambient temperatures and match durations. Estimated from Morante et al. (2007). Error bars represent standard deviation reported by Morante et al. (2007).**

environments. The majority of studies that have investigated fluid and electrolytes on performance have investigated continuous endurance sports and team sports rather than stop-and-start type sports such as tennis therefore those guidelines might not be appropriate for tennis players (Kovacs, 2008). As tennis matches consist of multipleand frequent interruptions that disrupt match-play, the nature of tennis clearly allows opportunities to take on fluids and electrolytes. Although studies have investigated fluid and electrolyte balance in tennis, few have been on elite-standard players. For a detailed discussion of the effect of fluid, electrolytes and hydration on tennis performance the reader is directed to reviews by Kovacs (2006a; 2006b; 2006c; 2008).

Sweat rates and electrolyte losses during exercise vary markedly in athletes and are dependant on environmental conditions. Figures 1 and 2 summarise sweat rates in women and men players respectively, and it is evident that sweat rates can range from 0.5 to exceptionally, 5 L·hr^{-1}. Lott and Galloway (2011) assessed fluid ingestion, sweat rates and electrolyte losses in 16 men national-ranked players during a simulated indoor match of mean duration of 68.1 ± 12.8 min. Intensity during match play was also assessed and Lott and Galloway (2011) reported that although intensity was variable, the majority of the time was spend in low-intensity activity. Mean sweat rates were 1.1 ± 0.4 L·hr^{-1} and fluid ingestion was 1.0 ± 0.6 L·hr^{-1} indicating that players were replaced the majority of fluid lost during match play. Reductions in whole-body sodium concentrations were 38 ± 12 mmol·L^{-1} and total sodium losses were 1.1 ± 0.4 g. It should be noted that large inter-individual differences both in sweat rates (0.3 – 2.0 L·hr^{-1}), fluid intake (0.31-2.53 L·hr^{-1}) and sodium losses (0.5 – 1.8 g) indicating that these

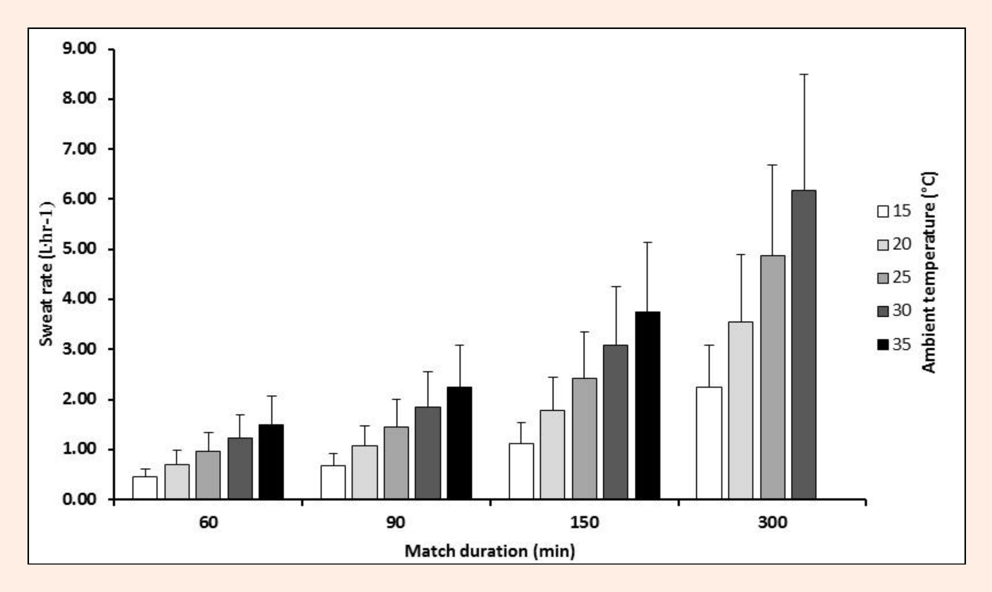

Figure 2. **Men sweat rate over a range of ambient temperatures and match durations. Estimated from Morante et al. (2007). Error bars represent standard deviation reported by Morante et al. (2007).**

characteristics should be assessed in tennis players to provide specific individualized guidance (Lott and Galloway, 2011). In one of the few studies conducted on elite-standard Players. Tippet et al. (2011) measured core temperature sweat rates and fluid ingestion in seven professional tennis players during an outdoor hard-court Women's Tennis Association sanctioned tournament. Data were collected in a mean temperature of 30.3°C ± 2.3°C (relative humidity was not reported). Mean sweat rate during match play was 2.0 ± 0.5 $L \cdot hr^{-1}$, and mean fluid ingestion 1.5 ± 0.5 $L \cdot hr^{-1}$.

Because of the large inter-individual variability both in sweat rates and electrolyte losses and the lack of data in professional tennis players, providing generic recommendations on fluid and electrolyte intakes is difficult. Fluid ingestion might be easier to control during training then during competition as typical match duration is variable. Nevertheless,, tennis matches have multiple breaks in play and players should ensure they use these opportunities to consume electrolyte beverages, particularly during warm and humid conditions. In a review on hydration and competitive tennis, Kovacs (2008) recommended that players should aim for 200 mL every change-over in mild to moderate temperatures of < 27°C but in temperatures greater than 27°C players should aim for ≥ 400 mL. Because of the variations in sweat rates and electrolyte losses among players, individual measures of these characteristics would allow player-specific guidance to be provided.

Sports foods and supplements

Despite tennis being a high-profile professional sport, few studies have examined the effects of sports foods and supplements on performance. This makes it difficult to provide specific guidance. Investigating the effects of supplements on tennis performance presents several challenges because of the number and inter-relationships of variables involved but mainly because of the lack of valid, standardised and reliable performance protocols that are sensitive enough to detect meaningful changes in performance. However, some studies have used the Leuven Tennis Performance Test which evaluates stroke quality in match-like conditions and measures ball speed and precision (Op't Eijnde and Hespel, 2001; Vergauwen et al., 1998).

Creatine

Creatine is arguably one of the most popular dietary supplements for athletes who seek to gain muscle mass and enhance strength and maximal-intensity exercise (Bemben and Lamont 2005). Creatine supplementation increases intramuscular phosphocreatine stores and several studies have demonstrated its ergogenic effects on sporting activities that primarily involve repeated short bouts of high-intensity exercise that require energy from the ATP-PC energy system (Branch, 2003). Therefore, the rationale for using creatine to enhance tennis performance has merit considering that tennis consists of movements that predominately use the ATP-PC energy system over prolonged durations.

Only two studies have investigated the effects of creatine supplementation on tennis performance. Op't Eijnde and Hespel (2001) examined the effects of creatine supplementation (4 x 5 g per day) on the Leuven Tennis Performance Test and a 70-m shuttle run. Eight well-trained tennis players with at least ten years experience ranked in the top 350 on the Belgian national ranking participated in a double-blind, randomised, crossover design. A five week washout period separated creatine and placebo trials. Creatine supplementation had no effect on either ball-speed or precision of strokes (Op't Eijnde and Hespel, 2001). Moreover, there was no improvement in the 70-m shuttle run after creatine loading. Although no improvement in performance was reported in their study, Op't Eijnde and Hespel (2001) concluded that creatine's longer-term effect of muscle hypertrophy could enhance ball speed and sprint ability. Pluim et al. (2006) recruited 36 competitive men tennis players who were of International Tennis Number 3 standard or higher to investigate the effects of creatine supplementation on tennis-specific performance indices. A double-blind, placebo-controlled parallel design was used where 24 players received 0.3 $g \cdot kg^{-1}$ of creatine with 0.24 $g \cdot kg^{-1}$ of carbohydrate per day and 12 players received a placebo. Players were tested on serve ball speed, forehand and backhand ball speed, arm and leg strength using bench press and leg press exercises, and intermittent running speed via three series of five 20-m sprints. Players were tested at baseline, after six days of creatine loading, and after a four-week maintenance phase for four weeks. Although players taking the creatine gained between 1-1.5 kg of mass, no changes occurred in the creatine group in any of the performance measures after the six-day creatine loading phase and after the four-week maintenance phase.

Based on the two available studies on effects of creatine supplementation on tennis performance, there appears to be no ergogenic benefit. However, it should be noted that additional studies are necessary to assess whether creatine has a longer-term effect of muscle hypertrophy that could enhance stroke ball speed and repeated-sprint ability.

Carbohydrate

There is an overwhelming body of evidence that carbohydrate supplementation delays fatigue during prolonged exercise and enhances performance (Coggan, 1991; Coyle 2004). The joint position statement on nutrition and athletic performance by the American College of Sports Medicine, Dieticians of Canada and the American Dietetic Association recommends that for exercise of more than one hour, 30-60 $g \cdot h^{-1}$ of carbohydrate should be ingested to enhance performance (ACSM, 2009). There is conflicting evidence on whether carbohydrate supplementation during tennis match-play enhances performance although it should be noted that the limited number of investigations could explain the equivocal findings.

Some studies have investigated effects of carbohydrate intake during controlled tennis settings. For a more detailed discussion on the effect of carbohydrate on tennis performance the reader is directed to a review by Kovacs (2006a; 2006b; 2006c). Burke and Ekblom (1982) assessed tennis-specific skills before and after two hours of tennis play and reported that the consumption of a carbohydrate-containing beverage was associated with improved skills (ball accuracy and jumping ability) rather than water alone, or no fluid. In addition, Ferrauti et al. (1997) reported that carbohydrate intake maintained blood glucose concentrations over the later stages of a 4-h tennis practice and improved sprint-test performance after tennis practice compared with a non-carbohydrate placebo. Similarly, Vergauwen et al (1998) reported that 0.7 $g\cdot kg^{-1}$ $BW\cdot h^{-1}$ of carbohydrate administered in a drink, enhanced stroke quality during the final stages of prolonged tennis play and reduced the number of mistakes more than a placebo. More recently, McRae and Galloway (2012) examined the effects of a commercially available isotonic carbohydrate drink on a pre-match skill test, a 2-hour tennis match and a post-match skill test. There were no differences in performance in both the pre- and post-match skill test for both carbohydrate and placebo conditions. However, one hour into the match simulation, players in the carbohydrate condition reported feeling more energetic and tenser than at baseline. Moreover, the carbohydrate condition enhanced both overall percentage of successful serves and serve returns during the match stimulation. It should be noted that McRae and Galloway (2012) concluded that the 2 hours of match play might not have induced sufficient fatigue to affect performance on the skill test.

Some studies have reported no performance benefit of ingesting carbohydrate during tennis. Mitchell et al. (1992) reported no benefit of ingesting carbohydrate during match play lasting 180 min. Similarly, Hornery et al. (2007) reported that a 6% carbohydrate drink had no ergogenic effect on tennis performance.

Although more research is required to confirm whether carbohydrate ingestion during tennis match play can enhance performance, there is enough evidence to advocate the ingestion of 30-60 $g\cdot kg^{-1}$ of carbohydrate during match-play (Burke and Ekblom, 1982; Ferrauti, 1997; Vergauwen et al., 1998; McRae and Galloway, 2012; Kovacs, 2006a; 2006b; 2006c).

Caffeine

Caffeine can enhance high- and maximal-intensity exercise performance and its ergogenic benefit might be attributable to its stimulatory effects on the central nervous system rather than its role in mobilizing of free fatty acids and sparing of muscle glycogen as previously reported (Davis and Green 2009). The rationale for the use of caffeine to enhance tennis performance could be that it reduces the perception of fatigue during prolonged match-play. It should be noted that few studies have examined the effects of caffeine on tennis performance.

Ferrauti and colleagues (1997) recruited 16 tournament tennis players (8 men and 8 women) and used a double-blind crossover design where all 16 players played in a 4-hour match simulation on three occasions. Each simulation included 30 min of rest after each 150 min bout. At the end of each 4-hour bout, tests of skill and speed occurred. Tennis was played outdoors (28°C, 42% relative humidity) and the three trials had of a beverage containing a placebo, carbohydrate or caffeine (260 mg for women and 364 mg for men) ingested before and throughout 4 hours of match-play. Caffeine supplementation did not benefit running speed both in the men and women players and similarly, had no effect on hitting accuracy or success during matches in men. However, the caffeine trial did enhance hitting accuracy and success during matches in the women compared with the placebo.

Vergauwen et al. (1998) recruited 13 well-trained male tennis players and used a double-blind crossover design where players complete three trials: placebo, carbohydrate (0.7 $g\cdot kg^{-1}BM\cdot h^{-1}$), and carbohydrate plus caffeine (5 $mg\cdot kg^{-1}$ BM) in a random order. Stroke quality was assessed using the Leuven Tennis Performance Test and sprint speed was assessed using a 70 m shuttle run. Both tests were undertaken before and after a two-hour match simulation. In the placebo trial, both stroke quality and the shuttle run performance during the post-test worsened ($p < 0.05$). In the carbohydrate trial, stroke quality was maintained and 70-m shuttle run times improved ($p < 0.05$) during the post-test. In the trial where caffeine was added to the carbohydrate, no further benefit occurred compared with the carbohydrate-only trial. Vergauwen et al. (1998) concluded that carbohydrate supplementation enhanced stroke quality during the final stages of prolonged match-play but the addition of caffeine to carbohydrate provided no further benefit. Although Vergauwen et al. (1998) stated that the caffeine dose in their study might have been excessive; a major limitation of their study was not to have a caffeine-only trial.

Twelve highly-trained men tennis players who trained between 15-20 hours per week and had at least five years of competitive experience participated in a study conducted by Hornery et al. (2007) that investigated the effect of caffeine supplementation on tennis match-play. In a single-blinded, counterbalanced design, players completed a prolonged tennis match simulation in an indoor hard court lasting approximately 2 h 40 min on four occasions. Trials included a placebo condition, a 6% carbohydrate condition, 3 $mg\cdot kg^{-1}$ BM condition, and a precooling and intermittent cooling condition. Carbohydrate supplementation and cooling strategies had no effect on tennis performance. However, the caffeine trial increased serve ball speed (165 ± 15 $km\cdot h^{-1}$) in the final set of the match simulation compared both with the placebo (159 ± 15 $km\cdot h^{-1}$, $P = 0.008$) and 6% carbohydrate supplementation (158 ± 13 $km\cdot h^{-1}$, $P = 0.001$) conditions. Hornery et al. (2007) concluded that caffeine supplementation in doses of 3 $mg\cdot kg^{-1}BM$ partly attenuated the effects of fatigue and increased serve ball speed during the final stages of a prolonged tennis match simulation.

Although outcomes of the few available studies on effects of caffeine on tennis performance are mixed, there is some evidence that caffeine supplementation in doses of 3 $mg\cdot kg^{-1}$ can enhance tennis performance during prolonged match play.

Contamination of supplements

The sports foods and dietary supplements market is saturated with various purportedly ergogenic aids to enhance strength, speed, endurance and recovery. However, few are substantiated by convincing scientific evidence. Some supplements in this review such as carbohydrates, electrolytes and caffeine can enhance tennis performance. However, it should be recognised that nutritional supplements can be a source of contamination and hence, a positive doping test. Various studies have shown that commercially available dietary supplements and ergogenic aids available over the internet or over-the-counter are contaminated with substances banned on the WADA list of prohibited substances (de Hon and Coumans 2007; Maughan, 2005). Moreover, tennis in particular has had its own high profile doping cases where positive tests for nandrolone occurred but were later cleared when it was concluded that the source of contamination could have been from an electrolyte supplement provided by ATP-endorsed trainers (Burke, 2007). Too ensure players are taking supplements that are evidence-based and free from contamination, it is good practice to seek sports nutrition advice from a qualified professional. Moreover, there are laboratories that offer the facility to test dietary supplements for contaminants that are in the WADA list of prohibited substances therefore, tennis professionals should use this facility to ensure that supplements are safe.

Conclusion

Considering the popularity of tennis worldwide there is surprisingly little literature on nutrition requirements of elite-standard tennis players. There are several factors for the lack of nutrition and tennis research such as restricted access to professional players and the lack of standardised, valid and reliable tennis-specific protocols. Nonetheless, with the limited data available along with other racket sport-specific research, a summary of nutritional guidelines for tennis is presented in table 5 Future research should investigate both dietary intakes and energy expenditures of professional men and women tennis players during major tournaments. Moreover, there are various supplements and ergogenic aids that require investigation into whether their use can enhance tennis performance.

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Key points

- Tennis players should follow a habitually high carbohydrate diet of between 6-10 $g\cdot kg^{-1}$ to ensure adequate glycogen stores, with women generally requiring slightly less than men. Protein intake guidelines for tennis players training at a high intensity and duration on a daily basis should be ~1.6 $g\cdot kg^{-1}\cdot d^{-1}$. Dietary fat intake should not exceed 2 $g\cdot kg^{-1}\cdot d^{-1}$.
- Caffeine in doses of 3 $mg\cdot kg^{-1}$ can provide ergogenic benefit when taken before and/or during tennis match play.
- 200 mL of fluid containing electrolytes should be consumed every change-over in mild to moderate temperatures of $< 27^{o}C$ but in temperatures greater than $27^{o}C$ players should aim for ≥ 400 mL.
- 30-60 $g\cdot hr^{-1}$ of carbohydrate should be ingested when match play exceeds 2 hours.
- During periods of travel, specific dietary requirements can be communicated with agencies and hotels prior to arrival and in the event that suitably nutritious foods are not available in the host country, players can bring or send non-perishable foods and goods where customs and quarantine laws allow.

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