CHAPTER I

INTRODUCTION

“When you do something best in life, you don’t really want to give that up - and for me it’s tennis.”  – Roger Federer

Professional tennis is playing in a wide variety of climatic conditions across the world, and players may be faced with travelling to, and competing in, a hot climate and on to a cooler one in quick succession. Most of the tennis tournaments are played outdoors in warm to hot climates. Even as the level of play and depth of competition continue to improve, the toughest opponent these players often face is the heat.

During certain parts of the competitive year, tennis players may be exposed to warm- hot ambient conditions for both training and competition. To date, there is limited evidence on the effects of hot environmental temperatures on tennis performance, although it is well known that exercise performance is reduced and physiological responses are exacerbated in the heat; which may also be further exacerbated by additional radiant heat sources from court surfaces.


REPORT ON 2014 AUSTRALIAN OPEN

Recently, 2014 - Australian open was held, where players had faced adverse climatic conditions, most of the matches played in the tournament above 40° C temperature. The reporter reported that its inhumane, it is not fair to anybody, to the players, to the fans, to the sport.

Australian Open organizers have been criticized for forcing players to compete in intense heat as temperatures hit 42° C (107.6° F) in Melbourne.

Canada's Frank Dancevic required medical attention after fainting in his first-round match and said it was "inhumane" to allow players to compete in such testing conditions.

Britain's Andy Murray says the incident may damage the event's reputation. "It doesn't look good for the sport when people are collapsing," he said.

"Most of the players are conditioned well enough to last in that weather but doing it for three or four hours is tough to recover from." Andy Murray during the tournament told that to re-evaluate the rules regarding extreme heat. "As much as it's easy to say the conditions are safe, it only takes one bad thing to happen and it looks terrible for the whole sport when people are collapsing, ball kids are collapsing, people in the stands are collapsing."

"Whether it's safe or not, I don't know," Murray said. "You just got to be very careful these days. There have been some issues in other sports with players having heart attacks. I don't know exactly why that is. or collapsing. In this heat, that's when you're really pushing it to your limits. You don't want to see anything bad happen to anyone."

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Even after this players have to stay and play the matches and for this Roger Federer told that "Depending on where you come from it has a bigger effect on you, this type of heat, then maybe humid heat, So it’s very personal, and it can become just a very mental thing and you just can’t accept that it’s hot. Just deal with it, because it’s the same for both."

During the tournament, other players agreed about the importance of trying to ignore the elements.

"You need to push yourself, because it’s easy to just go, Ah, I don’t want to push myself because it’s hot," Wozniacki said. "It’s the same for the other person, so you just need to try to pump yourself up all the time."

Del Porto said, "You are thinking about a lot more things than the tennis match," he said. "You are trying to drink a lot and always thinking about your body and not about the game."

Tim Wood, the tournament’s chief medical officer, said in a pre-tournament news conference, that he believed tennis players were actually at a lower risk for heat problems because of the anaerobic nature of the sport. Compared to continuous running events, which would tax the body significantly in extreme heat, Wood pointed to the frequency of breaks during tennis matches as the main difference.

"They sit down every five to 10 minutes for every 90 seconds at change of ends, so there is chance to lose some heat at that time, Tennis by and large is a low-risk sport, and that’s why, like cricket, we can play in these conditions and not be too concerned. We look into the health and wellbeing of players, but we know over the years in different parts of the country and world they play under these conditions. A lot of people get hot and look distressed and hot and bothered, as we all do. The actually risk to the health is relatively small compared to other sports."

"Look, the players don’t need to be warned about the weather," McEwan told reporters. "You only have to look at the paper and look at the media that’s being generated. They know what’s going to happen for the next five days. It’s like you go to
Wimbledon. You expect it to rain. You come to Melbourne and you expect it to be hot. If you don’t prepare for that, you can lead a horse to water, but you can’t make it drink, obviously.”

Wood also downplayed concerns about player dehydration.

“We have never had anybody die from dehydration on a tennis court,” he said. “Given the length of time tennis matches generally go for and the sweat rate of most normal, healthy athletes, they won’t get to a state where they get too critically dehydrated.”

Caroline Wozniacki told, “I put the [water] bottle down on the court and it started melting a little bit underneath — the plastic — so you knew it was warm”.

The reporter reported, “You can’t blame climate change entirely for hot weather, but you can say that it increases the risk of extreme hot weather events occurring. The planet’s atmosphere has been loaded with extra greenhouse gases, which gives the analogy of loading the weather dice to increase the chances of you rolling a six - or in this case, experiencing extremely hot days or seeing Snoopy”.

**TENNIS MATCHES IN HOT CONDITIONS**

Tournament tennis play often require athletes to compete in multiple matches per day over many consecutive days, sometimes for as long as two weeks. Many tournaments are played in hot conditions, which increases thermal stress and can lead to heat and hydration concerns for tennis players - both from a performance standpoint and a health and safety perspective. The negative effects of hypohydration (less than optimal hydration) and exercise-induced hyperthermia (increased body temperature) on exercise performance are well known. As tennis has no standard length for matches, and match times can range from 30 minutes to four hours, providing general recommendations is more challenging than for sports that have set match times. This is especially important

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for athletes with multiple matches or practice sessions in one day. If the fluid deficit is ignored, performance during subsequent exercise might be negatively affected. It is also important to consider that fluid replacement during exercise should also be considered hydration for the next exercise bout.

HEAT ISSUES IN TENNIS

Due to the intermittent nature and varied physical demands of tennis practice and competition, the maintenance of core body temperature within an optimal range is challenging – especially in hot conditions. The large majority of points in tennis last less than 10 seconds with rest periods lasting no more than 25 seconds. Such a work/rest ratio can cause large changes in body temperature, but allows ample time for fluid replacement and opportunities to help reduce the gradual rise in body temperature. During tennis play an athlete’s metabolic rate increases substantially compared to resting values, which then takes time to return to normal levels after tennis play. Very limited data are available on core temperature in tennis due to the difficulty of monitoring in a “live” tournament situation. Furthermore, traditional lab based experiments that have tried to simulate tennis may provide misleading data. In a tournament study of 14 and under national level boys, the average core temperature earlier in the day before a singles match was $37.67 \pm 0.38^\circ C$ and their average core temperature rose to $38.07 \pm 0.38^\circ C$ before the second match of the day (doubles). This increase in pre-match core temperature may be partially explained by the increase in wet bulb globe temperature (WBGT) from $29.1 \pm 0.5^\circ C$ before the singles matches to $31.3 \pm 0.5^\circ C$ before the doubles matches. During match play, core temperature expectedly rose for all athletes and wide variability between athletes was found.

However, in India the average temperature in summers is around $36^\circ C$ to $42^\circ C$, and maximum number of tennis tournaments held in the months of April to June. Tennis is an outdoor game and characterized by high-intensity efforts (i.e., accelerations, decelerations, changeovers, and upper arm involvement) interspersed with periods of

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various duration and low-intensity activity, during which active recovery (between points: 20 seconds) and sitting periods (between changeover break in play: 90 and 120 seconds) take place\textsuperscript{11} and mostly matches are held in the day time and it takes around 1 to 2 hours to complete the match. Therefore, players have to compete in very high temperatures.

**CORE TEMPERATURE**

In tennis, due to nature or environmental conditions and physical demands, core body temperature elevates and it is very difficult to maintain especially in hot and humid conditions. It is very hard to monitor the core body temperature in a live tournament situation. Therefore, few studies with simulated conditions or in laboratory conditions were conducted and various fluids were administered to see and check the core body temperature deterioration during play.

**BLOOD LACTATE**

Lactate production has been found to be variable in tennis research; those players who play longer points with shorter recovery times tend to produce higher lactate levels than those with short points with longer rest points (Kovacs, 2007). Elevations of blood lactate above 7-8 mmol/l correlate with declines in technical and tactical tennis performance (McCarthy -Davey PR, 2000). In hot and humid conditions, blood lactate production increases might be due to more amounts of heat production in the body and less amount of heat dissipation from the body. Fluid replacement can reduces the lactate production but which playing surface in tennis at high temperatures is producing more blood lactate is an issue. Martin et al., (2011) conducted the research on both the playing surfaces and observed that lactate production is more in clay surface as compared to hard surface.

SWEAT RATE AND ELECTROLYTE BALANCE

When tennis is played in hot environments, it is important that the athlete become acclimatized to perform at optimum levels. The acclimatized athlete will sweat earlier, to dissipate heat from the body that is why acclimatized athlete will have a higher sweat rate than those who are not acclimatized athletes. Acclimatized athlete also loses fewer electrolytes in sweat such as sodium, chloride and potassium than a player who is not acclimatized. During hot environment, fluid replacement is very important to reduce the sweat rate and to enhance the performance.

BLOOD GLUCOSE

For tennis players, blood glucose can be very important because tennis is a game which lasts for long duration and glucose stored in the muscle burns very quickly, but excess amount of glucose stores in the liver in the form of glycogen. This glycogen then converts into glucose and via bloodstream provides energy to the working muscles. It is important and critical that players understand which carbohydrates they should consume and when. However, liquid carbohydrate sources and foods containing simple carbohydrates may be used when it is necessary to raise the glucose level quickly during training or a match.\(^\text{12}\)

PLAYING SURFACES

Tennis is a game, which is played at different surfaces such as clay, grass and hard at the professional arena.

Tennis hard courts are made of synthetic/acrylic layers on top of a concrete or asphalt foundation and can vary in color. These courts tend to play medium-fast to fast because there is little energy absorption by the court, like in grass courts. The ball tends to bounce high and players are able to apply many types of spin during play. Flat balls are favored on hard courts because of the extremely quick play style. Speed of rebound after tennis balls bounce on hard courts is determined by how much sand is in the

synthetic/acrylic layer placed on top of the asphalt foundation. More sand will result in a slower bounce due to more friction\(^\text{13}\).

Therefore, recently it is found that the surface temperature of the synthetic turf was 37° F higher than asphalt and 86.5° F hotter than natural turf\(^\text{14}\). The solar illuminance and the surface temperature of outdoor sport surfaces were measured on August 11 at 11 am in the summer, the surface temperature of the artificial turf, the natural turf, the artificial turf, the clay track, and the tennis court were 67.0, 42.2, 63.9, 45.1 and 59.3 °c respectively was observed\(^\text{15}\). Therefore, it is clear that the temperature of hard surface is much higher than clay surface during high environmental temperature, which might cause more damage to tennis players. Proper precautions and fluids intake can overcome from these environmental effects. Buskirk et al., (1971) concluded that the heat transfer from the surface to the sole of an athlete's foot was significant enough to contribute to greater physiological stress that may result in serious heat related health problems\(^\text{16}\).

**FLUID SUPPLEMENTATIONS**

**Water**

Water is not typically thought of as a nutritional supplement. This is true even though exercise, especially in hot weather, forces water to become a nutrient requiring supplementation. Water accounts for 50-70% of human body weight, with body water existing in a balance between intra and extracellular compartments. Nearly all the chemical reactions that occur in the body directly involve water or components dissolved within water and these reactions are disrupted by changes in water balance. Water is vital for the formation of the macronutrients: carbohydrates, proteins and lipids. Digestion,


absorption, transportation, utilization, and elimination of all the substances we ingest or produce depends on their ability to dissolve in water\textsuperscript{17}.

Water serves as a solvent, creating the environment needed for cellular reactions to occur. Perhaps the most important reactions are those involving the electrolytes and ions, which depend on water balance between the cells and in the extracellular compartments. Shifts in electrolyte concentrations inside and outside the cell create the electrical potentials across the cell membrane, which initiate nerve impulses and muscle contraction. Water serves as the principal mechanism for heat removal during body temperature elevations. The energy expands during exercise; about 75\% - 80\% converts to heat. This heat can raise the body temperature dramatically and cause serious heat injury. However, the high specific heat of water and water's high heat of vaporization allows substantial heat removal via dry heat exchange and evaporation of sweat. These form the basis for thermoregulation. Finally, water functions as a shock absorber and lubricator of various body compartments and joints\textsuperscript{18}.

**Sports drink**

In the 1960s, Robert Cade, a scientist - physician working at the University of Florida, developed an oral fluid replacement for athletes that was designed to restore some of the nutrients lost in sweat. This product was eventually marketed as Gatorade (gator is the nickname for University of Florida athletes) and was the first of many glucose - electrolyte solutions (GES) and later, glucose-polymer solutions (GPS) to appear in the athletic marketplace. The three main ingredients in GES and GPS are water, carbohydrates and electrolytes. The major ingredients in these solutions are carbohydrates in the form of fructose, glucose, or sucrose and some of the major electrolytes. The sugar content ranges from about 5-10 percent depending on the brand. The caloric values range from about 6-12 calories per ounce. The major electrolytes include sodium, chloride, potassium, and phosphorus. GPS are designed to provide


\textsuperscript{18} Ibid
carbohydrate while decreasing the osmotic concentration of the solution, thus helping to minimize the effect upon gastric emptying\textsuperscript{19}.

Below et al. (1995) determined the fluid and carbohydrate ingestion on performance, core temperature and cardiovascular responses during intense exercise lasting 1h. At last carbohydrate and fluid ingestion equally improve cycling performance and their effects are additive\textsuperscript{20}.

**FLUID REPLACEMENT**

One of the major challenges faced by elite players is being able to replace the fluid and electrolyte losses that they will invariably experience in a range of environments, in order to increase their chances of avoiding dehydration and muscle cramping, and perform at their highest level. Players must be able to dissipate heat effectively, even in the most challenging conditions if they are to avoid rapid dehydration, and must ensure that they replace all fluid and electrolyte losses. This can often be very demanding since elite tennis match play has been previously shown to induce sweat rates of over 2.0 l/h\textsuperscript{21}, and players must implement fluid intake strategies that attempt to fully replace these sweat losses. Because of this, it is important that players understand the effects of dehydration and electrolyte losses on performance, and is aware of their own potential fluid and electrolyte losses during match play\textsuperscript{22}.

Bergeron et al., (2006) also investigated voluntary fluid intake and core temperature responses in adolescent players at around 26° C. Because of the highly competitive nature of elite tennis (and other sports), players seek out strategies or devices


to enhance performance and provide an advantage over opponents. Nutritional supplements, such as caffeine and carbohydrates, and cooling modalities are examples currently used by tennis players. The application of caffeine and carbohydrate supplementation in tennis is contended because their capacity to prevent fatigue and enhance performance has not been well established. Recognition of the benefits of dietary preparation for endurance activities has also led to attempts to increase the carbohydrate stores by consuming glucose solutions immediately before and during exercise. A considerable amount of attention has been paid to the composition of these carbohydrate solutions because of the need to achieve rapid gastric emptying and hence fluid replacement. The results of these studies provided evidence for the recommendation that the concentration of glucose solutions used for fluid replacement should be no more than 2.5% and of low osmolality.

The optimal amount of fluid consumption to maintain hydration is individualized dependent upon environment, intensity level, body mass and sweat rate (Bergeron et al., 1995a). It has also been suggested that 200 ml of fluid in every 15 minutes is an adequate rate to maintain body fluid balance at a warm environment (WBGT 27°C). This level of fluid should be increased in conditions that are greater than (WBGT 27°C). This recommendation is equal to 0.80L·hr⁻¹, which is less than half the amount of fluid

that can be lost due to sweating in hot conditions\textsuperscript{29,30}. Although fluid intake should be individualized per player, if situations do not support this individualization, it would be appropriate from the research, to recommend a fluid intake guide equal or greater than 400 ml of fluid every 15 minutes (1.6 l/hr)\textsuperscript{31}.

Searching of reviews, researcher finds that there is dearth in research to conclude which fluid is preferable and beneficial for the players to maintain their physiological and biochemical functions efficiently on both the playing surfaces. That is why researcher has the query and selected the problem whether in such high temperatures which fluid will help in maintaining the physiological and biochemical variables close to normal after playing tennis on hard and clay surfaces.

OBJECTIVES OF THE STUDY

➢ To investigate the effect of fluids on biochemical and physiological variables after simulated tennis match.
➢ To investigate the effect of playing surfaces on biochemical and physiological variables after simulated tennis match.
➢ To investigate the response pattern of playing tennis on different surfaces with intake of different fluids on biochemical and physiological variables.

RESEARCH QUESTIONS

➢ Whether, the effect of different fluids on selected physiological and biochemical variables are same or not after simulated tennis matches, irrespective of playing surfaces?
➢ Whether, the effect of hard and clay-playing surface on selected physiological and biochemical variables are same or not after simulated tennis matches, irrespective of fluids?
➢ Whether, there is an interaction effect between playing surfaces and fluids on selected physiological and biochemical variables after simulated tennis matches?

DELIMITATIONS

➢ The study was delimited to 10 Male tennis players of university level, age ranging between 18 to 28 years from Lakshmibai National Institute of Physical Education. The training age of the subjects was of minimum 2 years.
➢ Selected fluids i.e. water, carbohydrate drink, electrolyte drink and sports drink were further delimited.
➢ The fluids were delimited to Glucon- D as carbohydrate drink, Electral as electrolyte drink and Gatorade as sports drink.
➢ The study was also delimited to simulated tennis match experimental protocol, where tennis ball machine was used.
➢ The study was further delimited to Dunlop new balls i.e. ITF approved balls.
The study was conducted between 36° C to 42° C environmental temperature was further delimitation.

Following Physiological and Biochemical variables were also delimited.

- **Physiological variables:**
  - Sweat rate
  - Body Temperature

- **Biochemical variables:**
  - Blood Lactate
  - Blood Glucose
  - Electrolyte Balance
    - Serum Sodium
    - Serum Potassium

Two tennis playing surfaces i.e. hard and clay was further delimited.

Urination during the commencement of the experimental protocol was not allowed was another delimitation.

Only cotton clothes and light color clothes were allowed to wear during the experimental protocol was further delimitation.

**LIMITATIONS**

- Inspite of utmost efforts of the scholar to control different extraneous variables certain factors as climatic conditions, wind flow, dietary habits and emotional conditions etc. at the time of test might have influenced the results of the study were treated as the limitation of the study.

- Water loss due to insensible perspiration during the simulated tennis match was not measured and acted as the limitation of the study.
HYPOTHESES

Based on the literature gone through, research findings and scholar's own understanding of the subject area, the following hypotheses were formulated.

- There is a significant interaction effect between fluids and playing surfaces on selected physiological and biochemical variables.
- In each of selected physiological and biochemical variables, there is a significant difference among the means of various fluids group, irrespective of playing surfaces.
- In each of selected physiological and biochemical variables, there is a significant difference among the means of different playing surfaces group, irrespective of fluids.

SIGNIFICANCE OF THE STUDY

Professional tennis has become very competitive in the modern era. Every player trains very hard to achieve and sustain in the competitive arena. However, training itself is not a full-fledged way to achieve great heights. It also requires many different aspects to sustain and remain consistent at the top level.

Tennis is an outdoor game, where players have to play outside as well as have to face all the environmental circumstances. Tennis players have to play tennis in hot environment as well as have to give their best. So keeping all this in considerations, this study is conducted to solve as well as to resolve this lacunas and drawbacks, so that best and optimum performance from the players can be attained.

Therefore, the significance of the study is as follows:

- The results of the study will help in understanding which fluid is best preferable at high temperatures during play.
- The results will also help to determine which surface brings changes on selected physiological and biochemical variables and through which type of fluid it can be minimized or maximized at high temperatures.
- The results of the study will assist coaches and trainers to train players in tennis as per the requirement of the ground conditions.
The study will provide the knowledge about the different surfaces, which will help to identify which surface is better for specific purpose.

The result of the study will help in preparing the training schedules of tennis players according to the environmental conditions.

DEFINITION AND EXPLANATION OF THE TERMS

**Blood Glucose** – Blood sugar; the means by which carbohydrate is carried in the blood; normal range is 70 – 120 mg/dl.

The main sugar that the body makes from the food in the diet. Glucose is carried through the bloodstream to provide energy to all cells in the body. Cells cannot use glucose without the help of insulin.

**Body Temperature** - The temperature of the human body, which is warmer at the core (centrally) — usually between 36 – 37.5°C — than at the periphery (extremities).

Normal body temperature varies by person, age, activity, and time of day. The average normal body temperature is generally accepted as 98.6°F (37°C).

Body temperature in this study refers to oral body temperature measured orally through mouth.

**Carbohydrate Drink** - A sports beverage designed to replenish the glycogen (energy) stores and provide energy substrates to exercising muscles.

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A carbohydrate drink is a drink mostly used in sports and contains glucose polymers, formulated to replenish energy reserves during and after exercise. It is used to replenish the glycogen stores and provide energy substrates to exercising muscles.

**Clay Court** – Clay Court is one of the surfaces where tennis is played. These clay courts are made of clay (bichoo cankad) where strong base of bichoo cankad was laid down to 3 feet's and top layer of court was made of clay and sand.

**Electral** – Electral is a type of isotonic drink, which consists of electrolytes i.e. sodium, potassium, chloride, citrate, and dextrose. 21.8 g of electral in 1 litre of water supplies electrolytes, based on W.H.O formula.

**Electrolyte Balance** - Positively or negatively charged ions found throughout the body. The body uses the electrolytes to establish ionically charged gradients across membranes in excitable tissues such as muscle and nerves so that they can generate electrical activity. The most well known electrolytes are sodium (Na+), potassium (K+) and chloride (Cl-).

**Electrolyte Drink** – Electrolyte drink is an isotonic drink and not an energy drink, which contains electrolytes i.e. sodium, potassium, chloride, citrate and dextrose. Electrolyte drink is used to treat and prevent dehydration (the loss of too much water). It assists in

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the replacement of fluids and electrolytes and helps in maintenance of hydration in diarrhea, vomiting and other conditions where there is a loss of water and electrolytes\textsuperscript{39}.

**Gatorade** - A commercial sports beverage which contains fluid, carbohydrate and electrolytes developed by Dr. Robert Cade and Dr. Dana Shires to replace the nutrients lost during exercise and heavy sweating for long duration events\textsuperscript{40}.

**Glucose Polymer Solutions** – Fluid replacement beverages containing primarily water and glucose polymers\textsuperscript{41}.

**Glucose** - One of the most commonly occurring simple sugars in nature. It is the carbohydrate that humans rely upon for cellular energy\textsuperscript{42}.

**Hard Court** – Hard court is a form of surface or floor on which tennis is played. Tennis hard courts are made of acrylic layers on top of a concrete foundation. Acrylic paint is a fast-drying paint containing pigment suspension in acrylic polymer emulsion. Acrylic paints can be diluted with water, but become water-resistant when dry. Depending on how much the paint is diluted (with water) or modified with acrylic gels, media, or pastes, the finished acrylic painting can resemble a watercolor or an oil painting, or have its own unique characteristics not attainable with other media. Three layers were coated on the tennis courts, where experiment was performed.

**Insensible Perspiration** - Perspiration on the skin not detachable by ordinary senses\textsuperscript{43}.


Lactic Acid – The anaerobic end product of glycolysis; it has been implicated as a causative factor in the etiology of fatigue.\textsuperscript{44}

The end product of anaerobic glycolysis in which the glycogen in the absence of oxygen is broken down to lactic acid.\textsuperscript{45}

Simulated Tennis Match Experimental Protocol – A tennis match played against the ball machine, which is actually very similar to authentic tennis match in many aspects, having fixed intensity, density and duration on both the playing surfaces.

Sports Drink - Sports drinks are beverages whose stated purpose is to help athletes replace water, electrolytes, and energy after training or competition, though their efficacy for that purpose has been questioned, particularly after exercise which is only moderate.\textsuperscript{46}

Sweat Rate – Sweat rate is the rate at which sweat is produced by the body. Sweating is the process by which sweat is formed within the sweat glands of the skin and excreted out in order to dissipate heat.

Water – A tasteless, colorless, odorless fluid essential to life; composed of two parts hydrogen and one part oxygen (H\textsubscript{2}O).\textsuperscript{47}

\textsuperscript{44} Melvin. H. Williams. (1999). op. cit., p. 488.

