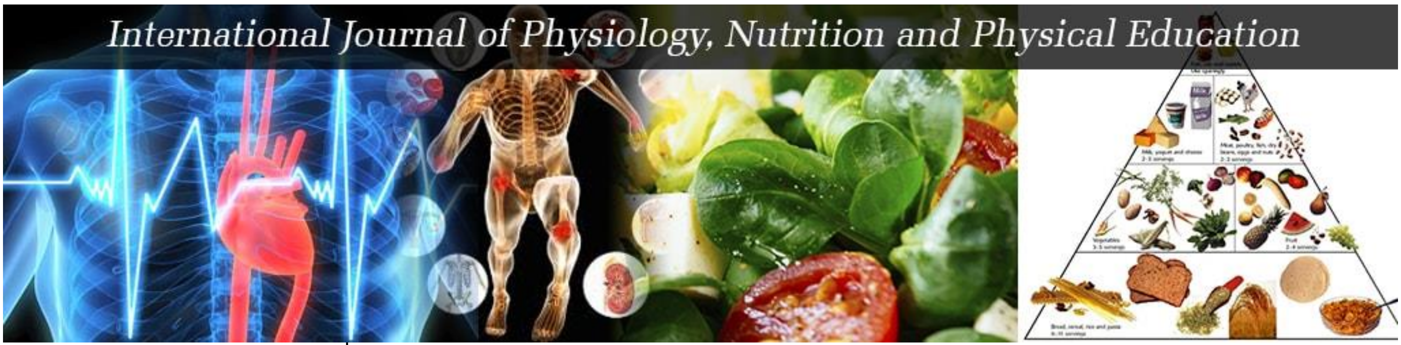

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Fluid supplements and playing surfaces effect on tennis players during simulated match at high temperature

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Abstract
The aim of this study was to compare the effect of consuming various fluid supplements while playing tennis on different playing surfaces on selected physiological and biochemical variables during simulated match at high temperature < 34 °C. Ten University level male tennis players, underwent eight treatment trials against the ball machine for 90 minutes, which had predetermined set protocol on Clay Surface (CS) and Hard Surface (HS); and consumed 1800 ml of different fluid supplements in each trial, namely Plain Water (PW), High Carbohydrate Drink (H-CHO), High Electrolyte Drink (H-ED) and Carbohydrate-Electrolyte Drink (CHO-E) in counterbalanced way. Two way repeated measures ANOVA were employed. It was concluded that CHO-E is the best drink on HS whereas on CS, CHO-E and H-ED are considered as best drink followed by H-CHO and PW respectively. This study shows that playing tennis on HS brings more physiological and biochemical changes than the CS at high temperature.

Keywords: Hard surface, clay surface, water, carbohydrate drink, electrolyte drink, simulated match

Introduction
Professional tennis is about to cross all the human limits; physically, physiologically as well as psychologically. Tennis is played in varied climatic conditions from cooler to hotter environment [1], certain competitions like Australian open exposes the tennis players to very hot condition. Due to which the performance and physiological responses of tennis players reduces and deteriorates rapidly. Although it is well known that exercise performance and physiological responses are reduced and exacerbated in the heat [2], still players have to perform, sustain and give their best effort in competition while playing in high temperature. In 2014, During Australian open players had faced adverse climatic conditions in which most of the matches were played in the tournament above 40 ºC (104° F) and many players had complaint regarding forcing the player to play at intense heat. Among those complaint, one of the Canadian player Frank Dancevic told reporters that "I think it's inhumane, I don't think it's fair to anybody, to the players, to the fans, to the sport, when you see players pulling out of matches, passing out". "Australian Open organizers have been criticized for forcing players to compete in intense heat as temperatures hit 42 ºC (107.6º F) in Melbourne" [3]. Playing tennis in a hot environment increases thermal stress, which ultimately deteriorates health and performance, if proper precautions are not taken [4, 5].
Tennis has no fixed time for matches; it varies from 30 minutes to several hours. However, the average length of one match is 1.5 hours and mean duration of point is 8.2 Sec [6]. Due to the intermittent nature, work/rest ratio and varied physical demands of tennis practice and competition, the maintenance of body temperature (BT) within an optimal range is very challenging especially in high temperature. Very limited data are available on core temperature in tennis due to the difficulty of monitoring in a live tournament situation.
In tennis players, glucose stored in the muscle burns very quickly. So, it's important for the players to consume liquid carbohydrate sources and foods containing simple carbohydrates during the match to raise and maintain the glucose level quickly. Another major challenge in a hot environment is to maintain the body fluid level by replacing the fluid and electrolyte losses. Since, the elite tennis match play has been previously shown to induce sweat rates of over 2.0 l/h. The amount of fluid required for different players to maintain the physiological and biochemical variables depends upon environment, intensity level; body mass and sweat rate (SR) [7].

Mark S Kovacs stated in his article that a competitive tennis player normally sweat around 2.0 L/hr. So, it would be better to drink 0.25 L on each changeover (assuming five changeovers per hour) to replace just 62.5% of the hourly lost fluid. If the player was trying to remain euhydrated (2.0 L•hr−1), then 0.40 L is needed on each changeover. Alternatively, 0.30 to 0.40 L of fluid should be consumed every 15 minutes of exercise (1.2 to 1.6 L/hr). These figures are chosen because they are equal to, or slightly higher than the approximate gastric emptying rate 1.2 L/hr. Any amounts larger than this would be a physiological challenge for the athletes and may produce gastrointestinal discomfort [6, 7]. In this study, looking into previous recommendations 1.2 L/hr of fluid supplement was given because the environment condition is extremely hot.

If the fluid deficit is ignored, performance during subsequent exercise might be negatively affected. Fluid replacement can reduce the lactate production and maintains physiological values of the tennis players. Martin *et al*. [8] conducted the research on both the playing surfaces and observed that blood lactate (BLa) production is more on clay surface (CS) as compared to the hard surface (HS), which might be due to longer points with shorter recovery times tend to produce a higher blood lactate level on CS than those with short points with longer rest points on HS [9].

Past researches show that CS brings more physiological and biochemical changes in tennis players as compared to the HS, which might be due to more playing match time on CS than HS. However in this study we had tested this phenomenon that which playing surface tends to produce more blood lactate level after the simulated tennis match.

Therefore, the aim of the study was to examine that, if intensity and duration are same on both the Playing Surfaces at high temperature, then which Playing Surfaces have less impact on physiological and biochemical changes on tennis players and which type of fluid can maintain the physiological and biochemical variables of tennis players and gives recovery faster although the concentration and ingredients of all the selected fluids were different, but which concentration and ingredient is best for the tennis player at high temperature is still missing in the past researches. The practical application of this study is to provide some recommended guidelines for tennis players and coaches regarding consumption of the best fluid supplement on both the Playing Surfaces at high temperature to enhance the performance and recovery as well as reduces the chances of dehydration.

2. Materials and Methods

2.1 Subjects

Ten university level male tennis players (age, range 18-28 years mean ± SD = 22.02 ± 2.35 years; training age = 3.8 ± 2.25 years; height = 174.9 ± 3.74 cm; weight 67.77 ± 8.01 kg; fat percentage by sum of 4 sides skin fold = 13.83 ± 2.62 mm; vital capacity 3.81 ± 0.49 ltr, resting heart rate = 59.6 ± 4 bpm) participated in this study. All were regular players and accustomed to high level of exertion, practicing for 10-12 hours per week. Subjects were asked to provide written, voluntary, informed consent prior to participation. The study was reviewed and approved by the Research Development Committee of Lakshmibai National Institute of Physical Education, India.

2.2 Design

This study was a planned, counter balanced and repeated measures research. In which repeated measures design with two factors (within – within) was used. Two factors: fluid supplements and Playing Surfaces were examined on selected biochemical and physiological variables during simulated tennis match at high temperature. To deal with this problem, each tennis player underwent eight treatment trials on CS and HS and consumed 1.2 l/h of fluid supplements in each trial, namely Plain Water (PW), High Carbohydrate Drink (H-CHO), High Electrolyte Drink (H-ED) and Carbohydrate-Electrolyte Drink (CHO-E) in counterbalanced way. BLa, BT, SR, Blood Glucose (BGL), Serum Potassium (K+) and Serum Sodium (Na) were measured in each trial after 90 minutes of simulated tennis match played against the ball machine, which had predetermined set protocol. It was hypothesized that HS brings more biochemical and physiological changes in tennis players as compared to CS and CHO-E is best to drink on both Playing Surfaces at high temperature.

2.3 Testing Procedures

Subjects performed a prolonged simulated tennis match of 3 sets (~ 1 hour 30 minutes) for 8 occasions. Matches were conducted on two surfaces; hard and clay. Four trials were conducted on HS and four trials on CS including four different interventions (fluid supplements) in a counterbalanced way. Trials were separated by 5 to 7 days for each subject. Subjects took rest for 36 hours, drank optimum amount of water to remain fully hydrated and Diet were standardized for 24 hours before each trial. The trial was conducted in between 09:00 A.M. to 02.00 P.M during summers. Before the experimental protocol, subjects consumed 200 ml of water in every 15 minutes [10] for 1 hour to remain hydrated, followed by pre test and then simulated tennis match was played against the ball machine, which had predetermined set protocol. Immediately after the simulated tennis match, post-test was taken. The test was conducted at high temperature above 34° C (which was measured by hygrometer - HTC Digital Thermo Hygrometer 103-CTH), as the environmental condition is too hot and humidity level is very low. Figure 1 illustrates the timeline of the experimental protocol and Figure 2 shows schematic illustration of simulated tennis match experimental protocol.

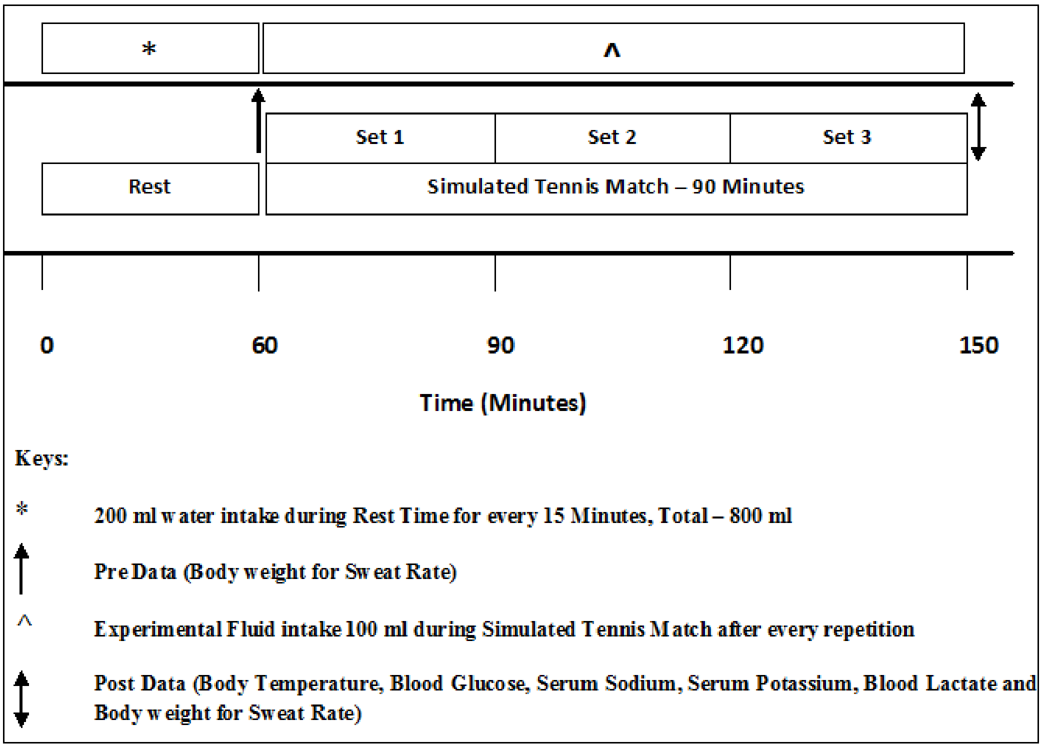


Fig 1: Diagram showing sequence of complete of experimental protocol

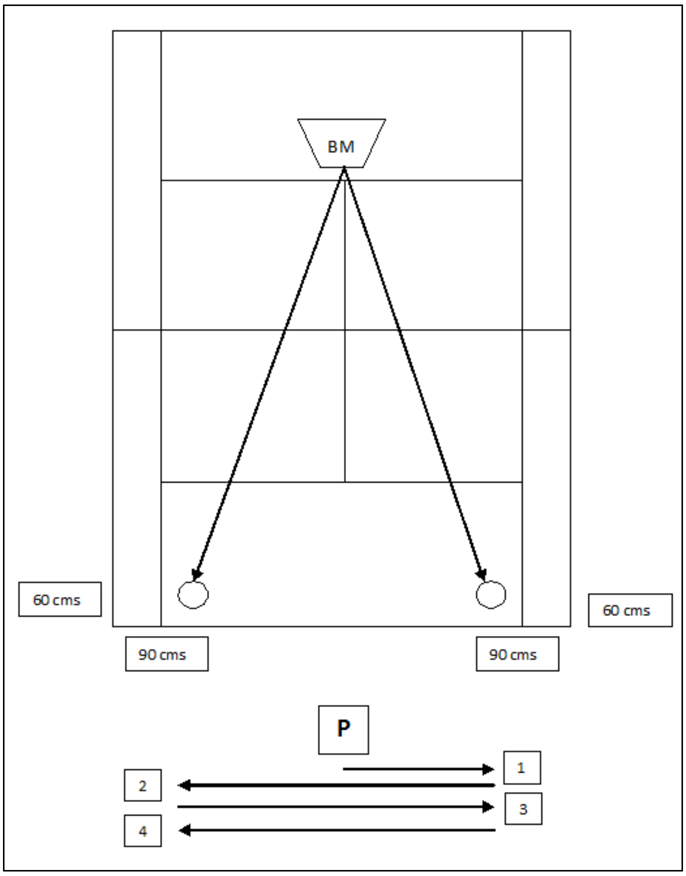


Fig 2: Schematic illustration of simulated tennis match experimental protocol *BM=Ball Machine; P=Players

2.4 Simulated Tennis Match Experimental Protocol

The protocol commenced with ball machine (tennis tutor plus player model) projecting 4 consecutive tennis balls at a frequency of 1 ball every 2.0 sec, with a velocity of 70 km/h, 70 cm over the net, and landing 60 cm from the opposite baseline and 90 cm from the singles sidelines [11]. The subjects had begun the experimental protocol from deuce court. The participant's role was to return each ball to the opposite end of the court and match the intensity as equal to the real match. After the completion of the rally, subjects rested at the baseline for 20 seconds, after which the next 8 seconds rally immediately commenced. This process continued until 8 points were completed. Thereafter, players sat and recovered courtside for 90 seconds and took their recommended fluid during that time. This above protocol comprised of 2 games which is equal to 1 repetition. Like this, 6 repetitions were performed for one set and three consecutive sets were played with 120 seconds rest between sets. The successive sets replicated the format of the first set. Each simulated tennis match time was 90 minutes.

2.5 Fluid Supplementations Strategies

After completion of one repetition subject ingested 100 ml of experimental fluid. In total 1800 ml (100 ml * 18 repetitions) of experimental fluid was consumed by the subject in one complete simulated tennis match.

2.5.1 Plain Water (PW): Normal water was consumed during experimental protocol.

2.5.2 High Carbohydrate Drink (H-CHO): Commercially available Glucon – D i.e. (glucose manufactured by Heinz India private limited, Aligarh) was administered. The ingested dose was 17.5 grams per 100 ml of water.

2.5.3 High Electrolyte Drink (H-ED): Commercially available Oral Rehydration salts i.e. (Electral based on W.H.O Formula manufactured by FDC Limited, Aurangabad) was administered. The ingested dose was 21.8 grams per litre of water.

2.5.4 Carbohydrate-Electrolyte Drink (CHO-E): commercially available Gatorade sports drink i.e. energy drink manufactured by PepsiCo, United States was administered. The ingested dose was 100 ml of lemon-lime-flavored Gatorade with 6% of carbohydrate.

2.6 Physiological and Biochemical Measures

BLa and BGL were analyzed from small capillary from either 3rd or 4th finger of the non dominant hand. Blood sample was taken and measured using Lactic Scout Analyzer (EKF diagnostics) and Glucometer (Accu Chek Active Glucometer), respectively. Venous blood samples (2 ml) were extracted from a superficial median cubital vein from the cubital fossa of the nondominant forearm to measure Na and K+. Samples were later send to a laboratory where it was examined via ion selective electrodes. BT was measured via digital thermometer (Dr. Morepen Digiclassic MT220 Hardtip Thermometer). SR was measured via weighing Machine (Digital Weighing Machine Glass Heuer HD201) where weight was measured in kg in a nude condition, then to calculate SR, formula was used (weight before the match – weight after the match) + fluid intake during the match. Environmental temperature and humidity was measured by hygrometer - HTC Digital Thermo Hygrometer 103-CTH, however WBGT was not measured due to unavailability of the Equipment. All the instruments were valid, calibrated and purchased from reputed firm.

2.7 Statistical Analyses

Two way repeated measures design was used as each subject underwent one trial under each fluid supplement on two different Playing Surfaces. However, data was collected twice before the match and after the match. Pre data was analyzed using two way repeated measures ANOVA (within-within) and results indicated that there was no significant difference among any trail. Then, the post data were analysed using two way repeated measures ANOVA (within-within) with provision for main effect of fluids and surfaces; and for interaction effect. In case of significant main effect result, bonferroni correction was employed for pair-wise comparisons to find the mean difference among the groups. In case of significant interaction effect, then one-way repeated measures ANOVA's was employed and Significance was recognized where $P < 0.05$. Results are reported as mean ± SD.

3. Results

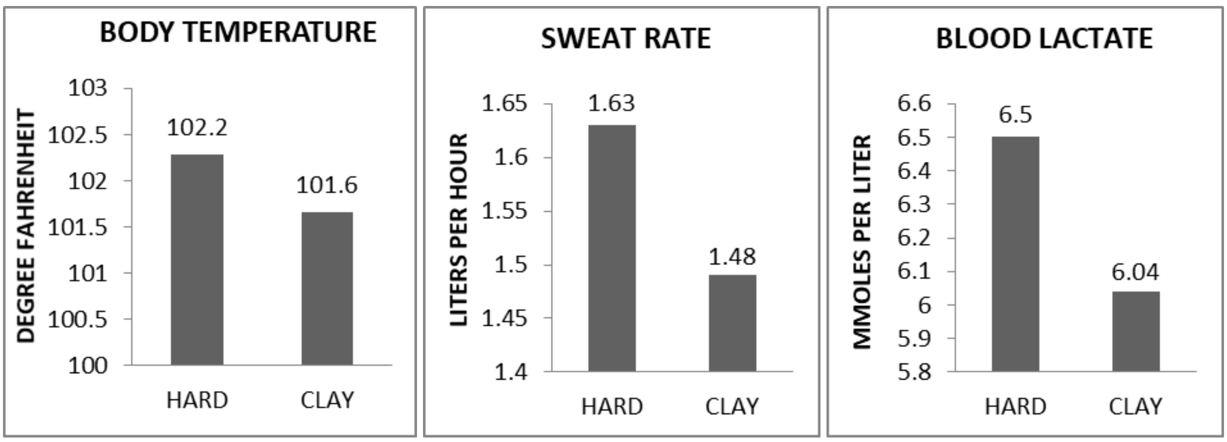
Table 1: illustrates environmental conditions between treatment conditions, values presented are mean ± SD

	HS-PW	HS-H-CHO	HS-H-ED	HS-CHO-E	CS-PW	CS-H-CHO	CS-H-ED	CS-CHO-E
Temperature (°C)	38.08 ± 3.14	37.45 ± 2.87	38.86 ± 3.03	39.34 ± 2.89	39.02 ± 3.31	38.43 ± 3.11	37.89 ± 2.96	38.67 ± 3.01
Humidity (%)	21.6 ± 1.95	20.9 ± 1.62	21.8 ± 1.73	21.1 ± 1.29	20.6 ± 1.56	21.5 ± 1.46	20.9 ± 1.64	21.5± 1.71

Abbreviations: HS-PW, Hard Surface Plain Water; HS-H-CHO, Hard Surface High Carbohydrate Drink; HS-H-ED, Hard Surface High Electrolyte Drink; HS-CHO-E, Hard Surface Carbohydrate Electrolyte Drink; CS-PW, Clay Surface Plain Water; CS-H-CHO, Clay Surface High Carbohydrate Drink; CS-H-ED, Clay Surface High Electrolyte Drink; CS-CHO-E, Clay Surface Carbohydrate Electrolyte Drink.

3.1 Playing Surface Effect

The Simulated match induced significant increase in BT & SR (P=0.000) and BLa (P=0.024) on HS than on CS (see Figure 3).



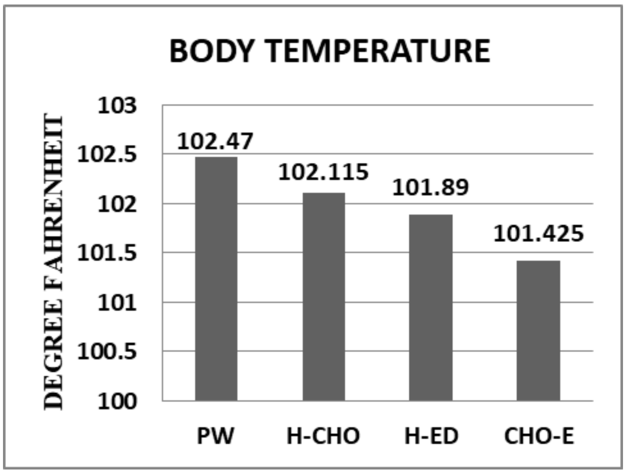
(A) (B) (C)

Fig 3: Effect of playing simulated tennis match on Hard and Clay Surface at high temperature on (A) Body Temperature (B) Sweat Rate (C) Blood Lactate

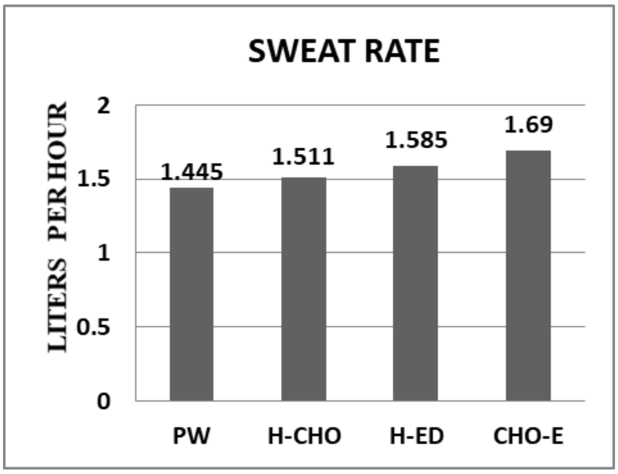
3.2 Fluid Supplementation Effect

There was significant main effect of fluid supplements on BT, SR & BGL (P=0.000), BLa (P=0.002), and Na & K+ (P=0.001).

CHO-E deteriorates the rate of increase of BT and BLa followed by H-ED, H-CHO and PW after simulated tennis match. SR, Na and K+ were significantly more in CHO-E followed by H-ED, H-CHO and PW. BLa was significantly more in PW followed by H-CHO, H-ED and CHO-E after simulated tennis match (see Figure 4).



(A)



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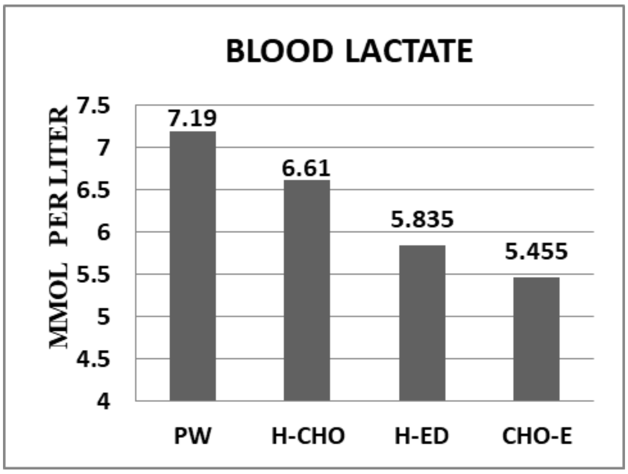

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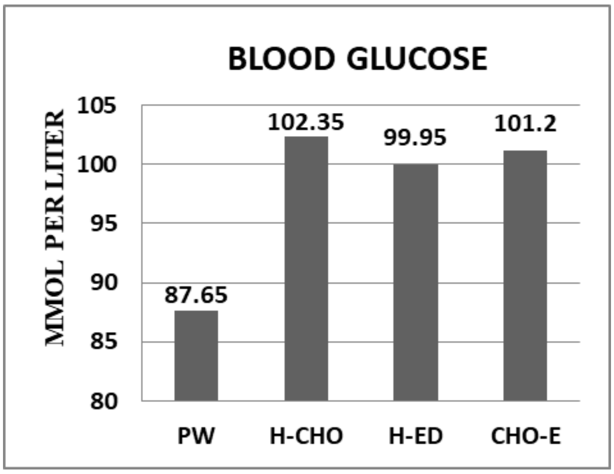

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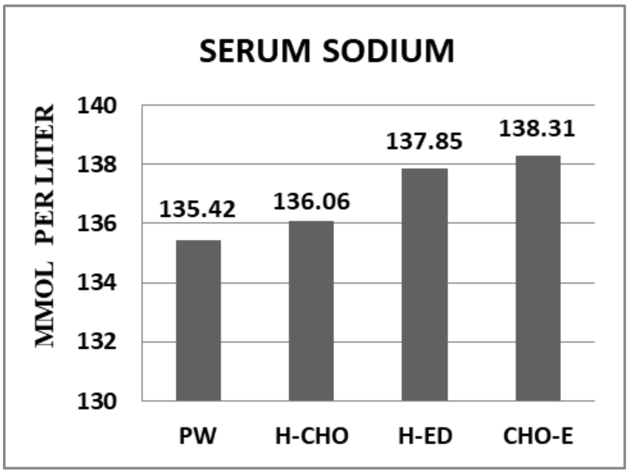
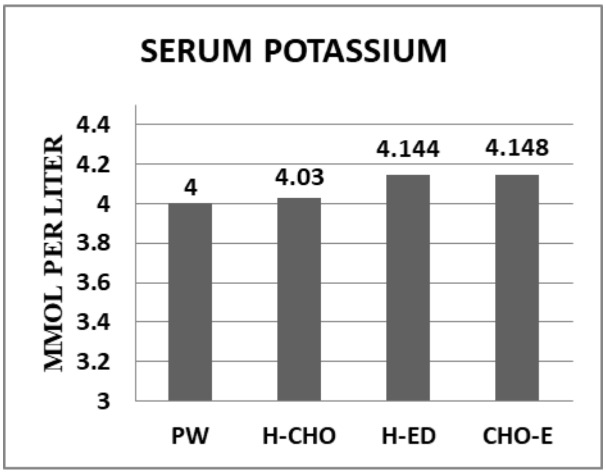


(E)



(F)

Fig 4: Effect of Various Fluid Supplementation during simulated tennis match at high temperature on (A) Body Temperature (B) Sweat Rate (C) Blood Lactate (D) Blood Glucose (E) Serum Sodium (F) Serum Potassium

3.3 Interaction Effect of Playing Surface and Fluid Supplementation

There was significant interaction between Playing Surfaces and fluid supplements (P=0.016) on SR and that dignifies that consumption of fluid is required more on HS than CS at high temperature (see Figure 5).

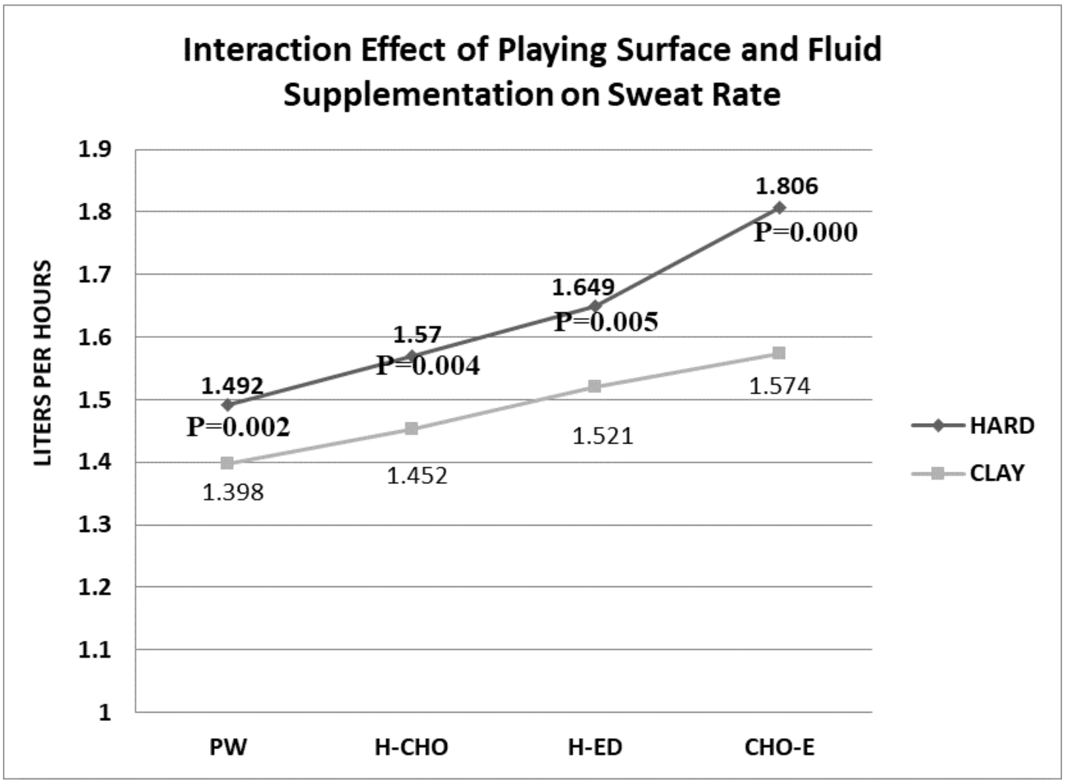


Fig 5: Interaction Effect of Playing Surface and Fluid Supplementation on sweat rate during simulated tennis match at high temperature

4. Discussion

The purpose of this investigation was to identify which commercially available fluid in market is more beneficial for the tennis players to maintain the efficacy of the body during the tennis match and which playing surface is more detrimental to reduce the physiological and biochemical efficacy of the player at high temperature during the match.

4.1 Playing Surfaces

Different Playing Surfaces was exposed to hot environment to investigate which surface is more detrimental to physiological and biochemical maintenance [12, 13]. Playing any sports in hot environment on synthetic turf, athletes experienced high temperatures than any other fields [12]. Researchers have also found that when the surface exposed to sunlight, the surface temperatures of synthetic turf are significantly higher than natural turfgrass [14, 15]. In the study of Buskirk *et al*. [14], he found that the surface temperatures of traditional synthetic turf were 10° C higher than the natural turf grass. This high temperature produces high amount of heat, which transfer from the surface to the sole of an athlete’s foot. Heat gain by the sole of the foot is required to dissipate by blood flow through sweating. Otherwise, it will significantly contribute to greater physiological stress that may result in serious heat related health problems. CS remains cooler under a hot sun as compared to HS, because in HS through the sole of the foot heat transfers from the surface to the body, which elevates the BT, due to which more blood flows towards the skin to dissipate heat through sweating [16], that’s why SR and BT increase more on HS than on CS. However, Poor prehydration status can also be responsible for high post BT [17]. However, Acclimation to the heat can lower an athlete's sweat-sodium concentration, but will increase SR during the match [16]. Similar findings regarding SR and BT on Playing Surfaces were seen in the study of Hornery *et al* [18].

BLa also increases more on HS as compared to CS. It might be due to two probable reasons, firstly decrease in the blood flow to active muscle by the increase in blood flow towards the skin or periphery to dissipate heat; due to which lactate uptake by the liver decreases because of reduction in hepatic blood flow and reduction of blood circulation in muscles [16]. Secondly, it has also been observed that muscle glycogen utilization increases in hot climate and this glycogen utilization activates both aerobic and anaerobic energy supply system which actually augmented due to elevated core temperature and dehydration [19]. However in the past researches the findings of blood lactate were reverse, there it was mentioned that Clay surface tends to produce more Blood Lactate than Hard surface, but the past researches were conducted in real match situation, not in simulated conditions. There was no significant difference between HS and CS on BGL, Na and K+. The reason might be due to the duration of the match, the experimental protocol commenced was of 90 minutes, which was not good enough to bring significant difference between the Playing Surfaces.

4.2 Fluid Supplements

Consuming the fluid before training or competitive event ensures hydration level of the athlete, so that he/she can perform at the best and maintain health. Different fluids have different ingredients, which helps to maintain the body physiologically and biochemically. Table 2 shows the ingredients of all three commercially available drinks.

Table 2: Ingredients of CHO-E, H-ED and H-CHO

Ingredients	CHO-E	H-ED	H-CHO
Dextrose Monohydrate (Grams)	32.4	3.375	72.48
Calcium (Milligrams)	0	0	123.96
Phosphorus (Milligrams)	0	0	72.92
Vitamin-D (I.U.)	0	0	218.76
Energy Value (Calories)	126	13	262.5
Sodium Chloride (Milligrams)	215	650	0
Potassium Chloride (Milligrams)	0	400	0
Sodium Citrate(Milligrams)	0	725	0
Osmolarity	280	245	Above 500
Weight for 500 ml of Fluid (Grams)	35	10.9	72.92

Playing tennis in hot environment can results in early fatigue, performance decrement and heat illness [20]. Therefore, sufficient amount of fluid and electrolytes are required to avoid this decrements and illnesses.

In this study, there was a significant difference among fluid supplements on all selected variables. The reasons might be due to availability of electrolytes in CHO-E and H-ED. The osmolarity level of CHO-E and H-ED was about 280 & 245 mOsmol/L, respectively; which is very close to osmolarity level of blood; which ultimately helps in rapid absorption of water in small intestine [21, 22], which increases the SR to control BT and electrolyte loses. Osmolarity level of H-CHO and water is about 500 and 0 mOsmol/L, respectively; due to which absorption process slows down as H-CHO and water osmolarity is far different from blood osmolarity.

Water is absorbed fairly readily by passive diffusion, and theoretically water absorption may actually be helped by concurrent absorption of glucose and sodium. Glucose and sodium interact in the intestinal wall; glucose stimulates sodium absorption, and vice versa. When glucose and sodium are absorbed, these solutes tend to pull fluid with them via an osmotic effect, thus facilitating the absorption of water from the intestine into the circulation. Research by shi and others [23], from gisolfi's laboratory has shown that multiple forms of carbohydrates such as glucose, fructose, polymers; enhances intestinal absorption of water. Each form of carbohydrate may have its own receptor for absorption and pull water with it [24].

Carbohydrate intake may be useful primarily in prolonged exercise, under conditions where one is exercising at a high level of intensity for hour or more and during warm environmental conditions the use of muscle glycogen may accelerate. But, in warm environmental conditions temperature regulation is of prime importance, water replacement should receive top priority. However, excess carbohydrate in the intestine may also cause a reverse osmotic effect, leading to gastrointestinal distress with symptoms such as abdominal cramping and diarrhea. Peters and others indicated that excess carbohydrate may pass to the colon, where bacterial fermentation may lead to excess gas production, flatulence, the urge to defecate, and gastrointestinal cramps [24].

The stomach can empty only a limited amount of glucose in a short period of time. If too much of glucose is present, the rate of gastric emptying is retarded, and glucose absorbs into the blood more slowly. Thus, ingestion of high concentration of glucose actually delays its utilization as a metabolic fuel. The recommended concentration of glucose is 3 to 5% weight/volume [25], or carbohydrate concentration (5 to 7%) [23], Whereas, Glucon-D recommends 17.5 Grams of glucose per 100 ml of water (17.5%), which reduces the fluid absorption process, due to which SR decreases and BT increases.

It is suggested to consume 200 ml of fluid in every 15 minutes to maintain the body fluid balance in a hot environment (WBGT 27 ºC). 26 In warmer conditions than (WBGT 27 ºC); the consumption of fluid should be increased than 0. 80L/hr which is actually less than the half amount of fluid lost in sweating [7, 27]. Therefore, in this study 1.2 l/h of fluid was given to the players during the simulated tennis match. However, endurance athletes must be careful not to ingest fluids at a greater rate than 800 ml per hour, except if it is too hot; otherwise, the fluid retained in the stomach may cause discomfort and may possibly hinder performance.

Playing tennis for long duration in a hot environment can lead to sodium losses [27]. The electrolyte i.e. Na and K+ was significantly more in CHO-E and H-ED because these beverages contain electrolytes, which maintained the electrolyte level of the body during the match. However, in PW and H-CHO, electrolytes are not available due to which as the match progresses, electrolytes comes out of the body through sweat, due to which it depletes and reduces the available electrolytes in the body. On the contrary BGL were significantly higher in H-CHO and CHO-E then H-ED and PW. It might be due to again ingredients of the fluids that contain glucose, which enhances the blood glucose level. However, water is not typically thought of as a nutritional supplement, it serves as a solvent, crating the environment needed for cellular reactions to occur [28]. It is generally agreed that ingestion of some liquid glucose such as CHO-E or glucose polymers during prolonged or moderate physical exercise will help spare muscle glycogen and delay or prevent hypoglycemia or low blood sugar levels [20, 24].

In this study, the BLa production was more with the consumption of PW followed by H-CHO, H-ED and at last, least in CHO-E. The reason might be the content of the fluids, CHO-E and H-ED contains electrolytes, which might help the player to avoid muscle cramps and increases palatability and accelerates the absorption of water after ingestion, which prevents dehydration even though the subjects were sweating at a very high rate [29]. Tennis is a muscular endurance sport, which produces muscular fatigue and only sufficient amount of electrolytes available in body can avoid it. This might be the probable reason why BLa production was more in H-CHO and PW because no electrolytes are available in them.

5. Practical Applications

Assessing the various fluid supplements, it is recommended that consumption of fluid CHO-E and H-ED is best to drink before and during the match to avoid dehydration on both the Playing Surfaces at high temperature. More cautiousness is required on HS at high temperature, because it can enhance heat related problems, if proper pre-hydration and hydration level is not maintained before and during the match.

6. Conclusion

The main findings from the study indicate that CHO-E ingestion during the simulated tennis match elevates the Na, K+, BGL, and SR and reduces the BLa and BT than other fluid supplement on both the Playing Surfaces. It was also found that if intensity, duration and density are same on both the Playing Surfaces at high temperature then HS elevates BT, BLa and SR than CS.

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