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EFFECTS OF DEHYDRATION, HYPERTHERMIA, COGNITION ASPECTS AND FATIGUE BALANCE ON SPORT PERFORMANCE

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ABSTRACT

EFFECTS OF DEHYDRATION, HYPERTHERMIA, COGNITION ASPECTS AND FATIGUE BALANCE ON SPORT PERFORMANCE

This dissertation presents two studies. The first is a systematic review, aimed at investigating the effects of hypohydration and fluid balance on athlete's cognitive function. PubMed, Sports Discuss, and Ebsco databases from 2005 to 2020 were searched for studies reporting on hypohydration, fluid balance, and heat on cognitive performance in sport. Search phrases included hydration, dehydration, fluid balance, mood, cognition, vigilance, decision-making, and brain. Participants in the studies received either fluid or none during exercise. Twenty-four trials (n=493 participants) from 24 articles met the inclusion criteria. Significant hypohydration, >2% body mass loss was reported consistently in 16 publications. Five articles reported that hypohydration was associated with heat stress and that limited fluid intake (3-5% body mass loss) impaired cognitive performance. Mood disturbance, fatigue, and ratings of perceived exertion constantly complemented hypohydration impairment on cognition.

The second study examined the effects of exercise heat-stress, hyperthermia, dehydration, and fatigue on cognitive performances in semi-professional athletes. Eighteen healthy, active male athletes from individual and team sports who met the following criteria were chosen to participate in the study: age (25 ± 5) years, weight (69.3±6.6) kg; height (172.5±7.8) cm, BMI (23.2±0.9) kg/m^2 and body fat % (9.2±1.8). Participants completed a cognitive and mood test battery prior, immediately after, and post 120 minutes of treadmill exercise. A soccer-specific intermittent treadmill exercise protocol was completed in four experimental trials in temperate (normothermic) and hot (hyperthermic) conditions. Participants were hydrated and dehydrated in both conditions. Trial conditions were normothermic 16.4±0.02°C and 52±1% relative humidity, while hyperthermic 33.9±0.3°C and 61±1% relative humidity. Response times for the Stroop effect and Visual search tasks were quicker (584 to 690ms, p=0.001; 1978 to 2213 ms, p=0.003) in the heat. Cognitive tasks showed that reaction time, visual process, motor speed, and mood were similar in normothermic (p=0.001).

Accuracy improved in hydrated hyperthermic by 1.2% ($p=0.002$) in Visual search. Total Mood Disturbance was significant in heat ($p<0.001$). Hydration status had no main effect in all cognition performance markers except for mood.

Exercise-heat stress, hyperthermia, dehydration, and hypohydration impaired cognitive performance and mood at higher levels of 3-5% body mass loss. The response times and accuracy improved following the cognitive testing in semi-professional athletes exercising in relatively humid, hot conditions. Athletic and cognitive performances were relatively affected by hypohydration, which can indicate an athlete's hydration status needs to be closely monitored during exercise.

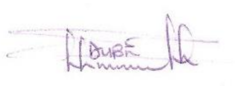
The findings of this study obtained from Eswatini individual and team sport athletes support that maintaining normal hydration has low physiological strain on athletic and cognitive performance.

Keywords:

Cognitive function, fluid replenishment, hypohydration, intermittent exercise, physiological strain

DECLARATION

By submitting this dissertation, I hereby declare that the work contained therein is my original work and has not previously in its entirety or part been submitted at any university for a degree. The co-authors of the articles, Dr. C Gouws (supervisor) and Dr. G Breukelman (co-supervisor) hereby permit the candidate, Mr. Adiele Dube, to include the articles as part of his MSc dissertation.



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Psalm 23:1

The Lord is my shepherd, and I shall not want.

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LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
BML	Body Mass Loss
CON	Control
DEHY	Dehydration
EUY	Euhydration
HYP	Hypohydration
HyN	Hydrated Normothermic
DehyN	Dehydrated Normothermic
HyHot	Hydrated Hyperthermic
DehyHot	Dehydrated Hyperthermic
HR	Heart Rate
LIST	Loughborough Intermittent
LSPT	Loughborough Soccer Passing Test
POMS	Profile of Mood State
RH	Relative Humidity
RPE	Rate of Perceived Exertion
SSITP	Soccer Specific Intermittent Treadmill Protocol
Tgi	Gastrointestinal Temperature
Ucol	Urine colour
Usg	Urine specific gravity
Uosm	Urine osmolality
TMD	Total Mood Disturbances
ΔBW	Change in body weight

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Daily, athletes are exposed to a range of environmental conditions like the sun, wind, humidity, and rain among others when performing physical activities (Wolf, 2016; Dunford and Doyle, 2017). Athletes depend upon their metabolic rate, clothing, environmental conditions, and nature of exercise to increase their body core temperatures significantly (Burchfield, 2015). This increase in body temperature elicits heat loss responding to increased skin blood flow and increased sweat secretion (Judelson et al., 2007; Jeukendrup and Gleeson, 2015; Burchfield, 2015).

Water and electrolytes are lost through sweat evaporation, resulting in heat loss during moderate to high-intensity exercise (Jeukendrup and Gleeson, 2015). If not properly restored, water and electrolyte imbalances (dehydration and hyponatremia) can negatively influence the athletes' exercise performance and possibly their health (Casa et al., 2005; Butts, 2018). Despite the commonly known importance of water in our bodies, adequate fluid intake is critical not only for survival, but also for helping to prevent cramps, heat exhaustion, heat stroke and thermoregulation. Unfortunately, many athletes do not seriously consider the effects of hydration during and after athletic acts for optimal performance (Shirreffs et al., 2004; Judelson et al., 2007; Jeukendrup and Gleeson, 2015). Hydration, body temperature, and fatigue play important roles in the functions of the body (McDermott et al., 2017).

The increased physical exertion during physical activity and athletic performance may make fluid consumption important (American Academy of Paediatrics Committee on Nutrition and Council on Sports Medicine and Fitness, 2011; Gamage et al., 2016). Hydration can be overlooked and undervalued as a component of peak athletic performance. Sawka (2000) and Wolf (2016), considered failure to replace lost fluids following physical exertion or heat exposure as voluntary dehydration, given the relationship between dehydration and increases in heat-related illness and decrements in physical performance. An overwhelming majority of laboratory studies conclude that dehydration, hyperthermia, and fatigue have a negative influence on the body's physiology (Montain & Coyle, 1992; González-Alonso et al., 1997; Sawka, 2000; Casa, et al., 2000; Sawka et al., 2001; Casa et al., 2005; Gamage et al., 2016).

A significant impact on the body's function and a decline in exercise performance is noted once water loss exceeds 2% of an individual's body mass (Sawka 2000; Butts, 2018). This hydration decrement results in a proportional decrease in VO_2 max of ~4-10%, decrease in muscle power ~ 3-10% and strength of ~10-17% (Montain & Coyle, 1992; González-Alonso et al., 1997; Casa, et al., 2000). Losses in excess of 5% of body weight can decrease the capacity for work by about 30% (Sawka, 2000). In addition to physical impairments, dehydration also impairs cognitive function, which includes reaction time, task performance, and mood state. Hydration and fatigue affect performance, cognition, and balance (Mudambo et al., 1997; Sawka, 2000; Judelson et al., 2007; Karslo, 2011; Jeukendrup and Gleeson, 2015; Gamage et al., 2016; McCartney et al., 2017). Thermoregulatory research studies have also shown that hyperthermia imposes thermoregulatory stress on the body, decreasing performance, muscle metabolism, and cognitive ability (Karslo, 2011; Gamage et al., 2016; McCartney et al., 2017). Core body temperature is the strongest limiting factor of performance in heat (Judelson et al., 2007; Wolf, 2016).

Every individual athlete has a unique and specific tolerance to heat exposure that may vary depending on fitness level, acclimatization, general health, body size, state of exhaustion, current diet, liquid and electrolyte consumption (Gamage et al., 2016; Trinies et al., 2016; McCartney et al., 2017). Anaerobic performances for example sprint athletes are generally less concerned about the effects of dehydration compared to aerobic performance by endurance athletes. However, the capacity to perform high-intensity exercise, which results in exhaustion within few minutes, is reduced by ~45% by prior dehydration equivalent to a loss on only 2.5% of body weight (Sawka et al., 2001). Although anaerobic performance offers little opportunity for sweat loss, athletes who travel in hot climates are more prone to experience acute dehydration, which continues for several days and can be serious enough to have a detrimental effect on performance in competition.

While much is known about dehydration, hyperthermia, and fatigue and their effects on the body, there are very few studies, if any, from Southern Africa that have directly looked at these three factors collectively. Additionally, there is little data of research to date performed on the effects of dehydration, hyperthermia, fatigue, cognition and balance on movement patterns and sports performance. Fatigue has been shown to change movement patterns, decrease in sports performance and an increase an individual's risk of injury (Padua et al., 2009; Di Stefano et al., 2009), alter stop-jump tasks, and therefore, increase the risk of non-contact anterior cruciate ligament injuries (Chappell et al., 2005).

During the past decades, most research conducted in Southern Africa were based on anthropometric and physical profiles of players and referees (Underlay et al., 2005; Banda and Grobbelaar, 2019) body composition and somatotype (Makaza et al., 2011; Toriola and Monyeki, 2012; Dube and Gundani, 2018). Others include a change in hydration status and aspects of cognitive function and profiles of primary school children (Trinies et al., 2016).

Literature reveals that there are few studies on examining the effects of dehydration, hyperthermia, fatigue factors on sporting performance and injury risks to athletes have been carried out in different countries other than Southern Africa (van Sumeren, 2011; Karslo, 2011; Butts, 2018; Nucciol et al., 2017). These studies have provided data that aided the understanding of how sports performance is affected by hydration status, fluid balance, hyperthermia, cognition aspects, and fatigue on movement patterns.

It is known that dehydration, hyperthermia, and fatigue individually decrease performance, cognition, and balance. Furthermore, what remains unknown is if the combined effect of all these will be enough to alter sports performance and put an individual at an even higher risk for injury. Since research and data on knowledge about the effects of dehydration, hyperthermia, and/or fatigue and their effects on sports performance in the Southern Africa context is scarce, this study needs to be conducted to further investigate this topic. This study identified the effects of dehydration, hyperthermia, aspects of cognition, and fatigue balance on cognitive and physical performance and the ways performance decrement can be prevented, which will be an important addition to Southern Africa literature. There is a great need to bring out a new knowledge base from an African context in this field.

1.2 PROBLEM STATEMENT

Eswatini professional athletes from various sport codes have not obtain awarded medal at very highly competitive events such as World Championships and Olympics for the past 2 decades. Despite the country's effort to professionalise sport through the Ministry of Sports, Culture and Youth Affairs, there has been notable decrease in sports performance, while sport-related injuries are skyrocketing at major competitions. To the author's knowledge, the interaction between sport-specific exercise in the heat and moderate dehydration on cognitive and physical performances has not been previously investigated in Eswatini. Although the different sporting codes are aware of hydration issues and fatigue, data on hydration versus cognitive and athletic performance remain unearthed. This negatively affects understanding possible methods to improve performance and prevent injury in the athletic populations considering a high record of prevalence of injuries, injury incidence rates, and related deaths in Eswatini (Dube et al., 2018).

1.3 AIM OF THE STUDY

This study aimed to identify the effects of dehydration, hyperthermia, aspects of cognition, and fatigue balance on sports performance. Although individual effects of dehydration and hyperthermia have been observed and discussed, the data are insufficient to conclude their combined effects on both anaerobic and aerobic athletic performances. There is a possibility that various exercise testing protocols were used. With the knowledge that dehydration, hyperthermia, cognition aspects, fatigue balance rarely occur independently during individual athletic performance, it is important to understand their combined effects on athletic performance and risk of injuries.

1.4 HYPOTHESES

H0: Balance on movement will not return to the baseline after recovery in dehydrated normothermic and dehydrated hyperthermic trials.

H1: Dehydration, hyperthermia, and fatigue will lead to a decrease in cognitive and physical performance during exercise.

H2: Fatigue will have the most detrimental effect on athletes during and after exercise.

H3: Combined effects of heat stress, dehydration, hyperthermia, and fatigue will increase injury risk.

1.5 THESIS STRUCTURE

This thesis was presented in article format as approved by the University of Zululand, consisting of three major parts, namely:

Chapter 1 presents the introduction, problem and states the aim and the hypothesis of this study, as well as the structure of the thesis.

Chapter 2 presents a Literature Review.

Chapter 3 presents Methodology of the study.

Chapter 4 presents the Results of the study.

Chapter 5 present the Discussion of the study.

Chapter 6 presents the Summary, Conclusion, Limitations, Recommendations, and Further research. The chapter is followed by a list of Annexures.

References of the thesis is according to the APA style as prescribed by the University of Zululand.

Two articles where accepted for publication – see Annexures E & F.

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CHAPTER 2: LITERATURE REVIEW: EFFECTS OF HYPOHYDRATION AND FLUID BALANCE IN ATHLETES' SPORT PERFORMANCE.

Introduction

Mega sporting events will continue to take place in diverse hot geographical environment across the globe as they have been in the past and in the present. As always, hypohydration can be expected in these events. The events include the Olympic Games, World Athletics Championships, and Federation International Football Association World Championships; Beijing 2008, Rio 2016, Doha 2019, Tokyo 2021, and Qatar 2022 (MacLeod, Cooper, Brandelow, Malcolm & Sunderland, 2018; Rodriguez, Piedra, Sanchez-Fernandez et al., 2020). With such exposure to hot environments, athletes in prolonged vigorous exercise, racket, and intermittent team sports experience significant and exceeding >2% body fluid loss due to thermoregulation (Rodriguez et al., 2020; MacLeod & Sunderland, 2012). Inadequate and/or no fluid loss replacement can cause endurance capacity impairment associated with physiological and cognitive function alterations (Belval, Hosokawa, Casa et al., 2019; Trangmar & Gonzalez-Alonso, 2019). Excessive dehydration impacts are a major cause of concern to athletic trainers and sports medical staff.

Dehydration and hypohydration deleterious effects on athletic performance and cognition have been widely researched (MacLeod et al., 2018; MacLeod & Sunderland, 2018; Trangmar & Gonzalez-Alonso, 2019). It is well known that a 2% body mass loss can impair endurance performance in humid and hot environments (Sawka, Burke, Eichner et al., 2007; Cheuvront & Kenefick, 2014). There has been limited research on the impact of hypohydration on athlete's cognitive performance and mood during individual and intermittent team sport (Nuccio, Bames, Carter & Baker, 2017; Zhang, Du Sum, Zhang & Ma, 2019). Literature has supported that dehydration may impair cognitive performance (Ely, Lovering, Horowitz & Minson, 2014; Taylor, Watkins, Marshall, Dascombe & Foster, 2015; Trinies, Chard, Mateo & Freeman, 2016) and functional task (Piil, Lundbye-Jensen, Trangmar & Nybo, 2017). However, it is known that rehydration may cause minimal or no effect on athletic, cognition and immunological performance if the outcome assessed is insensitive to the modest (up to 2% of body weight) fluid losses (Nuccio et al., 2017; MacLeod et al., 2018; Transgmar & Gonzalez-Alonso, 2019) Severe dehydration may aggravate fatigue, dizziness, confusion and in severe cases lead to delirium, coma, and death (Cian, Barraud, Melin & Raphal, 2001; Lieberman, Bathalon, Falcon, Kramer & Niro, 2005; D'Anci, Vibhakar, Kanter, Mahoney & Taylor, 2009; Ganio, Amstron,g & Casa et al., 2011; Amstrong, Ganio, Casa et al., 2012; Masento, Golighlty, Field et al., 2014). Various studies have demonstrated that heat stress and exercise-induced dehydration did not alter cognitive performance (Adam & Carter, 2008; Bandelow, Maughan, Shirreffs et al., 2010; Taylor et al., 2015; Belval et al., 2019). However, inconsistent conclusions exist in current literature (Trinies et al., 2016; Nuccio et al., 2017; Belval et al., 2019; Trangmar & Gonzalez-Alonso, 2019). Some studies have shown that discrepancies in literature may be due to task complexity, test duration, the magnitude of heat stress, and the test combined (Taylor et al., 2015; Piil et al., 2017).

Prolonged exercise in hot, humid environments with inadequate fluid replenishment may increase core body temperature (hyperthermia) to ~40℃ provoking athlete's mental status that worsens in moderately and untrained athletes (Nybo, 2008; Belval et al., 2019; Barnes & Baker, 2021). Although elite acclimated athletes may physiologically negotiate hyperthermic conditions, athletic trainers, sports scientists, and sports medical staff are working tirelessly to uncover cooling techniques to curb core body temperature, delay onset peripheral and central fatigue (Watson, Head, Pitiot et al., 2010; Wegman, Faude, Poppendieck et al., 2012; Belvel et al., 2019; Douzi, Duouy, Theurot et al., 2020; Barnes & Baker, 2021). Thus, researchers have investigated dehydration, hypohydration, and fluid ingestion aspects and their subsequent athletic performance effects (Nuccio et al., 2017; Rodriguez et al., 2020) which remains unclear. To date, no paper has reviewed and collectively discussed these aspects to equip professionals to gain better insights into the impact on individual and team sports performances. Therefore, this systematic review aimed to summarise the literature assessing the impact on hypohydration and fluid balance in relation to cognitive function in semi-professional to elite athletes exercising in humid and hot environments.

Dehydration, exercise-induced hyperthermia, cognitive aspects imbalance and fatigue are commonly known to occur during athletic practice or competition especially in the heat. It is known that dehydration, hyperthermia, and fatigue factors may independently cause reductions in athletic performance. Compounded effects of dehydration, hyperthermia, cognition aspects, fatigue and balance have been scarcely researched. Literature currently known about effects of these physiological insults on athletic performance will be discussed.

2.1 Dehydration

A moderate to a high intensity exercise in heat is known that hydration plays a significant role on the body functions (Karslo, 2011). Overwhelming literature based on laboratory studies show that dehydration negatively influence body's physiology and shown to have effects on balance, performance, and cognition (Casa et al., 2005; Carrasco, 2008; Karslo, 2011; Gamage et al., 2016; Dunford & Doyle, 2017; McDermott et al., 2017; Butts, 2018).

i. Physiological Effects

Dehydration has several general physiological factors which include significantly altered heart rate, stroke volume, cardiac output, and body core temperature (Casa et al., 2005; Dunford & Doyle, 2017; McDermott et al., 2017). Literature reveals that a body water deficit greater than 2% significantly affects physiologic function and performance (Sawka, 2000; Lieberman et al., 2005; Karslo, 2011; Trangmar et al., 2014; Trangmar et al., 2015; Jeukendrup et al., 2015; Gamage et al., 2016; McCartney et al., 2017). Sweating is the primary cause of body water and heat loss, though urination, respiration contribute small amounts of water loss (Casa et al., 2005). The table below summarises dehydration effects on physiology (heart rate, stroke volume, cardiac output).

Table 1. Summary of Dehydration effects on Physiology

References	Cardiovascular			Thermoregulation
	Heart rate	**Stroke volume**	**Cardiac Output**	**Temp °C**
Sureda et al. (2015)	N/A	N/A	N/A	Rise by 2.8°C
Pilch et al. (2014)	N/A	N/A	N/A	Rise by 1.2°C
Casa et al. (2010)	Increase by 10 bpm	N/A	N/A	Rise by 0.226°C
González-Alonso et al. (1997)	Increase 9 ± 1%	Decreases by 20 ± 1%	Decreases by 13 ± 2%	N/A
Montain et al. (1992)	Progressive increase	Decreases by 27%	Progressive decrease	Progressive rise
Sawka et al. (1985)	Increase by 4 bpm	N/A	N/A	Rise by 0.15°C

ii. Effects of Performance

Comprehensive literature on muscular performance from a variety of publications concluded that dehydration causes a decrement in most measures of anaerobic and aerobic performance (Judelson et al., 2007; Wolf, 2016; McCartney et al., 2017). Dehydration between 3-4% has been noted that it can cause performance decrement by: 2% muscle strength reduction, 3% muscle power reduction and 10% endurance reduction (Baker et al., 2007; Judelson et al., 2007). A 2% body weight decrease has been shown to cause performance reduction (Casa et al., 2005; Karslo, 2011). Fluid consumption following dehydration may improve continuous exercise performance under heat stress conditions, even when the body water deficit is modest and fluid intake is inadequate for complete rehydration (Murray, 2007; Lieberman, 2007; McCartney et al., 2017).

iii. **Cognitive Aspects**

The adverse effects of fluid loss on athletic and cognitive performance have been widely researched (Cian et al., 2001; D'Anci et al., 2009; Ganio et al., 2011). Literature on sport-specific exercise tests show that experimental investigations have demonstrated motor-skill impairments (MacLeod & Sunderland, 2012; Bandelow et al., 2010; Patel et al., 2007), recent systematic review and meta-analysis recognized significant decrements in aerobic and anaerobic exercise performance (Chang et al., 2012). Although evidence indicate an unfavourable effect of dehydration on cognitive function is less consistent (Carrasco, 2008), reduction in memory, mood state and perceptual bias has been experiential in some studies (Benton, 2011; Masento et al., 2014). Dehydration (fluid loss) amongst athletes has been easily observed (Lieberman, 2007; Judelson et al., 2007; MacLeod & Sunderland, 2012; Savoie et al., 2015), especially those who rely upon physical and mental proficiencies to either train or compete at elite levels. Therefore, such evidence provides the justification for fluid replacement recommendations.

iv. **Fatigue/ Balance Effects**

It is known that dehydration causes fatigue to occur (VanSumeren, 2011; Bandelow et al., 2010; Judelson et al., 2007). Body fluid dysregulation impairs mechanisms of thermoregulation (Casa et al., 2005) and increases cardiovascular strain during exercise, which negatively impact exercise performance (Clover, 2018; Judelson et al., 2007) and may compromise positive training-induced hemodynamic adaptations, hence fatigue (Wolf, 2016; Dunford & Doyle, 2017). Fatigue caused by dehydration may lead to decreased postural stability due to a lowered muscle efficiency and decreased proprioceptive sensitivity. Decreased postural stability can affect an athlete’s abilities during activity, leading to injury (McKinney et al, 2005). A significant decrease in performance on total Balance Error Scoring system (BESS) scores for both dehydrated conditions was noted in a trial carried by VanSumeren (2011). Literature reveals that decreased proprioception in athletic activity can be a result from both fatigue and dehydration and that dehydration alone can alter balance (Gauchard et al., 2002; Judelson et al., 2007; Wolf, 2016; Clover, 2018). Maintaining optimal hydration is a challenge during exercise especially exercises in the heat, due to the robust sweat rate, sweat sodium losses, heat acclimatization status, training status and daily fluid consumption (Karslo, 2011). Every individual is different; hence it was found impracticable to recommend a universal optimal fluid replacement strategy for all physically active individuals (Judelson et al., 2007; McCartney et al., 2017). Therefore, it creates a necessity for athletes to find a custom rehydration protocol to see which would work best for them.

2.2 Hyperthermia

It is important for athletes to keep themselves well hydrated for performance. When hypohydrated, heat dissipation ability is impaired, resulting in high body temperature (Sawka et al., 2015; Dunford & Doyle, 2017). Rapid increase in body core temperature and deteriorating thermoregulatory control may lead to coma and heat stroke (Dunford & Doyle, 2017; Bester, Kramer & Claassen, 2017).

i. Fatigue/Balance Effects

The previous studies revealed that dehydration did in fact cause an impaired ability to balance, but that those results were likely affected by additional influences of fatigue or hyperthermia (González-Alonso et al., 1997; Gauchard et al., 2002; González-Alonso, 2019; Trangmar & González-Alonso, 2019).

ii. Cognition Aspects

In addition to all other things, hyperthermia does to a subject's body, balance, cognition, and neuromuscular control may also be negatively affected (VanSumeren, 2011). Hyperthermia reduces ultimate functioning of the central nervous system (González-Alonso et al., 1999; Wolf, 2016). Lower extremity injury risk is increased when body awareness is compromised, such as in a situation where a subject has decreased cognitive function (Trangmar & González-Alonso, 2019).

iii. **Injury Risk**

Literature shows that hyperthermia directly affects many aspects of sport negatively; balance, fatigue, and cognition aspects increase a person's risk of injury (Casa et al., 2005; Dunford & Doyle, 2017). Previous BESS and Landing Error Scoring System (LESS) testing revealed that fatigue can change a subject's balance, exposing an injury risk (Judelson et al., 2007), hence likely that hyperthermia may influence injury risk (VanSumeren, 2011; MacLeod & Sunderland, 2012; Wolf, 2016). It can be noted that, a person exercising in the heat will eventually reach a point of fatigue; balance becomes altered, leading to increased injury risk. There is no direct evidence on having an elevated core temperature leads to an increased injury risk (VanSumeren, 2011).

The present study examined the effects of dehydration, hyperthermia, cognition aspects and fatigue balance on sport performance. 567 articles were potentially relevant. After the exclusion of duplicates, articles published before 2005, articles focusing on athletic performance, ageing, diseases, and children below 13 years, and a review of full-text versions, 24 articles were selected for the systematic review as shown in Fig 1 and Table 2.

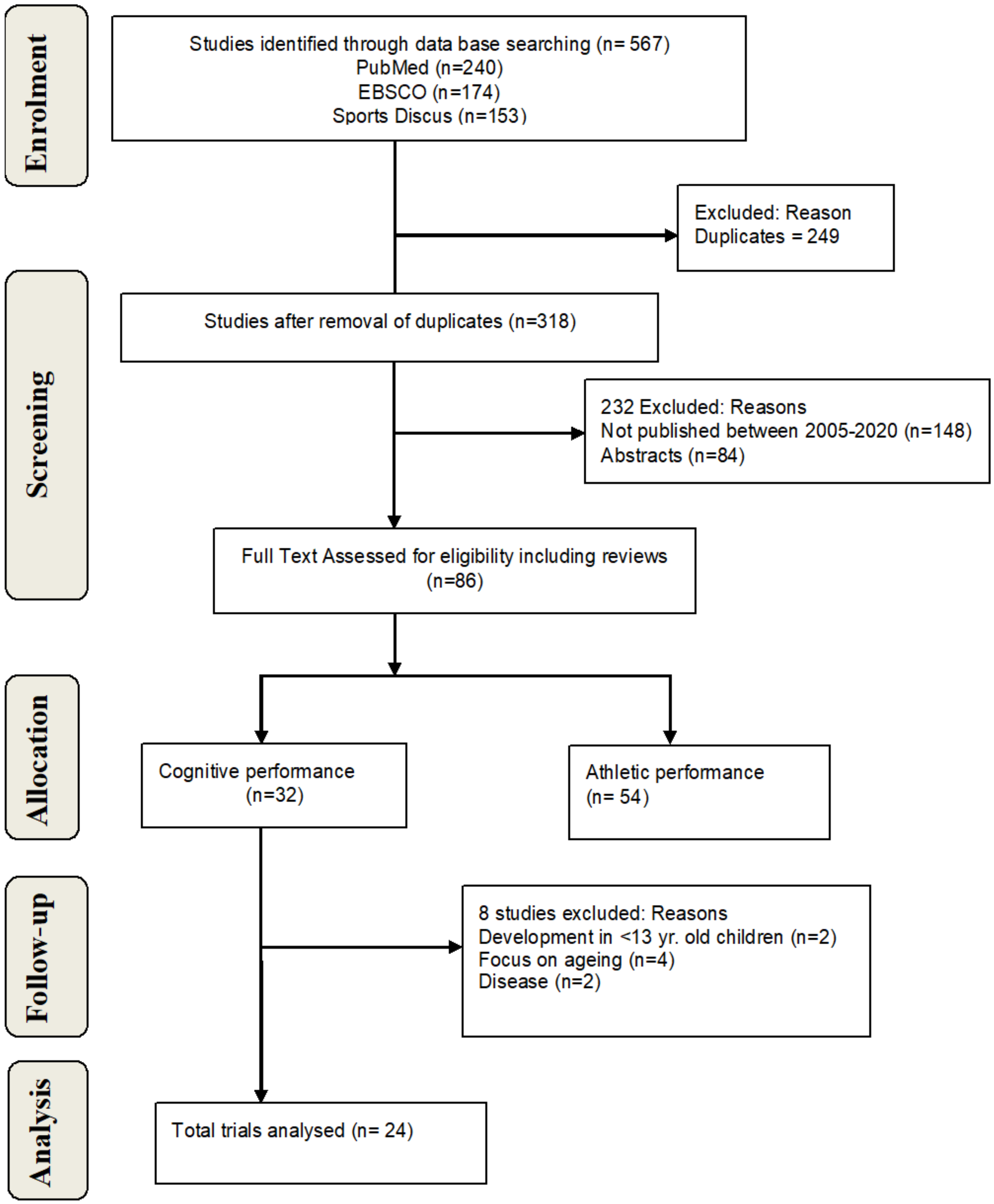

Fig.1. PRISMA Flow Chart of the study selection process

Table 2: Summary of research studies evaluating the effects of hydration levels on cognitive performance

Citation	Participants	Protocol	Hydration loss levels (% ∆ body mass	Fluid Type	Key Findings			Limitations
					Physiological and subjective measures	Cognitive domains assessed	Hyperthermia and Hypohydration effects on cognition	
Goodman et al.	N=15 12M, 3 Gender not revealed Military Defence Force 21-34yrs USA	Crossover designed, 90min self-paced military march in standardised military attire in the heat with a 20kg backpack Fluid restriction and or prescribed fluid intake throughout the exercise. Cognitive test battery Envir. Conditions: 39.5-41.8℃, 28-42% RH	2.28 (HYP trial- no fluid) 0.53 (EUY trial – Ad libitum fluid)	Ad libitum water	HYP: ↑Core body temp. ↑HR, ↑RPE, ↑Thirst. EUY: No significant difference in core body temp, perceived thirst	Information processing, memory, impulsivity, attention, and concentration, response time domains	HYP: ↓working memory ↓response times ↓attention task ↓depression ↓accuracy No significant effect on immediate or delayed memory, accuracy, and response speed.	Participants not blinded to hydration status
Wittbrodt et al.	N=13 7M, 6F 19-28yrs Healthy recreationally active adults USA	2-week; Counterbalanced 150min trial (intermittent exercise protocol): Three experimental; no exercise heat stress (CON), exercise heat seat stress with fluid replacement (EUY), exercise heat stress with dehydration (DEHY), exercise heat	3.1 DEHY, HYP (3.3 men 3.1 women) 0.2 EUY 0.0. CON	EUY, DEHY: water equivalent to sweat HYP: No fluid, only mouth rinse once per hour	↑HR, ↑Rectal temp., RPE, Thirst	Visuomotor functioning, Accuracy, reaction time	EUY, DEHY: Visuomotor performance impaired A significant effect on processing accuracy, and reaction time	Participants not blinded to hydration status

		stress without fluid replacement (HYP) Visuomotor Pacing Task (VMPT) Envir. Conditions: EUY, HYD, HYP : 45℃, 15% RH CON: 22℃, 30% RH						
MacLeod et al.	N=8 8F 19-22yrs Healthy unacclimatized elite hockey players UK	4 experimental sessions: 50min Hockey intermittent treadmill protocol with prescribed fluid intake to replace sweat loss; ad libitum water intake, or no fluid Cognitive testing after treadmill protocol Envir. conditions: Hot; 33.2-33.4℃, 58-60% RH Moderate; 13-19℃, 51-55% RH	HYP: ~2 no fluid EUY: ~ 0.0 No difference in ad water intake on moderate temp.	Ad libitum water	↑RPE ↑Thirst (HYP) prior to treadmill protocol No significant effect on HR and Temp (body core)	Process speed, working memory, perceptive discrimination, visual scanning/ processing speed	HYP: ↑Psychomotor function, visual scanning/ process speed EUY; ↑ working memory	Participants not blinded to hydration status
Piil et al.	N=139 139M 30-32yrs Recreationally active Cyprus, Denmark, Greece, Spain (Compiled in Greece)	Laboratory experiment: (EUY, DEHY) Occupational study (urine sampling), 8M for laboratory experiment in an environmental chamber with fluid replacement Motor-cognitive test	~ 2.0 (no fluid) 0.0 (fluid replacement)	Water	↑RPE, ↑Core body temp., ↑Thermal comfort, ↑Thirst ↑HR	Process speed, working visual scanning/ processing speed	No significant effect on cognitive domains	Participants unaware of the researcher's hypothesis and naive to the purpose of the studies

		battery pre-& post- Envir conditions: Manufacturing; 29℃, 25% H Agriculture; 29℃, 55% RH Police officers; 27℃, 50% RH Tourism; 30℃, 55% RH Construction; 26℃, 54% RH Environmental chamber; 40℃, 25% RH						
Van den Heuvel et al.	N=17 17M 25yrs Healthy, non-smoking Australia	Three Passive thermal-hydration protocol (water immersion) with states and then clamped using controlled, isotonic fluid administration. Unique immersion protocol establishment in the first trial and replicated in subsequent trials averaging 185min (137-242min) Envir. Conditions: Temperate; 34-35℃, Warm water; 40-41℃	3 and 5 (HYP) 0.0 (EUY trial)	sodium chloride NaCl+	↑HR, Thermal state, Core body temp., in HYP at 3% and 5%	Visual perception, working memory	↑Decision process modified ↓Depression ↓Discriminative ability (hyperthermia) No significant effect visual and working memory following 3-5% dehydration	Participants not blinded to hydration status
Gamage et al.	N=30 30M 22yrs, elite cricketers UK	Fluid restriction(4ml/kg/h) or fluid provision (12-15 ml/kg/h) during 2h of standardised cricket training	3.7 fluid restriction trial 0.9 fluid provision trial	Not reported	Not reported	Process speed, working memory, perceptive discrimination, visual scanning/	Not reported	Participants not blinded to hydration status Fluid type unknown

		Envir Conditions: Outdoors: 27.2-32.8℃, 66-89RH, ~2mph wind speed				processing speed		No validity or reliability testing of sport (cricket) skill
Wittbrodt et al.	N=12 12M Recreational active USA	Vigorous exercise intensity for 50mins Fluid assimilation time >50min Envir Conditions: Ambient temp 32℃, 65 RH	1.5	Water	↑ HR ↑altered skin temp. ↑ Thirst, ↑ fatigue	Process speed, working memory, perceptive discrimination, visual scanning/ processing speed	No effect	Participants not blinded to hydration status Exercise intensity not mentioned
Wilson et al.	N=8 8M Licensed jockeys UK	Exercise for 45 minutes Fluid assimilation time ~35min	1.8	Water	Not reported	Response inhibition	No effect	Participants not blinded to hydration status
Owen et al.	N=13 13M 22 yr olds, soccer semi-professional players UK	LIST protocol (90mims) with prescribed fluid intake to replace 89 sweat loss; ad libitum, water intake, or no fluid LSST and LLSPT performed after LIST protocol Envir Conditions: 19.4℃, 59.4 RH	0.3 (water intake) 1.1 (ad libitum water) 2.5 (no fluid)	Ad libitum water	↑ RPE (no fluid than water intake) ↑HR (no fluid than water intake and ad libitum water)	Process speed, working memory, perceptive discrimination, visual scanning/ processing speed	No effect	Participants were not blinded to hydration status
MacLeod et al.	N=8 8F 22yr olds, Elite field hockey players UK	2-day experiment Day 1: Baseline hockey skill measurement Passive heat stress (39.9℃, 73	~ 2 (HYP trial) Day 2: ~ 0 (EUY trial) No	Ad libitum water	↑RPE and ↑Thirst (HYPO) prior to treadmill protocol No	Process speed, working memory, perceptive discrimination, visual scanning/	↓ decision making time (skills test) ~7 slower (HYP vs EUY) prior to treadmill	Protocol, not field sport-specific but intermittent treadmill

		RH) → controlled fluid intake to induce HYPO or EUH Day 2: 60 min-hockey imitated and designed intermittent treadmill protocol Hockey skills test in a gymnasium Envir Conditions: Treadmill protocol; 33.3℃, 59 RH Gym 16.3 – 22.2℃,	difference in fluid intake Replacement fluid loss (88 vs 80) %		significant effect on HR and Temp (body core)	processing speed	protocol No significant effect on decision making time post treadmill protocol	protocol Use of Day 1 passive heat stress for Day 2 trials may be invalid Participants not blinded to hydration status
Hoffman et al.	N=10 10F 21 yr division 1 college Basketball player USA	40 min live scrimmage exercise Quick board lower body reaction agility, Dynavision D2- visual reaction time – all performed prior and post live scrimmage Envir Conditions: Indoors 22.6℃, 50.9 RH	2.3 no fluid) Not availed (water intake)	Water	No significant effect on HR and player load	Psychomotor function/process speed, visual scanning/processing speed	No significant effect on visual reaction time	Participants not blinded to hydration status No trial report for ∆ body mass during water intake Cognitive tests not validated prior
Brandenburg & Gaetz	N=12 12F 24yr Basketball Elite players Canada	A descriptive study covering 2 international indoor matches Envir Conditions: 22.5 – 23.5℃ 44-50 RH	1st match -2.1 to +5 2nd match -2 to +0.1	Diluted ad libitum and water according to individual taste	↑ HR	Process speed, working memory, perceptive discrimination, visual scanning/processing speed	No significant effect on field goal percentage Adverse relation (goal vs body mass	Carbohydrate has the confounding potential effect on Goal percentage

							loss in the 2nd match	No controlled trial (EUY)
Ely et al.	N=32 32M Healthy and non-heat unacclimated USA	3-week experiment EUY and HYP trials, 3h work-rest cycle, Counterbalance design Computer-based cognitive battery- 30min Assimilation time – 270 min Envir Conditions: 50℃, ~20 RH, Air speed 1.6ms⁻¹ Testing at 10, 20, 30, 40℃	4 Where a 4.5 loss incurred, the fluid replacement was done prior to proceeding with trials	Sodium chloride (NaCl) + water	HYP (no fluid replacement) ↑Thirst, ↑thermal discomfort ↑altered skin temp. ↑fatigue ↑HR	Psychomotor function/process speed, working memory, perceptive discrimination, visual scanning/processing speed	No significant effect on mood and cognition	Carbohydrate ingestion may have confounding potential effect on outcomes
Carvalho et al.	N=12 12M 14-15yr Basketball national team players Portugal	90 min training session HYP trials Basketball drills before and after training Envir Conditions: Indoors; 21.9-26.0℃, 48.3-54.1 RH	2.5 (no fluid) 1.1 fluid intake)	Ad libitum water	HYP trial: ↑RPE in	Process speed, working memory, perceptive discrimination, visual scanning/processing speed	Not availed	Participants not blinded to hydration status EUY (control) trial not available Basketball drill not validated prior
Ali et al.	N=10 10F Soccer Premier division players New Zealand	90min LIST protocol with fluid intake (15ml/kg) or without LSPT performed before, during, and after LIST Envir Conditions Not availed	2.2 (HYP) 1.0 (EUY)	Water	HYP trial: ↑RPE, core temperature, HR, blood lactate	Processing speed, perceptive discrimination, visual scanning	No significant effect; perceived activation and (dis-) pleasure	Participants not blinded to hydration status EUY (control) trial not available
Giano et al.	N=24 24M Physically fit	3-day laboratory experiment. DEHY +	1.59	Water	HYP trial: ↑RPE, core temp, HR	Process speed, working memory,	↑Processing speed and	Participants were not

	USA	Diuretic DEHY + Placebo EUY + Placebo Envir Conditions: 26.1-27.9℃, 54 RH, 3.5ms⁻¹ Wind speed				perceptive discrimination, visual scanning/ processing speed	working memory ↓Fatigue	blinded to hydration status
Bandelow et al.	N=20 20M University soccer players UK	Cognitive battery tests: Sternberg test Corsi block test, Finger tapping test Visual sensitivity test Trials before, at half-time, after the match HYP Envir Conditions: 34℃, 62 -65 RH	2.5	Ad libitum water Sports drink	Not reported	Process speed, working memory, perceptive discrimination, visual scanning/ processing speed	↓working memory (HYP) No significant in fine motor speed, working memory, reaction time	EUY trial not available (control) No sport-specific cognitive tests
D'Anci et al.	N=31 16M; 15F University lacrosse and rowing athletes USA	Study 1: HYP trial, EUY trial Coach-run, hard natural practice Cognitive test battery post-practice Envir Conditions. RH not stated Assimilating time 60-70min	2.0 (HYP) 0.1 (EUY)	Water	HYP trial: ↑Thirst, ↑POMS: tension, anger, fatigue, depression ↓ vigor	Vigilance attention, short-term memory, simple and choice reaction, map planning, visual perception, mathematical addition, mood	HYP: ↑Processing speed ↓Vigilance, depression (3-4%) No effect on spatial memory, reaction time, map planning, mathematical addition	Participants were not blinded to hydration status
D'Anci et al.	N=24 12M; 12F University lacrosse, rowing, and American football athletes USA	Study 2: HYP trial, EUY trial Coach-run, hard natural practice Cognitive test battery post-practice Envir Conditions RH not stated Assimilating	1.7 (HYP) +0.1 (EUY)	Water	HYP trial: ↑Thirst, ↑POMS: tension, anger, fatigue, depression ↓ vigor	Vigilance attention, short-term memory, simple and choice reaction, map planning, visual perception, mathematical addition, mood	No effect on short-term and spatial memory, reaction time, map planning, mathematical addition	No sport-specific cognitive tests administered

		time 60-75min						
Adam et al.	N=8 8M Active soldiers (6) USA	Heat exposure for 300 min Envir Conditions: 20℃, 50% RH Wind speed 1 to 2.2 m/s	3.0	No fluid	↑Thirst, thermal discomfort ↑altered skin temp. ↑fatigue ↑HR	Processing speed, working memory, perceptive discrimination, vigilance, visual scanning	No significant effect on cognitive domains	EUY trial not available (control)
Baker et al.	N=11 11M 17-28yr male competitive basketball players USA	Experimental: 3hr interval walking in heat chamber; HYP trials, EUY trials, 80 min stimulated match Attention variables test: baseline, post chamber, post-match Envir Conditions: 40℃, 20% RH (heat chamber), room temp. (indoor match)	HYP: 1%, 2%, 3%, 4% EUY: 0	No fluid Flavoured water	HYP trial (1-4%): ↑lightheaded, overheat, fatigue No effect of core body temp.	Attention variables, perceptive discrimination, vigilance, visual scanning	HYP trial (1-4%): ↑ commission and omission errors ↓response time (6-8%)	Participants were not blinded to hydration status Rationale of induced heat stress to attention variables test before a basketball match unrealistic
Edwards et al.	N=11 11M moderately active soccer players New Zealand	90 min exercise: 45 min cycling, 45 min soccer match (80 fluid loss replacement) Post-match mental concentration test (number identification) Envir Conditions: 24- 25℃, 47-55 RH (cycling), 19- 21℃, 46 - 57 RH (soccer match)	0.7 (fluid intake) 2.1 (mouth rinse) 2.4 (no fluid)	Water mouth rinse No fluid	↑ HR ↑thermal discomfort ↑altered skin temp. ↑ Thirst, ↑ fatigue	Processing speed, visual scanning	No significant effect on mental concentration	Participants were not blinded to hydration status The rationale of cycling before a match in soccer is doubtful
Serwah & Marino	N=8 8M 25yrs	90min discontinuous fixed-intensity	2.0 (full fluid)	Water	No fluid: ↑HR ↑Skin	Processing speed, working	No significant effect on	Participants were not

	Healthy volunteers Australia	exercise: 3 experimental conditions (full fluid replacement, half fluid replacement, no fluid Own bicycle mounted on the electromagnetically braked cycle trainer Envir. Conditions: 31.3℃, 62.1-64.5% RH Wind speed 2m/s	1.0 (half fluid) 1.7 (no fluid)		temp., ↑Thirst No effect of core body temp. in full and half fluid conditions	memory, perceptive discrimination, vigilance, visual scanning	cognitive domains	blinded to hydration status No sport can employ a discontinuous fixed-intensity nature of exercise protocol
Szinnai et al	N=17 8M 7F 25-33yrs Health non-smoking volunteers Switzerland	Experimental done in random order EXP; CON Female: Pre and post menstrual Men: Cognitive function test Envir. Conditions: Cognitive tests: 22℃	1.75 CON 3.26 DEHY	Mineral water	No fluid: ↑HR ↑Fatigue ↑Thirst ↓Alertness No significant effect in the control group	Processing speed, working memory, perceptive discrimination, vigilance, visual scanning, reaction time	No significant effect on cognitive domains in moderate dehydration	Participants were not blinded to hydration status

This literature review aimed to summarise literature assessing the impact of hypohydration and fluid balance on cognitive function in semi-professional to elite athletes exercising in humid, hot environments. The discussion considered the risk factors posed by an increase in sweat loss to ≥2% body mass loss. Major causes of hypohydration were discussed as environmental factors, exercise intensity, and/ or limited fluid replacement in relation to the brain and cognitive performance. Effects on cognitive performance and mood in the studies included in this review considered individual and team sports with training or competition duration of more than 1 hour (Nuccio et al., 2017; Douzi et al., 2020; Barnes et al., 2021). Although hypohydration risk levels may vary in different sports, the review takes the notion that individual risk factors among athletes may be altered between low- and high-level categories depending on humidity, timing day/season and intensity level, hydrating behaviours, social and cultural considerations.

2.3 Fluid balance and the Brain

The brain, a complex active part of the human body is known for its high metabolism. It accounts for ~15% of resting cardiac output and a relatively higher total body aerobic metabolism of ~20% (Lassen, 1985; Madsen, Holm, Herning & Lassen, 1993;). To maintain its high metabolism, the brain depends solely on adequate circulation of oxygen, metabolic substrates, and metabolic by-products elimination (Trangmar & Gonzalez-Alonso, 2019). Heat stress, hyperthermia, and dehydration are known physiological stressors to alter cerebral circulation and metabolism. Hypohydration was found to mediate brain function reduction by reducing cerebral blood flow and brain cell volume, hence increasing blood-brain permeability (Nuccio et al., 2017).

Exercise stimulus causes adjustments to Cerebral Blood Flow (CBF). A study by Kety and Schmidt (Kety & Schmidt, 1946) showed that CBF could not be altered during the athletic rest-to-exercise transition. Recent temporal resolution methods showed a ~20% CBF rise due to endurance and moderate exercise intensities (Ketty Y Schmidt, 1946; Madsen et al., 1993; Nybo & Nielsen, 2001; Sato, Ogoh, Hirasawa et al., 2011). Indeed, CBF is subdued with high exercise intensities and significantly surpass rest levels due to exhaustion (Moraine, Lamotte, Berre et al., 1993; Trangmar, Chiesa, Kalsi et al., 2017).

Progressive dehydration during individual and/ or intermittent team sports without concomitant hyperthermia increases CBF (Fan, Cotter, Luca et al., 2008). However, when the athlete is resting, a 1.5℃ increase in body core temperature causes a ~15% CBF reduction (Ogoh, Sato, Okazaki et al., 2013). It should be noted that both dehydration and hyperthermia changes CBF mechanisms in different exercises (Trangmar & Gonzalez, 2019), intensities, and environments. Dehydration ≥3% body mass loss during endurance exercise in a hot, humid environment reduces CBF due to cerebrovascular instability and cardiovascular drift (Kempton, Ettingur, Forster et al., 2011; Periard & Racinais, 2015; Watanabe, Stohr, Akiyama et al., 2020). In contrast, CBF reduction is attenuated when there is equilibrium between body fluid lost through sweating and fluid replenishment during exercise (Kempton et al., 2011; Amaoutis, Kavouras, Stratakis et al., 2017; Trangmar & Gonzalez-Alonso, 2019).

Heat-induced stress, hyperthermia, and dehydration effects on CBF are associated with prolonged aerobic exercise (Trangmar & Gonzalez-Alonso, 2019). Previous studies reveal that CBF reduction is worsened during acute-intensity exercise in hot and humid environments (Trangmar et al., 2014; Wittbrodt, Sawka, Mizelle et al., 2018; Trangmar et al., 2019; Batned & Baker, 2021) compared to cold and temperate environments. Similarly, elite athletes' dehydration levels during training or competition in hot environments are compensable despite reduced CBF and work rate than their untrained counterparts. When athletes maintain euhydration status, the mechanisms, and dynamics of CBF tend to normalise (Trangmar et al., 2017). Therefore, endurance exercising in a hot and humid environment provokes dehydration, and hyperthermia enhancing cerebrovascular strain with CBF decline.

2.4 Hypohydration and Cognition

Excessive dehydration (hypohydration) effects on cognitive performances have been widely researched across different ages and populations of varied physical fitness. Scientific evidence shows inconsistent findings. Some studies revealed that hypohydration does not affect cognition (McGregor, Nicholas, Lakomy & Wulliams, 1999; Edwards, Mann, Marfell et al., 2007; Adam, Carter, Cheuvront et al., 200) others showed a reduction in cognitive function among military, athletes, young healthy adults, and the elderly (Baker et al., 2007; D'Annci et al., 2009; Ganio et al., 2011; Van den Heuvel, Habarley, Hoyle et al., 2017; McCartheny, Desbrow & Irwin, 2017; Goodman et al., 2019; Wittbrodt et al., 2018). Despite evidence of fluid intake benefits on cognitive function observed, literature lacks a clear indication of better treatment efficacy on specific cognitive domains (McCartheny, Desbrow & Irwin, 2017; Belval et al., 2019). Cheuvront & Kenefick (2014) indicated a lack of clear mechanism by which hypovolemia or hyperosmolality cause cognitive impairment. Studies, however, consistently report hypohydration effects on brain function through 1-4% body mass loss reported in cognitive performance literature (Wittbordt et al., 2018; Belval et al., 2019; Barnes & Baker, 2021).

Prolonged exercise in hot environments without fluid replacement elevates core body temperature thereby creating a cognitive burden (Bandelow et al., 2010). The symptoms of hypohydration including thirst and negative mood states have an equal effect on accomplishing cognitive tasks and consequently impair function (Cheuvront & Kenefick, 2014; Nuccio et al., 2017). Cognitive trials conducted in less than 5 minutes after dehydration protocol ended found that ≤2.8% body mass loss induced through fluid deprivation had no impact on cognitive-motor performance (Serwah & Marino, 2006; Edwards et al., 2007; Ali, Gardiner, Foskett & Grant, 2011; Piil et al., 2017). Although many studies did not clearly show the time from the end of dehydration protocol to commencement of the cognitive tests, a significant raise in ratings of thirst, concentration, and ratings of perceived effort was found Edwards et al., 2007; (D'Anci et al., 2009; Piil et al., 2016). In all the above trials, the long-lasting effects of physiological stressors employed may obstruct fluid intake influencing cognitive performance (Nuccio et al., 2017, McCartney, et al., 2017).

Fluid replenishment attenuates Total Mood Disturbance in 3 of the 5 trials where mood was measured (D'Anci et al., 2009; Van den Heuvel et al., 2017; Barnes & Baker, 2021; Goodman et al., 2019). Considering that mood effects and cognition were independent, it should be noted that the above three findings were objective compared to the subjective (McCartney et al., 2017). However, if not clearly stated, self-reported mood questionnaires are subjective and consider mood effects as dependent variables. It is certain that the influence of fluid replenishment on cognitive function and mood needs further research (McCartney et al., 2017; Barnes & Baker, 2021).

Conclusion

Considering that most of the studies measured up to 2.7% body mass loss, the impact of hypohydration and fluid balance on cognitive performance in individual and team sports remains equivocal. In all the studies involved, measures of cognitive function altered include processing speed, vigilance, and reaction time for working memory. It is important to note that visuomotor reaction, mental concentration, and visual scanning and/ perception were not significantly affected by fluid balance and hypohydration. This inconsistency should inform the need to consider objectivity, subjectivity, validity, reliability, and sensitivity of cognitive function assessment tools for the athletic population. The current review serves to draw attention to areas for future research.

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CHAPTER 3: METHODOLOGY

3.1 RESEARCH DESIGN

Participants

Eighteen healthy male athletes aged (25 ± 5) years; weight (69.3 ± 6.6) kg; height (172.5 ± 7.8) cm; BMI (23.2 ± 0.9) kgm^{-2} were purposively selected to participate in this study. Participants were actively involved in individual sports (e.g., tennis, >2hr running) and team sports (e.g., hockey, football, rugby). All participants were involved in a minimal exercise of at least 6-8 hours per week at a moderate-to-vigorous intensity, a minimum duration of 1½ hours, with 4-5 training days per week. Given the wide range of sporting codes under consideration and variability in individual sweat rates, the unique interplay between intensity, duration and sweat rate was considered in unison. For example, a runner with a 2L/h sweat rate who completes a marathon in 2h will accumulate the same fluid losses as a runner with a 1L/h sweat rate that completes a tennis match in 4h. Despite purposive sampling, due to the Covid-19 pandemic and fast rate of infection, those on medical treatment were excluded even though they had participated in the initial experiments.

Ethical considerations

Participants were informed about all experimental procedures, discomforts, and associated risks before they completed the informed consent form. The University of Zululand's Ethical Advisory Committee (UZREC171110-030-PGM2021/72) approved the study.

Design

Participants completed the four experimental sessions. These sessions included two temperate conditions (normothermic: hydrated; dehydrated) and two hot environmental conditions (hyperthermic: hydrated; dehydrated). The trial averages for the normothermic conditions were 16.4±0.02°C and 52±1% relative humidity (RH), while the hyperthermic conditions were 33.9±0.3°C and 61±1% RH. The chosen temperatures were 17°C and 35°C, for moderate and hot environments respectively resembling dry season temperatures at 100–400m altitude.

Familiarisation

Participants reported to the sports emporium laboratory four times throughout the study. They were instructed to drink at least 500ml fluid before they sleep a night before and upon waking up before the beginning of the three familiarisation sessions. The second session was for gathering anthropometric measurements; heights, body mass, percentage body fat, VO_2 max, and sweat rate. Acute changes in body mass over an exercise bout were used to determine sweat rate, frequency of fluid replacement and fluid needs for recovery for that session. The Tanaka equation [Heart Rate max = 208 - (0.7 x Age)] was used to estimate the VO_2 max ml/kg/min = (22.351 x distance covered in kilomters) – 11.288 maximum heart rate (Cheuvront & Kenefick, 2014; Trangmar & González-Alonso, 2019; MacLeod et al., 2018). The third and fourth sessions involved wearing of the heart rate monitor, putting on a weighted vest equivalent to 12% of individual body weight on a 5% inclined treadmill with speed between 4.8 – 6.4 km/hr that one can sustain for the 90-minute duration, at age-predicted maximal of >90% heart rate. Pre-and post-exercise measurements to determine sweat rate were done. The Cognitive Performance test battery (Cooper et al., 2015) and the Profile of Mood States (McNair, Lorr, & Droppleman, 1992) were performed in all four sessions. All participants ingested a thermometer pill for gastrointestinal temperature (Tgi) (Bongers, Hopman, & Eijsvogels, 2015), 8-10 hours within 48 hours to the commencement of the first trial.

3.2 EXPERIMENT AND PROTOCOL’S

Experimental procedures

Each of the four test sessions begun with several physiologic measurements; baseline mass, urine specific gravity (Usg), urine colour (Ucol), core body temperature, heart rate (HR). Circadian influences were minimized by conducting trials during the same time every day from 0700–1100 hours. There was an interval of four days between trials to allow participants to recover adequately. Participants refrained from the consumption of caffeine, alcoholic beverages, and intense exercise for at least 48 hours before trials. Each participant was advised to drink at least 2L of water per day, at least 500ml before sleep to ensure that one arrives at the lab well hydrated. To maintain hydration during hydrated trial sessions, each participant rehydrated with water ad libitum. During dehydrated trial sessions, no fluid was given. In a case where the participant was in hypohydration before the trial, he was given 500ml fluid 30 minutes before a trial session. The treadmill exercise lasted 60 minutes with speed in the range between 4.8 - 6.4 km/hr at a 5% incline. Participant's previously selected speed was used in all sessions. Each participant wore a weighted vest equivalent to 12% of body weight during trials. The Tgi and HR were continuously monitored and recorded every 15 minutes. This exercise protocol was used to raise core body temperatures to a hyperthermic level and necessitate fatigue. A cognitive test battery was performed soon after treadmill intermittent exercise.

Soccer Specific Intermittent Treadmill Protocol

A Soccer Specific Intermittent Treadmill Protocol (SSITP) was used (Drust, Reilly, & Cable, 2000). This protocol includes jogging, running, and sprinting designed to stimulate the physiological demands for aerobic sporting activities. Cumulative mechanical and physiological stress particularly during the intermittent high intensity bouts of exercise may cause decrement sport performance and influence pattern of injury incidence hence use of SSITP to replicate activity profiles across a wide range of sporting codes. Familiarisation and trial sessions were performed using a motorized and programmable treadmill (Circle Fitness, M8 Led Treadmill, Taiwan). Ninety minutes of active movement was categorized in eight modes replicating a soccer match playtime, with 6 x 15min blocks separated by a 15-minute passive activity designed to imitate half-time. Jogging time and sprint pace for individualized protocol was equivalent to 75% (11± 2 km^{-1}) and 95% (14 ± 2km^{-1}) VO_2 max, a reflective of soccer and other team sport speeds (Drust, Reilly, & Cable, 2000; Nicholas, Nuttall, & Williams, 2000). Distance covered in each 15-minute activity profile was 1.62km, resulting in 9.72km travelled during the 90-minute activity duration (Greig, McNaughton, & Lovell, 2006). A

5% treadmill gradient was set as a reflection of the outdoor running energy cost at speeds used in the protocol.

Cognitive Testing

The CT battery consisted of the Stroop Effect Task (ST) and Visual Sensitivity Test (VST). This was for evaluating working memory, inhibitory control, and constant continual attention in sport. Participants were expected to complete the test in 15 minutes. Laptops with Millisecond-Resolution Timing single software package were used. To reduce noise distractions, participants wore ear protection during tests. These tests were performed as follows:

Stroop Effect Task

Stroop's (Stroop, 1935) 2-minute test demonstrates participants' sensitivity to interference versus suppuration of an automated response. Stroop Baseline Task (SBT) and Stroop Colour Task (SCT) were the two test levels included under the Stroop Effect Task (ST). The SBT baseline task had 15 stimuli which included a reading of colour names (congruent) and the SCT colour-interference task had 40 stimuli, front colour naming but not reading of printed colour name (incongruent). Within task test levels, each stimulus-coloured word is placed at the screen centre with a randomly presented target and distractor counterbalanced either on the left or right side. Participants were instructed to press the left or right key arrow to a specific point of the target word in the minimal possible time. The reaction times, accuracy to colour-meaning congruent and incongruent blends, and percentage scores were recorded for statistical analysis. To minimize manipulation of fast and slow reaction time, outliners in test levels when analysing a baseline of 2000ms, slower than 1300ms times, and faster than 100ms times were filtered and removed.

Visual Sensitivity Task (VST)

The VST was for the assessment of visuomotor response times. It consisted of two levels: the baseline and the complex levels. In these two levels, participants were asked to detect a triangle on the laptop screen. An instruction followed immediately to press a key in the shortest time possible to the target. Only touch screen laptops were used in this study. These displayed only valid stimulus responses and disregarded outliner responses. When one response was made new targets followed and appeared at a rate of at least 500ms random delays. Correct stimulus-response rate percentages were recorded for statistical analysis.

Visuomotor response time's distribution comprised of 20 targets for baseline levels formed from solid green lines drawn on a black background and in the complex level, 40 targets of random moving dots were distractors on the entire screen. The baseline level assessed simple visuomotor speed while the complex level initiated a complex visual component. Participants were instructed to draw a new visible dotted line on target triangles and as dotted points density gradually increases linearly with time a keypress is registered. After every 250ms, a new set of distractor dots were re-drawn on the screen. These stir up visual distracting effect of a glittery background. Filtration was done for a baseline of less than 300ms and greater than 850ms and complex level for greater than 6000ms to reduce unnecessary manipulation of response times and outliners.

Mood Testing: Profile of Mood States

A standardized POMS questionnaire was used to assess participants' moods on how they felt the experimental trial session went. This questionnaire consisted of seven subscales which included forty adjectives on a five-point scale that measured tension, fatigue, depression, vigour, anger, confusion, and esteem-related affect. Total mood disturbance (TMD) comprises of (depression+ tension + anger + confusion + fatigue) - (esteemed-related + vigour) (Grove & Prapavessis, 1992). Scores were evaluated by choosing one scale for each adjective that conforms to the individual participant's situation from a five-point scale. A 5-point rating was used to analyse all the participants' responses.

Temperature Assessment

To obtain the Gastrointestinal Temperature (Tgi), participants were instructed to remove the magnetic strip from the pill and ingest the telemetric temperature pill (Core Temp® Ingestible Body Temperature Sensor, HQ Inc, USA) with water 6 hours before the experimental trial to circumvent possible interaction with fluid ingestion (Bongers, Hopman, & Eijsvogels, 2015). Serial and calibration numbers were retained to the research team for record-keeping before trial sessions commencement. The participants were made aware that they will excrete the pill naturally. Tgi was recorded at a 15-minute interval.

Heart rate (HR) monitors were used before familiarisation and experimental trials. HR was monitored at 5 seconds intervals continuously using the Polar M430 GPS running watch (Polar Team System, Polar Electro Oy, Finland). The mean HR was calculated every 15-minute exercise interval.

Hydration Status Assessment

Changes in body mass, urine color and thirst upon awakening to track daily changes in hydration status. Participant's hydration status was confirmed by urine colour (Ucol), urine specific gravity (Usg), and urine osmolality (UOsmo). Ucol was measured using a validated urine eight-colour scale and Usg was measured using a clinical digital hand-held refractometer (Euromex RD.5712, Holland) with automatic temperature compensation. Previous studies reveal that Usg <1.020 and urine osmolality, UOsmo <850 mOsmol kg^{-1} and urine colour, Ucol <4 indicate dehydration (Shirreffs, 2003; Armstrong, 2007; Sawka & Noakes, 2007]. Samples were collected before and after the trial sessions from participants.

Perceptual Responses of Rate of Perceived Exertion, Thirst Sensation, and Fatigue Severity

The Borg-15-point scale, ranging from very light (MacLeod et al., 2018) to extreme unbearable (Sawka & Noakes 2007), was used to assess participants' Ratings of Perceived Exertion (RPE).

Visual Analog Scale was used to measure participants' subjective satiety and thirst sensation, VAS-T (Rolls, 1980). Thirst sensation was evaluated at baseline, post-trial, and recovery. The VAS-T has labels from the left, "Not at All," to the right, "Extremely." The participants were instructed to use a pencil to mark X on their corresponding levels of sensation.

A self-report, validated VAS with 18 subjective items was used to evaluate Fatigue Severity (VAS-F). Extreme labels on the VAS-F are from the left, lowest extreme (No Fatigue) to the right, highest extreme (Severe Fatigue) respectively [Tseng, Gajewski, & Kluding, 2010; Matias et al., 2019].

3.3 STATISTICAL ANALYSIS

Data collected during trials was initially recorded on a Microsoft Excel 2010 and later transferred and analyzed using SPSS v 23.0. Descriptive data were reported as mean ± standard deviation (M±SD) of these:

1-way (condition): score changes (post-pre, recovery-post, recovery-pre).

2-way (condition x time): baseline body mass, estimated total body weight loss (sweat loss), environmental condition.

3-way (condition x fluid x time): Gastrointestinal temperature and heart rate, RPE, Ucol, Usg, Uosm, fatigue.

4-way (condition x fluid x time x test level): Cognitive function test data from Stroop Effect Task, Visual Sensitivity Task, POMS.

Factorial repeated measures of analysis (ANOVA) were used to determine if the main effects were in environmental conditions (HY, DEHY, HY, DEHY) and the time (baseline, post, 1h and 2h), and any potential condition by time interactions of any measured variable, hence differences between and within the environmental conditions. Considering the complexity of cognitive function, data analyses, insignificant findings were not presented. The significance level was set at 5%. For all analyses with a prior level of significance of .05, Tukey HSD tests were conducted for post hoc testing where necessary. A mixed model of repeated measures ANOVA was used to investigate the effect of induced-heat stress, hyperthermia, and dehydration on changes in cognitive function and mood status while covarying fluid intake, BMI, age, oxygen saturation, and blood pressure.

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CHAPTER 4: RESULTS

Participant characteristics

A significant difference was observed after exploring the age, weight, height, BMI, and body fat mass ($p < 0.001$).

Environmental conditions

These sessions included two in temperate conditions (normothermic: hydrated; dehydrated) and two in hot environmental conditions (hyperthermic: hydrated; dehydrated). The trials in temperate (normothermic) conditions (HyN=16.3 ± 0.02°C; DehyN=16.5 ± 0.01°C) were lower compared to two in hot (hyperthermic) environmental conditions (HyHot= 33.4 ± 0.03°C; DehyHot= 34.3 ± 0.04°C) with $p < 0.001$. There was no statistical difference ($p = 0.314$) between hydrated normothermic and hyperthermic trials. Among the four conditions where $p = 0.010$; hyperthermic condition trials (HyN= 61 ± 1%; DehyN=61 ± 1°C) had greater relative humidity (RH) compared to normothermic condition trials (HyN= 52 ± 1%; DehyN= 52 ± 2%). The trial averages for normothermic conditions were 16.4 ± 0.02°C and 52 ± 1% RH, while the hyperthermic conditions were 33.9 ± 0.3°C and 61 ± 1% RH.

Heart Rate and Gastrointestinal Temperature

Participants' mean heart rate during the pre-test, post-test, and after is shown in Figure 1(a) below. There was a significant increase in heart rate from pre-test to post-test ($p < 0.001$) with many effects in hot conditions ($p = 0.001$) and where participants were restricted to fluid ($p = 0.010$). ANOVA revealed that after recovery HR for hot conditions was greater than the baseline for pre-test ($p = 0.005$). Figure 1(b) shows gastrointestinal temperature. Tgi increased from baseline to post-test in hot conditions ($p = 0.020$) compared to temperate conditions followed by a post-recovery decline in all four trials ($p < 0.001$).

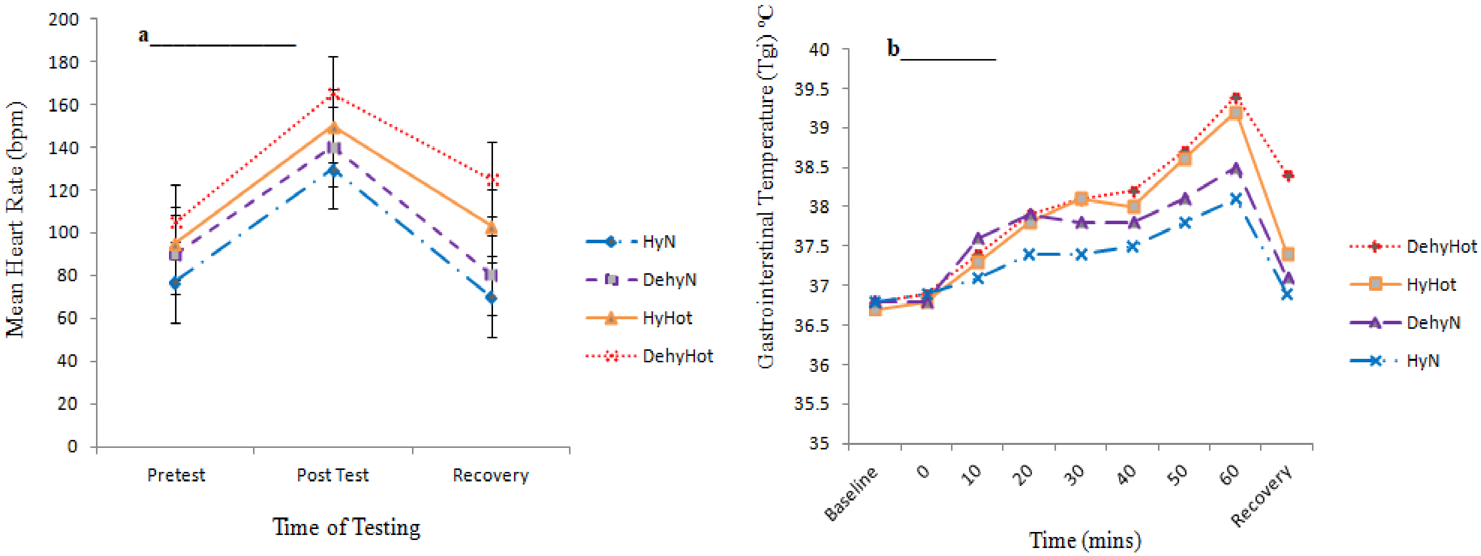

Fig 1: The heart rate (HR) and gastrointestinal temperature (Tgi) data (mean ± SD) observed during SSITP under; HyN: hydrated normothermic; DehyN: dehydrated normothermic; HyHot: hydrated hyperthermic; DehyHot: dehydrated hyperthermic. For (a), HR: main effect condition ($p=0.001$), time ($p=0.001$), hydration status ($p=0.010$) and $p=0.005$ for condition x time. For post-trial and recovery, $p<0.05$ between HyN and HyHot, while $p<0.05$ between HyN and DehyHot during post-trial. For (b), Tgi: main effect condition ($p=0.021$), time ($p<0.001$) and $p <0.001$ for condition x time. $P<0.05$ between HyN and DehyN (20-30mins), HyN and HyHot (baseline and recovery), HyN and DehyHot (60min).

Hydration Assessments

Baseline assessments for participants' hydration status (body weight, Ucol, Usg, Uosm) showed no main effect differences after the SSIP four trials between the conditions ($p=0.621$) and /or fluids ($p=0.751$; HyN= 68.69 ± 6.28kg; DehyN= 68.71± 6.53kg; HyHot= 68.71± 6.45kg; DehyHot= 68.71 ± 6.16kg). Also, no main effect difference was noted in ∆BW percentages between conditions ($p=0.054$) from baseline to post 120min after the trials. Urine color: There was significant main effect differences witnessed between condition ($p= 0.001$) and/ or fluid ($p=0.003$) trials, from baseline and 120min post trial (HyN= 3.1± 0.4; DehyN= 3.5 ± 0.05; HyHot= 3.7 ± 0.3; DehyHot= 4.1 ± 1.0). No main effect difference existed immediately post trial, fluid ($p=0.643$). Across all the four trials, no main effect difference existed in Usg (HyN= 1.016 ± 0.004; DehyN= 1.019 ± 0.005; HyHot= 1.023 ± 0.003; DehyHot= 1.028 ± 0.005) between condition ($p= 0.001$) and/ or fluid ($p= 0.002$) trials. Uosm (Fig 2d): There were no main effect differences witnessed between all condition ($p= 0.201$) and/ or fluid ($p= 0.593$) trials, from baseline to after 120min post trial, Uosm was <850mOsmkg^{-1} (HyN= 683 ± 101mOsmkg^{-1}; DehyN= 701 ± 105mOsmkg^{-1}; HyHot= 720 ± 102mOsmkg^{-1}; DehyHot= 740 ± 115mOsmkg^{-1}).

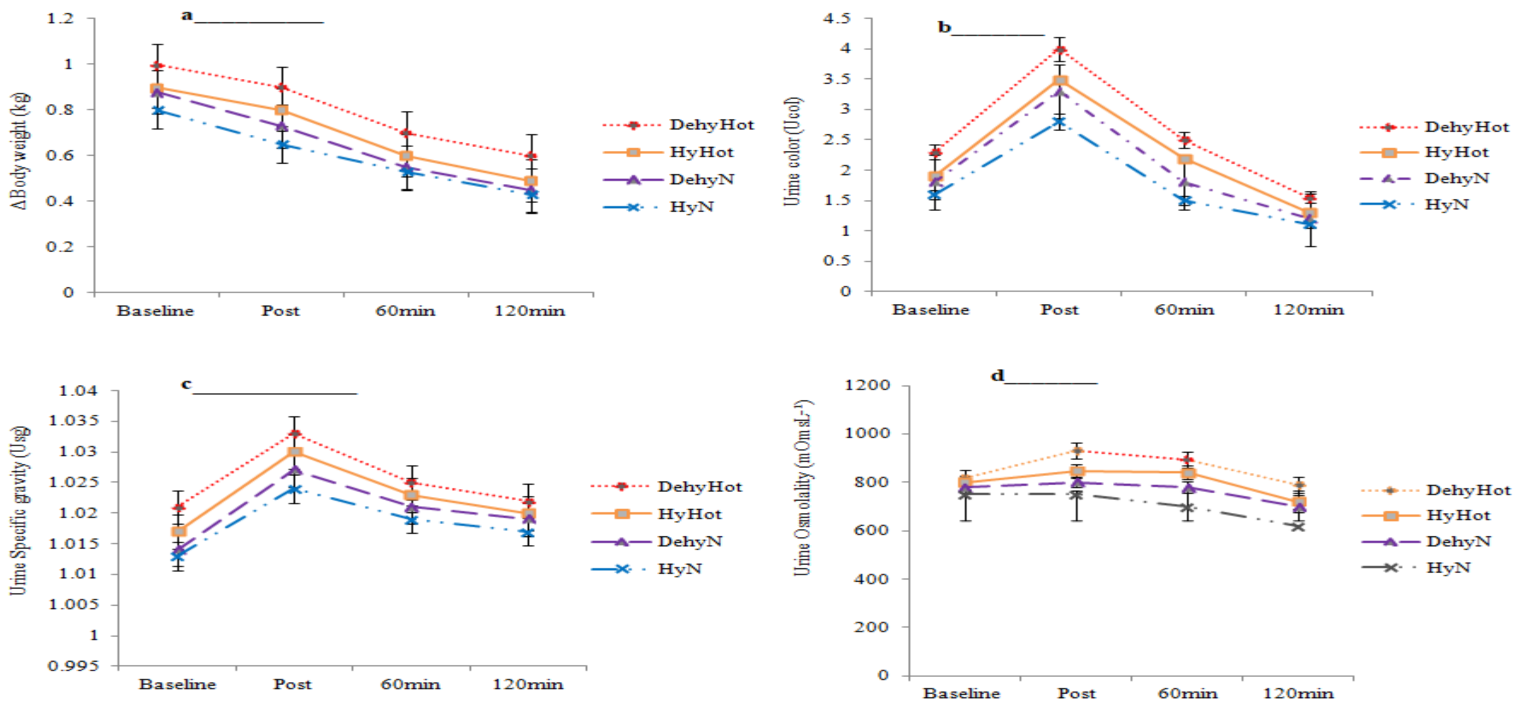

Fig 2: The hydration status measurements (mean ±SD). a). Change in body weight (ΔBW), b). Urine colour (Ucol), c). Urine specific gravity (Usg), and d). Urine osmolality (Uosm) observed during SSIP under; HyN: hydrated normothermic; DehyN: dehydrated normothermic; HyHot: hydrated hyperthermic; DehyHot: dehydrated hyperthermic. ΔBW: Main effect condition ($p=0.001$), time ($p<0.001$), condition x time ($p<0.003$). Ucol: Main effect fluid ($p<0.001$), fluid ($p=0.0026$), time ($p<0.001$), condition x time ($p<0.001$), and condition x fluid x time ($p=0.015$). Usg: Main effect condition ($p=0.001$), fluid ($p=0.002$), time ($p<0.002$) and condition x time ($p<0.001$). Uosm: Main effect condition ($p<0.001$), time ($p<0.001$) and condition x time ($p<0.001$). P<0.005) between: HyHot and HyN (baseline and 120min), HyHot and DehyN (immediate post trial), DehyHot and HyN (120min), HyHot and DehyHot (60min and 120min).

Perceptual Responses of Rate of Perceived Exertion, Thirst Sensation, and Fatigue Severity

There was a significant time effect ($p<0.005$) existing on perceptions of RPE, thirst sensation, and fatigue severity (Fig 3) in all SSIP four trials. On average, all participants after undergoing dehydration exercise in hot conditions; experienced greater perceptual response values (main effect condition, $p<0.001$; condition x time, $p=0.001$).

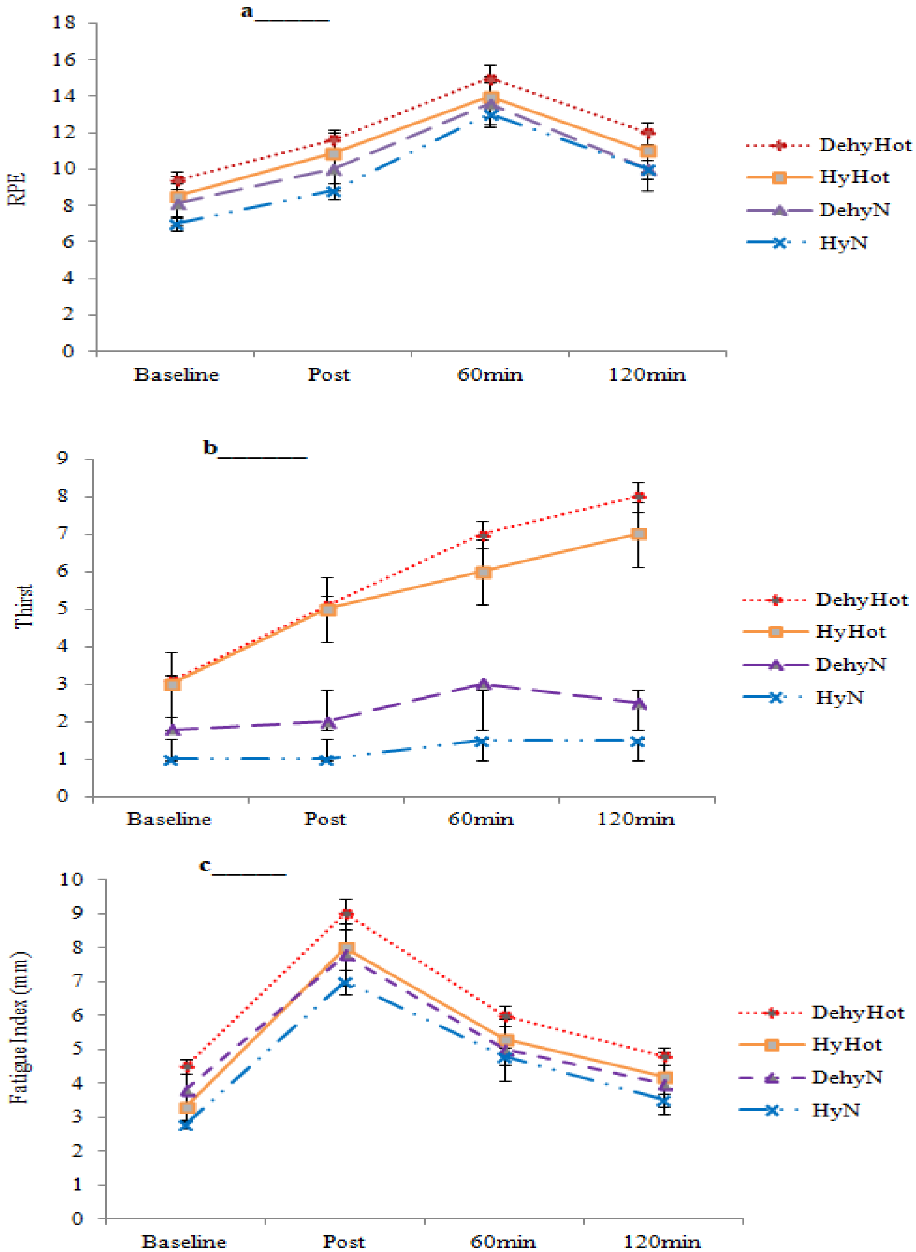

Fig 3. The perceptual responses (mean ±SD) of a. Rate of Perceived Exertion (RPE), b. Thirst, c. Fatigue, observed during SSIP under; HyN: hydrated normothermic; DehyN: dehydrated normothermic; HyHot: hydrated hyperthermic; DehyHot: dehydrated hyperthermic. RPE: Main effect condition ($p=0.001$), fluid ($p=0.032$), time ($p<0.001$), condition x time ($p<0.001$) and fluid x time ($p= 0.001$). Thirst sensitivity: Main effect fluid ($p<0.001$), time ($p<0.001$), fluid x time ($p<0.001$), (condition x fluid x time ($p=0.013$). Fatigue: Main effect condition ($p<0.001$), time ($p<0.001$) and condition x time ($p<0.001$). $P<0.005$) between: HyHot and HyN (immediate post trial) and HyHot and DehyN (post trial), DehyHot and HyN (120min), HyHot and DehyHot (baseline and 60min).

Cognitive Functioning Aspects

Tables 1 and 2 presents cognitive function assessment data; mood (POMS) and Stroop effect and visual sensitivity tasks. There was no main effect difference of condition (p<0.05) or fluid (p<0.05) on response times on mood (p=0.022), Stroop effect task (p=0.021) and visual search (p=0.034) across the assessments. POMS: There was a significant effect difference on hot condition (p<0.001) and fluid (p<0.001) on observed mood state. In all conditions with main effect fluid (p=0.001), a decrease was noted in participants' ratings of depression, anger, vigour while tension, confusion, and fatigue increased (Table 1).

Table 1: Profile of Mood State

POMS Variables	Condition	Pre-test	Post Test	Recovery
	HyN	2.20 ± 0.13	1.94 ± 0.12	2.40 ± 0.17
	Dehy	2.22 ± 0.11	1.98 ± 0.09	2.45 ± 0.14
	HyHot	2.27 ± 0.09	1.99 ± 0.09*	2.53 ± 0.13
Tension	DehyHot	2.35 ± 0.12	2.40 ± 0.11	2.76 ± 0.18
	HyN	1.96 ± 0.13	1.60 ± 0.11	1.79 ± 0.15
	Dehy	2.02 ± 0.14	1.65 ± 0.12	1. 82 ± 0.17
	HyHot	2.06 ± 0.11	1.68 ± 0.14	1.78 ± 0.12
Depression	DehyHot	2.11 ± 0.14	1.93 ± 0.15	1.98 ± 0.16
	HyN	2.06 ± 0.14	1.66 ± 0.12	1.67 ± 0.13
	Dehy	2.09 ± 0.15	1.74 ± 0.19	1.78 ± 0.15
	HyHot	2.64 ± 0.19	2.68 ± 0.20	2.88 ± 0.19
Confusion	DehyHot	3.01 ± 0.12	3.12 ± 0.21*	3.24 ± 0.20
	HyN	1.65 ± 0.11	1.32 ± 0.09	1.55 ± 0.15
	Dehy	1.66 ± 0.10	1.32 ± 0.07	1.56 ± 0.13
	HyHot	1.78 ± 0.12	1.40 ± 0.10	1.66 ± 0.14
Anger	DehyHot	1.89 ± 0.13	1.45 ± 0.10	1.57 ± 0.15
	HyN	3.09 ± 0.13*	3.36 ± 0.14*	2.59 ± 0.16
	Dehy	3.11 ± 0.12	3.42 ± 0.16*	2.76 ± 0.17
	HyHot	3.10 ± 0.10	3.40 ± 0.14	2.58 ± 0.15
Vigor	DehyHot	3.06 ± 0.12	3.35 ± 0.16*	3.05 ± 0.14
	HyN	2.93 ± 0.17*	2.50 ± 0.14*	3.66 ± 0.21
	Dehy	2.96 ± 0. 16	2.64 ± 0.15	3.71 ± 0.19
	HyHot	3.67 ± 0.12*	3.76 ± 0.19*	3.82 ± 0.20
Fatigue	DehyHot	3.98 ± 0.14	4.25 ± 0.16	4.28 ± 0.23
	HyN	7.49 ± 0.58	5.76 ± 0.43*	8.48 ± 0.59
	Dehy	7.56 ± 0.54	6.56 ± 0.48	8.89 ± 0.57
	HyHot	7.78 ± 0.62*	7.64 ± 0.45	9.01 ± 0.38
TMD	DehyHot	8.24 ± 0.56	7.82 ± 0.46	9.34 ± 0.61

*Condition x Reaction time, p=0.774; Post-hoc: DehyN & DehyHot (Pre-test) > DehyN & DehyHot (Post Test) p= 0.001)

Stroop Effect Task

Average response times (Table 2) were faster in hot condition post-test (Normothermic: pre-test 588 ms, post-test 690 ms (p=0.368; diff=0.15); Hyperthermic: pre-test 602 ms, post-test 584 ms (p=0.019; diff=0.26) condition x reaction time, p=0.581; Post-hoc: DehyN & DehyHot (Pre-test) > DehyN & DehyHot (Post-test), p=0.012). Colour interference did not exist with main effect either condition (p=0.043), fluid (p=0.026) or time on accuracy (p=0.031). Visual Search Task: Similar response times (Table 2) existed on baseline (normothermic 554ms, hyperthermic: 520 ms (p=0.748; diff=0.35) compared to quicker complex level response times (normothermic 2213 ms, hyperthermic: 1978 ms (p=0.003; diff=0.38); condition x reaction time, p=0.003; Post-hoc: DehyN & DehyHot (Pre-test) < DehyN & DehyHot (Post-test), p=0.001).

Table 2: Stroop Effect and Visual Search Task

Accuracy (Percentage)	Hyperthermic	Dehydrated (DehyHot)	Post Test	95.1 ± 3.1	92-100	95.9 ± 4.4	88-100	*Condition * Reaction time, p=0.581; Post-hoc: DehyN & DehyHot (Pre-test) ? DehyN & DehyHot (Post Test) p= 0.012*	99.7 ± 2.1	95.2-100	95.3 ± 6.5	90.9-100	*Condition * Reaction time, p=0.003; Post-hoc: DehyN & DehyHot (Pre-test) < DehyN & DehyHot (Post Test) p= 0.001*
			Pre-test	98.2 ± 3.5	90-100	94.8 ± 3.9	90-100		96.7 ± 1.8	94.2-100	98.2 ± 3.8	89.3-100	
		Hydrated (HyHot)	Post Test	98.2 ± 2.2	95-100	96.4 ± 2.2	94-100		96.7 ± 1.8	94.2-100	99.3 ± 2.0	94.3-100	
			Pre-test	95.1 ± 3.3	92-100	96.9± 2.1	94-100		97.8 ± 2.9	92.2-100	99.6 ± 1.3	96.2-100	
	Normothermic	Dehydrated (DehyN)	Post Test	98.2 ± 3.5	90-100	95.8 ± 2.4	92-98		96.7 ± 1.8	94.2-100	98.7 ± 0.9	97-100	
			Pre-test	95.8 ± 3.4	92-100	96.7 ± 2.9	90-100		96.7 ± 1.8	94.2-100	97.9 ± 2.4	92.1-100	
		Hydrated (HyN)	Post Test	98.5 ± 2.2	95-100	94.6 ± 4.8	88-100		100.0 ± 0.0	100-100	98.0 ± 1.6	95.8-100	
			Pre-test	98.2±2.4	95-100	96.4± 4.5	88-100		96.7 ± 1.8	94.2-100	98.1 ± 2.0	94.6-100	
Response Time (Milliseconds)	Hyperthermic	Dehydrated (DehyHot)	Post Test	553 ± 80	463-692	678 ± 96	567-852		495 ± 31	460-578	1904 ± 298	1362-2250	
			Pre-test	570 ± 74	500-782	743 ± 141	574-1022		500 ± 17	482-551	2054 ± 487	1227-2816	
		Hydrated (HyHot)	Post Test	573 ± 92	470-687	688 ± 128	543-848		478 ± 26	460-522	1839 ± 283	1223-2048	
			Pre-test	586 ± 83	472-746	713 ±150	548-1040		492 ± 20	468-510	1930 ± 278	1491-2334	
	Normothermic	Dehydrated (DehyN)	Post Test	557 ± 80	483-741	702 ± 91	617-869		492 ± 11	476-504	2108 ± 316	1292-2410	
			Pre-test	561 ± 58	491-674	716 ± 101	543-831		502 ± 26	488-554	2163 ± 540	1273-2767	
		Hydrated (HyN)	Post Test	571 ± 64	472-676	681 ± 96	561-879		510 ± 68	493-544	2105 ± 321	1650-2740	
			Pre-test	590 ± 60	480-688	713 ± 94	578-890		500 ± 10	465-530	2000 ± 421	1316-2700	
Level				Baseline M ± SD		Colour M ± SD			Baseline M ± SD		Complex M ± SD		
Test				Stroop Effect Task					Visual Sensitivity Task				

CHAPTER 5: DISCUSSION

The current study aimed at investigating the effect of exercise-heat stress, hyperthermia, progressive dehydration, and fatigue on cognitive functioning and sport performance in semi-professional athletes following soccer-specific interval training. The findings showed that dehydration has little impact on cognitive performance despite the existence of total mood disturbance in hot, humid environments (33.4℃, 64% RH). Similarly, reaction times did not change following fluid restriction during 90min exercise in warm (31℃), humid environment, 63% RH (MacLeod et al., 2018).

Literature findings indicate that exercise-induced heat stress contributes to impairment of visuomotor performance and unpleasant sensation regardless of fluid ingested during trials to match water lost. These corroborate findings by Wittbrodt and Millard-Stafford (2018), that meta-analysis, dehydration impaired visuomotor impairment within the first 5-minute finger-tapping task. This suggests that dehydration accompanied by hyperthermia negatively affects the brain and cognitive-motor domain functions. Therefore, we concluded that different dehydration and cognitive assessment methods, hypohydration degree, the volume of fluid ingestion, athletic dehydration experience, training level, and other additional variables influence alteration of cognitive performance in hot conditions (Masento et al., 2014; Barley et al., 2018; Piil et al., 2018; Sun, Cooper, & Tse, 2020).

The findings suggest that equal or higher thirst and thermal sensations, skin, and core temperature (Fig 1 and 3) were significant cognitive performance variables. These were shown in hyperthermic trial conditions where sensations, skin, and Tgi were high. A cognitive function improvement was observed compared to temperate conditions (Table 2). Similarly, Lee et al. (2014), found that exercising in heat improved accuracy during complex tests following cooling the neck to cause a decline in thermal sensation regardless of >39.5℃ body core temperature.

Results of this study showed that the post-trial percentage of body mass loss was 2.4% (DehyN) and 2.9% (DehyHot); respectively. These were similar to Edwards et al.

(2007), which observed that mild dehydration, up to 2.5%, during exercise in hot conditions does not affect cognitive function (Bandelow et al., 2010; Nuccio et al., 2017). In support of this, studies done for other intermittent sports pointed that >2% dehydration is a clear indication of hypothesized threshold to adversely cause cognitive performance (MacLeod et al., 2018; Baker et al., 2007). The study's practical significance may be reflected during some individual and intermittent sport skills performance competitive play in the heat.

When dehydrated and hyperthermic, fatigue development during endurance exercise in hot conditions, coupled with increased core body temperature and closer to maximal heart rate implicating the central nervous system (Bandelow et al., 2010; Trinies et al., 2016; Barley et al., 2018; Sun, Cooper, & Tse, 2020). This study hypothesized that central fatigue influenced physical and cognitive performance which were higher in hot conditions than temperate conditions (Table 1). Therefore, it is credible that TMD and altered fatigue influenced a decrease in physical and cognitive performance.

Limitations

The same movement speed used in SSITP did not reveal the fatigue level witnessed during competition/matches of varied sporting codes. Responses to effects on cognitive performance were group mean representations without considering an individual's physiological tolerance and differences.

Practical Implications

This study suggests that: a) increased fluid intake is necessary with prolonged or intense exercise due to increased sweat production. b) consider body size, acclimatisation status and thirst drive when developing hydration plans for individual athletes, c) athletic level has a great influence on cognitive function including athlete's reactions to physiological strain. d) during vigorous exercise (>70% VO2max) understand that gastric emptying may limit fluid absorption. Athletes can train their gut to improve gastrointestinal comfort or adopt strategies to increase fluid intake before and after exercise, e) measure local environmental conditions to determine the risk of high sweat rates resulting in large fluid losses. f) Increase fluid-replacement during exercise in hot and humid environments to account for increased sweat losses. g) athletes should be advised and encouraged to keep <2% dehydration during training and competition to avoid detrimental effects on athletic and cognitive performances.

Maintaining normal hydration has a low physiological strain on athletic performance. Performing prolonged exercise in temperate conditions improved cognitive function and mood despite hydration levels. Intermittent exercise improved general response times on cognitive performances. Response times for complex visuomotor improved in a heated environment. Cognitive performance for semi-professional athletes is relatively affected by ~2% dehydration following SSITP in hot conditions.

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CHAPTER 6: SUMMARY, CONCLUSION, LIMITATIONS, RECOMMENDATIONS AND FURTHER RESEARCH

6.1 Introduction

This chapter summarizes the study, its limitations, recommendations, conclusion, and areas of future research.

6.2 Summary

The study aimed to examine the effects of exercise-heat stress, hyperthermia, dehydration, aspects of cognition, and fatigue balance on sports performance. The thesis consisted of six parts; Chapter 1, 2, 3, 4, 5 and 6. In Chapter 1, the study presented the introduction, problem statement, aim, and the hypothesis, as well as its structure. Chapters 2, represent the Literature review; Chapter 3 presents the methodology; Chapter 4, presents the results; Chapter 5, presents the discussion; and Chapter 6, presents the summary, limitations, recommendations, conclusion, and areas of future research of the study.

In Chapter 2, the study systematically reviewed literature around the effects of hypohydration and fluid balance in athletes' cognitive performance. The effects of progressive body fluid loss on athletic and cognitive performance are known to result from exposure to environmental heat stress, morphologic factors, and limited fluid replenishment (Nuccio et al., 2017; Zhang et al., 2019; Piil et al., 2018). Indeed, athletes need to restore lost body water and maintain euhydration; however, during physical activity and structured exercise, athletes may fail to maintain a positive hydration status (Kenefick, 2018; Trangmar & González-Alonso, 2019). Internet searches from PubMed, Sports Discuss, and Ebsco databases revealed that hypohydration associated with heat stress and limited fluid intake (3-5% body mass loss) impaired cognitive performance. Mood disturbance, fatigue, and ratings of perceived exertion constantly complemented hypohydration impairment on cognition. Reviewed literature findings show that hypohydration impaired cognitive performance and mood at higher levels of 3-5% body mass loss.

Sport-specific cognitive protocols of accessing hypohydration and fluid balance in individual and team sports remain equivocal. Chapter 3 elucidates how exercise-heat stress, hyperthermia, dehydration, and fatigue affect cognitive performance among semi-professional male athletes. Using eighteen healthy, active male athletes from individual sports lasting more than 2 hours and team sports participated hydrated and dehydrated in both conditions. A soccer specific intermittent treadmill exercise protocol was completed in four experimental trials in temperate (normothermic) and hot (hyperthermic) conditions. A cognitive and mood test battery prior, immediately after, and post 120 min of treadmill exercise was used. The response times and accuracy improved following the cognitive testing in athletes exercising in relatively humid, hot conditions. Notably, semi-professional athletes' cognitive performances in selected individual and intermittent sports appeared to be relatively affected by hypohydration.

Development of personalized fluid intake plans that incorporate fluid availability characteristics of the sport or event are critical. Where there is a likelihood of hypohydration, be proactive and creative in making use of existing opportunities for fluid intake within sport rules and characteristics and be prepared to request for changes when there is a likelihood of a serious mismatch between fluid losses and the opportunity to address these. Practice intended competition drinking plans ahead of time to determine their suitability and allow time for readjustment so that sport performance is not compromised.

Chapter 4 presents cognitive function assessment data; mood (POMS) and Stroop effect and visual sensitivity tasks. There was no main effect difference of condition ($p<0.05$) or fluid ($p<0.05$) on response times on mood ($p=0.022$), Stroop effect task ($p=0.021$) and visual search ($p=0.034$) across the assessments. POMS: There was a significant effect difference on hot condition ($p<0.001$) and fluid ($p<0.001$) on observed mood state. In all conditions with main effect fluid ($p=0.001$), a decrease was noted in participants' ratings of depression, anger, vigour while tension, confusion, and fatigue increased.

Chapter 5 presented the discussion on hydration as a low physiological strain on athletic performance. Performing prolonged exercise in temperate conditions improved cognitive function and mood despite hydration levels. Intermittent exercise improved general response times on cognitive performances. Response times for complex visuomotor improved in a heated environment. Cognitive performance for semi-professional athletes is relatively affected by ~2% dehydration following SSITP in hot conditions.

6.3 Conclusion

Collectively, the results of this study suggest that semi-professional athletes need to rehydrate appropriately prior to exercising in hot, humid environments even in modest body water deficit. Maintaining normal hydration has low physiological strain on athletic and cognitive performance. Exercise-heat stress, hyperthermia, dehydration, and hypohydration impaired cognitive performance and mood at higher levels of 3-5% body mass loss. Semi-professional athletes' cognitive performances in selected individual and intermittent sports appear to be relatively affected by hypohydration and their hydration status needs to be closely monitored during training and competition.

Key points

i. This is the first laboratory study in Eswatini (Southern Africa) to examine the effects of exercise-heat stress, hyperthermia, dehydration, aspects of cognition, and fatigue balance in semi-professional male athletes' sports performance.
ii. The findings of this study provided individual and combined preliminary evidence of exercise-heat stress, hyperthermia, and dehydration effects on cognitive function.
iii. Both negative and positive effects on athletes' cognitive performance when exposed to temperate and hot conditions in individual and intermittent team sports.

6.4 Limitations

The study managed to discuss individual and combined effects of exercise-heat stress, hyperthermia, dehydration, hypohydration, and fatigue on cognitive function; however, it contains some limitations. Indeed, there is a possibility that detriments to cognitive performance are more likely when heat stress is involved. Chapter 2, table 1, participants were not blinded to hydration status. The use of fluid intake and no fluid cannot be comparable because euhydrated control may be confounded by dehydration effects protocol (McCartney et al., 2017). Involvement of the same gender (male) in a controlled environment may not depict the actual outdoor conditions during sports training or competition. Chapter 3, the sample size of 18 was determined by resources of especially expensive pill thermometer used for core temperature. The study used soccer-specific treadmill mill test (SSITP) and the fatigue test (VAS-F) to evaluate a wide range of sporting codes. Individual variability in terms of hydration levels, dehydration tolerance, high core temperatures and thermal sensation and thus their impact on physical and cognitive functions were not considered.

6.5 Recommendations

Based on the results of this study, the author recommends that:

i. Sports professionals, athletes, and parents should closely monitor individual's hydration status during exercise.
ii. Athletes should be encouraged to put on wearable biosensors during training and competition to monitor thermal state, and real-time physical exertion response.

6.6 Future Research

Following this study's results, future research projects may focus on investigating the effects of exercise-heat stress, hyperthermia, dehydration, aspects of cognition, and fatigue balance on sports performance using female participants or a combination of the genders. The outdoor environment could also be used for practical implications rather than the laboratory trial.

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ANNEXURES

ANNEXURE A: INFORMED CONSENT FORM

UNIVERSITY OF ZULULAND
RESTRUCTURED FOR RELEVANCE

1. Purpose and explanation of the tests:

I am aware that the primary aim of this study is to identify the individual and combined influence of dehydration, hyperthermia, cognition aspects, and fatigue balance on sport performance in order to understand possible methods to prevent injury in the athletic populations. A secondary focus will be to gain a better understanding of both lone and combined influences of dehydration, fatigue, and hyperthermia in order to implement individual prevention strategies to lessen injury risk in the athletic populations.

2. Possible risks or discomforts:

I am aware that an average to high amount of discomfort may be experienced during testing due to intense physical strains of this experiment. If I agree to participant the researchers or University will not be held accountable for injury or loss that occurs during testing. (see participant information for more information)

3. Responsibilities of the participant:

I am required to give information about my health status and be responsible to disclose any medical history or symptoms about myself that may occur during testing. I am also expected to report if I am taking any medication, and how often.

4. Expected benefits/ rewards from testing:

I am aware that the results obtained from this exercise testing may help in monitoring present and future injuries. It will assist in designing the correct injury prevention strategy specific to each individual or team.

5. Use of medical history:

I am aware that all information or results obtained from testing will be kept confidential and cannot be revealed to anyone without my consent as stated in health insurance portability and accountability act of 1996, American College of Sports Medicine (2014).

6. Freedom of consent:

As an athlete, my participation in this research is voluntary and I understand that I can stop the test at any point I desire and I am free to deny consent. I am aware that once I stopped I will not be asked to give the reasons for discontinuing.

7. Agreement

I hereby acknowledge that: I have read this form and I understand everything that is expected from me as a participant, regarding the tests, risks involved, responsibilities, the benefits expected. All the questions I had regarding the testing assessment research were answered to my satisfaction with clarity.

I, ___________________________ (Full Name of a Participant) give my consent to participate in the study.

Participant's Signature ____

Date ____

Tester's Name ____

Tester's ID____

Tester's Signature ____

Date ____

8. Contact details of the researcher

Mr. Adiele Dube

University of Zululand

Department of Human Movement Sciences

Cell Phone Number: +268 7829 3182 / Email Address: dubea2567@gmail.com

ANNEXURE B. PARTICIPANT INFORMATION SHEET

Introduction

You are invited to participate in a study conducted by Mr. Adiele Dube, MSc Sports Science student at University of Zululand, Department of Human Movement Science, South Africa. I hope to learn about the effects of Dehydration, Hyperthermia, Cognition Aspects and Fatigue Balance on Sport Performance. A second aim of the proposed study is to evaluate the effectiveness hydration in restoring performance in individuals who are dehydrated, fatigued, and have a high body temperature. You were selected as a possible participant in this study because you are athletic active, healthy male, aged 20-30, with above average fitness. This consent form will give you the information you will need to understand why this study is being done and why you are being invited to participate. It will also describe what you will need to do to participate and any known risks, inconveniences or discomforts that you may have while participating. We encourage you to ask questions now and at any time. If you decide to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form.

Why is this study being done?

I hope to identify the individual and combined of effects of dehydration, hyperthermia, and aspects of cognition and fatigue balance on sport performance. Secondly I am interested in examining how dehydration, hyperthermia, cognition aspects and fatigue balance expose athletes to injury risk. This information can help sports medicine professionals, coaching staffs, and physicians protect physically active persons to understand and implement individual strategies in preventing injury risk.

What are the study procedures? What will I be asked to do?

If you decide to participate, you will sign this form and complete a medical history questionnaire to ensure that you meet the inclusion criteria for the study. We expect to complete data collection from early October to early November 2021. To allow you to understand the commitment required to participate in this study, below is a figure illustrating the study timeline and testing days. The study consists of 60 minutes walking on treadmill putting on a weighted vest equivalent to 12% of your body weight, performing static stance for 12 seconds before performing BESS. The BESS test will include Single Leg Stance on a firm surface (SLFirm), Single Leg on a foam surface (SLFoam) and each stance will be held for 20 seconds and later completion of Profile of Mood States (POMS) Questionnaire.

Prior to all gymnasium visits, you will be instructed to avoid alcohol and strenuous exercise for 24 hours and caffeine for 8 hours before testing. You will also be asked to drink 500 ml (2 cups) of water 3 hours before and 250 ml (1 cup) 1 hour before the lab visit to ensure normal hydration upon arrival to the lab.

Baseline Testing and Familiarization visit

If you meet the inclusion criteria, I will schedule a familiarization session which will be approximately 60 minutes in duration. This gymnasium visit will occur in the Department of Sports, at UNESWA Sports Kwaluseni Main Campus and the Manzini Clinic. The familiarization visit procedures include the following:

1. Complete a training history questionnaire
2. Height, body mass, hydration, and body fat percentage determined 8 skinfolds
3. Maximal aerobic capacity (VO_{2max})
4. 30-minute run in the heat to determine sweat rate
5. Repeated box jumping
6. Psychomotor vigilance test

Height will be measured with a stadiometer without shoes and hydration via urine sample provided in clean cup.

Experimental Trials

Upon arrival for the control trial, body mass will be measured. In order to measure hydration status, you will be asked to urinate into a clean cup. If you are hypohydrated, you will be provided 500 ml of water and allowed to sit for 30 minutes, then retested. You will wear a heart rate monitor during all testing. Heart rate, body core temperature, perceptual, and skin temperature will be measured at baseline and throughout testing. You will perform the familiarization session will be attended at least 48 hours before the first test session to determine the participant's body composition, VO_2max, sweat rate, instruction on the use of an oral pill, wearing heart rate monitor, and walking on the treadmill at a standard speed 4.8 -6.4 km/hr and incline (5%) for 15 minutes while putting on a weighted vest equivalent to 12% of your body weight. Participants will be allowed to pick a speed within the 4.8 -6.4 km/hr range that is sustainable for the 60 minutes exercise protocol. Your height and weight are to be recorded prior to the familiarization session (using a stadiometer and calibrated scale to the 0.1kg) and will be also weighed post exercise to determine sweat rate via body mass change. Body composition measurements will be recorded using the International Society for the Advancement of Kinathropometry (ISAK 2011) protocol.

Prior to beginning the sweat rate test, participants will be provide a urine sample to measure urine specific gravity (Usg) and urine colour (Ucol) to ensure euhydration. You will be asked to consume 500ml of fluid before going to sleep the night before and upon waking to ensure euhydration prior to familiarization sessions. Hydration status will be measured upon arrival to the HPL via Usg or Ucol. If a Usg > 1.025 or Ucol ≥ 4 the participant will be provided 500ml of water and wait 30 minutes until starting the sweat rate test. After the exercise protocol, you will be instructed on the correct procedures for the balance assessment portion of trial and then asked to perform two correct repetitions of each task, or until they indicate they felt comfortable with the tasks. A static stance on a single leg which was held for 12 seconds, the Balance Error Scoring System tasks (single leg firm, tandem firm, single leg foam, tandem foam), and dynamic balance test (Time to Stabilization -TTS) will be tasks to be performed. Also, the participants will demonstrate the cognitive testing procedures for Stroop test, Visual Search and POMS following instruction on the correct protocol for completion of these tests.

What are the risks or inconveniences of the study?

Risk/Inconvenience	Risk Prevention and Mitigation
Delayed onset muscle soreness	You are a young, healthy, active person so the likelihood of developing soreness is lessened.

A fall during running	You are a young, healthy, active person so the likelihood of falling while running is lessened.
Musculoskeletal injury (muscle strain, ligament sprain, bone fracture)	You are a young, healthy, active person so the likelihood of developing a strain, sprain, or fracture is lessened. We will also provide you detailed instructions of the tasks before you exercise.
Exertional heat illness	You are a young, healthy, active person who has not experienced a heat illness in the recent past so the likelihood of developing a heat illness is only moderate. We will educate you about the symptoms and signs of exertional heat illnesses and you will notify one of the researcher assistants if you experience any of the symptoms or signs. Signs and symptoms may include: weakness, dizziness, feeling hot, cramping, vomiting, headache, nausea, tired, disorientation, or low blood pressure. Trained researcher assistants will monitor your heart rate, body temperature, and signs and symptoms of exertional heat illness. If deemed necessary, the researcher and assistants will immediately cold water immerse you to decrease your body temperature.
A disturbance of heart rhythm	You are a young, healthy, active person so the likelihood of developing a heart rhythm disturbance is very low. You have been screened for contraindications to vigorous exercise. At least two of the researchers is certified in CPR/AED will be present during all exercise sessions. In the unlikely event of a cardiac event, EMS will be activated.
Pill thermometer	No side effects or contra-indications have been found.

What are the benefits of the study?

You will benefit from having information regarding your general fitness and health such as body fat percentage and maximal oxygen consumption (typically ~R500 value). This study will increase knowledge of how being hot, tired, and dehydrated affects how we move. Also, we will better understand how proper hydration and body cooling influences poor neuromuscular control. These results will help exercise science, medical professionals and coaching staffs mitigate the musculoskeletal injuries during similar tasks and conditions. The results of this study may influence and encourage further education and research on the topic. We cannot guarantee, however that you will receive any direct benefits from this study.

How will my personal information be protected?

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. All recorded information will remain secured in a lockable office for a maximum period of 2 years after all publications are written. When information is entered into computer databases the information will not include your identifiable information. You will only be identified by an anonymous participant number on data sheets. There will only be one master list of these participant numbers that will be stored in the primary investigator's office. Information will be accessible only by the principal investigator and the student researchers. At the conclusion of this study, the researchers may publish their findings. Information will be presented in summary format and you will not be identified in any publications or presentations.

Will I receive payment for participation? Are there costs to participate?

If you complete the study, you will be compensated R100. If pparticipants do not meet VO_2max criteria and are not eligible to participate, they may not receive monetary compensation but could receive fitness assessment information, if requested, valued at R50. If you decide not to continue participation after the familiarization and first exercise trial, compensation will be prorated (R50). If you complete any portion of a single data collection session you will receive the appropriate payment. You are free to leave the study at any time, without retribution, prejudice, or negative consequences.

What happens if I am injured or sick because I took part in the study?

In the event you become sick or injured during the course of the research study, immediately notify the principal researcher or a member of the research assistants' team. If you require medical care for such sickness or injury, you will be referred to the Uneswa campus health centre or your primary care physician. Your care will be billed to you or to your insurance company in the same manner as your other medical needs are addressed. There is no monetary compensation for injury; each subject is responsible for all medical costs related to her or his care.

Can I stop being in the study and what are my rights?

You do not have to be in this study if you do not want to. Your decision whether or not to participate will not prejudice your future relations with University of Zululand's Department of Human Movement Science and UNESWA- Department of Sports. If you decide to participate, you are free to withdraw your consent and drop out at any time without penalty. You will be notified of all significant new findings during the course of the study that may affect your willingness to continue. If necessary, you may be withdrawn from the study at any time. Examples of withdrawal considerations are safety/medical concerns, missed appointments for trial sessions, non- adherence to procedures, disruptive behaviour during study procedures, and/or adverse reactions. The Ethics Committee on the Protection of Human Participants at University of Zululand's Department of Human Movement Science will review and approve the present research.

Whom do I contact if I have questions about the study?

If you have any questions, please email the principal researcher, Mr Adiele Dube (dubea2567@gmail.com or call +268 7829 3182. I will be very happy to answer them. The University of Zululand's Department of Human Movement Science Ethical Committee has reviewed and approved the present research. Questions regarding the rights of research participants may be directed to my Supervisor at the University of Zululand's Department of Human Movement Sciences, Dr Chantel Gouws on GouwsC@unizulu.ac.za.

ANNEXURE C: PARTICIPANT ASSESSMENT FORM

UNIVERSITY OF ZULULAND
RESTRUCTURED FOR RELEVANCE

Pre-health questionnaire

As you have volunteered to be a subject in this study, would you please co-operate and complete the following questionnaire to ensure you are suitable to take part in the study.

Date: _________

Initials: ____

Title:__________

Sex: M [ ] Other [ ]

DOB: __________

Phone (home): _____________________________________

Phone (work): _____________________________________

Address: ____

City: ____
Reasons for conducting this:

a. to examine the effects of dehydration, hyperthermia, aspects of cognition and fatigue balance on sport performance
b. to suggest individual strategies in preventing injury risk.

Have you ever been involved in any exercise science or sports studies research?

Are you currently involved as a participant in any research?

Yes No

If yes, state which:

____

____

General and medical information

Is your general health ok?

____

Have you suffered any injuries recently? If yes, specify

____

____

Have you had your blood pressure taken recently?

Date: _____________

Reading: _____________

By whom: _____________

Do you suffer from any medical conditions?	Yes	No

If yes, circle those that apply and add any relevant details:

Asthma (or other respiratory conditions)	------------------------	----------------------
Epilepsy Diabetes	------------------------	----------------------
High blood pressure	------------------------	----------------------
Cardiac/heart problems	------------------------	----------------------
Cancer	------------------------	----------------------
Osteoporosis	------------------------	----------------------
Digestive complaints	------------------------	----------------------
Thrombosis	------------------------	----------------------
Arthritis Tumour	------------------------	----------------------
Haemophilia	------------------------	----------------------
Other (please state):	------------------------	----------------------

Are you taking any medication? If yes, provide details.

Have you ever had any surgery? If yes, provide details.

____

Are you subject to any medical conditions?

____

Do you have any allergies? If yes, provide details.

____

Anything else of relevance?

____

____

Would you consider yourself to being physically fit or generally able in sport and exercise?

____

What are your current activity patterns?

a) Frequency: __________ exercise sessions per week

b) Intensity: Sedentary Moderate Vigorous

c) History: <3 months 3-12 months >12 months

d) Duration: __________ minutes per session

What types of exercise/s do you do?

____

____

Do you play or take part in sport? If yes, what sport, position and how often?

____

____

<u>Current Medical History</u>

Do you have any current injuries or medical conditions researcher should be aware of?

If yes, specify below

____

Provide details of the problem:

How: ____

When: ____

Why: ____

Symptoms: ____

What activities/movements/positions make this?

Worse? ____

Better? ____

Do you experience any pins and needles?

____

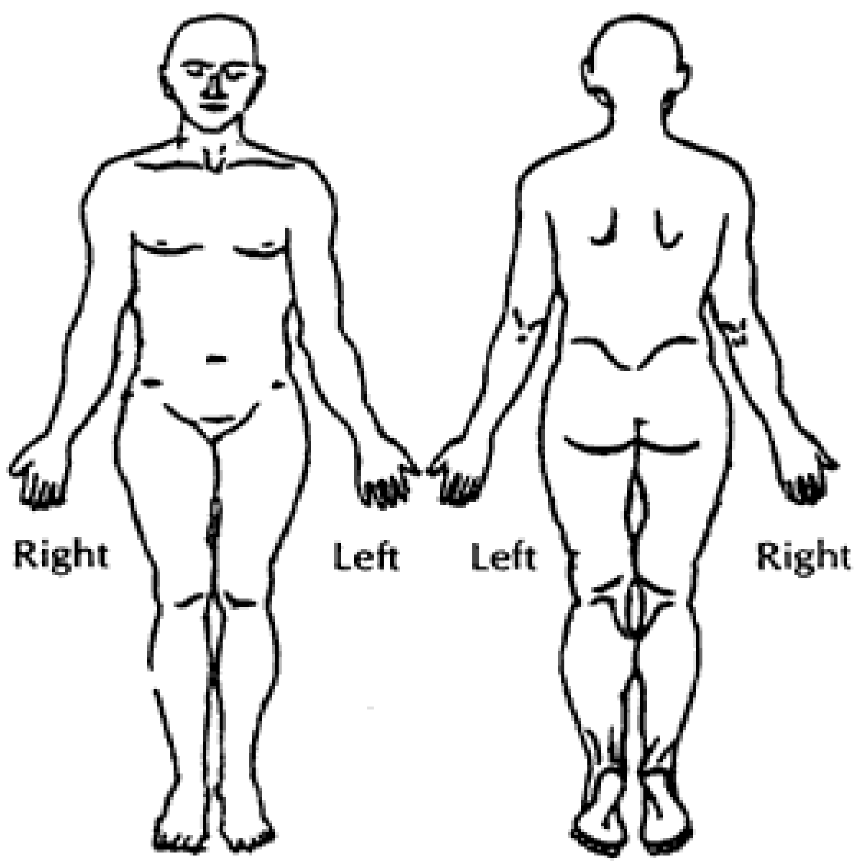
Do you experience any loss of power, strength and balance during a physical exercise?

Body chart

Mark on the body chart areas indicating where you once had an injury or severe pain, which made you to seek medical attention.

Observation (need permission off the client)

Consent from the client: Yes No



Symmetry	Ease of light clothes dressing	Compare left to right	Lumps/Scars	Inflammation	Any other?

Palpate (Consent)

Consent off the client: Yes No

Skin temp / Texture	Muscle tone	Swelling	Compare limbs	Muscle spasm	Skin colour

Movement

Consent from the client: Yes No

Flexion/ Extension	Abduction/Adduction	Left/Right flexion	Hyper mobile	Stiffness	Internal/External rotation

Decision to take part in the study: Yes/No

Participant signature: ___________________________

Date: ____

ANNEXURE D: PROFILE OF MOOD STATES

UNIVERSITY OF ZULULAND
RESTRUCTURED FOR RELEVANCE

Participant's Initials _______

Birth date _______

Date _______

Participant's Code No. _______

Directions: Describe HOW YOU FEEL RIGHT NOW by checking one space after each of the words listed below: FEELING

	Not at all	A little	Mod	Quite a bit	Extremely
Friendly	1	2	3	4	5
Tense	1	2	3	4	5
Angry	1	2	3	4	5
Worn Out	1	2	3	4	5
Unhappy	1	2	3	4	5
Clear-headed	1	2	3	4	5
Lively	1	2	3	4	5
Confused	1	2	3	4	5
Sorry for things done	1	2	3	4	5
Shaky	1	2	3	4	5
Listless	1	2	3	4	5
Peeved	1	2	3	4	5
Considerate	1	2	3	4	5
Sad	1	2	3	4	5
Active	1	2	3	4	5
On edge	1	2	3	4	5
Grouchy	1	2	3	4	5
Blue	1	2	3	4	5
Energetic	1	2	3	4	5

Panicky	1	2	3	4	5
Hopeless	1	2	3	4	5
Relaxed	1	2	3	4	5
Unworthy	1	2	3	4	5
Spiteful	1	2	3	4	5
Sympathetic	1	2	3	4	5
Uneasy	1	2	3	4	5
Restless	1	2	3	4	5
Unable to concentrate	1	2	3	4	5
Fatigued	1	2	3	4	5
Helpful	1	2	3	4	5
Annoyed	1	2	3	4	5
Discouraged	1	2	3	4	5
Resentful	1	2	3	4	5
Nervous	1	2	3	4	5
Lonely	1	2	3	4	5
Miserable	1	2	3	4	5
Muddled	1	2	3	4	5
Cheerful	1	2	3	4	5
Bitter	1	2	3	4	5
Exhausted	1	2	3	4	5
Anxious	1	2	3	4	5
Ready to fight	1	2	3	4	5
Good-natured	1	2	3	4	5
Gloomy	1	2	3	4	5
Desperate	1	2	3	4	5
Sluggish	1	2	3	4	5
Rebellious	1	2	3	4	5
Helpless	1	2	3	4	5
Weary	1	2	3	4	5
Bewildered	1	2	3	4	5
Alert	1	2	3	4	5
Deceived	1	2	3	4	5
Furious	1	2	3	4	5

Effacious	1	2	3	4	5
Trusting	1	2	3	4	5
Full of pep	1	2	3	4	5
Bad-tempered	1	2	3	4	5
Worthless	1	2	3	4	5
Forgetful	1	2	3	4	5
Carefree	1	2	3	4	5
Terrified	1	2	3	4	5
Guilty	1	2	3	4	5
Vigorous	1	2	3	4	5
Uncertain about things	1	2	3	4	5
Bushed	1	2	3	4	5

ANNEXURE E: PROOF OF ACCEPTANCE TO PUBLISH ARTICLE

From: kabaleimc@gmail.com

To: dubea2567@gmail.com

CC:

Subject: African Health Sciences - Decision on Manuscript ID WKR0-2021-03-0538.R1

Body:

03-Aug-2021

Dear Mr. Dube:

It is a pleasure to accept your manuscript entitled "Effects of Hypohydration and fluid balance in athletes' cognitive performance: A systematic review" in its current form for publication in the African Health Sciences. The comments of the reviewer(s) who reviewed your manuscript are included at the foot of this letter.

Thank you for your fine contribution. On behalf of the Editors of the African Health Sciences, we look forward to your continued contributions to the Journal.

Sincerely,
Professor James Tumwine
Editor-in-Chief, African Health Sciences
kabaleimc@gmail.com

ANNEXURE F: PROOF OF ACCEPTANCE FOR PUBLICATION

April 17, 2021

Statement

I would like to inform that the article on the title "Exercise-Heat Stress, Hyperthermia, Dehydration and Fatigue Effects on Cognitive Performance among Semi-Professional Male Athletes" authored by Dube Adiele, Gouws Chantell, Breukelman Gerrit J has been qualified for publication in Physical Activity Review, volume 10(1), 2022.

Sincerely

Prof. JDU Jacek Wąsik, PhD

Editor-in-Chief

International Scientific Journal "Physical Activity Review" e-ISSN 2300-5076, www.physactiv.eu

ANNEXURE G: PROOF OF CONFERENCE PRESENTATION

Day One - June 24, 2021	
Introduction, Welcome and Announcements 1: 15h30 – 15h45	
Introductions and Announcements	
Welcome by Sports Africa Network ; Dr. Martha Saavedra, University of California, Berkeley	
Opening Session: 15h45 – 17h00	
Panel 1: The Making of the Springboks	
Panel Chair: Louzanne Coetzee, University of the Free State	
Mark S Fredericks	Images That Lie: The Springbok Image In Mainstream Media
Parwine Patel	Rainbow World Champions? Questioning the impact of the Springboks' victory at Rugby World Cup 2019 on the South African Society
Derek Catsam	On Chester, Habana, and Siya (and Luyt and Cronje and Eben): Thinking Historically About 25 Years of Springbok Rugby Since 1995
Opening and Keynote 1: 17h15 – 18h20	
Remarks by :	
Prof S Muthwa, Vice-Chancellor, Nelson Mandela University	
Prof. Pamela Maseko, Dean of Humanities, Nelson Mandela University	
Keynote Address by Prof Ashwin Desai, Professor, Department of Sociology, University of Johannesburg	
Session 2: 18h30 – 20h00	
Panel 2: Women, Sports and Environment	
Panel Chair: Prof Cheryl Walter, Nelson Mandela University	
Mathew Ayodele	Women and Sports in Post-Colonial Nigeria, 1950-2000
Nobubele Phuza	A proposal for a (new) paradox of competitive netball
Shaabiera Sait David Bogopa	An Enquiry on Gender, Religion and Sport: The Case of Muslim Women Residing Inmalabar, Port Elizabeth
Bose Maposa	Understanding Botswana women's engagement in physical activity and exercise: Preliminary results of a pilot study
Round Table	
20h00 – 21h00	Research in African Sports
Prof. Peter Alegi, Michigan State University (Moderator)	
Nobubele Phuza, Nelson Mandela University	
Prof. Iman Nefil, Institut des Sciences du sport-sante de Paris, Universite de ParisProProf	
Dr. Solomon Waliaula, Maasai Mara University	
Day Two - June 25, 2021	
14h00 – 14h15	Introductions and Announcements
14h15 – 14h45	Keynote Address by Francoise Mbango, 2-time Olympic gold medalist, Triple Jump
Day 2 Panel Presentations	
Session 3: 14h45 – 16h15	
Panel 3: Bodies, Exercise and Society	
Panel Chair: Sam Masingi, University of the Free State	
Isaac A Oyewumi Adeolu O. Oyekan	Movement Competence Ambition Assessment among Human Kinetics Students in South-West Universities, Nigeria.
Athenkosi Kilane	Symbolic relations between athletes and society
✓ Adiele Dube	Exercise-Heat Stress, Hyperthermia, Dehydration and Fatigue Effects on Cognitive Performance among Semi-Professional Male Athletes ✓
Iorwase D. Kaka'an	Talent Search and Development in Nigeria: The Approaches to Football Delivery System by Aeson Football Club of Makurdi
16h30 – 17h00	Keynote Address by Aziz Daouda, Directeur Technique et du Développement de la Confédération Africaine d'Athlétisme
Session 4: 17h15 – 18h45	
Panel 4: Politics, Memory and Ruptures: PART I	
Panel Chair : Papa Owusu-Kwartend, Ohio University	
Mouhamadou N. Sarr	Les rois sportifs de l'égypte ancienne
Lyndon J. Bouah Christo De Coning	The Case for Sport in the Western Cape
Lorna J. Kimaiyo	The transformation of sports in Elgeyo-marakwet county, Kenya, 1895-1963
Pedro Mzileni	Local soccer clubs as underground trade union movements in Zwelitsha, Eastern Cape: 1970-1990
Session 5: 19h00 – 20h30	
Panel 5: Politics, Memory and Ruptures: PART II	
Panel Chair: Dr Noluntu Stella Dyubhele, Nelson Mandela University	
Lyndon J. Bouah	Chess in the Cold War between South Africa and Russia
Itamar Dubunsky	Israel-South Africa sportive ties in the Apartheid era
Hendrik Snyders	'Coincidental, parallel and common struggles': South African weightlifting, the international sports boycott and Artists and Athletes Against Apartheid c. 1948 – 1990
Bradley A. Morris	A historical-political perspective on physical education in South Africa during the period 1990-1999
Session 6: 20h45 – 22h00	
Panel 6: Sports Governance: Local, National & International	
Panel Chair: Prof. Simon A. Akindes, University of Wisconsin, Parkside	
Abdelhamid AIT BIHI	La « corporate gouvernance » : quelles implications pour les organisations sportives marocaines ?
Abdoun Nassir	De la collaboration entre le Comité National Olympique et Sportif du Cameroun (CNOSC) et le Ministère des Sports et de l'Education Physique (MINSEP): entre permanences et ruptures
Mory Sanou	Sport et développement le rôle modèle de l'école

ANNEXURE H: LANGUAGE EDITING CONFIRMATION

editeasy

editeasy

Contact Address: 14 Coucal Cover, Birdswood, Richards Bay, 3900.

Email: editeasy987@gmail.com **Telephone No**: 074 863 7120

22 April 2021

To whom it may concern

This is to certify that I, Adebola Fawole, have proofread the document titled: Effects of Dehydration, Hyperthermia, Cognition Aspects and Fatigue Balance on Sport Performance by Adiele Dube. I have made all the necessary corrections. The document is therefore ready for presentation to the designated authority.

Yours faithfully

Adebola Fawole

ANNEXURE I: ETHICAL CLEARANCE CERTIFICATE

UNIVERSITY OF ZULULAND
RESEARCH ETHICS COMMITTEE
(Reg No: UZREC 171110-030)

RESEARCH & INNOVATION
Website: http://www.unizulu.ac.za
Private Bag X1001
KwaDlangezwa 3886
Tel: 035 902 6273
Email: ViljoenD@unizulu.ac.za

ETHICAL CLEARANCE CERTIFICATE

<table>
<tr><td>Certificate Number</td><td colspan="8">UZREC 171110-030 PGM 2021/72</td></tr>
<tr><td>Project Title</td><td colspan="8">Effects of Dehydration, Hyperthermia, Cognition Aspects and Fatigue Balance on Sport Performance</td></tr>
<tr><td>Principal Researcher/ Investigator</td><td colspan="8">A Dube</td></tr>
<tr><td>Supervisor and Co-supervisor</td><td colspan="4">Dr C Gouws</td><td colspan="4">Dr G Breukelman</td></tr>
<tr><td>Department</td><td colspan="8">Human Movement Science</td></tr>
<tr><td>Faculty</td><td colspan="8">Science and Agriculture</td></tr>
<tr><td>Type of Risk</td><td colspan="8">Medium Risk – Data collection from people</td></tr>
<tr><td>Nature of Project</td><td>Honours/4th Year</td><td></td><td>Master's</td><td>x</td><td>Doctoral</td><td></td><td>Departmental</td><td></td></tr>
</table>

The University of Zululand's Research Ethics Committee (UZREC) hereby gives ethical approval in respect of the undertakings contained in the above-mentioned project. The Researcher may therefore commence with data collection as from the date of this Certificate, using the certificate number indicated above.

Special conditions:

(1) This certificate is valid for 1 year from the date of issue.
(2) Principal researcher must provide an annual report to the UZREC in the prescribed format [due date-31 March 2022]
(3) Principal researcher must submit a report at the end of project in respect of ethical compliance.
(4) The UZREC must be informed immediately of any material change in the conditions or undertakings mentioned in the documents that were presented to the meeting.

The UZREC wishes the researcher well in conducting research.

Professor Mashupye R. Kgaphola
University Research Ethics Committee
Deputy Vice-Chancellor: Research & Innovation

31 March 2021

CHAIRPERSON
UNIVERSITY OF ZULULAND RESEARCH ETHICS COMMITTEE (UZREC)
REG NO: UZREC 171110-30
31 -03- [illegible]
RESEARCH & INNOVATION OFFICE