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The Effects of Sodium Bicarbonate Supplementation on Simulated Soccer Performance

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by

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Abbreviations

Physiological Abbreviations:

ATP – Adenosine Triphosphate

ATP-PCr – Adenosine Triphosphate-Phosphate Creatine

BE – Base Excess

CO_2 – Carbon Dioxide

H^+ - Hydrogen Ions

HCO_3 – Bicarbonate

H_2CO_3 – Carbonic Acid

H_2O – Water

HR – Heart Rate

NaCl – Sodium Chloride

$NaHCO_3$ – Sodium Bicarbonate

PCr – Phosphate Creatine

PL – Placebo

RPE – Rating of Perceived Exertion

SB – Sodium Bicarbonate

VO_2 – Maximal Oxygen Consumption

Performance Abbreviations:

FT+15 – 15 Minutes Post Full Time

HT – Half Time

SD – Sprint Distance

TDC – Total Distance Covered

VR – Variable Run

VRD – Variable Run Distance

Statistical Abbreviations:

CI – Confidence Interval

ES – Effect Size

L – Large

M – Moderate

S – Small

SD – Standard Deviation

T – Trivial

V – Very Large

Other Abbreviations:

BW – Body Weight

Kg – Kilogram

Min – Minute

$Mmol \cdot L^{-1}$ – Millimoles per litre

NMT – Non-Motorised Treadmill

Contents:

Contents of Figures

Contents of Tables

Abstract

Introduction – It is well documented in football that players can enter a fatigued state during the latter stages of a game which can consequently reduce physical performance and therefore the match outcome. During football, high intensity running such as sprinting can alter an individual's acid-base balance and aid in fatigue occurring. Therefore it could be possible that supplementing sodium bicarbonate using a split pre-match and half time dosage protocol could be implemented in order to enhance the extracellular buffering of H^+, prevent fatigue and optimize football performance. The main purpose of this study, was to use sodium bicarbonate as a nutritional intervention and examine its effects upon simulated football performance.

Methods – Ten healthy male footballers (Mean age = 22.1 ± 2.4, height = 181.1 ± 3.4, weight = 73.9 ± 4.1) participated in this study in which adopted a double blind and randomised design. All participants completed two trials in which they consumed a placebo (PL: Sodium Chloride) in one trial and a supplement (SB: Sodium Bicarbonate) in the other. This occurred with the 1st sodium bicarbonate dose being 0.2g/kg/BW and consumed 30 minutes prior to testing and the 2nd dose being 0.1g/kg/BW which was consumed immediately at half time. The placebo dosage was 0.045g/kg/BW and was split into two equal doses and consumed at the same time points. All participants were required to complete the 90 minute football simulation on the non-motorised treadmill in each trial. During each trial, sprint distance, variable run distance and total distance were measured as performance variables. Blood samples were also collected for acid-base analysis. Also collected was oxygen consumption, heart rate, rating of perceived exertion (RPE) and gastro intestinal distress tolerability.

Results – The main findings of this study were; 1) Sodium bicarbonate supplementation resulted in a small beneficial effect upon total sprint distance; 2) Sodium bicarbonate supplementation resulted in a small negative effect upon total variable run distance and 3) Sodium bicarbonate supplementation resulted in a trivial effect upon the total distance covered. It was also found that sodium bicarbonate supplementation resulted in acid-base balance being

maintained during the latter stages, as well as a high tolerability to sodium bicarbonate amongst participants.

Conclusion – To conclude, the present study found that sodium bicarbonate can enhance sprint performance. However, it also highlights that variable run performance and therefore overall performance can be reduced when supplementing sodium bicarbonate during a football simulation. Future research is required looking into other possible interventions to counteract fatigue in football.

Chapter 1

Introduction:

1.1 Background:

Bicarbonate is a natural buffer system in the human body. Consuming bicarbonate in the form of Sodium Bicarbonate (SB) in the preparation phase of exercise has been reported to optimize the concentrations of blood bicarbonate as well as result in an increase in resting blood pH (Requena, Zabala, Padial, & Feriche, 2005). Therefore, consuming SB can potentially optimize an individual's extracellular buffering capacity. When an individual exercises at a high intensity, the process of anaerobic glycolysis occurs in order to provide the energy required. However a repercussion of this process is the accumulation of hydrogen ions (H^+) (Krustrup et al., 2006). The accumulation of H^+ leads to a reduction in the blood pH and results in the blood being more acidic. This increase in blood acidity hinders the sarcoplasmic reticulum to release calcium (Ca^{2+}), which inhibits the binding of actin and myosin and consequently inhibits the production of energy (Fabiato & Fabiato, 1978). The repression of these processes results in the breakdown of a specific enzymatic mechanism which aids muscle contraction and can ultimately result in fatigue (Cairns, 2006). Inducing the process of alkalosis prior to exercise by consuming SB can optimize an individual's buffering capacity as this can result in an increase in the removal of H^+ and therefore can aid in delaying fatigue during exercise (McNaughton, Siegler, & Midgley, 2008). Although SB supplementation has been extensively researched, there is currently no research exploring its effects on intermittent exercise that replicates the physiological load of actual match play in football.

With football being an intermittent sport, the nature of the game requires players to change activity approximately every 5s, in which over 1000 activity changes are performed with approximately 200 of these being performed at a high intensity (Bangsbo et al., 2006). Furthermore, key periods of the game in which can determine the match outcome require high intensity exercise to be performed by players. For that reason, it is essential for players to maintain repeated efforts of high intensity exercise in order for performance to be enhanced.

During football, players frequently perform repeated sprints in which are combined with short recovery periods and this is known as repeated sprint ability which can be an essential measure of physical performance (Rampinini et al., 2009). Within match play, players can complete up to 60 sprints, with durations approximately 2 to 3s and players performing sprints approximately once every 90 seconds (Mohr et al., 2003). This reiterates how essential the recovery period between sprints is. However, it is well documented that the ability to perform high intensity exercise such as repeated sprints is reduced towards the end of a game and the distances of high intensity running are reduced during the last 15 minutes (Kustrup et al., 2006; Mohr et al., 2003). Such exercise can cause disturbances in acid-base balance resulting in mechanisms of fatigue occurring.

Football related activity can cause H^+ to accumulate from ATP hydrolysis and glycolysis which reduce the blood pH level and provoke acidosis (Robergs et al., 2004). However, the blood pH level is at its lowest during the first 15 minute period of a game at approximately 6.80 whereas during the last 15 minute period it is approximately 7.00 (Bangsbo et al., 2007; Kustrup et al., 2006)). This increase in acidity from an optimal level hinders the binding of actin and myosin resulting in the breakdown of the enzymatic reaction needed for muscle contraction, consequently reducing force production and physical performance such as sprinting. Over the 90 minute match duration, bicarbonate concentration is reduced by approximately 3-4 $mmol \cdot L^{-1}$ leading to a reduction in buffering capacity and disrupting acid-base balance (Russell & Kingsley, 2012). Consuming SB as a nutritional intervention can increase the natural bicarbonate store and the extracellular buffer profile by approximately 4-6 $mmol \cdot L^{-1}$ (Bishop & Claudius, 2005). Increasing this can enable an increase in the removal of H^+ during recovery between sprints, therefore allowing recovery from high intensity exercise such as sprinting to be more efficient. As a result of this, acid-base balance is enhanced for players to be in an optimal condition for the continuation of high intensity running. Performance is then enhanced due to the maintenance of muscle contraction, therefore positively effecting repeated sprints. This performance enhancement as a result of SB supplementation can have a positive effect upon the match outcome as high intensity running is maintained.

1.1.1 Purpose:

In football, it is well documented that player's may enter a fatigued state during the latter stages of a game (Karakoc, Duzova, Polat, Emre, & Arabaci, 2005). Consequently, this can reduce an individual's physiological performance which can play a major role in inhibiting playing performance and can change the outcome of a game (Rampinini et al., 2010). With high intensity intermittent exercise altering an individual's acid-base balance, it is possible that inducing alkalosis through prescribing SB could be implemented in order to optimize the extracellular buffering capacity during a game (Russell & Kingsley, 2012) . Current research focuses mainly on single bout exercises and little consideration has been given to whether SB has an effect on team sport activity. Moreover, no attention has been paid to its effects during football or any football related activity, although research exploring acid-base balance in football has suggested doing so (Russell & Kingsley, 2012).

Therefore, the purpose of this research is to add to the little knowledge that exists in regards to using SB as a nutritional intervention during high intensity intermittent exercise that replicates the physiological load of team sport play. Furthermore, this study aims to present football players and their coaches with an evidence-base regarding SB dosage protocols.

1.2 Aims & Objectives:

To investigate the changes in acid-base balance and the effects of inducing alkalosis during a 90 minute football simulation which replicates the physiological load of actual match play.

Aims:

1) To create a SB stacking protocol that maintains acid-base balance during the latter stages of a 90 minute football simulation.
2) To investigate whether SB has an effect on physical performance during a 90 minute football simulation.

Objectives:

1) To analyse acid-base balance variables and the effect of SB on those variables.
2) To examine the effect of SB supplementation on group performance variables, specifically sprint and variable run distance.
3) To analyse the impact of SB supplementation on gastro intestinal distress and its practicality to be used in football.

Chapter 2

Literature Review

2.1 Team Sport Exercise and its Associated Fatigue:

The physiological term 'fatigue' can be characterised as the failure to sustain a specific force through the contraction of skeletal muscle (Fabiato & Fabiato, 1978). Fatigue, can be perceived as uncertain, with a number of components contributing towards fatigue as opposed to just one particular mechanism (Stringer, Casaburi, & Wasserman, 1992). These components can range from fluctuations in acid-base balance, such as increases in blood lactate (*lactate*) and the accumulation of hydrogen ions (H^+), to the depletion of an individual's muscle glycogen stores (Bangsbo, Johansen, Graham, & Saltin, 1993). It is well documented that intermittent exercise performed at a high intensity requires an increased rate of adenosine triphosphate (*ATP*) re-synthesis which is fuelled by the ATP-CP and anaerobic glycolysis energy systems (Price, Moss, & Rance, 2003). This is a result of the *ATP* that is stored in the muscle only having the ability to maintain contraction of skeletal muscle for approximately 3-5 seconds, so it is essential that *ATP* is re-synthesised through processes such as anaerobic glycolysis (Lavender & Bird, 1989). On completion of high intensity exercise it is important that players recover and this is when the aerobic system becomes dominant in allowing the removal of lactate and H^+, as well as allowing the re-synthesis of anaerobic energy for the reproduction of high intensity activity. During actual match play, each energy system contributes to assist in the efficient supply of the energy required for activity.

The three energy system used during football match play are the Adenosine Tri-Phosphate – Creatine Phosphate system, Anaerobic Glycolysis and oxidative phosphorylation (Bangsbo, Mohr, & Krustrup, 2006; Mohr, Krustrup, & Bangsbo, 2003). These three energy systems contribute during match play in football, however, it is dependent on the intensity of the exercise being performed as to which energy system is utilized (Bangsbo, Iaia, & Krustrup, 2007). Generally, the *ATP-PC* system plays a major role during short bouts of exercise that are of a high intensity such as sprinting (Costill, Verstappen, Kuipers, Janssen, & Fink, 1984),

whereas low to moderate intensity exercise such as jogging predominantly relies upon oxidative phosphorylation (Mohr et al., 2003). In football, all of these systems are crucial in supplying players with the much needed energy they require (Bangsbo et al., 2006).

Physiologically, football is a sport that can be distinguished by variations in intensity, with high intensity exercise being followed by lower intensity activity in order to optimise recovery and replenish much needed energy (Bangsbo et al., 2006). It has previously been suggested that following high intensity sprinting, creatine phosphate is depleted from type II muscle fibres (Krustrup et al., 2006). Moreover, it is argued that creatine phosphate depletion, specifically within type II muscle fibres, contributes significantly to the onset of fatigue, especially in short bouts of high intensity exercise (Smith et al., 2007). Research has reported that exercising maximally for a duration of 30 seconds can result in stored creatine phosphate being depleted between approximately 60 and 80% (Requena et al., 2005). However, with sprinting exercises within team sports such as football only lasting for between 3 and 5 seconds, the degradation of creatine phosphate and the process of anaerobic glycolysis are more than likely to occur (Bangsbo et al., 2006). Furthermore, the rate at which creatine phosphate is re-synthesised is highly dependent upon the creatine kinase enzyme, although the rate of this process can be shortened due to a reduction in the blood *pH* level (Russell & Kingsley, 2012). With team sport exercise such as football only having recovery periods of between approximately 15 and 30 seconds, it is not possible for creatine phosphate to be fully re-synthesised (Krustrup et al., 2006) and this adds importance to the roles that anaerobic glycolysis and oxidative phosphorylation play during football.

Previously, it has been established that glycolysis is heavily related to the accumulation of H^+ and consequently a reduction in the blood *pH* level (Bangsbo et al., 1993). Furthermore, it has been reported that as a result of this, acidosis occurs, which causes the rate of glycolysis to be reduced and can inhibit the specific enzymatic mechanism needed for muscle contraction to occur (Fabiato & Fabiato, 1978). In accordance to this, implications as a result of acidosis, effect the body‘s capacity to maintain acid-base balance (Mainwood & Renaud, 1985; Robergs, Ghiasvand, & Parker, 2004), which can effect an individual’s physiological performance during

the latter stages of a football match (Karakoc et al., 2005). It has been reported that the body uses a bicarbonate buffer in order to counteract the process of acidosis and delay fatigue which is known as alkalosis (McNaughton et al., 1991). However, during the latter stages of a football match, blood bicarbonate levels are reduced by approximately 3-4 $mmol \cdot L^{-1}$ of the resting value Russell & Kingsley, (2012), which can inhibit an individual's capacity to buffer bicarbonate and consequently result in fatigue (Karakoc et al., 2005). In addition to this, H^+ are still accumulating during this period and a balance is needed between production and removal (Krustrup et al., 2006). Moreover, it has been suggested that the bicarbonate buffer increases the production of lactate, which acts a transporter to export the accumulated H^+ out of the muscle (Nielsen, Hein, Svendsen, Secher, & Quistorff, 2002). Therefore, it could be proposed, that increasing an individual's blood bicarbonate level through the consumption of sodium bicarbonate (*SB*), will increase an individual's blood buffer capacity (Mc Naughton & Thompson, 2001). Furthermore, this could also create a balance between the production and removal of H^+ and prevent acidosis.

2.2 Acid-Base Balance

2.2.1 Overview:

The term acid-base balance indicates the equal balance between how acidic and how alkalinic a blood concentration can be (Hultman & Sahlin, 1980). Acid-base balance is heavily associated to H^+ as they play a major role in maintaining an individual's acid-base balance status (Mainwood & Renaud, 1985). In concentrations, acids dissociate which contributes a H^+ into the extracellular fluid, whereas bases allow the H^+ to be obtained (Mainwood, Renaud, & Mason, 1987). The term *pH* expresses the acidity or alkalinity of a solution and is used in order to measure H^+ activity in the blood and can indicate an individual's acid-base balance. *pH* designates the negative logarithm of the H^+ concentration. This association is conversely equivalent as when the concentration of H^+ elevates, the *pH* is reduced and vice versa (Hultman & Sahlin, 1980).

The *pH* of arterial blood is approximately 7.40 units and it is essential that this is maintained. Any slight fluctuations can cause enzymatic mechanisms to be inhibited, which results in the breakdown of specific chemical reactions, therefore hindering cell processes such as muscle contraction (Robergs, Hutchinson, Hendee, Madden, & Siegler, 2005). When the *pH* of arterial blood is considered to be significantly below 7.40, the acidity of the blood has increased and is therefore known as acidosis. However, when the *pH* of arterial blood is considered to be significantly higher than 7.40, the blood has become more alkalinic and is therefore known as alkalosis. In order for blood *pH* to be regulated and for acid-base balance to be maintained, there are specific mechanisms in which play key roles. Theses mechanisms are the buffer system, the respiratory system and the renal system.

2.3 Buffer Systems:

2.3.1 Overview:

Buffer systems are present in the body and they use quick acting chemical reactions in order to aid in reducing the fluctuations in the blood *pH* (Stringer et al., 1992). Buffers, involve a combination of a weak acid and its conjugate base and vice versa. A function of the buffer system is to prevent the importation and exportation of H^+ by otherwise engaging them, until an individual's acid-base balance can be returned to the correct status (Nielsen et al., 2002). It is known that in the body, a substantial amount of acid is consumed as well as a substantial amount being produced through natural metabolism. With buffering systems processing in the body, it prevents the body from substantial fluctuations in H^+ and therefore blood *pH* level (Hultman & Sahlin, 1980). The buffer system is made up of three separate buffers, the bicarbonate system, the phosphate system and the protein system.

2.3.2 Phosphate Buffer System:

The phosphate buffer system is predominantly an intracellular buffer and functions within the urine. The secretion of H^+ occurs in the urine and it is essential that this is buffered in order for maintenance of electrochemical gradients (McArdle, Katch, & Katch, 2009). Phosphates within the body permit high volumes of H^+ to be removed within the urine and this prevents substantial fluctuations in the *pH* of urine. The *pH* of urine is dependent on the extracellular fluid and its acid-base status which distinguishes the volume of acid phosphates and phosphate salts. When a phosphate ion is converted to acid phosphate through excretion, a sodium ion is delivered back into the body which allows a H^+ to be excreted within the urine (McArdle et al., 2009). Most importantly, this facilitates bicarbonate to be reabsorbed into the body to combine with the sodium ion in order to produce *SB*.

2.3.3 Protein Buffer System:

The protein buffering system is an intracellular buffer, however it can also contribute to extracellular buffering. This system requires a longer period of time to accomplish a balance within the extracellular fluid, which occurs as a result of gradual transportation of HCO_3 and H^+ through cell membranes (McArdle et al., 2009). A popular protein which is found in red blood cells is haemoglobin. Red blood cells incorporate a high volume of enzyme, which is specifically responsible for the reaction which converts water and CO_2 to carbonic acid, to HCO_3 and H^+ and vice versa. Haemoglobin is an important buffer in relation to H^+ and is predominantly the major element of the protein buffer system. This is due to the haemoglobin system which is specifically an intracellular system, having the ability to have an impact on the extracellular *pH* (McArdle et al., 2009). This system also accommodates for fluctuations in the *pH* when changes occur in the partial pressure of CO_2. The protein buffer system in general, is essential as it has the ability to distribute the effects of fluctuations in H^+ within the body, consequently reducing the change in *pH* (McArdle et al., 2009). Proteins within this system are responsible for exporting H^+ to the lungs as water and CO_2; however cellular proteins can be

restricted within the cell, which results in a gradual buffer and it may take a longer period of time for H^+ to be removed.

2.3.4 Bicarbonate Buffer System:

Out of all the three buffering systems in the body, the bicarbonate buffer system is the most prominent as it is associated with at least 75% of extracellular buffering. This system has two main components which are HCO_3 and CO_2 and they are controlled by the kidneys and lungs respectively (Robergs et al., 2005). This system is responsible for converting hydrochloric acid to carbonic acid by weakening the concentration through the addition of *SB*. Carbonic acid is formed due to the combination of H^+ and HCO_3, which when dissociated produces CO_2 and *H2O* (Greenhaff, Gleeson, & Maughan, 1987). This reaction can also be reversed.

When exercise occurs and H^+ are accumulated, this reaction occurs in order to export the CO_2 which has been produced from exercise (Green, 1997). Consequently, this system can acknowledge a reduction in the accumulation of H^+ and otherwise engage the CO_2 for exportation, by reversing the reaction so it associates with H_2O to form carbonic acid. The newly formed carbonic acid then dissociates to form H^+ and HCO_3 which consequently increases the alkalinity and regulates the blood *pH* (Hultman & Sahlin, 1980). This relates heavily to the Henderson equation. In support of this, a reduction in blood *pH* through an increase in the partial pressure of CO_2 can cause acidosis to occur (Robergs et al., 2004). However, an increase in blood *pH* can stem from an increase in the concentration of HCO_3, which can result in alkalosis occurring (Robergs et al., 2005).

In accordance to this, it has previously been suggested that the bicarbonate buffer system can utilise an increased concentration of HCO_3, by increasing lactate production to regulate acid-base balance (Nielsen et al., 2002). It has been demonstrated that H^+ are carried using lactate transporters in order to be exported out of the muscle cell. An increase in the exportation of H^+ would not only develop the extracellular concentration to become more alkalinic but would also facilitate the exportation of lactate (Nielsen et al., 2002).

2.4 Overview of Other Mechanisms:

2.4.1 Respiratory Mechanisms:

The respiratory system defends the body as a result of acid-base fluctuations and functions after the different buffer systems. The respiratory system interacts and is responsible for exporting CO_2 out of the lungs due to the accumulation of H^+(McArdle et al., 2009). This system can alter the respiratory rate in order to counteract the changes in the *pH* of extracellular fluid. Furthermore, this system can be directly related to the HCO_3 buffer system as an increase in PCO_2 causes a reduction in *pH* and vice versa. During high intensity exercise, H^+ accumulate which results in an increase in PCO_2 however, respiratory compensation occurs, ventilation is stimulated and PCO_2 is reduced therefore preventing a change in *pH* and preventing exercise from being inhibited (McArdle et al., 2009).

2.4.2 Renal Mechanisms:

The renal mechanisms depend heavily upon the kidneys and their responsibility to regulate acid-base status through exporting excess acids and bases in urine. Although renal mechanisms are generally slower than other systems, they contribute to the regulation of acid-base balance on a long term basis (McArdle et al., 2009). These mechanisms can regulate H^+ by reabsorbing and producing HCO_3 as well as secreting H^+. This is known as renal compensation and can occur as a result of changes in the extracellular *pH* level. For acid-base balance to be maintained, it is essential that there is a balance between the production and the removal of H^+. When alkalosis is induced, excess HCO_3 is excreted due to its inability to be reabsorbed, and this results in homeostasis being achieved. However, during acidosis HCO_3 has the ability to be reabsorbed; HCO_3 is produced and accumulated H^+ are excreted in the urine. The newly produced HCO_3 is transported to the extracellular fluid and is available for the buffering of H^+ and consequently can result in homeostasis (McArdle et al., 2009).

2.5 Sodium Bicarbonate and its Associated Fatigue:

SB can aid in maintaining an individual's acid-base balance by increasing natural bicarbonate concentrations which are used as a buffer. The buffer system acts to regulate the accumulation of H^+ and consequently regulate the blood *pH*. The supplementation of *SB* is most efficient for exercise of a high intensity due to the energy requirements for exercise being a result of anaerobic glycolysis (Requena et al., 2005) .When this energy system is used during exercise pyruvic acid is converted into lactic acid which directly facilitates glucose to be converted to energy (McArdle et al., 2009). However, exercise can be hindered by the combination of glycolysis and *ATP* hydrolysis producing H^+, which reduces the blood *pH* as well as making the blood more acidic and provoking fatigue (Robergs et al., 2004; Requena et al., 2005).

During exercise, ingesting a buffer such as *SB* may aid in increasing the buffer capacity by making the blood *pH* more alkalinic (McNaughton, 2010). For the continuation of exercise at a high intensity, it is important to lower the levels of increases in H^+ (Robergs et al., 2005). It has been revealed previously, that elevated levels of H^+ inhibit performance as well as aid in hampering the relationship between actin and myosin for muscle contraction (Requena et al., 2005).

Research establishes that the HCO_3 buffer mechanism is one of the most influential buffering agents (McArdle et al., 2009). HCO_3, buffers H^+ before they diffuse into the blood stream metabolically using lactate transporters produced during exercise (McNaughton et al., 2008). Furthermore this study revealed, HCO_3 exports H^+ through processes of ventilation, as HCO_3 is bound with H^+ which results in the formation of H_2CO_3 and ultimately is exhaled out the body as CO_2 and water. The kidneys process H^+ as a fixed acid for excretion and the renal system continues to maintain acid-base balance (McNaughton et al., 2008).

Consuming *SB* as a supplement can result in a more alkalinic *pH*, however the buffer of H^+ is present in blood plasma and not in working skeletal muscle (Verbitsky, Mizrahi, Levin, & Isakov, 1997). Furthermore, it was suggested by Verbitsky et al., (1997) and corroborated by

Cairns, (2006) that the ergogenic effect of *SB* can aid in improving the contraction of muscle during exercise due to an increase in muscle buffering capacity.

2.5.1 Effects on Performance:

SB has been used as a supplement in a variety of different exercise modalities, with the majority of them exploring its effects on short, repetitive, high intensity exercise. Lavender & Bird, (1989) reported that performance had been enhanced during cycling sprints after an acute consumption of *SB*. It was found that a prescription of 0.3g/Kg/BW resulted in a significant increase in the average power output during the cycle sprints, as well as peak power. In relation to shorts bursts of high intensity exercise, Bishop, Edge, Davis, & Goodman, (2004) revealed that *SB* supplementation had a positive effect on five 6 s cycle sprints. Results demonstrated that a significant increase in total work performed had occurred (16.5±3.1 kJ) when compared to the placebo trial (15.7±3.0 kJ), as well as a significant improvement in power output during sprints 3, 4 and 5. A significant increase in time to exhaustion was reported by Van Montfoort, Van Dieren, Hopkins, & Shearman, (2004) during a sprint to exhaustion exercise. The mean results show that it had taken 77.4 s to reach exhaustion during the placebo trial, whereas the *SB* trial had taken 82.3 s. These studies establish that *SB* can facilitate in enhancing exercise which is short in duration and high in intensity.

Although a substantial amount of research has found that *SB* has the ability to induce alkalosis, it has not always resulted in the specific exercise performance being enhanced. A study by Zabala et al., (2008), found no significant effect on performance or RPE during repetitive wingate testing with a rest period of 30 minutes during *SB* supplementation. Furthermore, the same outcome was achieved by Zabala et al., (2011) who had replicated his previous study but modified the rest period by reducing it to 15 minutes. Again, no effect on performance had occurred although subjects had reached a state of alkalosis during exercise. Research by Siegler & Gleadall-Siddall, (2010) investigated SB supplementation and its effect on 25 metre swim sprints. Results showed that although blood buffering was enhanced, swim time had decreased by 2% during the *SB* trial when compared to the placebo trial. With a number of studies finding

no effect, it has been suggested that factors such as training status, incorrect dosages and sample size may have contributed to the outcome.

Previously, research has examined the efficacy of *SB* and its effects on high intensity short duration exercise. In 1992, McNaughton found that SB consumption resulted in a significant increase in peak power during a 60 second maximal cycle exercise (McNaughton, 1992). In relation to this, Goldfinch, Mc Naughton, & Davies, (1988) reported that inducing alkalosis resulted in significantly quicker times during a 400 metre run when comparing the SB and placebo trials. However, SB doesn't always have a positive effect on performance during high intensity, short duration exercise. A study by Horswill et al., (1988) reported that SB had no significant effect on the total work completed during a sprint cycle exercise lasting for 2 minutes.

In the current research, *SB* and its effect upon intermittent exercise have been found, however only little attention has been paid to its effects on team sport activity. In 2005, Bishop and Claudius investigated the effect of a *SB* stacking protocol on specific intermittent hockey exercise (Bishop & Claudius, 2005). Seven female subjects consumed 0.2g/Kg/BW 90 minutes prior to and 20 minutes prior to exercise commencing. The exercise consisted of 2 halves on a cycle ergometer protocol, each 36 minutes in duration, in which subjects had to exercise in 2 minutes blocks which included: maximal 4 s sprints, 100 s of active recovery at 35% of VO_2 max, and 20 s of rest. Although no significant differences occurred, an increase occurred in the total work performed during 7 of the 18 second half sprints.

Research conducted by Price et al., (2003) demonstrated that SB supplementation had a positive effect on peak power during sprinting whilst cycling intermittently for 30 minutes. Another study that explored *SB* and its effect on a specific sport simulation was that of Wu, Shih, Yang, Huang, & Chang, (2010). Wu and co-authors used 9 male tennis players and prescribed them with a stacking protocol of 0.3g/Kg/BW 90 minutes prior to exercise and 0.1g/Kg/BW after completion of the 3rd game. They investigated SB and its effect on simulated tennis match performance, and found that a state of alkalosis had been reached. Most importantly, the results

showed that stroke consistency was maintained during the SB trial and that stroke consistency had declined significantly during the placebo trial. These studies establish that SB can enhance exercise performance during high intensity intermittent exercise by buffering extracellular H^+, reducing pH and consequently preventing fatigue.

In contrast to this, research has been conducted previously that has found that SB supplementation has had no effect on high intensity intermittent exercise. Tan et al., (2010) explored the effects of SB consumption (0.3g/Kg/BW) on match performance during a simulated water polo match which lasted 59 minutes. The simulation included 56, ten metre sprints and Tan's results reported that a state of alkalosis had been reached amongst subjects, however there was no significant difference in mean sprint time between the SB and placebo trials. Another study that reported no effect of SB supplementation is that of Price & Cripps, (2012). Price investigated SB supplementation and its combined supplementation with glucose during 45 minutes of intermittent cycling. However, no differences were reported in relation to sprint performance between the two trials. It has been suggested that finding no effects of SB supplementation on high intensity intermittent exercise can be a result of a variation in the participants training status whether it be high or low.

To summarise, studies reporting an increase in performance have been those which have incorporated a reliable and valid protocol and have used SB supplementation which has caused greater fluctuations in acid-base balance towards alkalosis. Therefore it can be suggested, that the beneficial effects of using SB to induce alkalosis can depend upon the physiological demands of the specific exercise to reach a state of acidosis that inhibits performance.

2.5.2 Dosage and Ingestion Strategy:

2.5.3 Timing:

Throughout the literature there has been inconsistency in how long prior to exercise commencing *SB* should be consumed in order for it have an optimal effect on performance (Carr, Slater, Gore, Dawson, & Burke, 2011). With a substantial volume of studies focusing on its effect on performance, there is only limited research that has explored loading strategies

prior to exercise commencing (Siegler, Midgley, Polman, & Lever, 2010a). The inconsistency in this area can be perceived through substantial differences in consumption time, which can range from 60 minutes prior to exercise to 150 minutes prior to exercise (Lavender & Bird, 1989; Siegler & Gleadall-Siddall, 2010). There are a number of investigations that have permitted the timing of consumption to be 60 minutes prior to exercise, however it is evident that performance was not enhanced when used during a variation of exercise modalities (Price & Simons, 2010). In contrast to this, Price et al., (2003) demonstrated that consuming 0.3g/kg/BW of *SB* 60 minutes prior to exercise resulted in an increased power output during sprinting.

There has been research conducted in which has explored consuming *SB* 90 minutes prior to exercise that resulted in an increase in total work performance (Bishop et al., 2004). Furthermore, it was discovered by Artioli et al., (2007) that consuming *SB* 90 minutes prior to exercise, resulted in an increase in power output. A study conducted by Potteiger, Webster, Nickel, Haub, & Palmer, (1996), analysed *SB* and it's time to absorption and revealed that 120 minutes is the optimal time required for the body's HCO_3 concentration and blood *pH* to peak. However, a study by Siegler et al., (2010a) investigated a number of different ingestion times and there effect on the extracellular buffering profile. It was suggested that 0.2g/Kg/BW should be consumed 40 minutes prior to exercise and that 0.3g/Kg/BW should be consumed 60 minutes prior to exercise in order for an individual's extracellular buffering profile to reach its peak.

2.5.4 Dosage:

Within the current literature exploring *SB* supplementation, a number of investigations have used the same prescribed dose. McNaughton, (1992) analysed five different doses of *SB* (*0.1, 0.2, 0.3, 0.4* and *0.5g/Kg/BW*) and its effect on anaerobic exercise in the mode of a 1 minute cycle. It was identified that the *0.1g/Kg/BW* prescription had no effect, however all other doses had an effect on performance, specifically the *0.3g/Kg/BW*, which resulted in the largest effect on variables, total work and peak power. In relation to acid-base status, it was found that all doses which had an effect on performance had resulted from alkalosis occurring. However,

other studies have used similar prescriptions and no effect had been identified, suggesting that allowing alkalosis to occur during exercise may not always be beneficial (Stephens, McKenna, Canny, Snow, & McConell, 2002; Tan et al., 2010; Zabala et al., 2011; Zabala et al., 2008).

More recently, scientists have taken into consideration the outcome of McNaughton's study, with the most frequent and optimal dosage being *0.3g/Kg/BW* (McNaughton, 1992). Furthermore, scientists accept that this prescribed dose has the potential to cause ergogenic effect as well as limiting the risk of gastro intestinal implications (Carr et al., 2011). This prescription has been shown to increase an individual's blood *pH* by 0.03-0.04 units and allowed the blood HCO_3 concentration to increase by 4-6 $mmol \cdot L^{-1}$. This dose combined with an optimal ingestion time can have a positive effect on performance.

2.5.5 Acute Dosage vs. Chronic Dosage:

The two main methods of administering *SB* for consumption are the acute and chronic methods. A substantial amount of the research present in this area has used the acute method which can consist of *0.3g/KG/BW* which is consumed 60-90 minutes prior to exercise. Bishop et al., (2004) used this acute method to analyse it effects on 6 5 s cycle sprints. It was discovered that the blood *pH* and HCO_3 concentrations were increased and there was an increase in the total work completed during the 5 sprints for all subjects.

The other method which is chronic, consists of consuming a greater amount such as *0.5g/KG/BW* of *SB* over a number of days (Burke & Pyne, 2007) . Previous studies have investigated this and decided that this type of dosage regime could have more of an effect than the acute method. This was demonstrated by McNaughton et al., (1999) who analysed a chronic loading regime of *0.5g/Kg/BW* over a 5 day period and its effects on a 60 second cycle. It was found that there were increases in total work completed as well as power output. Furthermore, McNaughton suggested that chronic loading permits the body to store extra HCO_3 which can be used for an increased level of buffering and consequently increase the performance of exercise (McNaughton et al., 1999).

Consequently, before Burke's study was conducted, it was decided by McNaughton & Thompson, (2001) to conduct a study investigating the difference between the acute and chronic loading methods. The study consisted of individuals consuming *0.5g/Kg/BW* of *SB* over a six day period before completing a 90 second high intensity cycle. Furthermore, individuals completed this cycle twice; however on the 2nd completion they had consumed an acute dose of *0.5g/Kg/BW* 90 minutes prior to exercise commencing. They established that the outcome of both methods were similar in improving performance, however the chronic loading method increased total work output and maintained improvements two days after the loading had finished. This suggested that chronic loading maybe a more effective regime for individuals preparing for multiple events over a number of days and this was given the term 'serial loading' by Burke & Pyne, (2007). Serial loading consisted of reduced doses of *SB* over a number of days so no supplementation was needed on the day of exercise and gastro intestinal distress would be avoided (Burke & Pyne, 2007).

In contrast to the above findings of chronic loading, it was reported by Carr, Slater, Gore, Dawson, & Burke, (2012) that both acute and chronic loads of SB have no effect on performance during a 2000 metre row. Likewise, both acute and chronic loading methods had no effect on performance during a 200 metre swimming session (Joyce, Minahan, Anderson, & Osborne, 2012). However, a number of studies had previously used the same acute loading protocol used in Joyce's study and found significant improvements in performance (Lavender & Bird, 1989; McNaughton et al., 1999; Price et al., 2003; Van Montfoort et al., 2004).

A study that differs to existing research in relation to the acute vs. chronic debate is that of Bishop & Claudius, (2005). This study differed and involved a stocking protocol where individuals consumed *0.2g/KG/BW 90* minutes prior to exercise and 20 minutes prior to exercise. Although the dosage regime differs enormously to that of other studies it still had significant effects on 7 of 18 2nd half sprints during specific hockey intermittent exercise. In relation to this Wu et al., (2010) conducted an investigation into the effect of *SB* supplementation on simulated tennis match performance. Wu used a stacking protocol in which 9 male tennis players consumed *0.3g/Kg/BW* 90 minutes prior to the simulation, with a further

dose of *0.1g/Kg/BW* on completion of the 3rd game of the simulation commencing. It was reported that all subjects reached a state of alkalosis and performance was increased through stroke consistency.

2.5.6 GI Distress:

Research conducted previously reiterates that gastro intestinal distress such as vomiting, stomach cramps and diarrhoea are heavily associated to the consumption of *SB* (Carr et al., 2011; Siegler,Midgley, Polman, & Lever, 2010b) . A study by Price & Simons, (2010) reported that *SB* supplementation had no effect on high intensity running, with 4 out of the 8 subjects experiencing GI distress. However, many studies have reported how influential *SB* loading can be without any gastro intestinal distress or effect on an individual's health (Barber, 2010; Bishop & Claudius, 2005; Douroudos et al., 2006; Stephens et al., 2002). Van Montfoort et al., (2004) examined the effects of *SB* supplementation on a sprint to exhaustion exercise. He discovered that there was an increase in endurance performance and no subjects experienced GI distress. With there being a limited number of studies exploring *SB* supplementation on team sport activity, it was suggested by Hespel et al., (2006) that the ergogenic effect which results from ingesting *SB* would not be worth the risk of gastro intestinal distress in such activity as football. Consequently, it is still perceived this way in the literature at present, although studies have shown how effective different loading regimes such as acute, serial and chronic loading can be (Douroudos et al., 2006).

2.6 Summary:

In football, it is well documented that players may enter a fatigued state during the latter stages of a game. This can cause a significant reduction in the player's overall performance, consequently changing the outcome of a game. With fatigue stemming from a combination of separate mechanisms in football, it is evident that when individuals reach a state of acidosis their buffering capacity is somewhat limited. It can be suggested that enhancing an individual's buffering capacity by inducing alkalosis, through the consumption of *SB,* can aid in delaying fatigue by preventing the accumulation of H^+. Therefore, with an individual's buffering capacity

being enhanced, fatigue is delayed and it can allow players to continue exercising intermittently at a high intensity. It can be proposed, that constructing a specific dosing strategy using $SB_{,}$ will allow an individual's buffering capacity to be maintained during the latter stages of a game and consequently improve physiological performance.

Chapter 3

Method

The purpose of this current study was to examine whether the supplementation of SB would maintain an individual's acid-base balance, and whether it would enhance an individual's performance when completing a football simulation. The experiment was a randomized, double blind, placebo controlled design. During both trials, performance markers for sprint distance, variable run distance and total distance were measured. Acid-base markers were also measured which included bicarbonate (HCO_3), pH, lactate (La) and base excess (BE). Also measured were maximal oxygen consumption (VO_2), heart rate (HR), Rating of Perceived Exertion (RPE) and Gastro Intestinal Distress.

3.1. Participants

Ten healthy male football players from Hull University Football Club were selected to participate. The mean (±SD) have been used as statistical analysis for subject characteristics age, height, weight and resting heart rate which can be seen in Table 1. The study was approved by the research ethics committee of the University of Hull. All of the different testing procedures were completed at The University of Hull.

Table 1. The mean (±SD) participant characteristics.

Characteristic	Mean (±SD)
Age	22.1 ± 2.4
Height (cm)	181.1 ± 3.4
Body Mass (kg)	73.9 ± 4.1
Resting Heart Rate (beats·min^{-1})	72 ± 8.2

3.2. Initial Consultation

The participants attended an initial consultation meeting which consisted of the them being briefed both verbally and in writing of the study's requirements, benefits and other information such as side effects. During this, it was extremely important that all participants had fully understood specific information in relation to the study before consenting. It was policy that all participants had to complete the approved departmental medical questionnaire (Appendices A) and informed consent forms (Appendices B). The completed medical questionnaires were checked for participants who had reported existing medical conditions that may inhibit the proposed testing procedures, and if so the participant/s were withdrawn from the study with immediate effect. This also occurred if participants were currently taking any other form of supplement and if they had consumed sodium bicarbonate in the previous 28 days. All participants were informed that they could withdraw from the study at any time and they could do so without giving specific reason. Any participant/s would be kept anonymous and relating information would be kept confidential.

3.2.1. Familiarisation

A period of weeks before the scheduled testing commenced it was necessary for all participants to complete three familiarisation sessions. The first familiarisation session consisted of the initial screening procedures such as measuring the participants' height, body mass and resting heart rate. The participants' height was measured using the Holtian stadiometer (Holtian Ltd, Crymych, Dyfed), the participants' body mass was measured using the SECA balance scale (Vogel & Halke, Hamburg, Germany) and the participants' resting heart rate was measured using the heart rate watch and chest strap (Polar Electro, OY, Finland). The following two sessions consisted of all participants habituating to relevant equipment and recording their individual peak sprint speed. However, this was specifically the Woodway Non-Motorised Treadmill (Woodway, Weil an rhein, Germany) and the relevant intermittent soccer performance test (iSPT) protocol (Abt, Reaburn, Holmes, & Gear, 2003; Aldous et al., 2014).

3.2.2. Supplementation Procedure

It was decided from the pilot study (Appendix C) that a volume of 0.3g/kg/BW of sodium bicarbonate would be administered to participants in two doses. This would occur with the 1st dose being 0.2g/kg/BW and consumed 30 minutes prior to testing and the 2nd dose being 0.1g/kg/BW which was consumed immediately at half way. The placebo dosage (Sodium Chloride: 0.045g/kg/BW) was split into two equal doses. In both of the placebo/supplement trials, all participants were required to consume the relevant doses of either the supplement or placebo, prescribed in the form of gelatine capsules in order to reduce the risk of gastro intestinal distress. It was necessary that all participants consumed the prescribed doses with 250 mL of water over a 5 minute period.

3.2.3. Exercise Testing

Participants had been following specific food diet guidelines which had been created specifically for this study (Appendix D). The guidelines were followed 3 days prior to testing and on the day of testing. This was monitored by participants completing a food diary over this period, in order for all participants to have the same diet leading up to testing. For the exercise testing, all participants were required to attend the laboratory in their training kit with adequate footwear. On arrival participants consumed the 1st dose of sodium bicarbonate. Following this, participants' then had a 10 minute rest period in which specific equipment was measured up to each individual. After the rest period, participants' took their position and completed a 10 minute football specific warm up on the Woodway Non-Motorised Treadmill. On completion, participants' then had 5 minutes to walk on the treadmill. Immediately after the walking period the intermittent soccer performance test (iSPT) commenced. When reaching the half time period, the 2nd dose of sodium bicarbonate was consumed. Once the 15 minute half time period was completed, participants were back in the starting position and completed the second half of the iSPT. All participants completed this exercise testing twice, either consuming the supplement or placebo on either occasion. During this specific variables were measured and are mentioned in the section 3.2.5.

3.2.4 Intermittent Soccer Performance Test (iSPT)

The intermittent soccer performance test consisted of two 45 minutes halves separated by a 15 minute half time interval on a non-motorised treadmill (Aldous et al., 2014). The protocol allowed participants to interact with a computer and the pacer performance software (Innervation, Pacer Performance System Software, Lismore, Australia) as they followed a target line to equal using a line representing their own speed, which was created by the football specific movement. Participants were instructed to match the target speed as closely as possible. The iSPT instructed participants using audio cues, alerting them of specific movement changes. The protocol included seven different movements that were individualised as a percentage of the participant's peak sprint speed. The activity profile of the iSPT was based on a previous motion study exploring football match play (Bangsbo, Norregaard, & Thorso, 1991). This protocol allowed variables such as total distance, sprint distance and variable run distance to be measured. Although the iSPT doesn't include football specific movements such as jumping, turning, kicking etc, it has good reproducibility between trials, resulting in similar variables and physiological data to that of actual match play data. The performance variables measured during the iSPT are reliable, with high reliability scores when compared to other protocols (Aldous et al., 2014). With the protocol being individualised on peak sprint speed, the iSPT allows the protocol to be specific to each participant resulting in a better reflection of their individual physiological capacity compared with other simulations. Overall, the iSPT shows its validity and reliability in reference to the physiological load and performance variables (Aldous et al., 2014), which establishes the iSPT as suitable for a current nutritional intervention study.

3.2.5. Measurement of Variables

During the exercise testing, specific variables were measured every 15 minutes in order for analysis. Blood samples were collected in duplicate every 15 minutes, from 30 minutes pre exercise to 15 minutes post exercise using the finger prick method, in order to measure HCO_3, pH, lactate and BE. Both samples were then analysed and the mean for each variable was recorded. Mean peak distance was measured during the sprinting periods as well as the variable runs, and total distance covered was also measured using the Woodway Non-Motorised

Treadmill and the specific Pacer Performance computer software. O_2 Consumption was measured over a specific 2 minute period every 15 minutes during the simulation using the Cortex Metalyzer 3B (Cortex Biophysic, Leipzig, Germany). Heart rate was continuously measured using a heart rate monitor from the beginning of the simulation to 15 minutes post exercise (Polar Electro, OY, Finland). RPE (Foster et al., 2001)(Appendices E) and GI distress were also measured continuously throughout, starting 30 minutes prior to the simulation starting through to 15 minutes post exercise using specific charts.

3.2.6. Gastro Intestinal Distress Questionnaire

In order to determine if any distress had occurred, all participants were required to complete the GI Tolerability Questionnaire (Appendix F), which commenced at pre ingestion and was completed up until 15 minutes post exercise (Siegler, Marshall, Bray, & Towlson, 2012). The questionnaire asks the participant to rate the severity of nine symptoms at every 15 minute period, with each symptom represented by a 10 cm visual analogue scale (VAS), with no symptom at the left of the scale and severe at the opposite end (Wewers & Lowe, 1990). This allows participants to rate the severity of the symptoms experienced, if any, by marking a line on the VAS. The nine symptoms in which were measured were; nausea, flatulence, stomach cramps, belching, stomach ache, urgency of bowels, diarrhoea, vomiting and bloating of the stomach.

3.3. Statistical Analysis

The mean ± SD have been used to report all values. Data analysis has been completed using Hopkins post crossover spreadsheet in Microsoft Excel for Windows (Hopkins, 2007a). The data analysis estimates the effect of sodium bicarbonate which is expressed as Cohens effect sizes (ES). Differences between trials was analysed using the following descriptors for effect sizes (< 0.2 = trivial, 0.2 - 0.6 = small, > 0.6 - 1.2 = moderate, > 1.2 - 2.0 = large and > 2.0 = very large). The precision of the estimate was indicated by 90% confidence intervals (CI) . This identifies whether the effect of sodium bicarbonate is practically beneficial, trivial or harmful in relation to performance (Hopkins, 2010).

.Chapter 4

Results

4.1 Performance Variables:

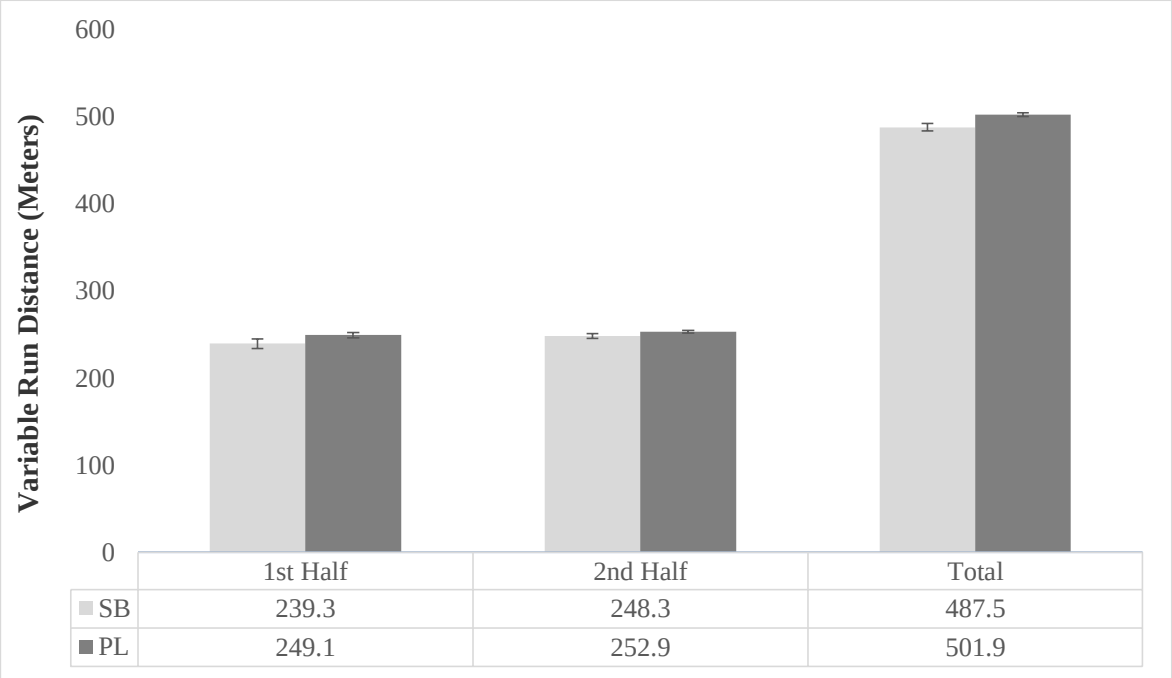

Figure 1. The mean (±SD) variable run distance for the placebo and sodium bicarbonate trials during the 1st half, 2nd half and the total variable run distance during the football simulations. SB = Sodium Bicarbonate, PL = Placebo.

In relation to variable run distance, Figure 1 highlights that sodium bicarbonate supplementation lead to reductions in variable run distance in each half of the simulation and consequently resulted in a reduction in the total variable run distance. The relevant inferential analysis for the performance outcomes for variable run distance is represented in Figure 2.

Table 2. The mean (±SD) for total distance and sprint distance for the placebo and sodium bicarbonate trials during the 1st half, 2nd half and the total during the football simulations.

	Total Distance (Meters)		Sprint Distance (Meters)	
	SB	PL	SB	PL
1st Half	4421.2 ± 294.9	4402.5 ± 226.9	446.1 ± 37.4	436.7 ± 36.4
2nd Half	4387.8 ± 300.8	4369.2 ± 215.4	442.6 ± 34.2	431.0 ± 30.9
Total	8809.1 ± 525.4	8771.7 ± 434.2	888.7 ± 32.1	867.7 ± 30.2

In relation to sprint distance, Table 2 highlights that sodium bicarbonate supplementation lead to increases in sprint distance in each half of the simulation and consequently resulted in an increase in the total sprint distance.

Table 2 also highlights that sodium bicarbonate supplementation lead to minimal increases in the total distance covered in each half of the simulation and consequently resulted in a small increase in the total distance covered. The relevant inferential analysis for the performance outcomes are represented in Figure 2.

4.1.1 Inferential Analysis of Performance Outcomes

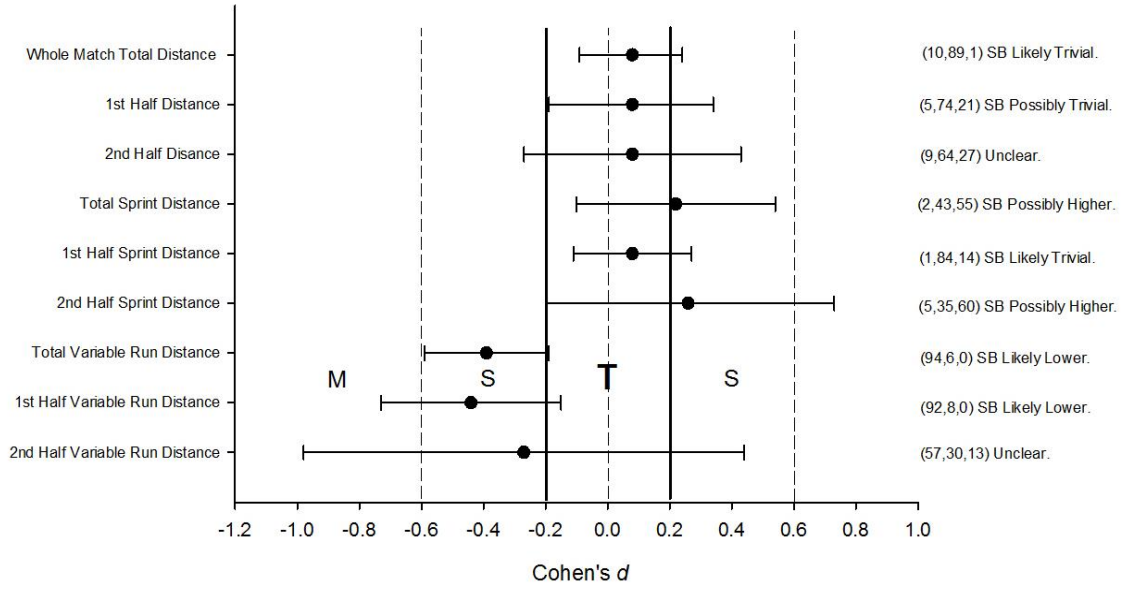

Figure 2. The mean difference as a Cohen's effect size (± 90% CI) for performance outcome variables between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate, SB = Sodium Bicarbonate.

In relation to the performance outcomes, Figure 2 highlights that sodium bicarbonate supplementation can possibly have a small positive effect upon the total sprint distance with an increased effect occurring in the 2nd half. However, it identifies that sodium bicarbonate supplementation can have a small negative effect upon the total variable run distance.

4.2 Acid-base Variables:

4.2.1 Blood pH

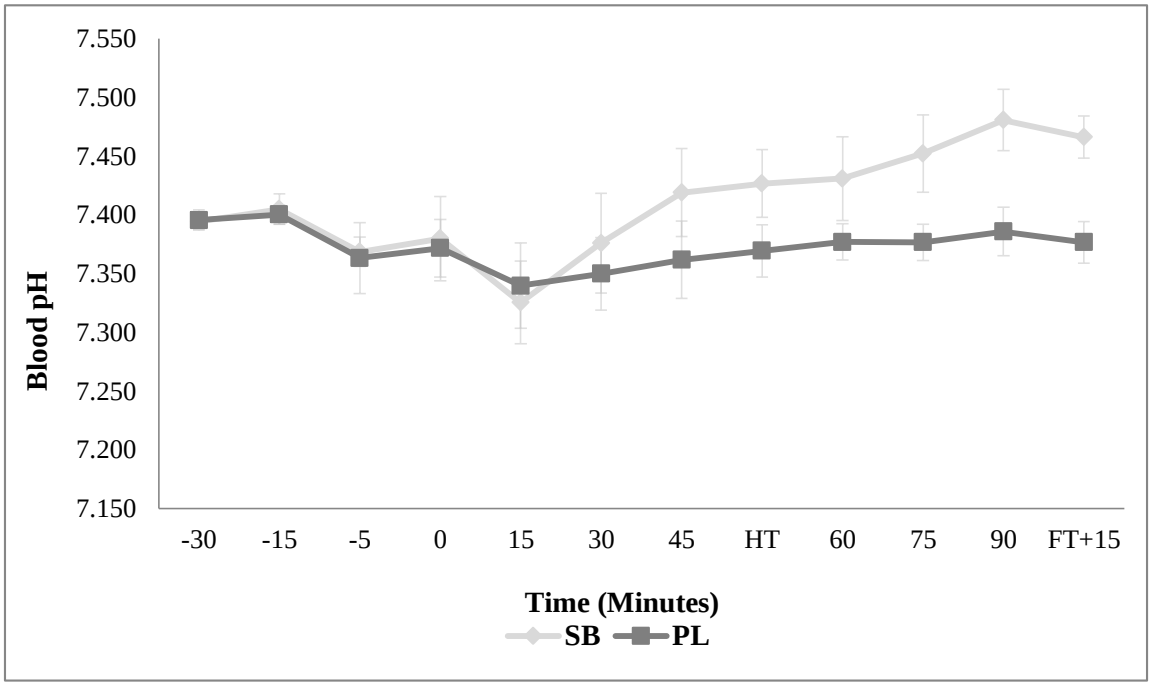

Figure 3. The mean (±SD) blood pH at different time points during the football simulations for both the placebo and sodium bicarbonate trials. SB = Sodium Bicarbonate, PL = Placebo, HT = Half Time, FT+15 = 15 Minutes Post Full Time.

In relation to blood pH, Figure 3 highlights that sodium bicarbonate supplementation resulted in an increased pH from the 30th minute, with specific relation to the increased pH during the latter stages at the 75th and 90th minute. The relevant inferential analysis for blood pH is represented in Figure 4.

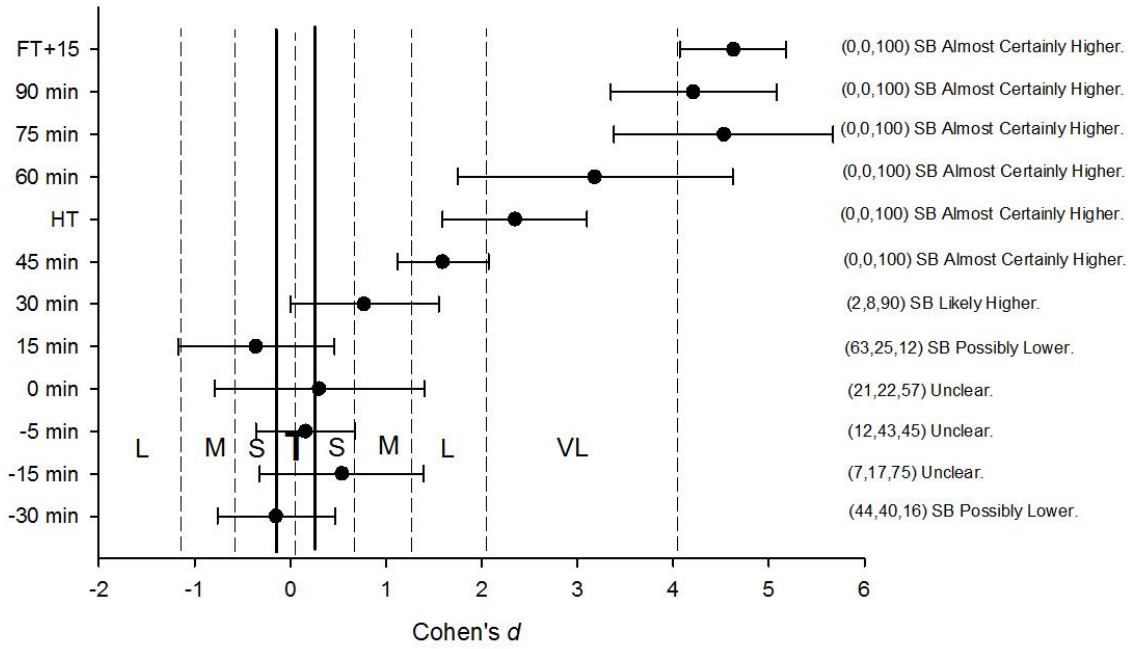

Figure 4. The mean difference as a Cohen's effect size (± 90% CI) for blood pH at each time point between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate, L =Large, VL = Very Large, HT = Half Time, FT+15 = 15 Minutes Post Full Time, SB = Sodium Bicarbonate.

In relation to blood pH, Figure 4 highlights that the sodium bicarbonate dosage protocol has had a positive effect upon the pH during the latter stages of the simulation. This can be identified by the very large effects which occur during the 60th, 75th, and 90 minute which resulted in an increased pH.

4.2.2 Blood Bicarbonate

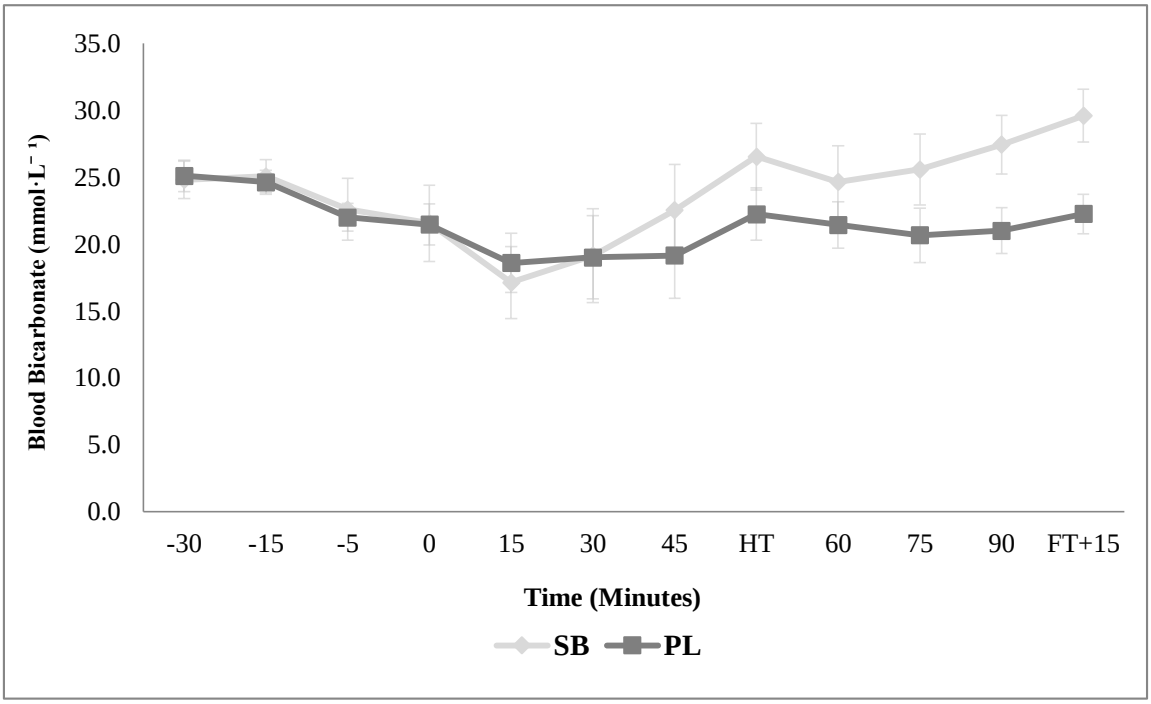

Figure 5. The mean (±SD) blood bicarbonate concentration in (mmol·L^{-1}), at different time points during the football simulations for both the placebo and sodium bicarbonate trials. SB = Sodium Bicarbonate, PL = Placebo, HT = Half Time, FT+15 = 15 Minutes Post Full Time.

In relation to blood bicarbonate, Figure 5 highlights that sodium bicarbonate supplementation resulted in an increased blood bicarbonate concentration from the 30th minute, with specific relation to the increased blood bicarbonate during the latter stages at the 75th and 90th minute. The relevant inferential analysis for blood bicarbonate is represented in Figure 6.

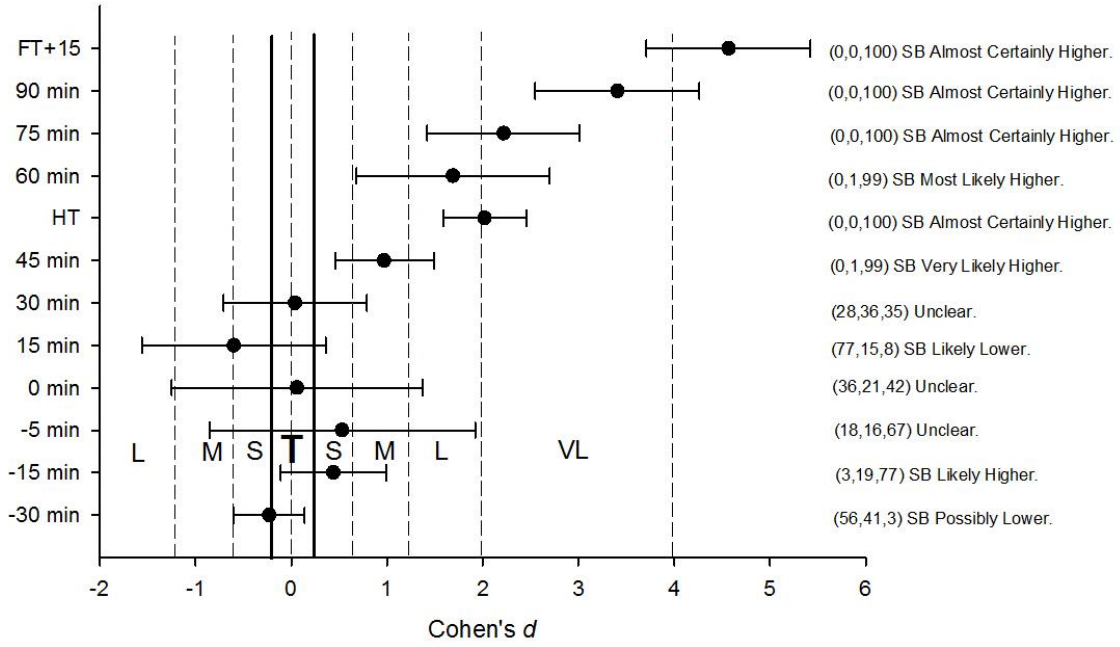

Figure 6. The mean difference as a Cohen's effect size (± 90% CI) for blood bicarbonate at each time point between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate, L =Large, VL = Very Large, HT = Half Time, FT+15 = 15 Minutes Post Full Time, SB = Sodium Bicarbonate.

In relation to blood bicarbonate, Figure 6 highlights that the sodium bicarbonate dosage protocol has had a positive effect upon the blood bicarbonate during the latter stages of the simulation. This can be identified by the very large effects which occur during the 75th and 90th minute which resulted in an increased blood bicarbonate concentration.

4.2.3 Blood Lactate

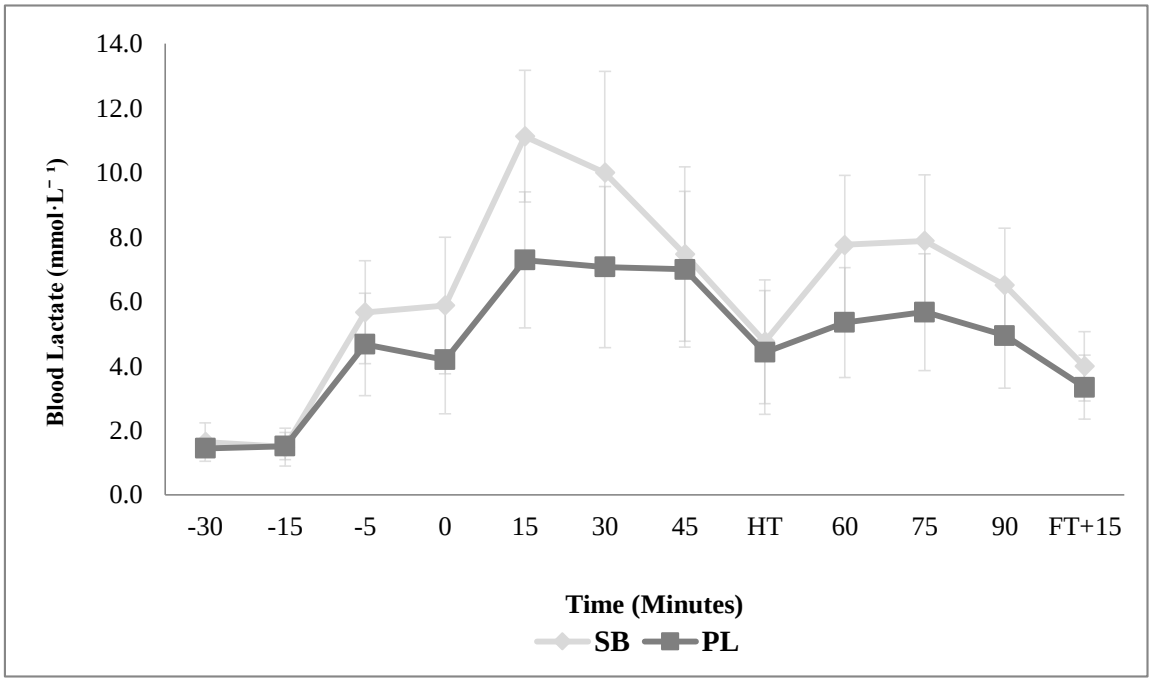

Figure 7. The mean (±SD) blood lactate concentration in (mmol·L^{-1}), at different time points during the football simulations for both the placebo and sodium bicarbonate trials. SB = Sodium Bicarbonate, PL = Placebo, HT = Half Time, FT+15 = 15 Minutes Post Full Time.

In relation to blood lactate, Figure 7 highlights that sodium bicarbonate supplementation resulted in an increase in blood lactate at all the time points during the simulation, with the peak value occurring in the 15th minute and increases occurring during the latter stages at the 75th and 90th minute between trials. The relevant inferential analysis for blood lactate is represented in Figure 8.

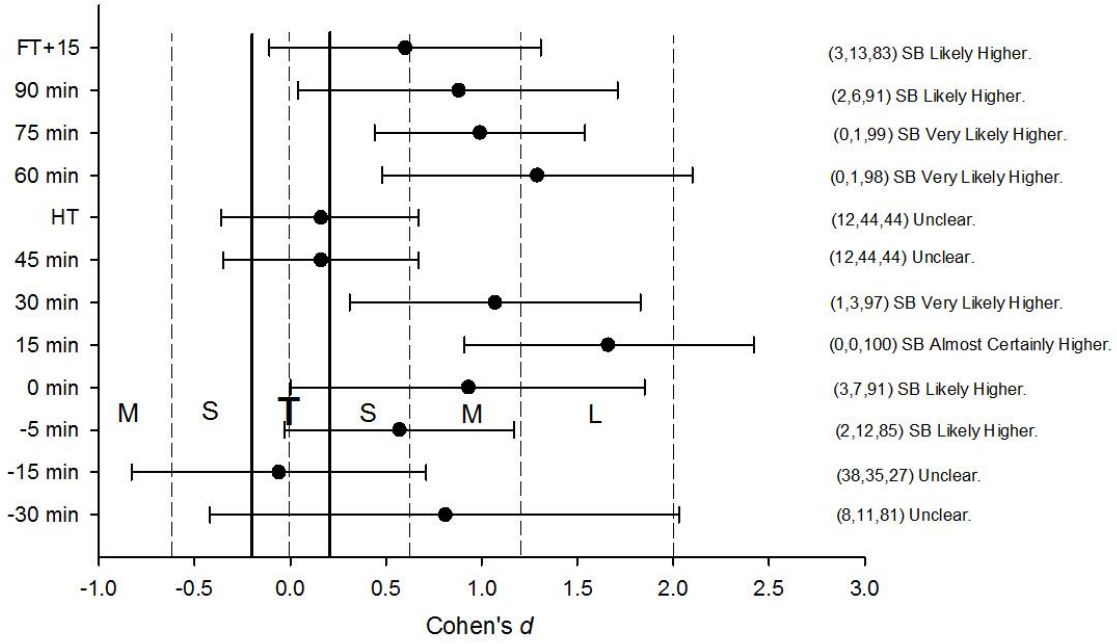

Figure 8. The mean difference as a Cohen's effect size (± 90% CI) for blood lactate at each time point between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate, L = Large, HT = Half Time, FT+15 = 15 Minutes Post Full Time, SB = Sodium Bicarbonate.

In relation to blood lactate, Figure 8 highlights that sodium bicarbonate supplementation resulted in an increased blood lactate concentration, with moderate increased effects occurring during the latter stages at the 75th and 90th minute and large increased effects occurring in the 15th and 60th minute.

4.2.4 Base Excess

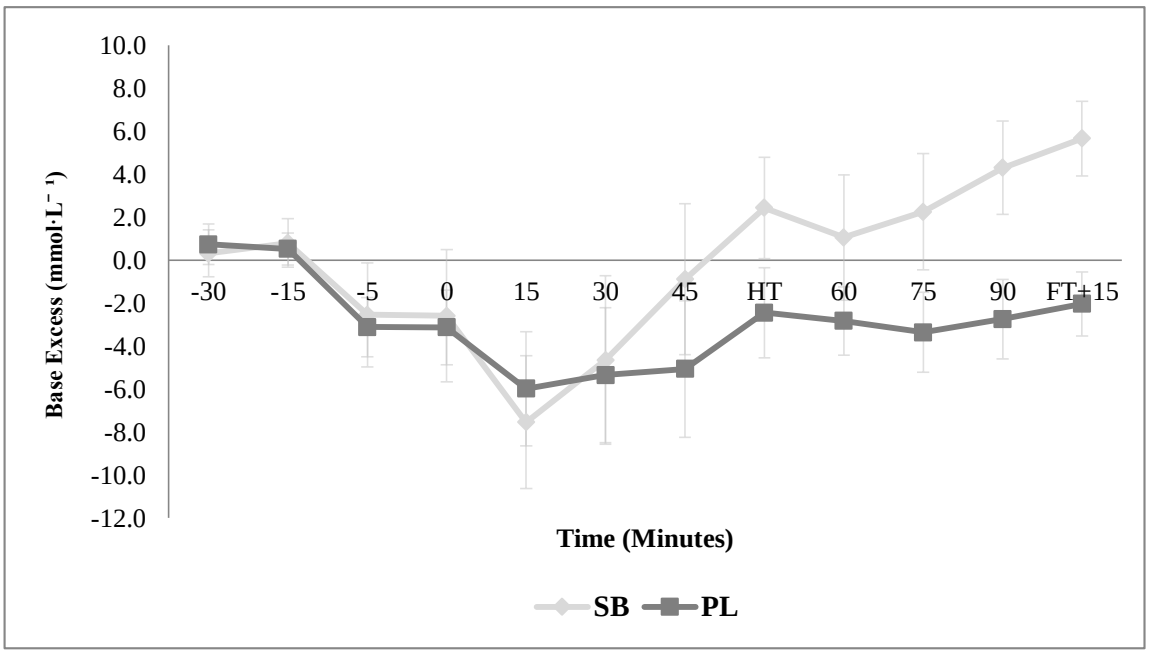

Figure 9. The mean (±SD) base excess in (mmol·L^{-1}), at different time points during the football simulations for both the placebo and sodium bicarbonate trials. SB = Sodium Bicarbonate, PL = Placebo, HT = Half Time, FT+15 = 15 Minutes Post Full Time.

In relation to base excess, Figure 9 highlights that sodium bicarbonate supplementation resulted in a positive increase in base excess from the half time period, with specific reference to the positive base excess levels during the latter stages at the 60^{th}, 75^{th} and 90^{th} minutes. The relevant inferential analysis for base excess is represented in Figure 10.

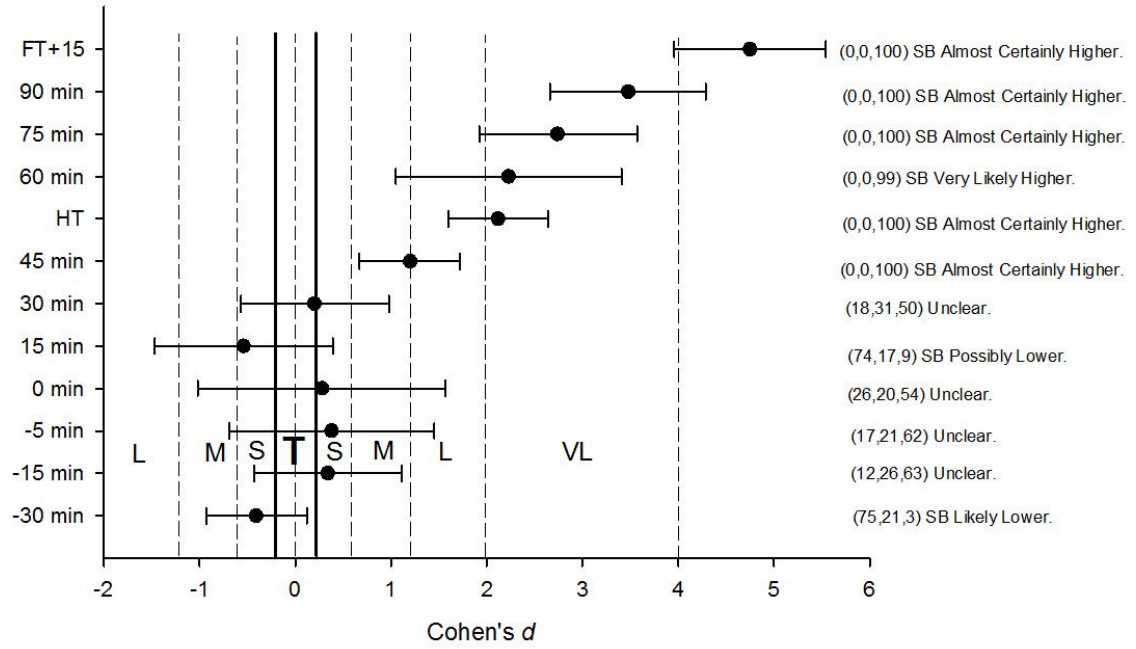

Figure 10. The mean difference as a Cohen's effect size (± 90% CI) for base excess at each time point between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate, L = Large, VL = Very Large, HT = Half Time, FT+15 = 15 Minutes Post Full Time, SB = Sodium Bicarbonate.

In relation to base excess, Figure 10 highlights that sodium bicarbonate supplementation had a positive effect upon base excess with specific reference to very large positive effects occurring in the latter stages during the 60th, 75th and 90th minutes.

4.3 Physiological Variables

4.3.1 Heart Rate

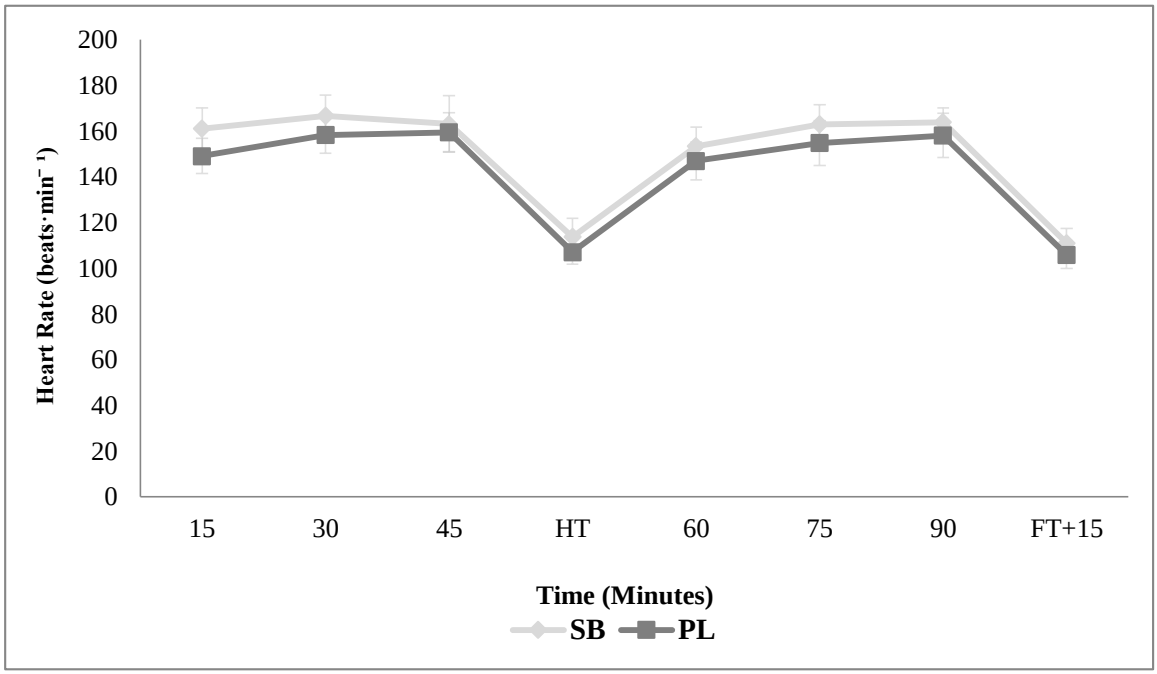

Figure 11. The mean (±SD) heart rate in (beats·min^{-1}), at different time points during the football simulations for both the placebo and sodium bicarbonate trials. SB = Sodium Bicarbonate, PL = Placebo, HT = Half Time, FT+15 = 15 Minutes Post Full Time.

In relation to heart rate, Figure 11 highlights that sodium bicarbonate supplementation resulted in an increase in heart rate during the simulation with the biggest difference between the two trials occurring in the 15th minute. The relevant inferential analysis for heart rate is represented in Figure 12.

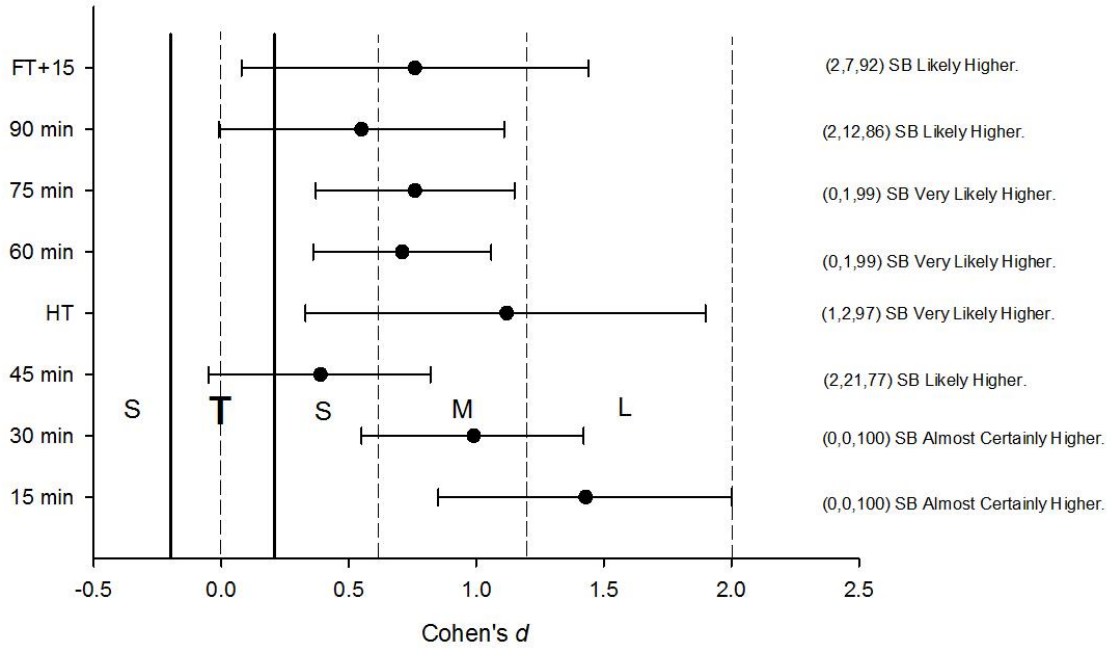

Figure 12. The mean difference as a Cohen's effect size (± 90% CI) for heart rate at each time point between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate, L = Large, HT = Half Time, FT+15 = 15 Minutes Post Full Time, SB = Sodium Bicarbonate.

In relation to heart rate, Figure 12 highlights that sodium bicarbonate supplementation resulted in an increase in heart rate during the simulation, with the largest effect occurring in the 15th minute and a small and moderate effect occurring in the latter stages at the 90th and 75th minute respectively

4.3.2 VO_2

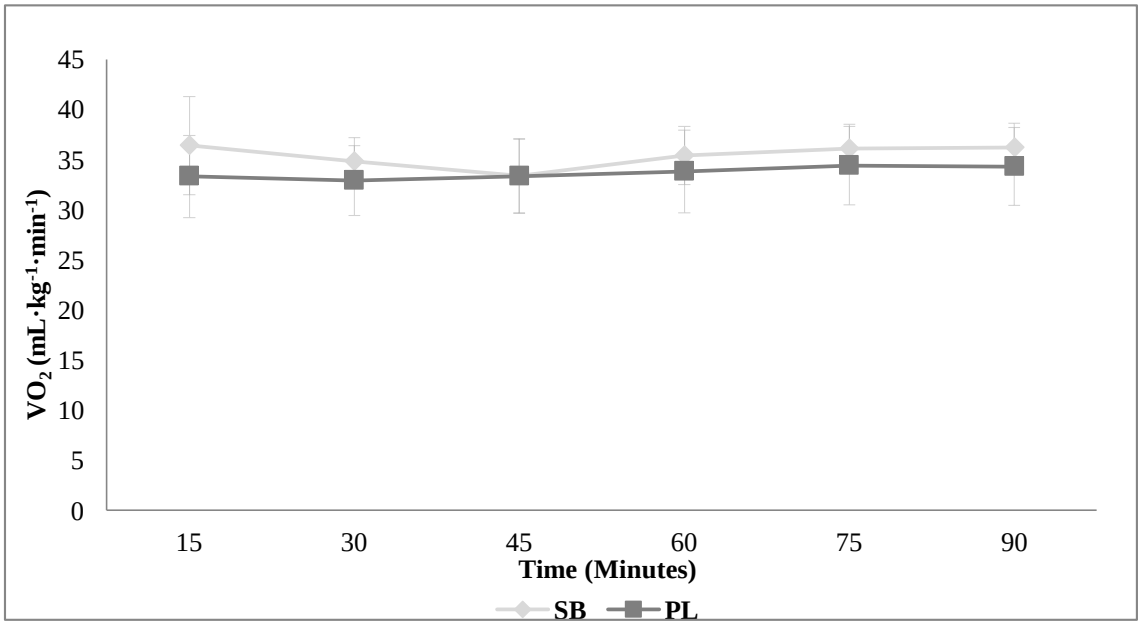

Figure 13. The mean (±SD) VO_2 in ($mL \cdot kg^{-1} \cdot min^{-1}$) for a specific 2 minute period at different time points during the football simulations for both the placebo and sodium bicarbonate trials. SB = Sodium Bicarbonate, PL = Placebo.

In relation to VO_2, Figure 13 highlights that sodium bicarbonate supplementation resulted in an increase in VO_2 at every time point with the largest difference between the two trials occurring in the 15^{th} minute. The relevant inferential analysis for VO_2 is represented in Figure 14.

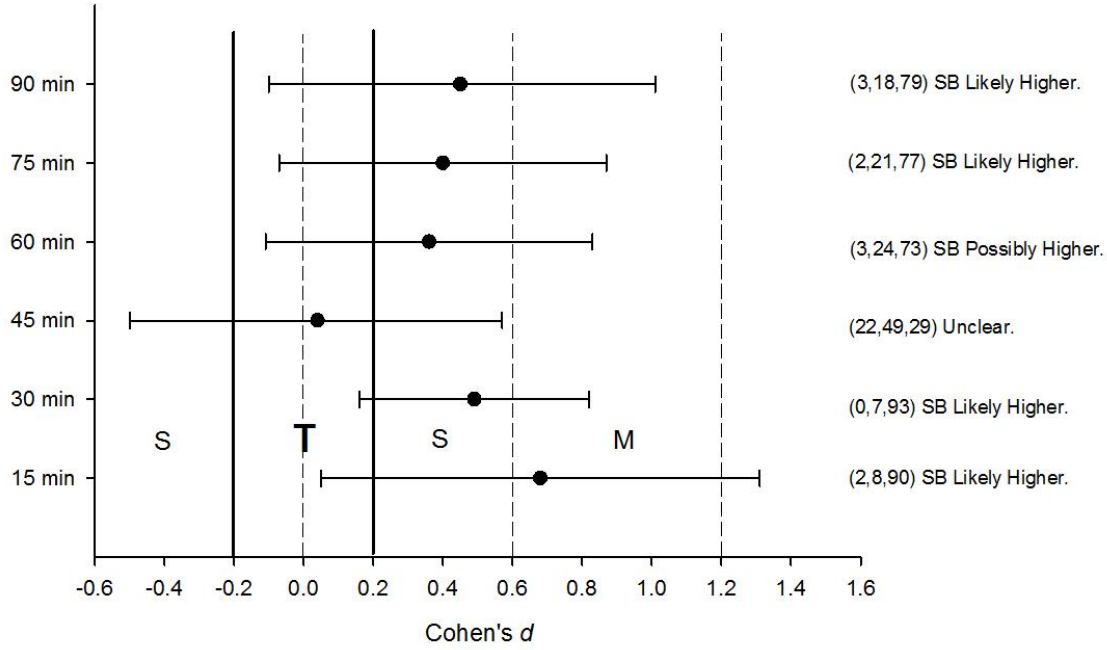

Figure 14. The mean difference as a Cohen's effect size (± 90% CI) for VO_2 at each time point between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate SB = Sodium Bicarbonate.

In relation to VO_2, Figure 14 highlights that sodium bicarbonate supplementation resulted in an increased VO_2 during the simulation, with a moderate increased effect occurring in the 15th minute and small increased effects occurring in the 30th and 60th minutes as well as in the latter stages at the 75th and 90th minutes.

4.3.3 RPE

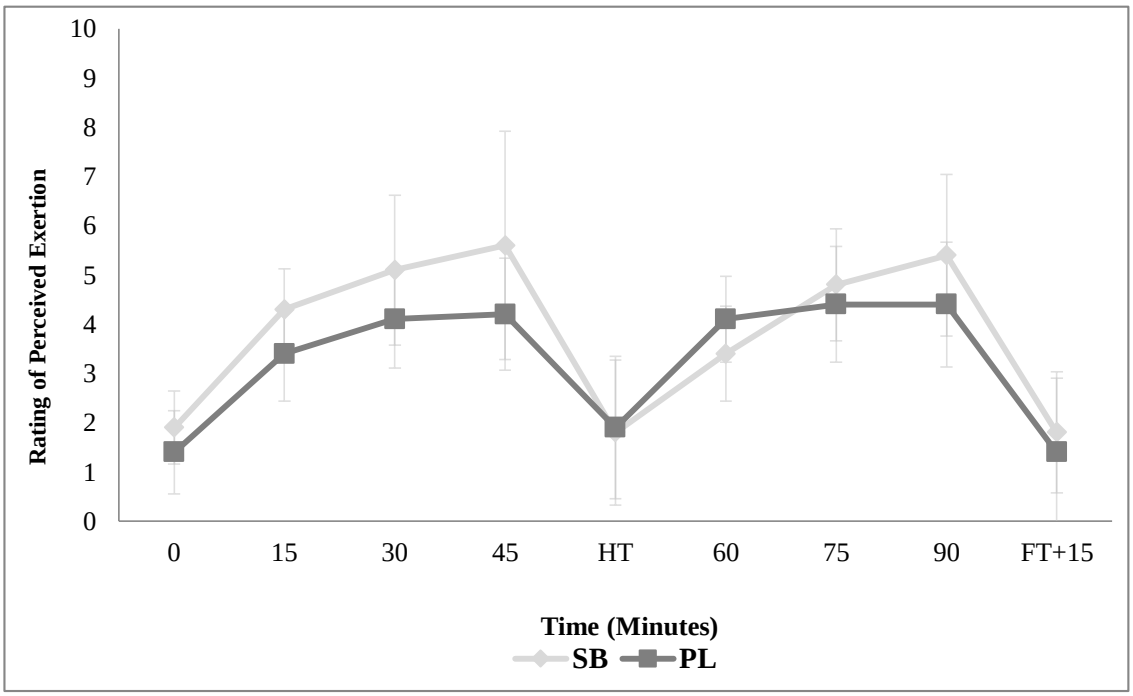

Figure 15. The mean (±SD) rating of perceived exertion at different time points during the football simulations for both the placebo and sodium bicarbonate trials. SB = Sodium Bicarbonate, PL = Placebo, HT = Half Time, FT+15 = 15 Minutes Post Full Time.

In relation to RPE, Figure 15 highlights that sodium bicarbonate supplementation resulted in an increase in the session RPE, with the 1st half rated higher during the SB trial, a reduction in the 60th minute and an increase in the latter stages at the 75th and 90th minute between trials. The relevant inferential analysis for the rating of perceived exertion is represented in Figure 16.

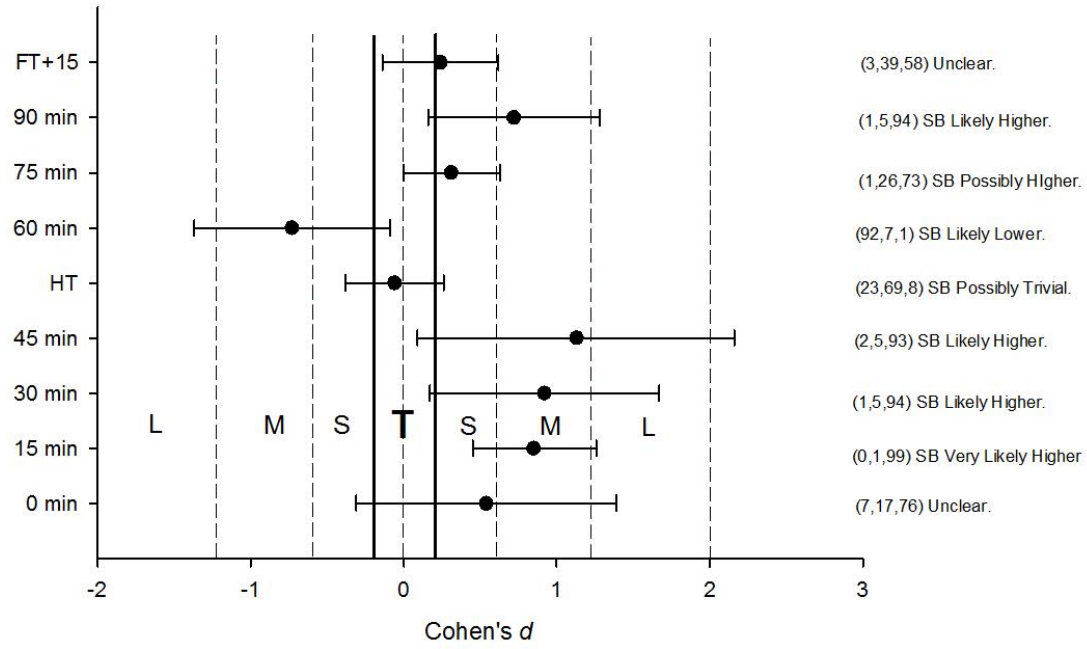

Figure 16. The mean difference as a Cohen's effect size (± 90% CI) for RPE at each time point between the placebo and sodium bicarbonate trials. T = Trivial, S = Small, M = Moderate, L = Large, HT = Half Time, FT+15 = 15 Minutes Post Full Time, SB = Sodium Bicarbonate.

In relation to RPE, Figure 16 highlights that sodium bicarbonate supplementation resulted in an increase in the rating of perceived exertion, with specific reference to moderate increased effects occurring in the 15th, 30th and 45th minute, a moderate decreased effect in the 60th minute and a small and moderate increased effect occurring in the latter stages at the 75th and 90th minute respectively.

4.4 Subjective Feeling

Table 3. The mean (±SD) score, for the severity of each gastro intestinal distress symptom, pre exercise, during the 1st half and during the second half for both the placebo and sodium bicarbonate trials.

Symptom	Pre		1st Half		2nd Half	
	Placebo	SB	Placebo	SB	Placebo	SB
Nausea	0.3 ± 0.4	0.3 ± 0.2	0	1.0 ± 0.4	0.0 ± 0.1	0.2 ± 0.2
Flatulence	0.1 ± 0.2	0	0	0	0	0
Stomach Cramping	0	0	0	0	0	0
Belching	0.2 ± 0.3	0.1 ± 0.1	0	0.6 ± 0.2	0.1 ± 0.1	0.1 ± 0.1
Stomach Ache	0	0	0	0	0	0
Bowel Urgency	0	0	0	0	0	0.1 ± 0.1
Diarrhoea	0	0	0	0	0	0
Vomiting	0	0	0	0	0	0
Stomach Bloating	0.1 ± 0.2	0	0	0	0.3 ± 0.3	0.1 ± 0.1

The above scores are judged on a scale out of 10 for each symptom with 0 being no effect and 10 being a severe effect. From the table above it is evident that it contains extremely low VAS scores as a result of an extremely high tolerance to sodium bicarbonate amongst subjects. Therefore no statistical analysis was conducted.

Chapter 5

Discussion

5.1 Effects of Sodium Bicarbonate on Performance

5.1.1 Sprint Distance:

In the present study, SB supplementation resulted in a small performance enhancement during sprinting. Participants covered a greater distance and this could be due to an increase in the total work performed. Although all of the effect sizes are positive in favour of SB, small enhancements were evident in the 15th, 60th and 75th minute and trivial enhancements were evident in the 30th, 45th and 90th minute. Overall, SB supplementation has had a beneficial effect upon sprint performance, consequently resulting in a small increase in the total distance covered. It could be suggested that this enhancement could be a result of SB allowing participants to work harder and therefore increasing the total work performed during sprints. Furthermore, SB supplementation could have resulted in the acid-base recovery between sprints being optimised, therefore enhancing performance. The results of this study are consistent with previous findings. Bishop & Claudius, (2005) found that a stacking SB dosage protocol resulted in a significant difference in the work completed during 7 of the 18 second half sprints when performing specific intermittent hockey exercise. Bishop & Claudius, (2005) suggested that the improved second half performance may have been due to an enhanced glycogenolytic/glycolytic flux and an increase in glycogen utilisation as a result of an increased blood bicarbonate concentration. This study corroborates the findings of Bishop & Claudius, (2005) that SB supplementation results in a small increase in sprint performance during prolonged intermittent exercise.

Furthermore, this investigation supports the findings of Price et al., (2003). Price et al., (2003) reported that SB supplementation enhanced performance due to an increase in acceleration during sprints. Price et al., (2003) stated that the enhancement in sprinting performance occurred due to an increased bicarbonate concentration and that can be crucial in optimising acid-base recovery between sprints. In relation to this study, it could be suggested that SB allowed

participants to recover sufficiently in-between sprints, subsequently allowing them to accelerate harder during sprints and therefore increasing sprint distance. In contrast to this, Price & Cripps, (2012) found that there was no significant difference in work done or peak power during sprinting between the PL and SB trials during prolonged intermittent cycling.

5.1.2 Variable Run Distance:

In the current study, variable run distance was measured as a performance variable during the simulation (Aldous et al., 2014). In contrast to the sprint distance, SB supplementation resulted in a harmful effect on variable run distance. The effect sizes are generally negative with small to moderate harmful effects occurring in the 30th, 45th, 75th and 90th minute. In contrast to this, a trivial enhancement occurred in the 15th minute with a small performance enhancement occurring in the 60th minute. As a whole, SB supplementation has had a harmful effect on variable run performance and consequently directly affected the total distance covered. It could be suggested that the harmful effect of SB on variable run distance could be a conflicting effect of a performance enhancement in sprint distance. With sprint distance being enhanced from a possible increase in the total work completed, it could be suggested that participants had not fully recovered during the period between performing the previous sprint and performing the following variable runs. Variable runs occurred in blocks of four, lasting six seconds each at approximately 80% of the participant's peak sprint speed, with an eight second active recovery period between each run. The nature of these runs combined with a partial recovery from sprints could have increased the physiological cost leading to a reduction in performance. It can be identified from the results that the only positive effects SB had on variable run performance occurred after the combination of SB consumption and an increased recovery period (PRE, HT) which could propose that an increased recovery period may have been needed. In relation to previous findings, no other study in the literature has found SB supplementation to cause a harmful effect on a performance variable during prolonged intermittent exercise. However, it is worth taking into consideration that the present study is the first study to look at SB supplementation and its effects on the physiological aspects of a football simulation.

5.1.3 Total Distance Covered:

During this investigation, SB supplementation resulted in a minimal increase in the total distance covered. However, the difference in the total distance covered between the PL and SB trials is trivial which suggests that SB's effect on the total distance covered is minimal. Although the effect is only minimal, it could be suggested that SB supplementation resulted in a minimal increase in the total work completed. In relation to the present study, Price & Cripps, (2012) investigated the effects of SB and a glucose and SB combination on prolonged intermittent exercise. Results showed that a minimal increase in the total work completed had occurred between the PL and SB trials. Like the current study, the increased difference for the SB trial was only minimal and Price & Cripps, (2012) stated that the total work completed between the PL and SB trials approached significance ($P = 0.075$). In support of this, the findings of Bishop & Claudius, (2005) demonstrated that a minimal increase occurred in the total work completed during the 2nd half when exploring the effects of SB on intermittent hockey exercise. Similarly, the increased difference for the SB trial in the present investigation was only minimal and Bishop & Claudius, (2005) identified that the total work completed between trials approached significance *(P = 0.08)*. In terms of this current experiment, it can be suggested that SB supplementation can aid in increasing the total distance covered by allowing an increase in the total work completed during sprints. Overall, SB supplementation has had a positive effect upon sprint performance and a negative effect upon variable run performance.

5.2 Effect of Sodium Bicarbonate on Physiological Response

The ingestion of SB resulted in a higher blood bicarbonate concentration which can be idntified by an increase in the blood pH and is supported by changes in base excess. The peak values in the SB trial occurred during the latter stages of the simulation, which was intended, as the final 15 min of a match is the most important in terms of goal scoring (Abt, Dickson and Mummery, 2002). These results suggest that SB has been successful in increasing the extracellular buffer profile. In support of this, an increase in the extracellular buffer profile from an increased bicarbonate concentration is heavily related to a higher anaerobic energy conribution which was identified by an increaese in blood lactate (Requena et al., 2005). In

comparison to previous research that have investigated SB on prolonged exercise, the acid-base results of this study support those which have previously been discovered with the peak pH levels have ranging from 7.45 to 7.49, with peak blood bicarbonate levels ranging from 28 $mmol \cdot L^{-1}$ to 32 $mmol \cdot L^{-1}$ (Bishop & Claudius, 2005; McNaughton et al., 1999; Price et al., 2003; Price & Cripps, 2012; Tan et al., 2010). The peak blood lactate level of the present study reached 11.1 $mmol \cdot L^{-1}$ in the SB trial and 7.3 $mmol \cdot L^{-1}$ in the PL trial, where previous studies have ranged from 3.4 $mmol \cdot L^{-1}$ to 12 $mmol \cdot L^{-1}$ when investigating SB on prolonged exercise (Bishop & Claudius, 2005; McNaughton et al., 1999; Price et al., 2003; Price & Cripps, 2012; Tan et al., 2010).The increases in blood pH and the blood bicarbonate concentration in the current experiment, along with the previous literature suggest that blood buffer capacity has been increased and a state of alkalosis could have been reached. However, if this has occurred, it is debateable as to why a specific performance variable has been harmed, specifically when a higher anaerobic enrgy conribution has been identified by increases in lactate.

There are a number of mechanisms that can be associated to an increased lactate level. It could be proposed that an increase in blood lactate is the result of lactic acid combining with SB to form carbonic acid and sodium lactate. In support of this, it could be suggested that when bicarbonate is shifted into plasma, bicarbonate buffers the lactic acid and dissociates into $H+$ and positive lactate ions consequently increasing the level of blood lactate. The $H+$ combine with bicarbonate and form carbonic acid and lactate ions combine with sodium from SB to form sodium lactate. As a result of this, carbonic acid is formed and blood pH is moderated (Requena et al., 2005). The results of this study support this mechanism with increases in the blood lactate level also being supported by increases in blood pH. Furthermore this can be directly related to an increase in sprint distance. Another proposed mechanism is that an increased lactate level is strongly associated with a higher anaerobic energy contribution and an increase in the glycogenolytic flux as a result of greater phosphofructokinase activity (Bishop & Claudius, 2005). Furthermore, in the present study it could also be suggested that the production of $H+$ and lactate could have exceeded the removal, resulting in muscle contraction being inhibited

after anaerobic activity which supports the reduction in variable run performance (Requena et al., 2005).

Anaerobic activity is high in intensity and both the simulations sprinting and variable runs could be categorised as anaerobic. It could be proposed that SB consumption has allowed participants to work harder during sprints due to bicarbonate buffering *H+* out of the muscle during sufficient recovery periods and producing a higher anaerobic energy contribution for short intense bouts (Bishop & Claudius, 2005; Price et al., 2003). However, it is evident that SB supplementation increases by products such as lactate and *H+* during anaerobic activity. Although this occurs, it can be demonstrated that the recovery period between sprints is sufficient enough for excess *H+* to be removed from the muscle and this is evident by a small performance enhancement. However, the recovery period of 8 seconds between variable runs could be classed as insufficient for SB to have an effect although this recovery period is reflective of the sport. This insufficiency upon the repetitive bouts of anaerobic exercise could contribute to the harmful effect on variable run performance (Bangsbo et al., 2007; Di Salvo et al., 2007).

In relation to the activity profile of the simulation, participants were required to complete a pattern of specific activity prior to variable runs occurring which included a 6 second maximal sprint. It could be suggested that with a maximal sprint occurring just minutes prior, it could be possible that this activity has directly affected variable run performance. It is evident that when compared, the sprint prior to variable runs occurring, on average, is higher for the SB trial (*PL = 27.91 ± 0.34*) (*SB = 28.44 ± 0.93)*. Therefore it could be proposed that this increase in sprint distance has resulted in a reduction in variable run distance.

Moreover, when variable runs occur, it could be proposed that participants are still recovering from the increased by-products of sprinting and performing the block of four variable runs could result in the increase in by-products exceeding the enhancement in buffering capacity, resulting in a reduction in performance. The body may struggle to buffer increased by-products out of the muscle due to a hindered recovery process during variable runs, therefore increasing

the physiological cost as the demand for oxygen is greater than the supply available and consequently inhibiting the re-synthesis of anaerobic energy (Bangsbo et al., 2007; Krustrup et al., 2006). This is evident in the present study's physiological data as increases in VO_2, HR and RPE all occurred during the SB trial. No previous study that has investigated SB on prolonged exercise has found to have increased physiological data. With oxygen demand not being achieved due to the supply available, this inhibits the recovery process directly increasing HR and allowing the blood pH level to become more acidic as a result of lactate and $H+$ production exceeding removal. This increase in pH breaks down the enzymatic activity required for muscle contraction which directly affects the force produced and consequently reduces performance (Requena et al., 2005).

With the results suggesting that participants have to work harder physiologically during the SB trial, it could be proposed that an increased bicarbonate concentration is not efficient enough in exporting increased by-products out of the muscle during recovery, and it could be suggested that this provokes temporary fatigue. In support of this, some studies (Krustrup et al., 2006; Mohr et al., 2003) have revealed that an increase in blood lactate and reductions in blood pH and phosphate creatine during football, can possibly contribute to suggest that temporary fatigue has occurred. In relation to this study, it could be proposed that the increase in sprint performance during the SB trial ,has resulted in a reduction in phosphocreatine and the recovery period between sprints and variable runs is insufficient enough for *ATP* to be fully resynthesized for the reproduction of the anaerobic energy required. Furthermore, with the degradation of phosphocreatine potentially contributing to the temporary fatigue that has occurred, it is evident that the limited oxygen availability could have possibly hindered phosphocreatine re-synthesis. With reduced blood pH and the degradation of phosphocreatine contributing to fatigue, it can be suggested that these are the key components that combine to reduce the rate of the cross bridge cycle during muscle contraction, consequently reducing performance in the present study.

In the present study, it could be suggested that the temporary fatigue which occurs, is due to a combination of a hindered recovery and the nature of variable runs which could actually induce fatigue towards the end of the simulation when supplementing SB. This could be evident in the

results as variable run performance decreases during the 75th and 90th minute and it is quite possible that this has directly affected the reduction in sprint performance at this time. It is clear that SB has caused participants to work harder physiologically and has subsequently provoked a fatigued state. It could be questioned that if the recovery periods during variable runs were increased, would an increase in variable run distance and sprint distance occur consequently increasing the total distance covered and reducing the physiological cost. However, it could be proposed that recovery periods during football specific movements that are ~ 80% in intensity are too short for SB to have an effect.

From the content discussed in the above paragraphs, it is quite possible that the prior activity, specifically sprinting, has resulted in variable run performance being hindered during the SB trial due to a decrease in blood pH and the inability to reproduce anaerobic energy through phosphocreatine re-synthesis during the recovery periods. It is evident that a relationship has been created that demonstrates that an increase in sprint distance can result in a reduction in variable run performance when supplementing SB, which consequently can reduce physiological performance. A reduction in physiological performance when supplementing SB in football inevitably proposes that SB and football are not a practical combination. Although the dosage strategy was successful in enabling the pH to peak during the latter stages, as well as enabling a high tolerance to SB amongst participants, the facts of this study show that SB is not practical to be used in football due to a harmful effect on a performance variable. However, although the total performance outcomes demonstrate that SB supplementation can harm variable run performance, it is worth taking into consideration that sprinting performance was enhanced.

5.3 Limitations

During the present study, a number of limitations were identified. The first limitation is that the testing was conducted during the pre-season period. Between players, there will be a variation of fitness levels which could have affected performance and consequently group results. Furthermore, the 1st trial along with other personal training could have enhanced participant's fitness in between trials. This would mean that participants could have had an enhanced fitness

level for participation in the 2nd trial which could have consequently affected performance. To avoid this in future research, it would be recommended that testing should occur when all participants are in a state of peak fitness.

The second limitation is in regards to the non-motorised treadmill. It is well documented that performing exercise on a non-motorised treadmill can increase energy expenditure. This is due to the force of the harness pulling the participant backwards. This does not occur in actual match play and could have caused an increase in the energy utilised during the simulation which subsequently could have affected performance. When performing exercise on a non-motorised treadmill, there is no procedure for preventing this from occurring and it may be suggested that a simulation could be more sufficient when performed in a different modality.

Another limitation is in relation to the simulation. Although the simulation is based on a footballer's activity profile, it does not take into consideration other football specific movements. This includes movements such as jumping, turning, moving backwards and kicking. These movements are essential in football and if added to the simulation could increase the physiological demand. For future research, it could be recommended that such simulation could be modified in order to adopt these football specific movements.

Another limitation is in relation to the study sample size. The testing period saw 10 participants fully complete the testing required. Having only 10 participants can limit the study by effecting the relevant statistics as well as the interpretation for the study outcomes. The aim was to collect data for 15 participants however it can be difficult to recruit participants for such a demanding protocol.

Chapter 6

Conclusion

To conclude, this study evidently suggests that sodium bicarbonate supplementation can have both positive and negative effects upon simulated soccer performance. It establishes that sodium bicarbonate supplementation can enhance an individuals acid-base balance during the latter stages of a game, which is evident in the relevant blood acid-base findings. This enhancement in acid-base balance can enable a small positive effect on an individuals sprint distance, consequently improving sprint performance. However, as a result of this, a small negative effect occurs during variable runs consequently reducing variable run performance. This study has formed a relationship which proposes that an increase in sprint performance can directly effect and reduce variable run performance when supplmenting sodium bicarbonate during a soccer simulation. It can be proposed that a possible reasoning for these outcomes is due to sodium bicarbonate allowing participants to worker harder physiologically during sprints, which has resulted in full recovery being inhibited prior to variable runs occuring. An increased physiological cost, reduced blood pH and the inability to reproduce anaerobic energy through phosphocreatine re-synthesis could have contributed to the occurrence of temporary fatigue, which has consequenlty reduced overall performance. As a result of this, this study inevitably establishes that sodium bicarbonate supplementation is not practical to be used in football due to a harmful effect on a performance variable. From this study, it is recommended that more research is required exploring the mechanisms of fatigue in football, and subsequent research is needed looking into other possible interventions to counteract such issues.

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Chapter 8

Appendices

The referenced appendices are on the following pages.

Appendices A:

Department of Sport, Health & Exercise Science

Informed Consent Declaration

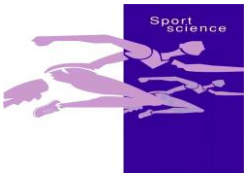
Project title	Changes in Acid-Base Balance and the Effect of Inducing Alkalosis during a 90 minute Football Protocol.
Principal investigator	Name: Dr Grant Abt Email address: G.Abt.hull.ac.uk Contact telephone number: 01482 463397
Student investigator (if applicable)	Name: Thomas Bennett Email address: T.C.Bennett@2012.hull.ac.uk Contact telephone number: 07999357770

Initial		Please
	I confirm that I have read and understood all the information provided in the Informed Consent Form (EC2) relating to the above project and I have had the opportunity to ask questions.	☐
	I understand this project is designed to further scientific knowledge and that all procedures have been risk assessed and approved by the Department of Sport, Health and Exercise Science Research Ethics Committee at the University of Hull. Any questions I have about my participation in this project have been answered to my satisfaction.	☐
	I fully understand my participation is voluntary and that I am free to withdraw from this project at any time and at any stage, without giving any reason. I have read and fully understand this consent form.	☐
	I agree to take part in this project.	☐

.....	.....	.....
Name of participant	Date	Signature
.....	.....	.....
Person taking consent	Date	Signature

Appendices B:

University of Hull
Department of Sport, Health,
and Exercise Science



Pre-Exercise Medical Questionnaire

The information in this document will be treated as strictly confidential

Name:
.....

Date of Birth: ..... Age: ..... Sex:
.....

Blood pressure: …… Resting Heart Rate: …….

Height (cm): ……. Weight (Kg): ……

Please answer the following questions by putting a circle round the appropriate response or filling in the blank.

1. How would you describe your present level of **exercise** activity?
   Sedentary / Moderately active / Active / Highly active

2. Please outline a typical weeks exercise activity

……
……..
……

3. How would you describe your present level of **lifestyle** activity?
   Sedentary / Moderately active / Active / Highly active

4. What is your occupation? ……..

5. How would you describe your present level of fitness?
   Unfit / Moderately fit / Trained / Highly trained

6. Smoking Habits
   Are you currently a smoker? Yes / No
   How many do you smoke …….. per day
   Are you a previous smoker? Yes / No
   How long is it since you stopped? ..... years
   How many did you smoke? ..... per day

7. Do you drink alcohol? Yes / No

If you answered **Yes** and you are male do you drink more than 28 units a week?

Yes / No

If you answered **Yes** and you are female do you drink more than 21 units a week?

Yes / No

8. Have you had to consult your doctor within the last six months? Yes / No
If you answered **Yes**, Have you been advised **not** to exercise?

Yes / No

9. Are you presently taking any form of medication? Yes / No
If you answered **Yes**, Have you been advised **not** to exercise?

Yes / No

10. To the best of your knowledge do you, or have you ever, suffered from:

a Diabetes? Yes / No **b** Asthma? Yes / No

c Epilepsy? Yes / No **d** Bronchitis? Yes / No

e ✸Any form of heart complaint? Yes / No **f** Raynaud's Disease Yes / No

g ✸Marfan's Syndrome? Yes / No **h** ✸Aneurysm / embolism? Yes / No

I Anaemia Yes / No

11. ✸Are you over 45, and with a history of heart disease in your family? Yes / No

12. Do you currently have any form of muscle or joint injury? Yes / No

If you answered **Yes**, please give details…….
……
…….. …..

13. Have you had to suspend your normal training in the last two weeks? Yes / No

If the answer is **Yes** please give details…….
……..
……..
…….

14. ✸ Please read the following questions:

a) Are you suffering from any known serious infection? Yes / No
b) Have you had jaundice within the previous year? Yes / No
c) Have you ever had any form of hepatitis? Yes / No
d) Are you HIV antibody positive Yes / No
e) Have you had unprotected sexual intercourse with any person from an HIV high-risk population? Yes / No
f) Have you ever been involved in intravenous drug use? Yes / No
g) Are you haemophiliac? Yes / No

15. As far as you are aware, is there anything that might prevent you from successfully completing the tests that have been outlined to you? Yes / No.

IF THE ANSWER TO ANY OF THE ABOVE IS YES:

a) **Discuss with the test administrators or another appropriate member of the department.**

b) **Questions indicated by (✸) answered yes: Please obtain written approval from your doctor before taking part in the test.**

PLEASE SIGN AND DATE AS INDICATED ON THE NEXT PAGE

Participant Signature: ……Date……

Test Administrator:……...Date……

Parent (if minor)…….Date: …….

THIS SECTION IS ONLY REQUIRED FOR RETURN VISITS!

For any future testing sessions it is necessary to verify that the responses provided above are still valid, or to detail any new information. This is to ensure that you have had no new illness or injury that could unduly increase any risks from participation in the proposed physical exercise.

ANSWER THE FOLLOWING QUESTION AT EACH REPEAT VISIT.

Is the information you provided above still correct, and can you confirm that you have NOT experienced any new injury or illness which could influence your participation in this exercise session?

Repeat 1	Yes / No*	Signature:	Date:
*Additional info required:			
Repeat 2	Yes / No*	Signature:	Date:
*Additional info required:			
Repeat 3	Yes / No*	Signature:	Date:
*Additional info required:			

Repeat 4	Yes / No*	Signature:	Date:
*Additional info required:			
Repeat 5	Yes / No*	Signature:	Date:
*Additional info required:			

Appendices C :

Pilot Supplementation Procedure

During the planning of this study, it was decided that a pilot study would be conducted in order to create a specific sodium bicarbonate dosage regime, in which could be used during a 90 minute football simulation. A pilot study was needed in order to determine the most suitable protocol, in terms of maintaining elevated levels of bicarbonate throughout a 90 minute period, as well as making sure gastro intestinal distress was prevented.

This consisted of four participants attending three resting sessions and three cycle sessions. During these sessions 0.3/kg/BW was split into two doses being A) 0.1 & 0.2, B) 0.15 & 0.15, C) 0.2 & 0.1. The three resting sessions consisted of all participants consuming the 1st dose of each protocol, before being monitored for two hours. The 2nd doses of each protocol were consumed 45 minutes into the rest sessions. Blood samples were collected every 15 minutes.

The three cycle sessions consisted of all participants taking the 1st doses of each protocol. It was then required for them to use the perceived readiness to exercise chart to indicate that they felt comfortable to begin and when this was indicated exercise commenced. All participants were required to cycle intermittently for 45 minutes. Blood samples were collected every 15 minutes.

After all pilot study testing had been completed, the results were analysed in order to determine which protocol would be used and how long prior to exercise the 1st dose would be consumed, as the 2nd dose was fixed at half time. Following this, further testing was carried out as three participants' completed the football simulation using Dose's B and C. After completion, results were analysed and it was decided that the 1st dose would be 0.2g/kg/BW consumed 30 minutes prior to the simulation commencing and the fixed half time dose would be 0.1g/kg/BW.

Appendices D:

Diet Guidelines for 3 Days Prior to Testing

*The specific foods below are just guidelines so make sure something with a similar nutritional content is consumed.

Breakfast 08:00:
Food: Four slices of white bread with jam, two whole meal bread rolls with a little butter and jam, with two small tubs of yoghurt.
Fluid: Two cups of tea (without sugar).

Lunch 12:00:
Food: Four slices of whole meal bread with a small amount of butter, one egg, two tomatoes, two packets of raisins, two bananas, and a bowl of salad.
Fluid: Three glasses of skimmed milk and one cup of coffee (without sugar).

Dinner 17:30:
Food: One bowl (large) of spaghetti with minced meat (beef), half an onion, one tin of skinned tomatoes, and a bowl of salad.
Fluid: Two glasses of skimmed milk.

Snacks
Food: One Apple, one packet of raisins, one bag of sweets
Fluid: Two cups of coffee (without sugar) and one litre of juice.

Diet Guidelines for Day of Testing

*The specific foods below are just guidelines so make sure something with a similar nutritional content is consumed.

Breakfast 08:00:
Food: Large bowl of porridge made with jumbo oats, skimmed milk, and water with a tsp of sugar.

Fluid: Fresh fruit juice or Tea/coffee.

Lunch 12:00:
Food: Chicken breast with whole-wheat pasta, medium serving of vegetables or salad
Fluid: Water

*On the next page is a food diary for the 3 days prior to testing and the day of testing. It is essential everything you consume is written into the food diary.

	-3	**-2**	**-1**	**Day of Testing**
Breakfast				
Lunch				
Dinner				
Snacks				

Appendices E:

Rating of Perceived Exertion Scale (Foster et al 2001)

Classification	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximum

Appendices F:

Sodium Bicarbonate Ingestion

Visual Analogue Scale (VAS)

A Visual Analogue Scale (VAS) is a measurement that tries to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured. Operationally a VAS is a horizontal line, 100mm in length, anchored by word descriptors at each end. You will be asked to mark the point that you feel represents your perception of your current state with a line on the scale.

Pre-ingestion

Nausea

No symptom _____ Severe symptom

Flatulance

No symptom _____ Severe symptom

Stomach cramping

No symptom _____ Severe symptom

Belching

No symptom _____ Severe symptom

Stomach ache

No symptom _____ Severe symptom

Bowel urgency

No symptom _____ Severe symptom

Diarrhoea

No symptom _____ Severe symptom

Vomiting

No symptom _____ Severe symptom

Stomach bloating

No symptom _____ Severe symptom

*The above questionnaire was repeated every 15 minutes after ingestion.