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AN INVESTIGATION INTO POTENTIAL METHODS OF IMPROVING THE FITNESS STIMULUS ASSOCIATED WITH SMALL-SIDED GAMES IN SOCCER

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An Investigation Into Potential Methods Of Improving The Fitness Stimulus Associated With Small-Sided Games In Soccer

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Abstract

An Investigation Into Potential Methods Of Improving The Fitness Stimulus Associated With Small-Sided Games In Soccer.

Background: Methods that simultaneously target physical, technical and tactical components of soccer could be an efficient use of training time. Small-sided games (SSGs) have previously been investigated demonstrating that variables, such as player numbers and pitch dimensions, can significantly influence the physical response (Aguiar et al. 2012). Inconsistent study designs limit precise conclusions about the influences separate variables have on game intensity, with authors only speculating that game intensity can be controlled through different methods or variable manipulation (Hill-Haas et al. 2011). A lack of evidence in the literature examining if the training load exerted from SSGs can be regulated warrants for research expansion in this area. **Objectives:** The present investigation is designed to test the hypothesis that the physical response from SSGs can be regulated based on real time objective heart rate (HR) data without being detrimental to the frequency of technical actions. **Design:** Cross sectional, repeated measures design. **Method:** Fourteen male semi-professional soccer players were recruited from a Scottish Junior North Super League club. Players were randomly separated into two teams of six, with a reserve pool of four. The same teams were played whenever possible. Every player performed a Yo-Yo Intermittent level 2 test. Eight testing sessions were performed thereafter consisting of 3 x 6 vs. 6 SSGs. Four conditions were each tested twice; baseline (BL), after game sprint (AGS), in game sprint (IGS) and self monitoring (SM). **Results:** Each intervention prescribed, resulted in a significant increase in HR and rate of perceived exertion (RPE) compared to BL, yet no significant differences were established between interventions. Percentage of maximum HR = BL (86.6 ± 4.6%), IGS (89.6 ±3.2), SM (89.91 ± 3.7) and AGS (90.1 ± 3.3). The AGS intervention recorded a significantly greater mean value for time spent in HR zone 90-100% compared to BL. RPE values across all games was significantly lower in BL displaying the lowest recorded mean (6.2 ± 0.68) followed by AGS (6.73 ± 0.45), IGS (6.73 ± 0.69) and SM (6.90 ± 0.50). Percentage of forward passes for IGS recorded the only notable difference between technical actions, resulting in 11.8% more passes towards the opponents' goal in comparison to BL. **Conclusion:** The present study has investigated innovative methods that present clear evidence to strongly suggest that the interventions could be beneficial to improve soccer performance. Each intervention may also produce specific intensities due to multiple direct and indirect mechanisms, which may further influence game dynamics and increase the complexity of the training response. All interventions used in the current study require further testing to more clearly assess whether they should routinely be used.

Key Words: **small-sided games, soccer intensity, soccer training, soccer fitness, real time heart rate data**.

Authors Declaration

I hereby declare that this thesis has been composed by myself and has not been presented or accepted in any previous application for a degree, and is a record of work carried out by myself unless otherwise stated; all quotations have been distinguished by quotation marks and all sources of information acknowledged.

Hamish Munro **Date 31/10/2014**

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Table of Contents

List of Abbreviations

$\%HR_{max}$	Percentage of maximum heart rate
ACSM	American College of Sports Medicine
AGS	After game sprint
ANOVA	One way analysis of variance
ATP	Adenosine triphosphate
BL	Baseline
BLa^-	Blood lactate
CR	Category ratio
CV	Coefficient of variation
GPS	Global positioning monitoring
HIIT	High Intensity Interval Training
HR	Heart rate
HRM	Heart rate monitoring
HR_{max}	Maximum heart rate
IGS	In game sprint
ITT	Incremental treadmill test
km	Kilometres
LT	Lactate threshold
m	Metres
min	Minutes
RPE	Rate of perceived exertion
s	Seconds
SM	Self monitoring
SSGs	Small-sided games
VO_{2max}	The maximum volume of oxygen utilised by the body at or near maximal effort measured in millilitres of oxygen used in one minute per kilogram of body mass
Vs.	Versus
yds	Yards
Yo-Yo IR1	Yo-Yo Intermittent Recovery test level 1
Yo-Yo IR2	Yo-Yo Intermittent Recovery test level 2

List of Figures

List of Tables

List of Tables

Chapter one: Introduction

1.1. Background of Soccer Training

Association football, otherwise known as soccer, is a sport that requires highly developed technical, tactical and physical capabilities to play at a professional level (Castagna et al. 2009). Coaches are continually examining training methods that simultaneously target these components, as this is an efficient use of training time (Dellal et al. 2012). Game-based conditioning sessions, such as small-sided games (SSGs) where a condensed version of soccer is played on a reduced pitch with fewer players (i.e., 1 vs. 1 to 8 vs. 8) are increasing in popularity. Current research has recognised SSGs to be effective for concurrently developing a player's tactical and technical ability (Little and Williams 2006, Rampinini et al. 2006, Hoff et al. 2002). However, despite the appeal of using game-based conditioning to improve physical fitness, many authors merely speculate that game intensity could be controlled through variable manipulation or interventions (Hill-Haas et al. 2011). There is a distinct lack of evidence in the literature examining if the training load exerted from SSGs can be regulated, rationalising the demand for research expansion in for this area (Hill-Haas et al. 2009a, Aguiar et al. 2012).

Training load can be separated into two forms, internal and external load. The internal training load is consequential to the physiological stimulus exerted on the individual from the training session. This stimulus is typically quantified by measuring heart rate (HR), blood lactate (BLa^-) or rate of perceived exertion (RPE) (Impellizzeri et al. 2004). On the other hand, the coach typically dictates the external training load through the use of modifying distance, duration and recovery, which could be dependent on the session objectives (Hill-Haas et al. 2010). Target setting is commonly used with external load by measuring time, distance or player-tracking technology (e.g., 3 x 1200 m running at 5 $min \cdot km^{-1}$ or 10 x 40 m sprints at maximum velocity) (Impellizzeri et al. 2005, Rampinini et al. 2005). It is vital for coaches to possess the capability to monitor and manipulate both the external and internal training loads. This is important because understanding the mechanisms of internal training load is particularly critical in team based training, where the external load is consistent between players but may result in a considerably different internal load, which will ultimately determine adaptations (Impellizzeri et al. 2005, Rampinini et al. 2004). Therefore, it is acknowledged that greater importance should be placed on regulating the internal load in order to achieve maximal gains, especially if there is variance in factors such as training background, current fitness ability and age (Bouchard and Rankinen, 2001).

Optimising the training response can involve quantifying an athlete's current training status and whether they are adapting favourably to the training prescribed (Borresen and Lambert 2009). Conventionally, the prescription of exercise throughout the soccer season has largely been instinctive, with the variables of intensity, volume, frequency and duration of training being increased based on intuition, emulation or amongst the belief that an increase in training will develop performance improvement (Borresen and Lambert 2008). Additionally, group exercises are frequently favoured over individual based drills as coaches can easily measure external load. Consequently, decreasing the prospect of each player receiving a detailed training load based on their particular capabilities (Hoff et al. 2002). This approach to training prescription may not be conducive for optimal physiological adaptation and can raise the potential for injury through overtraining as well as not providing sufficient stimulus for players with superior fitness levels (Alexiou and Coutts 2008). A current limitation within the literature is that there is no universally accepted method to quantify total training load within individual or team sports, or across varying modes of exercise (Impellizzeri et al. 2004). Some authors use various combinations of HR, RPE, BLa^- or player distance monitoring as objective and subjective measures of game intensity rather than complete training load (Hoff et al. 2002, Helgerud et al. 2002, Owen et al. 2004). Researchers also suggest optimal training intensity should induce similar technical and physiological stresses in comparison to those experienced during competition, in order to maximise performance (Hoff et al. 2002, Dellal et al. 2011a). Soccer training at competition intensity can familiarise the player with the speed, commonly referred to as 'tempo' of match play, creating adaptations through the physiological stimulus, which will better prepare the player for game requirements (Di Salvo et al. 2007).

Literature in the area of soccer generally recommends that coaches reduce training games, creating small sided teams, in order to increase the frequency in which game actions occur as well as develop aerobic fitness abilities (Rampinini et al. 2006, Hill-Haas et al. 2009c). SSG designs can inevitably be dependent on specific training objectives and factors inherent within the team such as player condition, stage of season, post game recovery, pre-game preparation and technical capabilities of players as well as the team's strategic and tactical objectives, all of which may need to be considered (Clemente et al. 2012). Regulating training to correspond with the intentions constructed on the factors described above can require the analysis of physiological and technical demands. Studies that observed different task constraints (i.e., pitch dimensions, player numbers, rules and coach encouragement) concluded each variable to influence measures of physical load as well as technical performance (i.e., the number or passes, possessions and shots)(Little and Williams, 2007, Dellal, et al. 2008, Clemente et al. 2012). The results from other studies reinforce the importance for methodical planning and intensity monitoring in order to best achieve the session's goals (Jones and Drust 2007, Dellal et al. 2008, Little and Williams 2006). Also, no assurances can be made that the same SSGs design will replicate results throughout the season, especially where variances are unavoidable such as team selection through injury or absence and fluctuations in player motivation. Thus, coaches face an arduous task in order to adjust SSGs to meet the objectives, where they must be dynamic and adaptable in their methods. Furthermore, it might be difficult for coaches of all levels of experience to simultaneously access each player's work rate visually without bias devoid of the aid of scientific data (Impellizzeri et al. 2004).

1.2. Research aims

The primary aim of this study was to investigate a series of interventions designed to augment physiological responses during SSGs in semi-professional soccer players. Individually worn HR monitors (HRM) and session RPE provided real time objective and subjective measures of internal load, respectively. In addition, the technical performance of each intervention was recorded and assessed. A positive outcome would be if the intervention could increase physiological response but have minimal negative impacts on the technical aspects of the game. Specific outlined aims were:

1. To compare the HR and RPE responses during interventions.
2. To analyse technical performance through descriptive statistics.
3. To evaluate the practicality of each intervention.

1.3. Significance of the Present Study

The outcomes from this study will add to current sports and exercise science research through the expansion of knowledge, contributing insight to a relatively new area of research. The study will investigate a unique area of SSGs, which at present is only speculated and unpublished; therefore it may assist future studies exploring interventions or exercises trying to regulate intensity. Sports teams and coaches may find the results useful in planning sessions, which may aid in the periodization and recovery programs if internal intensity is closely monitored. Moreover, training team based sports as a group comes with the inherent risk of delivering the same external load resulting in possible internal load variations throughout the team (Hill-Haas et al. 2011). By influencing the stimulus through various concepts or rule manipulation, it may be possible to increase the potential SSGs has on each player. There is further potential to create a platform for players to reach their maximum effort output by reducing possible game constraints such as, positional or tactical restrictions. Interventions could also target specific players who may require an additional stimulus, yet, not compel those who are deemed to be working hard enough to further exert themselves (Impellizzeri et al. 2004). Appropriately premeditated training schedules, which take into consideration individual training load, can aid players to adapt favourably to the stimulus and avoid excessive loads, which can over exert players to burnout from adverse neuromuscular, cardiovascular as well as hormonal variations (Kenttä and Hassmén 1998).

The fundamental concepts of methods used to increase SSG intensity may be transferable to other team sports that are applicable such as rugby, hockey, Australian rules or Gaelic football. The concept may also be used as an educational tool for both the coach and player; by illustrating the desired intensity players are capable of performing at. This may be highly beneficial in regard to long-term gains, especially for younger players who might be under the illusion they are exercising at a near maximal intensity but data may highlight scope for further exertion. Finally, the precise percentage of soccer training time dedicated to SSGs is unclear as variations can be seen between playing level, phase of season and coach preferences. However, SSGs are used in the vast majority of training session from when a player begins a sport until they retire. The prevalence SSGs are utilised could target performance enhancement through relatively small gains, which may have substantial long term benefits as well as allowing coaches to take full advantage of training time by targeting technical, tactical and physical components simultaneously.

Chapter two: Review of literature

The review of literature assesses major aspects that are fundamental to SSGs and soccer. The initial section examines movement patterns, major energy systems and relationships between playing levels to investigate physical demands of the sport. The chapter also investigates understandings of popular methods used to quantify game intensity and the technologies used including, HRM, BLa^-, RPE and global positioning monitoring (GPS). Commonly tested variables that highlight variations of intensity during SSGs such as pitch size, player number and rule modification are also discussed and highlighted. The review concludes by evaluating potential methods to regulate exercise intensity.

2.1. Physiological Demands of Soccer Performance

Soccer is widely accepted as the most popular sport in the world in regards to both the number of participants and spectators (Helgerud et al. 2002). Matches involve 2 x 45-minute halves separated by a 15-20 minute half-time break. A short period of added time is played at the end of 90-minutes, typically lasting 3-4 minutes (Bradley et al. 2009). The last four decades has seen the physiological demands of soccer being increasingly investigated (Fox and Matthews 1974, Ekblom 1986, Bangsbo et al. 1991, Mohr et al. 2003a). With advancements in nutrition, sports science, technology and pitch maintenance, the intensity of soccer games are increasing, as are the physical requirements of the players (Ekblom 1986, Fox and Matthews 1974, Bradley et al. 2009). Quantifying the physical capacity of elite soccer players may give suitable insight into the demands of top-flight leagues through measuring and analysing the physiological responses of the player during match play as well as providing a means of tracking changes over time (Bradley et al. 2009).

Research examining the total mean distance covered frequently reports professional outfield players cover approximately 10 km per game with goalkeepers covering approximately 4 km (Di Salvo et al. 2007, Dellal et al. 2011b). The comparison between studies warrants caution due to differences in technologies used and subsequent measurement error involved. It is reported that global positioning systems (GPS) and computer based tracking systems may have an error of approximately 4.8 and 5.8%, respectively on actual distance covered (Edgecomb and Norton 2006). Meanwhile, other methods may rely on skilled operators that can have subjective influences on outcome measures. A study by Roberts et al. (2006) used time-motion analysis techniques, which has been shown to report low intra-operator and inter-operator reliability for total distance calculated between two experienced operators (0.5% and 0.9%, respectively)(Roberts et al. 2006). Di Salvo et al. (2007) reported greater mean distances of 11.39 ± 1.02 km, ranging from 5.7 to 13.75 km across 30 matches compared to values derived from Dellal et al. (2011b). A higher mean could also be the result of the analysis of elite competitions, as it has previously been suggested that superior teams cover greater distances (Rampinini et al. 2009).

Relatively large ranges and standard deviations are reported in studies tracking player distances, most likely due to vast differences in positional demands and player variability (Roberts et al. 2006, Di Salvo et al. 2007, Dellal et al. 2011c). A frequent limitation of this type of research is the failure to report playing time by each player. For example, a player substituted in the early period of the game for either injury or tactical reasons will have considerably less opportunity to cover a greater distance in comparison to those who complete 90-minutes. As a result of not reporting individual playing time, players and team mean values could be substantially reduced. It may be worthwhile for future studies to report mean distance covered per minute of playing time in conjunction with total mean distance and playing time. Average values of total distance covered only offer a small insight into soccer performance as movements performed require a detailed analysis in order to access game patterns and energy requirements (Bradley et al. 2009).

The metabolic contribution to soccer performance is complex due to the multi-faceted nature of the sport, being characterised as random, dynamic, intermittent and varying intensities of continual movement (Jouaux 2007). A large majority of game actions are sub-maximal locomotion, consisting of slow speed running (35 - 40%), walking (30 - 35%) and moderate speed running (20%)(Bangsbo et al. 2006). The remaining 5-15% of actions is considered to be explosive movements (e.g., jumping, tackling, duels, shooting, heading passing and changes of direction) (Bradley et al. 2009, Drust et al. 1998, Krustrup et al. 2010, Mohr et al. 2005). A study analysing top level soccer leagues found sprinting occurs on average once every 90 seconds (s), lasting 4 s and covering a distance of approximately 25 – 30 m (Bradley et al. 2009). The physical actions of soccer stimulate a physiological match intensity, expressed as a mean and measured as a percentage of maximum heart rate (HR_{max}), to typically range between 80-90% of HR_{max} and near lactate threshold ((LT) the onset of blood lactate accumulation) (Krustrup et al. 2010).

Displaying mean values over the duration of an entire game can neglect important statistics. High intensity sessions, which accumulate lactate, are typically interspersed with low intensity recovery periods to aid in the removal of metabolic by-products and vary in relation to playing intensity and game progression (Bangsbo et al. 2006). Thus, mean values game intensity may not give a true reflection of game profile patterns, which typically fluctuate or can be influenced by game duration. A 28% increase (83 ± 26s Vs. 65 ± 20s) in recovery time has be recorded in the last 15 min compared to the first 15 min in high intensity running in English FA Premier League soccer matches (Bradley et al. 2009). The later periods of matches have also seen an increase in the distance covered at walking (Di Salvo et al. 2007) and a decrease in frequency of match involvements (passes, shots, tackles) as well as speed of running, demonstrating fatigue patterns occur (Bloomfield et al. 2007, Bradley et al. 2009). These movement patterns transpire in an unplanned sequence, further complicating the intricate task of conditioning players to meet the demands outlined above.

It is clear by the duration and actions of the sport that anaerobic and aerobic energy systems have integral roles in the production of energy in the form of Adenosine Triphosphate (ATP) converted from food by cells in the body. The aerobic pathway of energy typically produces acetyl coenzyme A through the oxidation of macronutrients (carbohydrates, fats and proteins), which then undergoes a complex series of chemical reactions resulting in the production of carbon dioxide and hydrogen and a further two molecules of ATP (Robergs, Ghiasvand, Parker, 2004). This second phase is known as the Krebs cycle and by-products (hydrogen) are further converted to energy in a final stage by oxidative phosphorylation, otherwise known as the electron transport chain. The hydrogen combined with enzymes (NAD and FAD) before passing through a series of reactions and ultimately provides energy for the phosphorylation of Adenosine diphosphate (ADP) to form a greater number of ATP (x34) (Bouchard and Rankinen, 2001). Anaerobic energy pathways involve two main energy systems, ATP-PC system and anaerobic glycolysis. The ATP-PC system requires the enzyme creatine kinase to breakdown phosphocreatine into creatine and phosphate. During the breakdown of phosphocreatine, the energy released allows for ADP and phosphate to form ATP, fuelling energy for high intensity activity (Robergs, Ghiasvand, Parker, 2004). Similar to glycolysis, anaerobic glycolysis converts glycogen to glucose by a series of enzymes. The difference between the two pathways is the presence of oxygen (Bangsbo 1994). During anaerobic conditions, insufficient oxygen is available to breakdown pyruvate into acetyl coenzyme A, creating hydrogen ions (Bouchard and Rankinen, 2001). As a result, pyruvate binds with some of the hydrogen ions, converting them into lactate, in an attempt to buffer the acidosis (Robergs, Ghiasvand, Parker, 2004).

Research investigating muscle ionic transportation and metabolism by examination of soccer players during intermittent exercise in a laboratory through analysis of femoral and arterial venous blood samples as well as biopsies from exercising muscles, report energy contribution to be 98% aerobic and 2% anaerobic (Bangsbo 1994). While precise percentage separations may vary between population samples or be influenced by the methods used during investigations, strong evidence through the physiological analysis of heart rate and blood sample data acquired during match play suggest the greatest contribution to the replenishment of ATP is through the aerobic energy systems (Drust, Rilley and Cable et al. 2000). Others have used innovations in knowledge, mixed methods, systematic reviews and advancements in technology energy system and it is generally agreed approximately 90% of soccer energy metabolism is aerobic (Jouaux 2007, Stølen et al. 2007). A highly trained aerobic system is vital to reduce recovery time in-between periods of high and low intensity actions as well as allowing for increased interaction potential (Stolen et al. 2005). This theory is supported with evidence from studies demonstrating relationships between maximal oxygen uptake (VO_{2max})

(the maximum volume of oxygen utilised by the body at or near maximal effort measured in millilitres of oxygen used in one minute per kilogram of body mass - $mL \cdot kg^{-1} \cdot min^{-1}$) and greater distance covered throughout a game, which increased the number of technical actions (Bangsbo et al. 1991, Helgerud et al. 2001, Wisløff et al. 1998), as well as extended periods of high intensity running (Helgerud et al. 2001). Studies have shown that increasing aerobic endurance can increase soccer performance by increasing the distance covered during a match, which can increase the influence a player has on the outcome of the result due greater involvement in game actions (Aguiar et al. 2012).

Despite the dominant percentage of energy coming from aerobic sources, there is still substantial anaerobic energy turnover, which the actions are considered to be imperative to game winning situations (Stølen et al. 2007). Anaerobic energy systems do not take over the task of ATP regeneration completely at higher intensities of exercise, but rather augment the energy supply provided from mitochondrial respiration (Robergs, Ghiasvand, Parker, 2004). A well-trained anaerobic system can aid in producing energy for high intensity powerful actions as well as being able to perform these actions repeatedly throughout the match (Bangsbo 1994). Actions such as jumping, sprinting, shooting could be the crucial moments that accumulate to be the outcome of a players performance or the teams result. The by-products of anaerobic energy can also reduce the production of ATP; therefore, for maintaining high levels of energy, efficient energy systems are important for the regeneration of energy and removal of by-products (Robergs, Ghiasvand, Parker, 2004).

The notion suggesting physical performance varies depending on playing level is supported by evidence comparing data from different clubs. Early research demonstrated a positive relationship between performance results, endurance capacity and physical strength in soccer between the teams who finished top and bottom of the elite Norwegian league (Wisloff et al. 1998). The study is limited due to only examining two teams of the league. Further support is added through the analysis carried out by recent studies. Lower ranked teams from Denmark recorded significantly inferior values of high-intensity running; total distance and maximal running distance compared to players from higher ranked teams of the Italian Serie A league (Mohr et al. 2003). Data collected from different countries have demonstrated a relationship between endurance capacity and performance results. Hungarian and Siberian studies have all established greater VO_{2max} values for higher ranked teams (Ostojic 2000). Reference values determined by laboratory controlled test for top-level soccer players typically range from 55 – 70 $mL\cdot kg^{-1}\cdot min^{-1}$ (Bangsbo et al. 1991, Casajús, 2001, Kemi et al. 2003, Stølen et al. 2005), although it is possible for players to score outwith this range with some individual values reported greater than 73 $mL\cdot kg^{-1}\cdot min^{-1}$ (Silva et al. 1999). Da Silva et al (2008) found a range of 49.5 – 67.6 $mL\cdot kg^{-1}\cdot min^{-1}$ for 32 peer-reviewed articles but the inclusion of multiple direct and in-direct VO_{2max} tests, younger and lower league players may have resulted in inferior figures. Improvements of performance have been associated with higher recorded VO_{2max} levels due to a greater ability to offset fatigue through an enhanced oxidization of lipids as well as sparing of glycogen and lower lactate production (Henriksson and Hickner, 1996). Due to the relationship with performance, VO_{2max} has received much attention in the soccer literature with studies looking at how to best develop this marker to improve endurance capacities in soccer players (Aguiar et al. 2012).

Improving soccer endurance has seen widespread investigation through the use of assorted methods such as high-intensity interval running (HIIT) and more soccer specific methods of drill or game based exercises (Owen et al. 2004). Recently, teams appear to utilise SSGs more frequently in an attempt to provide a sufficient training stimulus (Aguiar et al. 2012). SSGs vary in format but comprise of two opposing teams, ranging from 1 vs. 1 to 8 vs. 8, playing on a pitch smaller than regulation size. Session intentions differ dependent on objectives set out by the coach and can exclude the use goalposts, where the aim is to preserve possession of the ball (Impellizzeri et al. 2006). When goalposts are used, they can be unguarded or employ goalkeepers where game formats may reflect accustomed soccer rules or restrict the number of ball contacts before the player must relinquish possession (Owen et al. 2014). Nevertheless, in order to ensure that SSGs are appropriate the intensity and metabolic nature of the session should be high and equivalent or above that highlighted in the previous sections. Similarly, the energy systems required for competitive soccer should be taxed in a related manner to target training principles of specificity (Castagna et al. 2009). To access if the desired effort, which is being applied, promotes physiological adaptations that have been shown to increase overall soccer performance, it may best be achieved through monitoring individual player responses (Jones and Drust 2007).

2.2. Quantifying Exercise Intensity during SSGs

Intensity typically refers to how hard an individual is working based on a scale relevant to their maximum capability (e.g., a weight lifter working at 75% of their one repetition maximum) (Little and Williams 2007). The aim of training can be to improve physical endurance capacity by targeting specific physiological systems (Hill-Haas et al. 2010). Measuring intensity could therefore be advantageous in order to match individuals work rate with the demands on muscle cells through relevant metabolic pathways. Intensity is not only important for targeting appropriate energy systems, but it can also be beneficial in the periodization of athletes training (Borresen and Lambert 2009). Monitoring exercise intensity can increase the likelihood of athletes receiving an appropriate stimulus, thus lowering the incidence of under or overtraining, which can both have detrimental consequences to performance (Laursen 2010). Soccer training intensity during SSGs is commonly measured through HR analysis, blood lactate (BLa^-) sampling, rating of perceived exertion (RPE) and player tracking.

2.2.1. Heart rate

Advancements in technology permit the practical application of heart rate monitoring during soccer training and SSGs, giving coaches objective data of the internal training load as well as increasing the precision of player monitoring (Achten and Jeukendrup 2003). Heart rate is measured through use of chest straps that contain a receiver electrode and a signal transmitter using short-range telemetry to a base station connected to a computer allowing for real-time viewing of data. There are limitations suggested in the literature for the use of HR equipment during soccer training activities. For example, it has been suggested that HR may underestimate training intensity during high anaerobic activities, especially during SSGs with fewer players (Hill-Haas et al. 2009a). Evidence demonstrates greater perceived exertion but lower HR during 2 vs. 2 in comparison to games involving additional players (Hill-Hass et al. 2009). Despite the proposed limitations, HR monitoring has shown to be both reliable and valid for determining training intensity during soccer training. Espisoto et al. (2004) investigated physiological demands of a soccer specific circuit consisting of walking, jogging, sprinting, dribbling, passing and changes of direction compared to laboratory running on a treadmill. The HR/VO_{2max} relationship was examined using the same HRM and portable breathing systems for each test and the researchers found no significant difference between the conditions. Similarly, another study compared exercises performed in the laboratory and throughout 5 vs. 5 SSGs and shown that the relationship is similar between the two settings (Castagna and Belardinelli 2004). The results of others suggest that HR monitoring is a valid and reliable means of determining training intensity.

The relationships established between clinical and field tests as well as the reliability of modern equipment have increased the popularity of HRM during SSGs (Aguiar et al. 2012). HRM has involved studies using variations in methods to quantify the value established. Peak HR, HR reserve and percentage of maximum HR have all been used in studies to display the results. (Coutts et al. 2009, Dellal et al. 2008, Owen et al. 2103). Simply comparing average beats per minute (BPM) does not constitute a valid indicator of internal load when accessing multiple participants, as HR is an intrinsic value determined by multiple influencing factors such as, stroke volume, age, genetics, training history, climate, diet and medication (Clemente et al. 2012). Instead, it is vital to calculate HR_{max} for each player in order to express HR as a percentage, making the value relevant to the individual's cardiac systems response to the exercise. A generally used formula of 220-age has been reported to significantly overestimate HR_{max} particularly in younger populations (Sitkowski et al. 2007).

Other methods such as maximal testing are increasing in popularity to distinguish HR_{max} due to the tests being sensitive to physiological adaptations and contain high reproducibility (Bangsbo, Iaia and Krustrup 2008). Additionally, results obtained from the shuttle sprint test and the Yo-Yo Intermittent Recovery level 1 (Yo-Yo IR1) exhibit a relationship between high intensity distances covered during match play (Mohr et al. 2003). The Yo-Yo IR1 test involves a 20m run separated by a 10m dynamic recovery, for duration of 10 – 20 min (termination at maximal exhaustion). The running speed at which the test is carried out is thought to tax the aerobic system greater and the anaerobic system less in comparison to soccer match intensity (Bangsbo, Iaia and Krustrup 2008). Similarly, 20s separates the shuttle test comprising of 6 x 6 -7s sprints recovery and considered unrelated to match-play patterns (Bradley et al. 2010). The Yo-Yo Intermittent Recovery test level 2 (Yo-Yo IR2), consistent with level 1 set-up but with increased running speed, is regarded to be closely related to soccer, as the test taxes the energy systems in a game-specific manner (Bradley et al. 2010). Krustrup et al. (2006) tested elite Scandinavian soccer players who performed 2 – 4, Yo-Yo IR2 tests as well as incremental treadmill test (ITT) and compared for reliability, validity and physiological responses. The results found the distance covered test-retest coefficient of variation was 9.6% (N = 29) for the Yo-Yo IR2 and significantly correlated to ITT performance (r = 0.74) and VO_{2max} (r = 0.56). This study demonstrates that the Yo-Yo IR2 test is reproducible and can be used to evaluate a soccer player’s ability to perform intense intermittent exercise with a high rate of aerobic and anaerobic energy turnover. Specifically, the Yo-Yo IR2 test was shown to be a sensitive tool to determine both VO_{2max} and HR_{max} with maximum HR values comparing very closely to those established in a laboratory (99±1%)(Krustrup et al. 2003).

2.2.2. Blood Lactate

As running speed and duration of exercises increase, a point may be reached where the break-down of glycogen for energy resulting in lactate (glycogenolysis) and the conversion of glucose to pyruvate (glycolysis) occurs at a rate quicker than the metabolic by-products can be removed from the working muscles (conversion to water and carbon dioxide) (Robergs, Ghiasvand and Parker 2004). This point is known as the lactate threshold (LT) and the synthesis of energy during anaerobic glycolysis above LT causes increases accumulation of lactate in the blood stream, allowing for blood lactate (BLa^-) to be measured through blood sample analysis (Robergs, Ghiasvand and Parker 2004). This method has been used extensively as an objective measure of exercise intensity, typically during incremental and progressive protocols. Although the use of BLa^- sampling is widespread in measuring soccer intensity, the results are often disputed due to the patterns witnessed in match play.

The intermittent intensity of soccer involves intervals above LT followed by low intensity recovery periods, which remove lactate from the working muscles (Krustrup et al. 2006). Using BLa^- to access the intensity across the complete duration of a soccer game may only represent the final portion of the match because of the recovery periods of low intensity removing metabolic by-products (Hill-Haas et al. 2011). Moreover, there is a delay in the BLa^- response, consequently, this phenomenon distorts true intensity across longer durations and may represent only recent BLa^- concentrations. Additionally, BLa^- concentration is considered to increase exponentially, whereas HR increases linearly (Hill-Haas et al. 2011). Therefore, relatively slight changes in intensity result in greater differences in BLa^- compared with HR. Meaning a linear relationship would more closely reflect training intensity at any given point compared to an exponential relationship that may continue to show increases of BLa^- even though exercise intensity remains constant. This is supported by noticeable variations in results found by Rampinini et al. (2007) typical error expressed as a coefficient of variation (CV) ranged from 2.0 to 5.4% for $\%HR_{max}$ but from 10.4 to 43.7% for blood lactate concentration across the same sessions of SSGs. Therefore BLa^- is not a valid indicator of intensity during SSGs, especially longer game durations, and alternative methods should be used (Hill-Haas et al 2011).

2.2.3. Rating of perceived exertion

Contemporary research involving the athlete's global perception of physiological and psychological interpretation of effort has resulted in the ACSM (American College of Sports Medicine) endorsing RPE as an appropriate process for evaluating exercise intensity (Williams and Eston 1989). Since this research, the RPE scale is one of the most widely used concepts for the subjective self-assessment of a global report for fatigue, strain, discomfort and/or effort in regards to exercise (Robertson and Noble 1997). The popularity is perhaps based on the method being low-cost, easy to administer, non-invasive and the close connection observed between objective variables such as HR (Little and Willlams 2007). The original tool proposed by Borg (1982) consists of a scale of 6 – 20, where 6 = at rest and 20 = exhaustion. The 6-20 RPE Borg scale has potential limitations, as the scale does not incorporate a ratio scale that many people may subconsciously perceive (Foster et al. 2001). For example, one person who perceived an exercise as 8 and the following exercise as 16 does not necessary equal a result where they found the second exercise twice as strenuous.

Since the early research on RPE, various alternative scales have been proposed ranging from a 9 to 21 point scale. Foster et al. (2001) adapted the Borg scale to a 0-10 scale in order to evaluate training load (see table 2.1). This method has been used in soccer training research (Rampinini et al. 2004, Impellizzeri et al. 2007, Coutts, Rampinini et al. 2009). The main advantages are the inclusion of a category ratio scale (e.g., 4 should equal double the intensity of 2) as well as 0-10 being commonly used in many disciplines, which people may generally be readily accustomed to (Foster et al. 2001). The CR-10 scale has been shown to test well against objective markers and RPE is regarded to be an effective indicator of exercise intensity believed to have high validity (r = 0.80 ± 0.90) (Chen et al. 2002).

Table 2.1: Category Ratio 0 – 10 Rating of Perceived Exertion Scale (Foster et al. 2001).

Rating number	Rating description
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximal

Research on RPE has concentrated on the correlation between physiological measures of HR, BLa^- and VO_{2max} in particular; however, the strength of RPE is to perceive an overall global perception including psychophysical factors that may not be highlighted from physiological markers alone. A meta-analysis by Chen et al. (2002) investigating the strength of the relationship between RPE and numerous physiological criterion measures, such as HR, VO_{2max}, ventilation and respiration rate also examined gender, type of RPE scale used, mode of exercise, protocols and study quality, found previously suggested RPE correlations may not be as high as earlier understood and is predominantly dependent on six criterion; 1) Fitness/activity level 2) Exercise type (e.g., cycling, swimming or running) 3) Exercise protocol (e.g., continuous, intermittent, progressive, random, maximal or sub-maximal) 4) RPE mode 5) Study quality and 6) RPE scale (15-point, 21-point, 9 point or category ratio 1-10). The study found during random intermittent exercise the validity coefficients between RPE and HR (n=176) as well as BLa^- (n=150) were r = 0.40 ± 0.62 and 0.32 ± 0.58 respectively, at 95% confidence intervals (Chen et al. 2002). In agreement, Green et al. (2005) previously demonstrated that RPE taken following each session of 5 × 2 min interval cycling was moderately correlated to BLa^- (r = 0.43). Taken together, these results provide further support to the validity of RPE as measure of global exercise intensity during interval training. Although several studies have reported that session RPE to be a valid indicator of overall perception of effort for intermittent aerobic soccer-specific exercises (including SSGs) training, it may not be a valid substitute for physiological (HR and BLa^-) based methods. Nonetheless, due its psychophysical foundations, session RPE measures may be a more valid global measure of exercise intensity during high-intensity intermittent exercise such as SSGs (Alexiou and Coutts 2008).

2.2.4. Player Tracking

Technological developments in recent years have allowed for distance and speed in sport to be measured using GPS devices (Townshend et al. 2008). Initially created strictly for the use by the U.S. army, GPS became accessible for civilian practice during the 1990's (Dobson and Keogh 2007). A complex system of 24 orbital satellites transmit a uniquely coded series of radio signals, which the GPS system can decipher a precise location using a minimum of 4 satellites and trigonometry calculations (Witte and Wilson 2004). Applying GPS devices to sporting situations permits the monitoring and recording of running speed and distances covered by each player. Also, software applications enable coaches and exercise scientists to construct summary reports based on complete sessions as well as analyse real time data (Aughey and Falloon 2010). Further advances in technology have reduced the size and mass of the GPS receiver, making the device lightweight and wearable during soccer practice (MacLeod et al. 2009). Unfortunately, the miniaturisation increases the cost of each unit making it relatively expensive, especially when monitoring larger groups (Larsson 2003).

The biggest limitation for the use of GPS is therefore perhaps the cost as recent investigations detailing the reliability and validity report less that 5% for the CV when GPS distance is compared to a pre-measured running track (Aughey and Falloon 2010). Studies have also evaluated GPS for the use during team sports where rapid and frequent changes of direction can occur. Protocols involved individuals completing a standard measured track, which was constructed to replicate team sport movement patterns. Total distance measured out for the course compared against total distance covered calculated by GPS showed a disparity of 1.5% (Morris et al. 2009). An additional study using the same method found the CV for maximum speeds and total distance covered were 2.3 and 4.8%, respectively (Coutts and Duffield 2010). Authors from both studies speculate that the slight discrepancies of results could be partly due to players deviating from the marked course. The precise monitoring of positional data allows for speed to be analysed through dividing distances logged and the time between each charted position (Worringham et al. 2008). Studies have demonstrated approximately 65% of speed to be within 0.4ms-1 of true speed calculated through 1 Hz GPS devices with 45% within 0.2ms-1 (Witte and Wilson 2004). These results suggest GPS monitoring to be a reliable and valid method to measure speed and distance covered in team sports. Although equipping participants with GPS devices may be advantageous by providing additional data, the overall cost for team-sports is frequently not financially viable.

2.2.5 Summary of Quantifying Intensity

Quantifying exercise can be beneficial for performance enhancement through increasing the likelihood that training is performed at predetermined intensities. Measuring and monitoring intensity can also aid in developing programs that are applicable to the individual, session's aims and relative to the overall training calendar. Technological advancements have increased the accessibility, practical application and accuracy of equipment used to measure intensity during soccer training. Commonly, four general methods are utilised in the literature HR analysis, BLa^-, RPE and player tracking. HR and RPE have been demonstrated to successfully measure internal load and when used in conjunction with one and other, they can offer a more complete global measure of objective and subjective measures. Tracking each players speed and distance can be a reliable method to examine external loads, but can be expensive to measure team sports. While each method for measuring intensity has strengths and weaknesses, laboratory validity measures do not strictly translate to accurately reflect the intensity during SSGs. The intermittent nature of SSGs can mean BLa^- is only a true measure of the latter periods of games rather than a representation of the whole game. The methods used for measuring intensity can be based on the suitable variables of interest but may need to compromise around the availability of equipment.

2.3. Variability during Small-Sided Soccer Games

Soccer is a multifaceted sport as players can compete at a high level with different combinations of capacities within technical, tactical and physical areas. Mixed ages, positional demands and training history add in the accumulation of diverse factors, which may give valid insight into why noticeable variability can be seen in the sport. Variability is conceivably the most influential reason as to why coaches favour running based drills over SSGs as a format to improve soccer endurance (Aguiar et al. 2012). The major concern being that SSGs may not provide a high enough intensity for each player, which is considered to incur physiological adaptions (Rampinini et al. 2007). Variability can be separated into two main types; inter-player differences across a group of players and intra-player differences between the same players across different sessions.

One of the main influences on inter-subject variability is perhaps due to a range of specific aerobic fitness that can be found within a football team (Hill-Haas et al. 2008, Williams and little, 2006). When grouped together, positional differences in fitness are visible. Midfielders regularly record the highest VO_{2max} and cover the greatest distance during match play in comparison to attackers and defenders (Di Salvo et al. 2006). However, separation into over simplistic groups may not provide an appropriate model. The modern game has evolved complex tactical systems that can greatly impact a player's role depending on formation and/or opponents. Withers et al. (2008) discovered that full-backs (external defenders) covered significantly greater distances compared to central defenders. Likewise, a well-controlled study by Dellal et al. (2011b) separated midfielders into three categories, central defensive, central attacking and wide (external) midfielders. Dellal et al. (2011a) examined the technical and physical demands of SSGs and performed positional separation analysis that revealed differences in mean values of central defenders (81.7%HR_{max} ± 2.3) and wide midfielders (86.3%HR_{max} ± 2.4), underlining positional variability. Although mean distance values were relatively similar for midfielders (11247.3 m for defensive midfielder and 11004.8 m for attacking midfielder), the separation due to modifications in roles is valid as disparities are seen between total distances covered with and without ball possession. The defensive midfielders on average covered 93.3 m compared to 138.1 m sprinting when their team were in possession of the ball. When the opposition had the ball, the defensive midfielder performed 103.3 m sprinting compared to 71.9 m for the attacking midfielder (Dellal et al. 2011b). This is primarily due to the key responsibilities that come with distinct positional roles, where player's biggest influences may be to try and score and create a goal or be predominately defensive and try and stop goals being conceded.

Significant differences have also been found amongst the number of headers, tackles, sprints and distance covered amongst different playing positions (Bradley et al. 2009, Dellal et al. 2011a, Di Salvo et al. 2007, Di Salvo et al. 2009). Data collected from 600 top division matches in Spain and England revealed attackers had significantly greater number of heading duals (6.3 ± 3.0 and 18.5 ± 6.9) compared to all other positions and central attacking midfielders the least (2.5 ± 1.3 and 6.7 ± 2.5). Not only does this data demonstrate positional differences, geographical variances are also evident with English matches scoring significantly higher in all positions, suggesting distinct playing styles between the two leagues. Further research is required to compare a larger sample size containing data from a variation of countries in order to make conclusions.

The secretive nature of soccer research means there is limited data on intra-player variability, but of the few studies conducted, the variance is reported to be generally high in soccer matches. A large number of players (485) were measured across 10 full games and reported a mean CV of 16.2 ± 6.4 % (95 % CI = 15.6 – 16.7 %) for high intensity running and 30.8 ± 11.2 % (95 % CI = 29.9 – 31.7 %) for total sprint distance. A lower variance has been established during SSGs in comparison to full-sized games with consistent physiological results. Little and Williams (2006) repeated 2 vs. 2 and 8 vs. 8 SSGs and tested for intra-player reliability using a paired t-test. No significant differences between games were observed for HR with ratio limits of agreement to display 95% error limits of 1.8–3.8%. Inter-participant variability remains one of the key issues surrounding SSGs as a method to effectively stimulate physiological adaptations (Hill-Haas et al. 2011). This is largely influenced by the lack of control coaches have on the players in terms of distances and speed in which they run. Many coaches feel that less motivated players may not exert themselves entirely, as they are not being monitored or visually seen to complete targeted distances (Aguiar et al. 2012). Traditional methods that isolate physical fitness, such as HIIT, are frequently favoured over SSGs to provide a sufficient stimulus to increase endurance capacity, as this method has been described to display lower inter-player variability. Additionally, the distance a player runs in a given duration can be easily identified and precisely recorded. Indeed, some studies have shown HR during HIIT to be half the variation in comparison to SSGs, with the CV = 5.9 and 11.8 %, respectively (Dellal et al. 2008). However, randomisation was not possible due to the team’s strict training schedule, thus making it unclear if any order effect took place. In contrast, randomised studies have found CV for HR to range from 2.0 to 5.4% for SSGs and to compare well against laboratory controlled tests (treadmill running and cycle ergometry) for reproducibility (Williams and little 2006, Impellizzeri et al. 2006, Rampinini et al. 2007).

2.4. Game Intensity

The literature contains many examples of studies targeting specific training intensities in order to improve physical endurance for soccer players (Aguiar et al. 2012). Much of the attention has been placed on improving markers such as VO_{2max} due to the strong relationship that has been demonstrated with soccer performance and delaying the onset of fatigue. A study examining the development of VO_{2max} for players performing four sets of 4-minutes of running at 90-95%HR_{max} twice a week for 8-weeks showed that VO_{2max} increased by 11% (from 58.1ml/kg/min to 64.3ml/kg/min) (Helgerud et al. 2001). The control group did not carry out extra conditioning for these 8 weeks and they did not improve VO_{2max}. Based on the results of this study, performing traditional soccer training without extra-conditioning may not develop VO_{2max} although, no information was given about the soccer trainings that were performed. Furthermore, the two groups had different volumes of training, making it unclear weather it is the HIIT training providing the adaptions or simply from an increased volume. Another study where the same interval format was used on Champions League players resulted in similar increases of VO_{2max} levels (Helgerud, Kemi and Hoff 2003). Helgerud et al. (2001) investigated the influence the 8-week program has on game actions and found an increase of 20% in total distance covered, a 23% increase in involvements with the ball and doubled the number of sprints, further highlighting the advantages of a high VO_{2max} in soccer for professional soccer players (Helgerud et al. 2001, Hoff et al. 2002). These results have lead researchers to believe an average intensity of >90%HRmax for 4 minutes separated by lower intensity recovery periods to be optimal for increasing aerobic endurance. It is unclear if these values are in fact optimal as this format only appears to be replicated rather than expanded in the literature. It is suggested that this duration is optimal due to the intensity, making longer games unsustainable through the onset of fatigue, thus reducing the capabilities of performing high intensity actions during the 2nd, 3rd and 4th games. In relation to SSGs, studies that established an average across all games of less than 90%HR_{max} suggest game-based conditioning does not evoke a sufficient physiological response (Gabbett and Mulvey, 2008; Hill-Haas et al. 2009a). There are however, numerous studies that have been able to establish a >90%HR_{max} for SSGs, which the authors speculate that game formats could be controlled to regulate a desired training intensity and be used to increase VO_{2max} (Little and Williams 2006, Rampinini et al. 2007, Kelly and Drust 2009).

2.5. Variables Affecting SSG Intensity

Exercise intensity during SSGs has been shown to be appropriately measured using HR, RPE and GPS systems (Aguiar et al. 2012). SSG formats can be altered substantially to target the aims set out by the coaches, but many independent variables may influence the individual and overall player intensities (Clemente et al. 2012). The main factors investigated in the literature comprise of player number, pitch dimensions, coach encouragement, use of goals and/or goalkeepers rule as well as modification. The proceeding sections will discuss each factor and the influences that have been demonstrated to occur during SSGs studies in soccer.

2.5.1. Player Numbers

Recent investigations have demonstrated that the number of players in each team can influence the perceptual, physiological and time motion characteristics observed (Aroso et al. 2004, Hill-Haas et al. 2009a, Katis and Kellis, 2009, Sampaio et al. 2007, Owen et al. 2004, Rampinini et al. 2007). It is also common practice for training games to involve one team with a numerical advantage to practice under and overload situations as well as utilise every player when an odd number of players are present (Hill-Haas et al. 2010). Although smaller game formats generally evoke the greatest intensity, it is problematic when trying to conclude a theme on player numbers. Playing formats of 2 vs. 2 to 4 vs. 4 frequently demonstrate the greatest HR values (see table 2.2), with lower intensities for formats with less and more players. Meanwhile, others found no significant differences between game formats when different player numbers are accessed (Hill-Haas et al. 2009a, 2010, Impellizzeri et al. 2006, Katis and Kellis 2009, Little and Williams 2006, Owen et al. 2004, Rampinini et al. 2007).

Table 2.2: Maximal heart rate values according to different player number SSG formats

SSG Format	$\%HR_{max}$ range	Reference
1 vs. 1	75-80	Dellal et al. 2008
2 vs. 2	88-91	Hill-Haas et al. 2009a, Little and Williams 2006
3 vs. 3	87 - 90	Katis and Kelis 2009, Little and Williams 2006, Rampinini et al. 2007
4 vs. 4	85-90	Hill-Haas et al. 2009a, Little and Drust 2008, Litlte and Williams 2006, Rampinini et al. 2007
5 vs. 5	82-87	Hill-Haas et al. 2009c, Little and Williams 2006, Rampinini et al. 2007
6 vs. 6	83-87	Hill-Haas et al. 2009c, Katis and Kelis 2009, Little and Williams 2006, Rampinini, et al. 2007
8 vs. 8	71 - 88	Dellal et al. 2008, Little and Williams 2006.

Less attention has been applied to investigate the relationship between player numbers and BLa^-. However, there is agreement within these studies that as player number decreases, BLa^- increases (Hill-Haas et al. 2009a, Impellizzeri et al. 2006, Rampinini et al. 2007). Similarly, studies incorporating RPE have followed the same pattern, as greater values were recorded in studies where player numbers were reduced (Aroso et al. 2004, Hill-Haas et al. 2010, Impellizzeri et al. 2006, Rampinini et al. 2007). In regards to technical actions, Jones and Drust (2009) found significant differences between smaller and larger game formats for the number of ball contacts. The smaller game format, 4 vs. 4, observed double the frequency of ball contacts per player, recording 36 ± 12 compared to 13 ± 7 for 8 vs. 8. Games with fewer player numbers have also demonstrated to contain a significantly greater number of tackles, dribbles, short passes and shots when 3 vs. 3 formats were compared against 6 vs. 6 (Katis and Kelis 2009). On the other hand, the larger game format involved a significantly higher number of longer passes and head contacts with the ball. Studying the physiological, perceptual and technical responses due to player numbers can be problematic as researchers are may be faced with a dilemma between examining player numbers within consistent pitch dimensions or investigating the practical application of exploring player numbers in relation to a relevant pitch size.

2.5.2. Pitch Dimensions

Pitch dimensions set out by the coach will ultimately determine the pitch area. Typically, the shape reflects full-size pitches with the length between opposing goals being greater than the width of the pitch, creating a rectangle (Hill-Haas et al. 2011). Playing areas regarded as small may increase the frequency at which duals occur because of the close proximity of players simultaneously reducing the time a player has on the ball to make a choice, targeting aspects such as decision making under pressure from an opponent (Little and Williams 2006). Larger game formats are thought to increase the distance players have to cover in the same time frame, potentially increasing intensity as well as allowing more opportunity for longer and loftier passes (Katis and Kelis 2009). The primary limitation of pitch area research is there does not appear to be a general consensus on which dimensions are best suited to the appropriate number of players. For example, two studies both examined 3 vs. 3 games but pitch area ranged from 240 m^2 to 2500 m^2 (see table 2.3)(Rampinini et al. 2007, Gabbett and Mulvey 2008).

Table 2.3: Maximal heart rate values according to different pitch size SSG formats

SSG Format	Min area m^2	Max area m^2	$\%HR_{max}$ range	Reference
1 vs. 1	100	100	75-80	Dellal et al. 2008
2 vs. 2	400	800	88-91	Hill-Haas et al. 2009a, Little and Williams 2006
3 vs. 3	240	2500	87 - 90	Katis and Kelis 2009, Little and Williams 2006, Rampinini et al. 2007
4 vs. 4	240	2208	85-90	Hill-Haas et al. 2009a, Little and Drust 2008, Litlte and Williams 2006, Rampinini et al. 2007
5 vs. 5	240	2400	82-87	Hill-Haas et al. 2009c, Little and Williams 2006,Rampinini et al. 2007
6 vs. 6	2400	2700	83-87	Hill-Haas et al. 2009c, Katis and Kelis 2009, Little and Williams 2006, Rampinini, et al. 2007
8 vs. 8	2400	2700	71-88	Jones and Drust 2007 Dellal et al. 2008, Little and Williams 2006.

Where separate studies have investigated pitch area, other independent variables can vary substantially, making it difficult to conclude on the effectiveness of the practices (Aguiar et al. 2012). For instance, there have been studies that have reported no differences between physiological responses when player numbers remained constant but pitch area increased (Kelly and Drust 2008). Despite these findings, the majority of research has found game intensity to increase with pitch area (Tessitore et al. 2006, Rampinini et al. 2007). A study by Rampinini et al. (2007) increased pitch area by 20% creating small, medium and large areas for 3 vs. 3 to 6 vs. 6 formats and found physiological responses (HR and BLa^-) and RPE to be higher in the larger area games. Larger based games can also target energy systems differently compared to small-based formats. Blood lactate variation in small pitch formats have been seen, which may have arisen due to different anaerobic demands from high intensity actions. Additionally, others have concluded that larger pitch sizes tax the aerobic energy system greater due to longer linear running requirements travelling from each goal zone (Tessitore et al. 2006, Rampinini et al. 2007). The technical actions observed during varying pitch sized formats were found to have no significant differences for the rate of occurrences of dribbling, passing, interceptions, headers and receiving the ball (Tessitore et al. 2006, Kelly and Drust 2008). Other actions, such as number of shots and tackles have been shown to be significantly higher in smaller area games, largely due to the proximity of the opponents and the goalposts, hence more frequently the opportunity arises for both to occur (Owen et al. 2004).

2.5.3. Coach Encouragement

Coach encouragement can be seen as a method to increase motivation and confidence through support by visual and/or verbal cues (Balsom 1999). Many authors agree that coach attendance and encouragement could influence player behaviour and ultimately play a crucial role in the outcome of SSGs (Bangsbo 1998, Couts et al. 2004, Hoff et al. 2002, Mazzetti et al. 2000, Rampinini et al. 2007). One of the few studies that have isolated coach encouragement found increased physiological (HR and BLa^-) and perceptual (RPE) responses (Rampinini et al. 2007). The study was robust due to the systematic testing of SSGs with and without coach encouragement across three different pitch sizes (small, medium and large), for 3 vs. 3 to 6 vs. 6 formats. The authors also found that the effect sizes revealed coach encouragement had the greatest impact on the results, followed by number of players then pitch area.

2.5.4 Rule Modification

The practices of SSGs during training do not necessary have to comply with regulation soccer rules and modifications are commonly implemented to challenge players or alter the constraints of the game (Owen et al. 2014). Rule modifications include incorporating (or not) the offside rule, kick-ins instead of throw-ins, various methods of scoring (e.g., must complete 5 passes before shooting), goal position and limiting the number of touches of the ball per player (Hill-Haas et al. 2010). Hill-Haas et al. (2010) monitored HR and RPE during various modified games and reported a mean game intensity of 84.0%HR_{max} ± 4.4 games played where goals are only counted if all attacking players are in the front two-zones of the pitch. An additional rule was added where two neutral players played on the widths of the pitch and a goal could not be scored until they had touched the ball. This rule change appeared to result in a significantly lower game intensity of 81.2%HR_{max} ± 4.7. Although the study tested various game sizes and the practical aspect of combining rules which occur in practice, separating each modification may have given additional insight on the direct influences of each rather than the addition of rules. This is important so the individual effect as well as the interaction effect can both be analysed and provide a greater understanding.

2.5.5. Use of Goalkeepers

Goalkeepers have been shown to produce significantly different movement patterns and physiological responses compared to outfield player (Di Salvo et al. 2007). The distinctive physiological positional demands result in the exclusion of goalkeepers for data analysis, but the inclusion for SSGs can influence the outfield player's responses. Decreases in HR have been observed during 4 vs. 4 games with and without the use of goalkeepers (Mallo and Navarro 2008). Meanwhile, a different study found an increase in residual HR by approximately 11% during 8 vs. 8 games with goalkeepers compared to the same format without (Dellal et al. 2008). The contrast of results may be related to the disparity of game formats used as previous research has highlighted player number and pitch size can also influence SSG intensity (Rampinini et al. 2007). Testing with and without goalkeepers requires systematic testing across multiple game formats in order to be more conclusive. It is plausible that the addition of goalkeepers can influence player behaviour by being more organised to defend the goal as well as motivating players through the increased challenge and satisfaction of scoring (Aguiar et al. 2012). Playing with goalkeepers may also change the tactical perspective of the players as the game may become more directional, with a specific target of scoring a goal. The exclusion of playing SSGs with goalkeepers emphasises ball retention strategies, which can include static shielding of the ball, although an important skill and aspect of soccer this can reduce overall distance covered and game intensity (Clemente et al. 2012).

2.5.6. Summary of Variables Affecting SSG Intensity

There is enough evidence in the literature demonstrating that SSG intensity can be substantially influenced by the game format (Hill-Haas et al. 2009a, Little and Drust 2008, Litlte and Williams 2006, Rampinini et al. 2007). The findings on separate variables are inconclusive due to inconsistent game designs of player numbers, pitch size, rules and game length. However, general themes can be gathered from the results of others. Smaller based games generally produce the highest intensity as these have fewer players, therefore a greater number of intense actions per player as well as less opportunity for rest (Hill-Haas et al. 2009a, Little and Williams 2006). Larger based games may witness lower intensities and fewer ball contacts per player, but game dynamics can offer advantages such as longer passes that are not possible smaller games (Hill-Haas et al. 2009a). Careful consideration may need to be taken in designing the SSG format, with variables being designed to meet the needs of the specific group. Age, playing level and fitness abilities have the potential to be influenced differently to the same SSG stimulus (Aguiar et al. 2012).

2.6. Regulating Exercise Intensity

Numerous methods are used to aid sport scientist in the periodization of training, routinely through monitoring and regulating exercise intensity (Borresen and Lambert 2009). Regulating exercise involves individuals working to a pre-intended intensity or load, which can be achieved through various methods or techniques. The Internal training load experienced within and between individuals can vary despite application of the same external training load, emphasising the need to adjust the stimulus to reach the desired outcome, otherwise known as autoregulation (Meeusen et al. 2006). The recent increase in popularity for regulating training based on the acute internal response might be due to the potential benefits of the concept. Autoregulation is thought to avoid plateaus in adaptations that traditional linear periodization can have over longitudinal periods (Rhea et al. 2002). Another benefit is autoregulation is believed to take into account unforeseen fluctuations in sleep, hydration, nutrition and motivation that other training methods can neglect. Autoregulation is a relatively modern concept and lacks methodical investigation, especially across diverse disciplines or sports (Borresen and Lambert 2009).

The majority of the research has been carried out for strength training and has shown to be a successful method. Rhea et al. (2002) separated participants into linear periodization and an autoregulation group where equated workloads were carried out. The results produced no significant differences between hypertrophy or body composition, but the autoregulation group observed significant strength gains in comparison. The results produced approximately double the percentage gains for the autoregulation group for bench press (14.4% ± 10.4 and 28.8% ± 19.9) and leg press (25.7% ± 19.0 and 55.8% ± 22.8). The initial strength differences observed between the two groups could be a possible limitation of this study. After the first test, the linear periodization group scored substantially higher for baseline tests for bench press (83 kg vs. 67 kg) and leg press (267 kg vs. 230) meaning they could be more highly trained therefore closer to their maximum strength potential, lowering the opportunity for larger percentage gains (Bangsbo 2008). A similar study by Mann et al. (2010) used a homogenous group, which added additional support for the use of autoregulation training. The study found significant increases for division one (American) football players in one repetition maximum (RM) bench press, one RM squat and 225 lb. bench RM.

Specific autoregulation training during soccer remains unpublished to the author’s knowledge; nonetheless, SSGs are frequently viewed as a similar concept that may allow players to work to their own capabilities. After reviewing the literature, there appears to be some evidence supporting SSGs to be able to deliver a session that has relatively low variability yet evoke a high enough internal load to produce adaptations (Little and Williams 2007). Yet, there are also studies that have reported higher levels of variability (11% CV) and relatively lower game intensities (70%HR_{max})(Dellal et al. 2008). Various authors conclude studies by stating they believe SSG intensity could indeed be controlled through variable manipulation alone. However, the research appears to offer substantial disparities meaning precise variable control may not be transferable between different formats or populations. Further research is required for controlling intensity based on independent variables and an alternative approach could be to focus on direct manipulation of the dependent variables

2.7. Dependent Variables

The general approach to studies investigating SSGs intensity involves monitoring the training load, adjusting the independent variable(s) and then re-measuring the responses (Aguiar et al. 2012). No study to the author's knowledge has been carried out that attempts to directly manipulate the dependent variables (HR and RPE) within the same session in order to control the game intensity (Aguiar et al. 2012). That is, recent investigations record data and analyse the information post-session, meaning modifications to adjust the training intensity could only be suggested for the following session. Regulating training intensity for each individual would be highly beneficial as there are many fluctuating factors (i.e., motivation, food intake, hydration, sleep, feedback, previous exercise and recovery strategies), which can significantly and influence training effort (Dellal et al. 2008). Additionally, differences in positional roles and player endurance capacities, may require individualised training programmes to generate an appropriate internal load as apposed to generic running drills that can constrain those who have higher aerobic fitness levels and/or over train those of a lower level (Bradley et al. 2009, Dellal et al. 2010, Di Salvo et al. 2007, Rampinini et al. 2007, Hill-Haas et al. 2009b).

Individualised training programmes may cause isolation and unrest within the team as it goes against traditional soccer logic to provide fitter players with the greatest volume of training as well as missing out on team cohesion (Rampinini et al. 2007). Hence, it could be advantageous to devise sessions where all factors are considered and for training intensity to be determined by real time objective data. Therefore, the purpose of this study was to augment the internal load of SSGs through the use of interventions, whilst monitoring real time objective data. Technology now permits the viewing of live HR information rather than exclusively relying on the subjective opinions of coaches, which can be biased or require vast experience in order to identify slight differences between training sessions. This means that coaches or analysts require considerably less training and experience in the sport to possess the skills required to evaluate the workload of the session. Increasing internal training load based on real time data would give the opportunity for each player across the spectrum to work at a relevant intensity regardless of the situation (Hill-Haas et al. 2011).

2.8. Review of Literature Summary

Clear relationships between playing level and fitness capabilities have been demonstrated in soccer as well as aerobic capacity and delaying the onset of fatigue (Mohr et al. 2003). Targeting specific training zones to improve physical fitness may require sessions to be monitored in order to tax the relevant systems without under or overtraining players (Borresen and Lambert 2009). It is suggested that SSG training is best monitored via a combination of variables with some authors recommending placing greater priority on players HR and RPE (Hill-Haas et al. 2007). Although SSGs have been demonstrated to evoke intensities considered to create adaptations on physical fitness, there remain inconsistencies in the literature suggesting SSG intensity might not be transferable to different groups of players. Inconsistent SSG design also means separate variable conclusions are unclear and further research is required (Dellal et al. 2008). Many authors speculate game intensity can be controlled through the manipulation of variables such as pitch dimensions and rule modification but this area requires further research to be conclusive (Hill-Haas et al. 2011). New concepts, such as autoregulation training, have been successful in other disciplines and the concept proposes many advantages that make investigation worthwhile (Rhea et al. 2002).

Chapter three: Methods

3.1. Research Design

The study used a cross sectional, repeated measures design in order to investigate the intensity and technical actions during four different conditions across SSGs. Three interventions were used where: 1) internal load was accessed and players with a low intensity performed a sprint after each game, 2) internal load was accessed and players with a low intensity performed a sprint during the game and 3) players monitored their own intensity through the use of a wristwatch. The fourth condition involved no interventions so the game could be used as a control to monitor if any differences occur. Data were collected over a 6-week period across August and September, during the competitive playing soccer season for a Scottish Junior North Super League team.

3.2. Study Overview

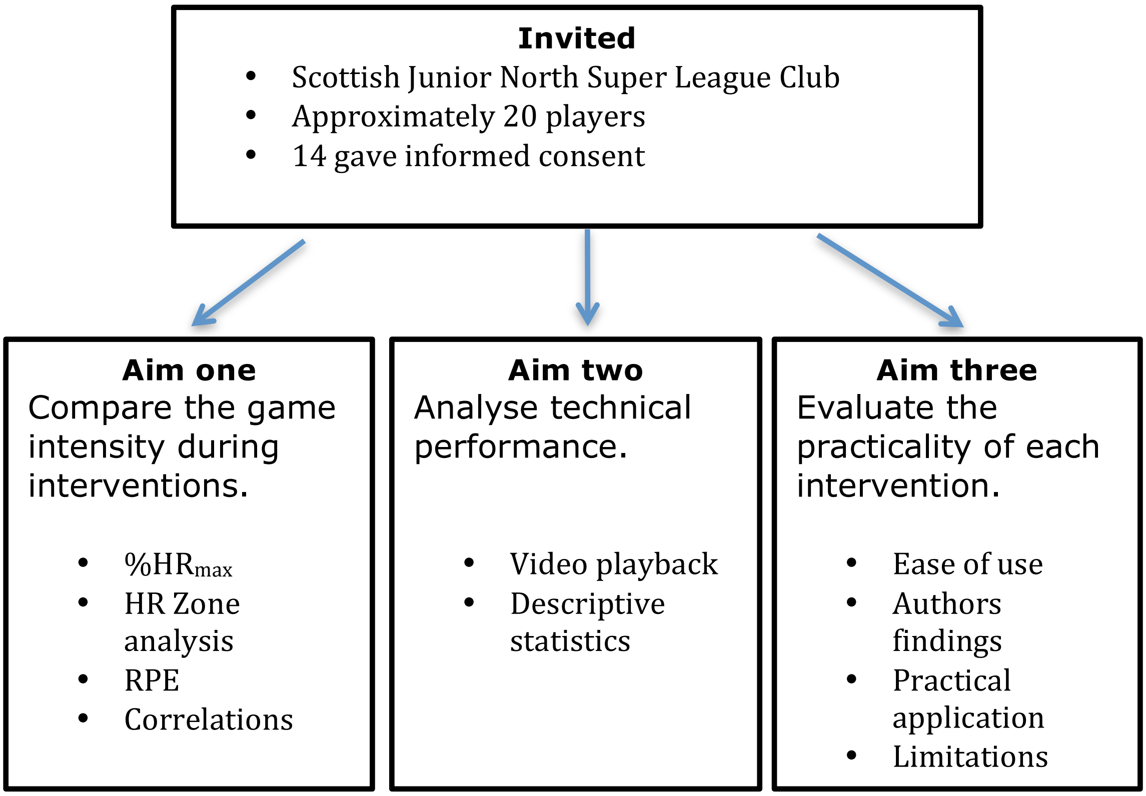

Figure 3.1: Schematic overview of the present study

3.3. Population and Sample

Fourteen (male) outfield semi-professional football players (mean ± *SD)* age = 25.9 ± 2.7 years, mass = 78.6 ± 4.7 kg, height = 181.7 ±4.5 cm, were recruited. The group consisted of 5 defenders (3 external and 2 central), 5 midfielders (2 external and 3 central) and 4 attackers in order to provide balance between the teams. The coaching staff defined player positions, based on where each player primarily plays in competition. Fourteen participants were selected to ensure that the required number of games could be completed in a short as possible time frame to minimise the likelihood of adaptations confounding the results, but also so that there was some consistency over the level of the sample. Ten players were selected at random and split into 2 teams with 4 reserves. The same teams were used wherever possible, but if injury or absence occurred between sessions, a player chosen at random from the reserve group replaced the injured/absent player. Each player received an information sheet (Appendix 1), which included detailed description about the aims and objectives of the study as well as the potential risks. Before testing commenced, each player also completed a PAR-Q (Appendix 2) to screen for any medical conditions or prescriptions, which may influence results. Participants were not considered for testing until they met the inclusion criteria of the PAR-Q and provided written informed consent (Appendix 3).

3.4. Experimental Approach to the Problem

Players began the study by performing a Yo-Yo-IR2 test in order to gain each individual's maximum HR. Separate training sessions were used for interventions to try and augment SSG intensity. A standard game used as a control and three interventions were derived from research based on the sections above; 1) Baseline (BL), 2) after game shuttle (AGS), 3) In-game sprint (IGS) and 4) Self-monitoring (SM). Each intervention was performed twice (see figure 3.2). The purpose of the interventions was to enhance the physiological stimulus without deteriorating the technical aspects in comparison to the control game. Each intervention (including the control) was conducted twice in order to access the consistency of results. Each session began with a standardised warm-up performed by the coach, followed by 3 x 6-minute SSG games with a 2-minute intermission between games (see figure 3.3). Game formats of 6 vs. 6 in each game were based on those by Little and Williams (2006) as they were demonstrated to be reliable. Testing intervention order was randomised to eliminate order effects. Intermission periods were not analysed. Water and/or sports drink consumption was ad libitum. Current research suggests that HR monitoring is valid for determining training intensity during SSGs and was used in conjunction with RPE for objective and subjective measures (Esposito et al. 2004).

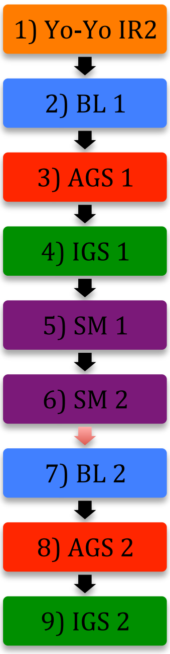

Figure 3.2: Overview of 9 testing sessions. Yo-Yo IR2 = intermittent recovery test level 2, BL = Baseline, AGS = After-game shuttle, IGS = In-game sprint and SM = Self-monitoring, 1 = test 1 and 2 = test 2.

Figure 3.3: Overview of each session. Int. = intermission.

3.5. Protocol

During the 2-weeks period prior to intervention testing, participants undertook the Yo-Yo IR2 test in order to establish individual maximal heart rate (Krustrup et al. 2003). The uppermost HR values recorded throughout the test equalled HR_{max} for each subject as used by Dellal et al. (2012). The participants were accustomed with the Yo-Yo IR2 procedure, therefore did not require further familiarisation. Players began on the start line and ran 20 m and back at a predetermined speed provided by the sound of audio cues (see figure 3.4). After the 40 m run (20 m x 2), players performed a slow recovery 5 m run and returned to the start line (10 m). The Yo-Yo IR2 has been shown to be a simple and valid method to obtain an individual's maximal HR (Bangsbo et al. 2008). Krustrup et al (2002) investigated the physiological response and reproducibility of the Yo-Yo intermittent recovery test and its application to soccer by testing 37 elite soccer players. Players from the Krustrup et al (2002) study performed between two and four Yo-Yo tests and were compared against incremental treadmill testing (ITT). Maximum HR, taken as the peak value obtained during testing, was regarded as similar between the IIT and Yo-Yo testing (189 ± 2 vs. 187 ± 2 bpm, respectively). The test-retest CV for the Yo-Yo test was 4.9%, which justifies the author's conclusion that the test has high reproducibility and sensitivity as long as protocols are consistent and strictly adhered to (Krustrup et al. 2004). The Yo-Yo test was also selected as it closely reflects the running patterns in soccer as well as taxing the relevant energy systems of the body (anaerobic and aerobic), meaning it is a specific test for the sport (Castagna et al. 2006).

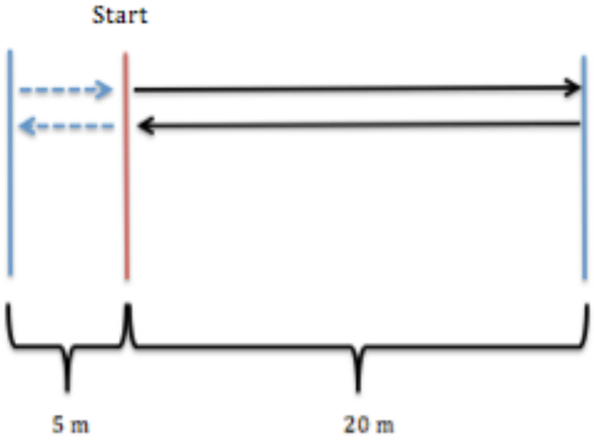

Figure 3.4: Schematic of the Yo-Yo intermittent recovery test

All testing sessions were carried out during the teams competitive playing season with respect to the teams training schedule, as no testing was carried out 48 hours before or after competition due to preparation and recovery strategies. Each session started at the same time of day in order to limit the effects of the circadian variations on the HR data (Drust et al. 2005). Testing was carried out at the beginning of the training session to limit effects from fatigue due to any prior exertions (Mohr, Krustrup and Bangsbo 2005). SSGs were played on the usual training ground of the team on an artificial 4th generation surface. Participants were asked to maintain their typical diet of high fluids and carbohydrates in order to reduce possible nutritional variables, however, a food diary was not kept, therefore nutritional intake was not analysed (Rampinini et al. 2006).

Participants performed one intervention per testing day for 8 sessions (4 interventions repeated twice) including a standardised 10-minute warm-up at the beginning, involving dynamic stretches. Sessions were performed 1-2 times per week, depending on the team’s fixtures and were performed between 3-7days apart. Players resumed normal training after testing, nullifying the need for a cool down as part of the study. Spare footballs surrounded the pitch for immediate restarts. Coaches were allowed to give feedback during games and intermissions, but were not permitted to stop sessions. The same coaches as well as the number of coaches (3) were consistent throughout.

3.5.1. Baseline

No conditions outwith standard soccer rules were placed on the games (i.e., players could take any number of touches and score from anywhere) and standard rules applying with throw-ins and corner kicks being taken. The offside rule did not apply due to the practicality of it not commonly being applied in training and lack of qualified officials. The other interventions followed the same game rules as BL but each had separate conditions or instructions according to the specific intervention.

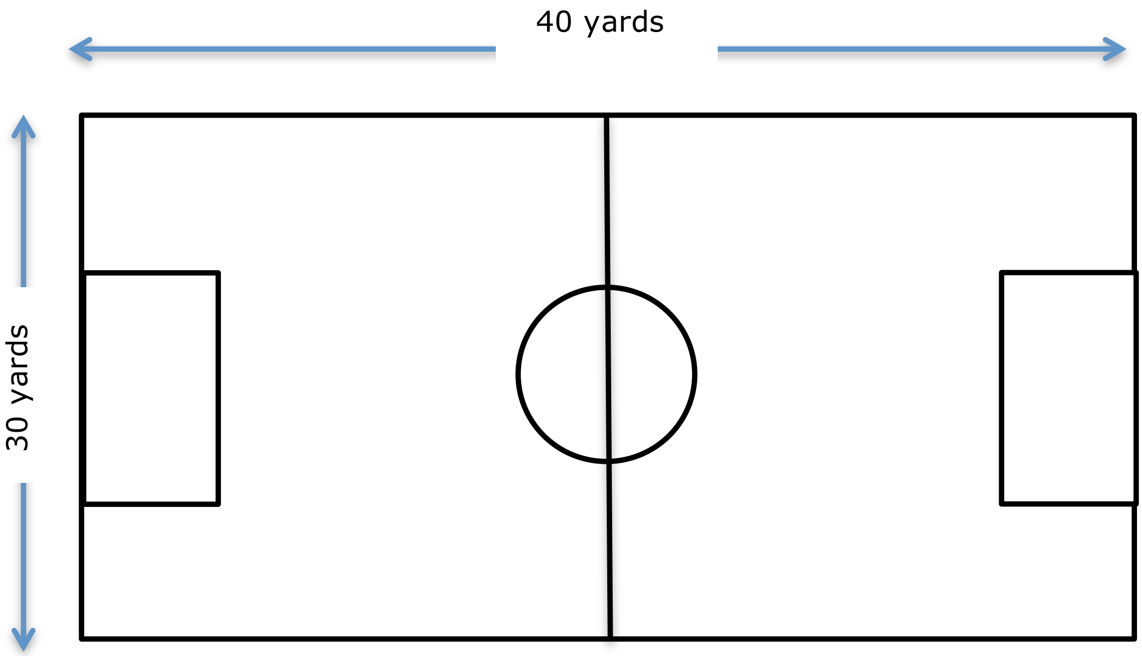

Figure 3.5: Schematic of pitch layout

3.5.2. After Game Sprint Intervention

The AGS intervention involved an analysis of average %HR$_{max}$ across each game and players performed a shuttle run during the intermission, if they had an average <90%HR$_{max}$. A laptop was setup beside the pitch, which received a transmission from the HR monitors and individual HR were displayed on the screen. Total shuttle run distance was chosen on the basis of pilot studies and research conducted by Boddington et al. (2004) where players performed a 20 yard shuttle of 5 yard separations (i.e., 5 yards sprint and returned to the start, 10 yards sprint and returning to the start, 15 yards sprint and returning to the start line and 20 yards sprint returning to the start)(see figure 3.5). Live streaming data was marked when the game began and then marked after 6-minutes and the software calculated then displayed each participant's average %HR$_{max}$. This process was repeated for each game.

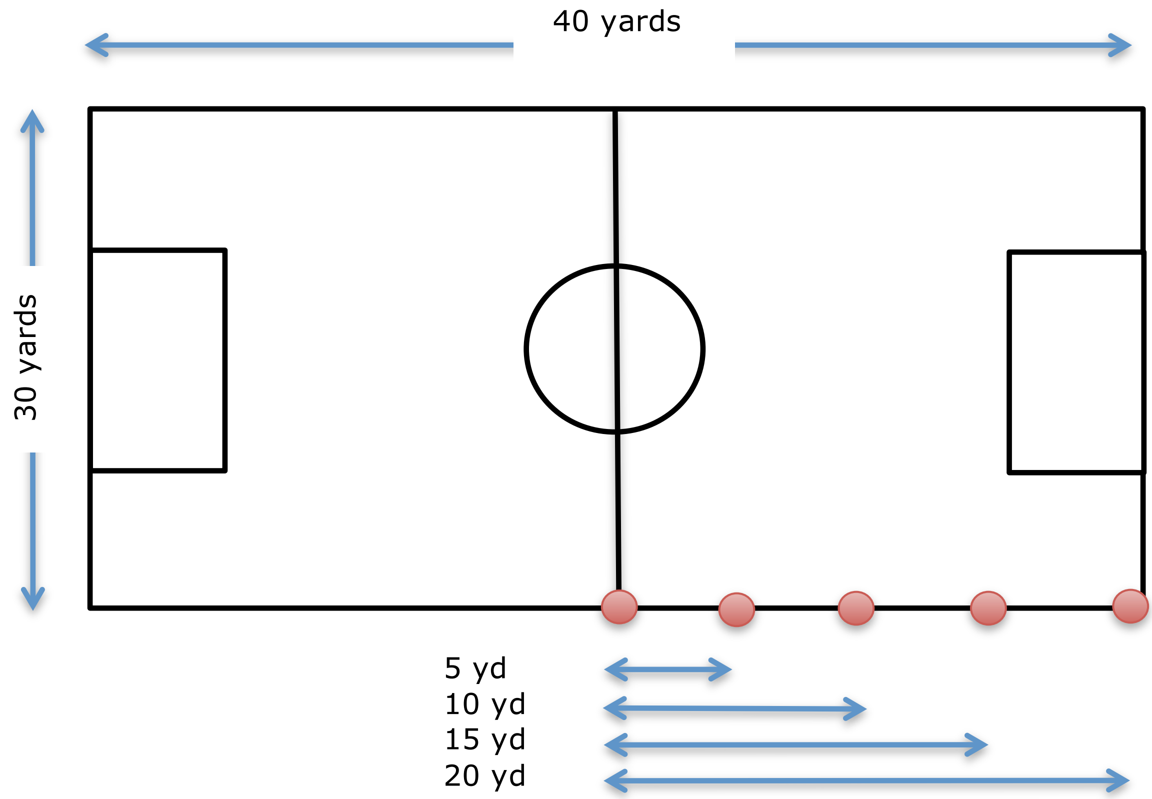

Figure 3.6: Schematic of AGS layout. Red dots represent specific cone placement for the shuttle run.

3.5.3. In-Game Sprint Intervention

The IGS intervention used live-streaming analysis from each game to determine which two players (one from each team) had the lowest $\%HR_{max}$. The two players with the lowest $\%HR_{max}$ had to perform a sprint around a marker, set 10 yards behind their respective (defending) goal (see figure 3.6). Players did not have to perform the sprint if their HR = $>90\%HR_{max}$ allowing for possible situations where no player or only one player may have to perform the sprint. Sprints were conducted every 30 s (excluding the first 30s of each game allowing players to raise their HR). Average $\%HR_{max}$ was taken every 30s where the player from each team displaying the lowest $\%HR_{max}$ performed a maximal sprint. The researcher monitored this and the coach gave verbal encouragement.

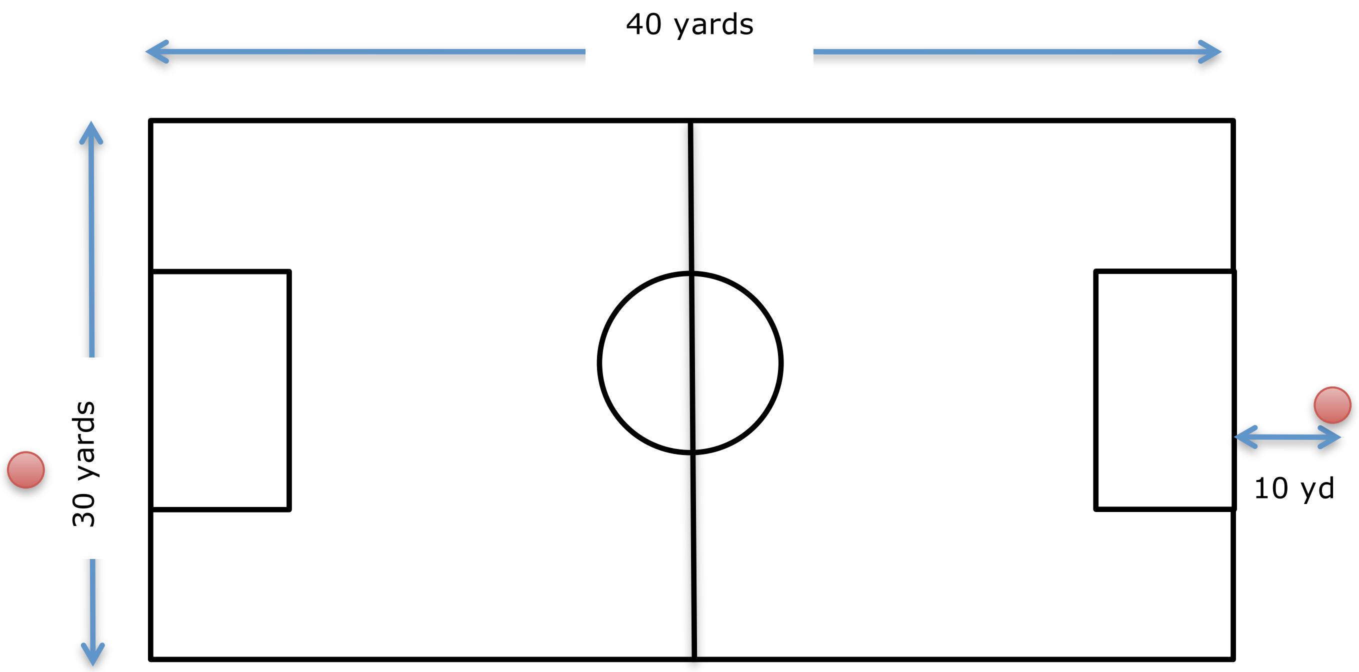

Figure 3.7: Overview of IGS layout. Red dots represent specific cone placement, which selected players had to sprint around

3.5.4 Self Monitoring Intervention.

The SM intervention involved players being educated so they were aware of their maximum HR as well as the important to maintain a HR that equalled 90% of their maximum. Players wore a polar wristwatch that displayed their own HR via a transmission from an individually worn chest strap. Players were instructed to monitor their wristwatch display during natural breaks in the game (i.e., throw-ins, corner kicks, goals and slow passages of play). Checking the watch during natural breaks may lower the distraction of the player and reduce the chance of SM being detrimental to technical aspects of the game.

3.6. Game Format Rationale

The game format was derived from a review of the literature, in which SSGs with more players typically elicited lower HR ranges (i.e., 3 vs. 3 and 4 vs. 4 = 87 – 91%$_{HRmax}$ compared to 6 vs. 6 and 7 vs. 7 = 70 – 87%HR$_{max}$), therefore larger numerical player based games may require greater intervention in order to evoke a higher game intensity (Little and Williams 2007, Rampinini et al. 2007, Katis and Kellis 2009, Rodríguez-Marroyo, Pernía and Villa 2009). Game sizes of 6 vs. 6 was ultimately decided over 7 vs. 7 based on the greater number format requiring a pool of players beyond the number of players available in the testing squad. For example, 7 vs. 7 would require 14 players playing with an additional pool of players to replace injured or absentees, which could substantially increase total testing duration. A short total testing duration typically involves lower fluctuations for intra-player physical capacity through adaptations or deterioration (Bangsbo 2008). Several pitch sizes were tested during the piloting phase from 60 x 40 to 30 x 40 yards based on pitch sizes of others using 6 vs. 6 (Katis and Kellis 2009, Little and Williams 2007). From pilot testing, coach feedback and the authors experience, 30 x 40 yards was used as larger pitch dimensions appeared to have a detrimental impact on tactical shape and team formation that became unrealistic and less soccer specific, particularly when players showed different fatigue rates. Reduced pitch dimensions (30 x 40 yards) appeared to have a balance of sufficient area per person but adequately confined to engage aspects of soccer such as reactions and the ability to perform under player pressure.

Only two teams were decided upon as anymore competing would considerably modify a simple work:rest ratio of a two team format where the recovery duration is not stipulated by the playing time of the other teams. An intermission of 2-minutes creates a 3:1 ratio and permits sufficient time for individual data to be collected. This is consistent with other studies (Dellal et al. 2008). Goal dimensions were 12 feet wide by 6 feet high and goalkeepers were excluded in the physiological and perceptual analysis due to the vast difference in positional roles but participated in the games and technical analysis. The football clubs physiotherapists determined injury status and only players given permission for full training were considered. Individuals were excluded from testing sessions, which were regarded as injured, by the physiotherapist. Players on medication that could influence HR were excluded from the investigation, as this would have given a false representative of the readings throughout testing e.g., Beta-blockers lower the heart rate and are commonly prescribed for high blood pressure and anxiety. Conversely, medication such as antidepressants can increase the HR, which would again alter the true readings throughout (Suni et al 1998 and Suni et al 1998(b)). The PAR-Q screened for this.

3.7. Dependent Variables

3.7.1. Rate of Perceived Exertion

The 10-point rating scale proposed by Foster et al. (2001) was selected to measure RPE, which determines internal intensity (how difficult the players found the session) and exercise load. This method appears more frequently in the literature in comparison to the 15-point Borg scale and the category ratio scale may make it easier to understand (i.e., 4 = twice as hard as 2)(Coutts et al. 2009, Impellizzeri et al. 2005). Players stated their mean RPE rating, which was recorded at the immediate end of every SSG. All participants were familiarized with the scale before testing.

3.7.2. Heart Rate

HR was measured using short-range telemetry Polar Team^2 Pro System (Polar Electro OY, Kempele, Finland) set to record every second. Live streaming of HR information reduced recording error as any disconnections/transmission problems were detected and solved immediately. After each training session, HR data were transferred to a password protected laptop computer, from which Polar software was used to analyse and export data to Excel XP (Microsoft Corporation, USA). Average percentage of maximum heart rate (%HRmax) was calculated for each person by expressing the average HR across each game as a percentage of the individuals HRmax (%HRmax = (SSGs mean HR/HRmax) x 100). For the analysis, 5 HR zones were classified for each individual; 50-60%HR_{max} = zone 1, 60-70% = zone 3, 70-80%HR_{ma}x = zone 3, 80-90%HR_{max} = zone 4 and >90-100%HR_{max} = zone 5 predetermined by the HR software and used in previous studies (see table 3.1) (Foster et al. 2001, Quinn et al. 2010). These zone percentages are separated by even increments and offer a diverse range of percentages. Soccer displays intermittent intensity patterns of low and high periods, which may require a broader range compared to studies investigating continuous exercises (Foster et al. 2001). The time spent in each zone was used to calculate percentage of time spent in each zone to display a clear assessment of results (Quinn et al. 2010).

Table 3.1: Summary of heart rate analysis zones used to quantify internal (HR)

HR zone	**%HR$_{max}$**
Zone 1	50-60
Zone 2	60-70
Zone 3	70-80
Zone 4	80-90
Zone 5	90-100

Reference: (Foster et al. 2001, Quinn et al. 2010)

3.7.3. Technical Analysis

Two fixed digital video cameras (Panosonic, SDR-S15, Osaka, Japan) were positioned around the SSGs area (one positioned at the midway point to the side of the pitch, with the other behind one of the goals) at a distance of approximately 20 m and elevation of 5 m utilizing the team's stadium seating in order to access the player's technical performance. The hand notational system similar to that previously employed by Owen et al. (2004) was used to access 13 discrete gameplay actions summarised in table 3.2. These actions were ultimately decided upon as to give information from when a player receives the ball until the other team retain possession as well as the events in-between. Total frequencies aid in accessing game tempo while percentage success is associated with skill level (Owen et al. 2014, Dellal et al. 2011b)

Table 3.2: Summary of the technical variables recorded

Technical Action	**Definition**
Total Passes	Player in possession sends the ball to a teammate (e.g. using the foot, thigh or chest; using various techniques such as ground, lofted, chip, flick or volley; over short or long distances).
% Successful Passes	The % of passes that reached a player of the same team.
% Forward passes	The % of passes that were played towards the opposition goal
% Forward pass success	The % of passes that reached a player of the same team that was played towards the opposition goal.
Ball possessions	The number of times ball possession is turned over between the two teams.
Passes Per Possession	The number of passes completed per possession.
Dribbles	Player in possession, with ball at feet, runs with ball, beats or attempts to beat an opponent.
Tackles	An action intending to dispossess an opponent who is in possession of the ball.
Shots	Player in possession meaningfully sends the ball towards the goal in an attempt to score.
% Shots on Target	The % of shots that are within the frame of the goalposts.
Goals	The number of times the ball crosses the goal line, between the goal posts without a prior infringement.
Lost Balls	The number of times the ball exits the pitch parameter.
Interceptions	The number of times a player contacts or stops the ball from reaching its intended target.

3.8. Data Analysis

The data are presented as means ± standard deviations (SD). Consistency of each dependent measure was calculated by testing for differences between testing sessions 1 and 2. Scores were calculated for mean HR (as %$HR_{max)}$, RPE and technical data. Factorial ANOVA's were used to analyse the data (mixed design, within factors, 2x4x3). Where 2 levels for the number of tests (each intervention repeated) 4 levels for the number of interventions and 3 levels for the number of games played in each session. Technical performance data were expressed as descriptive statistics using means and percentages. The normality of the data was verified with Shapiro-Wilks tests in order for a parametric statistical test to be used. Where significant main effects were obtained, post hoc tests were used to identify where differences lay. Effect sizes were quantified according to the benchmarks outlined by Cohen (1969). Partial eta squared (η_p^2) benchmarks for small, medium, and large effect sizes equal 0.0099, 0.0588, and 0.1379, respectively. Correlations were determined using Spearman's Rho and the categorisation can be seen in table 3.3. All statistical analysis was performed using SPSS Statistical Analysis Software for Windows (SPSS, version 17.0, Chicago, USA). The level of statistical significance was set at $p < 0.05$.

Table 3.3: Summary of Correlation strengths categorisation. (Dancey and Reidy 2004):

Value of the Correlation Coefficient	Strength of Correlation
1	Perfect
0.7 - 0.9	Strong
0.4 - 0.6	Moderate
0.1 - 0.3	Weak
0	Zero

Chapter four: Results

4.1. Consistency between Repeated Tests

Results were averaged for each game but not across sessions (i.e., each intervention resulted in 6 average HR values, games 1, 2 and 3 from test session 1 and games 1, 2 and 3 from test session 2). The responses recorded for the initial set of tests did not differ significantly from the second set of tests for *Average* %HR$_{max}$ measured across each game *[F*(1,216) = 2.87, *p* = 0.09*,* $\eta_p^2 =$ 0.01], the mean percentage of time spent in separate HR zones [*F* (1,216), *p* = 0.19 – 0.78, $0.001 < \eta_p^2 < 0.008$] and RPE measured at the end of the game [*F*(1,216) = 0.06, *p* = 0.80*,* η_p^2 <0.001]. These results provide some evidence of consistency between test 1 and test 2 across these variables, therefore only results from the first session will be analysed.

4.2. Heart Rate Data

4.2.1. Average %HRmax measured across each game

Mean HR data across each game for individuals were compiled to form the overall mean for each intervention. There was a significant main effect for intervention type for %HR$_{max}$ [*F*(3,108) = 11.47, *p* <0.001*,* $\eta_p^2 = 0.24$)]. A Bonferroni post-hoc test revealed that mean %HR$_{max}$ across all games was significantly lower in BL (86.6 ± 4.6%) compared to all others, IGS (89.6 ±3.2), SM (89.91 ± 3.7) and AGS (90.1 ± 3.3). No interaction effects (game × intervention) were discovered [*F*(3,108) = 0.79, *p* = 0.59*,* $\eta_p^2 = 0.04$], whereas a significant effect for game number was found [*F*(2,108) = 4.73, *p* = 0.01*,* $\eta_p^2 = 0.08$](see figure 4.1). The post-hoc also revealed game 3 to be significantly greater (*p* = 0.01) than game 1. No other significance was observed between games.

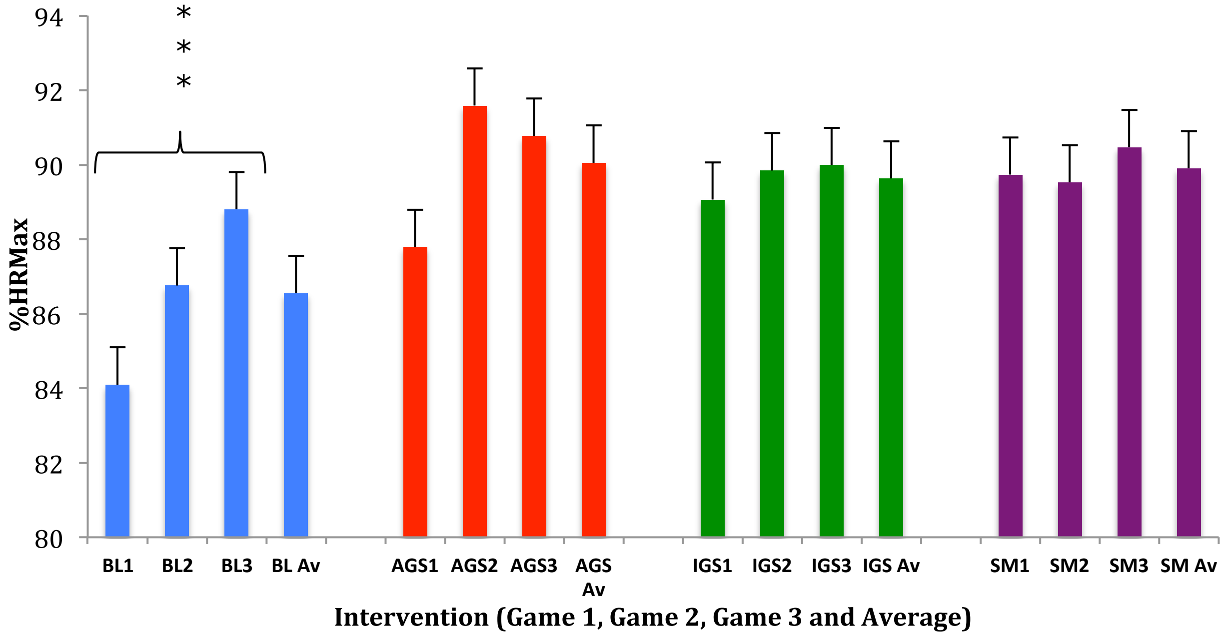

Figure 4.1: The average heart rate responses measured as %HR$_{max}$ for all players across each game (3x6min) as well as average across games 1, 2 and 3 BL = Baseline, AGS = After-game shuttle, IGS = In-game sprint and SM = Self-monitoring.

*** = Significant difference from all interventions. (p <0.001)

Generally, %HR$_{max}$ increased 1.2 ± 1.6% on average between consecutive games for all interventions. BL displayed moderately consistent linear increases of 2.7% (game 1 - game 2) and 2.0% (game 2 – game 3). AGS intervention exhibited both the greatest increase and decrease for all interventions between 2 successive games 3.8% (game 1 – game 2) and -0.8% (game 2 – game 3). IGS intervention showed a below average increase amongst both sets of games 0.8% (game 1-2) and 0.2% (game 2-3), while intervention SM had an initial decrease of -0.2% (game 1 – game 2) before increasing between the later games 0.9% (game 2- game 3).

Similar trends can be seen between interventions, with %HR$_{max}$ being higher in games 2 and 3 in comparison to game 1, with the exception of the SM group, where a slight decrease in intensity between games 1 and 2 (89.7 ± 3.3 to 89.5 ± 4.2%, respectively) can be seen. Game 3 witnessed the greatest mean %HR$_{max}$ for 3 out of 4 interventions, AGS witnessing a different trend where the greatest mean was observed in game 2. BL intervention Game 1 resulted in an average 84.1 ± 5.6%HR_{max}, where as interventions AGS, IGS and SM recorded respective mean values of 3.7, 5.0 and 5.6% greater. Game 2 witnessed similar increases of 4.8, 3.1 and 2.8% for interventions AGS, IGS and SM, respectively, against a BL value of 86.8 ± 4.9%HR_{max}. Although Game 3 observed increases for interventions AGS (2.0%), IGS (1.2%) and SM (1.7%) in comparison to BL 88.8 ± 4.22%HR_{max}, the size of the increases were relatively smaller in relation to those seen between games 1 and 2.

4.2.2. Percentage of Time Spent in Separate Heart Rate Zones

On average, 0.8 ± 1.9% of the total playing time of SSGs was spent in HR zone 50-59% (see figure 4.2). There was a statistically significant main effect for intervention type ($p < 0.001$) (see table 4.1). More time was spent in the HR range 50-59% for BL in comparison to all other interventions ($p < 0.05$). HR Zone 50-59% witnessed a game effect [$F(2, 108) = 4.1$, $p = 0.02$, $\eta_p^2 = 0.04$] but no interaction effects were observed.

Table 4.1: Statistical data determined from a factorial ANOVA for each separate HR zone for the main effect of intervention.

HR Zone	***F* (3,108)**	***p***	η_p^2
50-59%	7.71	<0.001***	0.10
60-69%	16.34	<0.001***	0.19
70-79%	4.89	0.003**	0.06
80-89%	3.66	0.01*	0.05
90-100%	2.99	0.03*	0.04

* Significant difference ($p < 0.05$)

** Significant difference ($p < 0.01$)

*** Significant difference ($p < 0.001$)

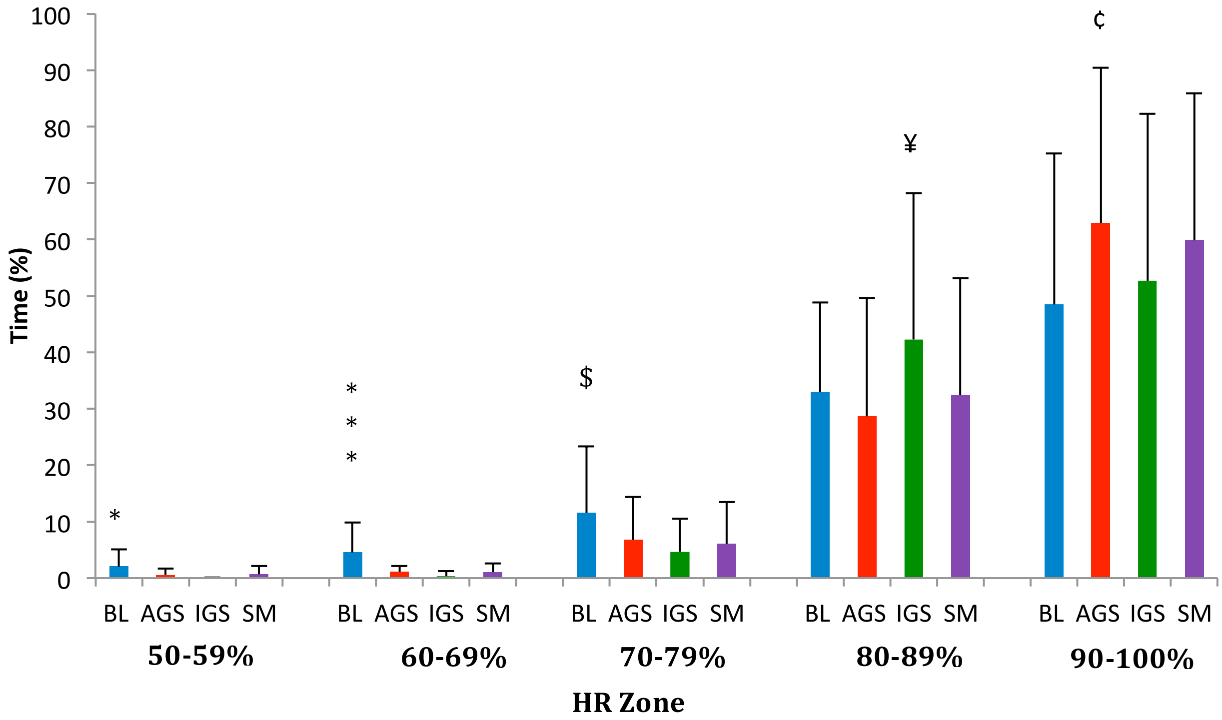

Figure 4.2: The analysis of intervention type and mean percentage of time spent in separate heart rate zones for each intervention. BL = Baseline, AGS = After-game shuttle, IGS = In-game sprint and SM = Self-monitoring.

* Significant difference from all interventions for HR zone 50-59%(*p* < 0.05)

*** Significant difference from all interventions for HR zone 60 -69% (*p* < 0.001)

$ Significant difference from IGS and SM interventions for HR zone 70-79% (*p* < 0.05)

¥ Significant difference from AGS intervention for HR zone 80-89% (*p* < 0.05)

¢ Significant difference from BL intervention for HR zone 90-100% (*p* < 0.05)

A total playing time of 1.8 ± 1.7% was spent, on average, in HR zone 60-69% while playing SSGs. There was a statistically significant main effect for intervention type for HR Zone 60-69% (*p* < 0.001). More time was spent in the range 60-69% for BL in comparison to all other interventions (*p* < 0.001). No game or interaction effects were observed.

HR zone 70-79% observed an average playing time of 7.3 ± 10.7%. There was a statistically significant main effect for intervention type for Zone 70-79% (*p* = 0.003). More percentage of time was spent in the HR range 70-79% for BL compared to all other interventions, significantly greater than two interventions

($p < 0.05$ IGS and SM interventions). No game or interaction effects were observed.

Players were exposed on average to 34.1 ± 12.3% of playing time in HR zone 80-89% for all interventions. There was a statistically significant main effect for intervention type for Zone 80-89% ($p = 0.01$). The intervention IGS recorded the greatest mean value for HR zone 80-89%, while AGS intervention recorded the lowest. A significant difference was only established between IGS and AGS interventions ($p < 0.05$). No significant game effects were discovered, but there was a significant interaction effect $F(3, 108) = 0.3$, $p = 0.02$, $\eta_p^2 = 0.008$.

Around half (56.0 ± 30.0%) of the average playing time was spent above 90%HR_{max}. There was a statistically significant main effect for intervention type for Zone 90-100% ($p = 0.03$). The intervention AGS recorded the greatest mean value for HR zone 90-100%, while BL recorded the lowest. A significant difference was only established between AGS and BL interventions ($p < 0.05$). There were no significant game effects revealed, but a significant interaction effect $F(3, 108) = 0.55$, $p = 0.008$, $\eta_p^2 = 0.02$ were established.

4.3. Perceptual responses

The overall mean RPE score was 6.6 ± 0.4, which suggested that player's comprehensive perception of a session was considered to be between hard and very hard (see figure 4.3). There was a statistically significant main effect for intervention type, [$F(3,108) = 7.29$, $p < 0.001$, $\eta_p^2 = 0.32$)]. A post-hoc analysis test revealed that mean RPE values across all games was significantly lower in BL displaying the lowest recorded mean 6.2 ± 0.68 followed by AGS 6.73 ± 0.45, IGS 6.73 ± 0.69 and SM 6.90 ± 0.50.

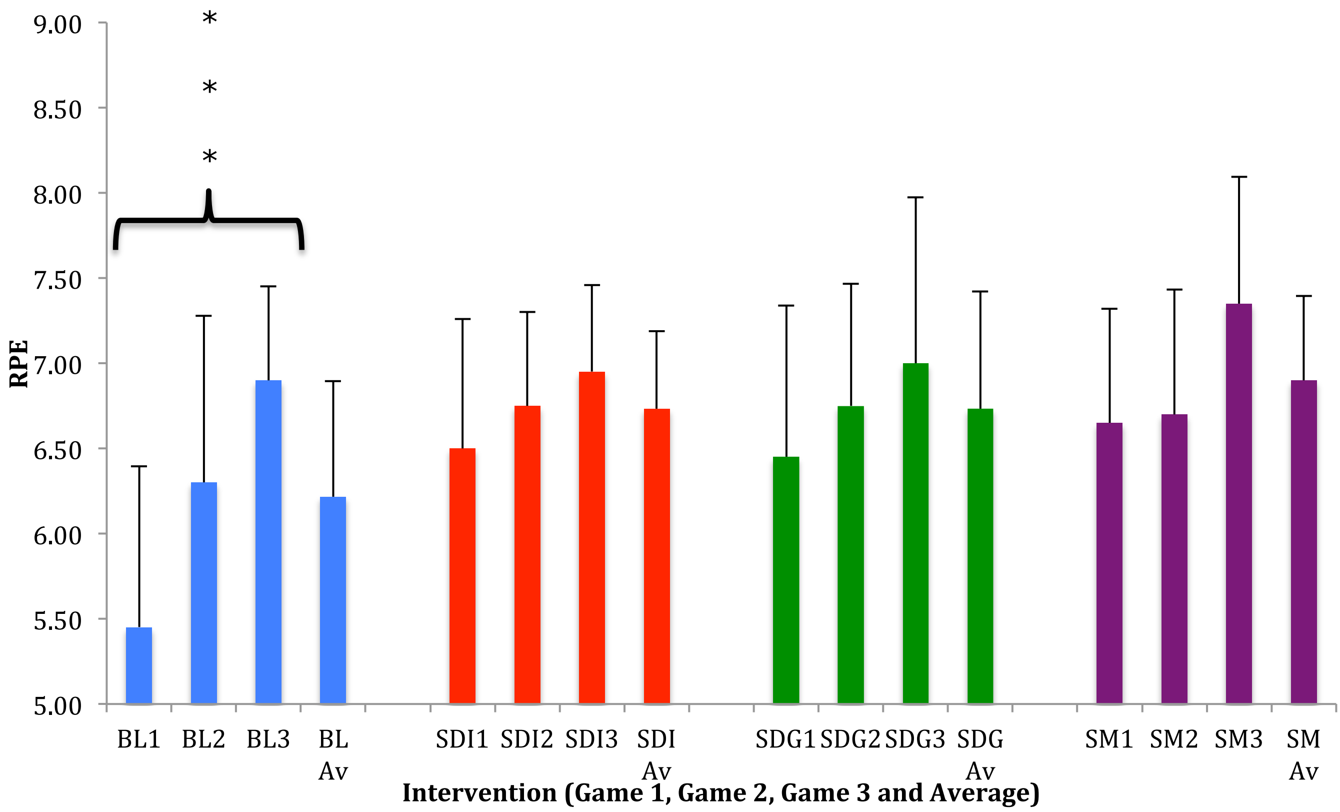

Figure 4.3: The average perceptual responses measured using RPE for all players across games 1, 2 and 3 as well as average across all games (Av). BL = Baseline, AGS = After-game shuttle, IGS = In-game sprint and SM = Self-monitoring.

*** = Significant difference from all interventions (*P* < 0.001).

Analysis revealed the number of games played to have a significant effect [*F*(2,108) = 23.6, *p* = <0.001, $\eta_p^2 = 0.12$]. Additionally, a significant interaction effect (game × intervention) was established [*F*(3,108) = 2.33, *p* = 0.04, $\eta_p^2 =$ 0.12]. Interventions displayed similar trends to that of %HR$_{max}$ being higher in games 2 and 3 in comparison to game 1; conversely, for all interventions RPE increased as the number of games played increased. Game 3 recorded significantly greater (*p* = < 0.001) RPE values compared to games 1 and 2. No other significant values were observed. BL, AGS and IGS all displayed comparable trends with gradual, linear increases in mean RPE scores across each game with values ranging from 0.2 – 0.8. SM intervention witnessed the smallest RPE increase between games 1 and 2 (0.05), with a larger increase between games 2 and 3 (0.65). The largest increase occurred during BL intervention between game 1 and game 2 (0.85).

4.4. Relationships between %HRmax, Perceptual Load and Endurance Capacity

Individual RPE values were plotted against the respective %HR$_{max}$ values across all interventions to access relationship. A positive linear trend can be seen (see figure 4.4).

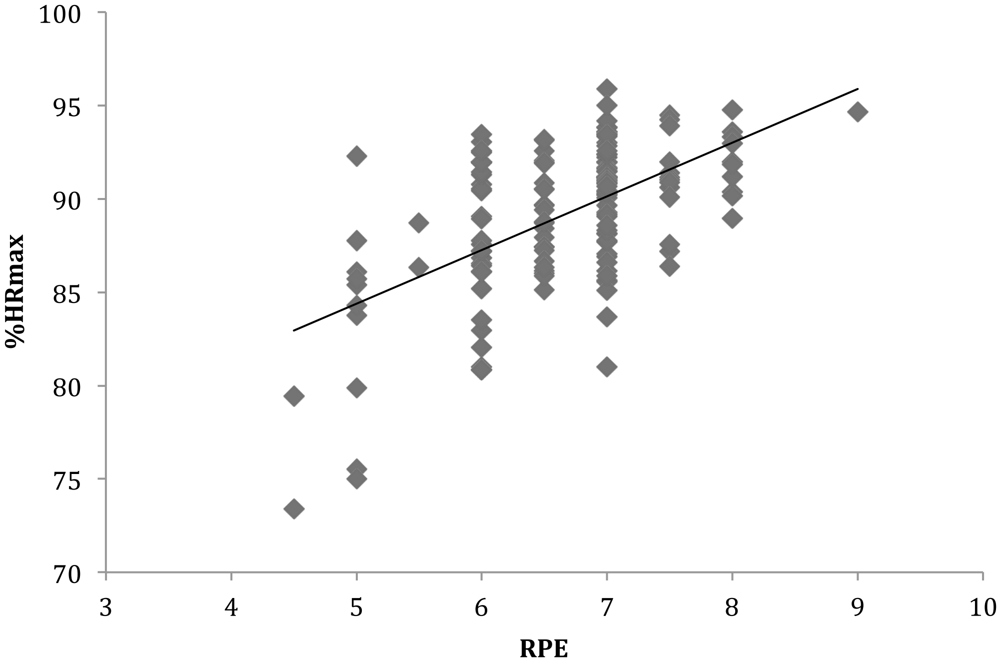

Figure 4.4: Relationship between individual RPE and respective %HR$_{max}$ values across all results (n = 150).

To explore the relationship between player's endurance capacity and the internal load as well as perceptual load, the result of each player's Yo-Yo IR2 test was compared against their relevant mean %HR$_{max}$ (see table 4.2) and RPE scores (see table 4.3). Total distance covered during the Yo-Yo IR2 for each player was compared against the dependant variables using Spearman's Rho correlation to assess the strength of correlations. The majority of results produced negative correlations between total distance covered during the Yo-Yo IR2 test and mean %HR$_{max}$ values.

Table 4.2: Correlations between total distance covered during Yo-Yo IR2 test and mean %HR_{max} for game 1, game 2 game 3 and average across all 3 games (n = 10).

	Game 1	**Game 2**	**Game 3**	**Average**
BL	-0.11	-0.36	-0.28	-0.25
p	0.76	0.30	0.44	0.49
AGS	-0.27	-0.50	-0.35	-0.41
p	0.46	0.14	0.32	0.24
IGS	-0.34	-0.11	-0.13	-0.20
p	0.38	0.76	0.73	0.57
SM	0.39	0.05	-0.06	0.09
p	0.27	0.89	0.86	0.81

BL = Baseline, AGS = After-game shuttle, IGS = In-game sprint and SM = Self-monitoring.

Table 4.3: Correlations between total distances covered during Yo-Yo IR2 test and mean RPE for game 1, game 2, game 3 and average across all 3 games (n = 10).

	Game 1	**Game 2**	**Game 3**	**Average**
BL	-0.05	-0.33	-0.32	-0.26
p	0.89	0.35	0.38	0.47
AGS	-0.34	-0.26	-0.74*	-0.64*
p	0.34	0.47	0.02	0.04
IGS	-0.62	-0.09	0.17	-0.18
P	0.05	0.80	0.63	0.62
SM	0.10	-0.11	-0.33	-0.17
p	0.78	0.76	0.36	0.65

BL = Baseline, AGS = After-game shuttle, IGS = In-game sprint and SM = Self-monitoring.

* Significant difference ($p < 0.05$)

No significant correlations were established between average %HR_{max} across all games and Yo-Yo IR2 test. All games recorded negative correlations with the exception of games 1 and 2 for SM intervention. Negative correlations were recorded between total distance covered during the Yo-Yo IR2 test and mean RPE values for nearly all interventions and games with the exception of game 1 for the SM intervention. The correlation between total distance covered during the Yo-Yo IR2 test and mean RPE value for IGS game 3 (6.8 ± 1.2) resulted in the only positive correlation. No significant correlations were observed for RPE ($P > 0.05$).

4.5. Frequency of Sprints

Interventions AGS and IGS required players to perform a sprint at particular periods of testing if they were below 90%HR_{max}. Tables below (4.4 and 4.5) display data for individuals' game rank in relation to total distance covered during the Yo-Yo IR2.

Table 4.4: The number of shuttle sprints performed by each player across game 1, game 2, game 3 and total runs for AGS. Ranked in accordance of distance covered during the Yo-Yo IR2 (1 being the greatest distance covered and 10 the least).

Game Rank	AGS1	AGS2	AGS3	AGS Total
1	1	1	1	3
2	1	1	1	3
3	0	0	0	0
4	1	0	1	2
5	0	0	1	1
6	0	0	0	0
7	1	0	0	1
8	1	1	0	2
9	1	0	0	1
10	1	0	0	1

Table 4.5: The number of sprints performed by each player across game 1, game 2, game 3 and total runs for IGS. Ranked in accordance of distance covered during the Yo-Yo IR2 (1 being the greatest distance covered and 10 the least).

Game Rank	IGS1	IGS2	IGS3	IGS Total
1	4	3	4	11
2	0	0	0	0
3	0	0	1	1
4	0	0	0	0
5	1	1	0	2
6	1	1	2	4
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	2	2	1	5

It is apparent from the result that the highest ranked players typically performed the greatest number of sprints for both interventions. No other distinguishable pattern can be determined from AGS intervention. IGS intervention generally had a notable difference; players' who recorded the lowest rank for Yo-Yo IR2 also recorded the second highest or second equal highest number of sprints. Player patterns can also be seen where individuals either performed the maximum number of sprints, minimum number or categorised in-between.

4.6. Technical analysis

Video replay analysis revealed many of the technical data variables for interventions to be similar to BL values. AGS, IGS and SM interventions observed relatively slight differences compared to BL for total passes per game of 1.0, 2.0 and 6.9% as well as comparable percentage differences for successful passes -0.6, -0.4 and 2.7%, respectively (see table 4.6). Percentage of forward passes recorded a notable increase for IGS intervention resulting in 11.8% more passes towards the opponents' goal in comparison to BL. All interventions recorded a greater number of dribbles over BL values (9.4 – 10.6%) as well as

2-3 less tackles per game on average. No other variables produced substantial differences between any interventions, as results are comparatively consistent.

Table 4.6: Technical variables per game associated with 6 vs. 6 SSGs monitored during training in male soccer players (means ± SD. n = 10).

	BL	AGS	IGS	SM
Total Passes	99.0 ± 9.6	100.0±12.0	101.0±17.1	105.8±10.9
%Successful Passes	86.1 ± 5.0	85.5 ± 4.4	85.7 ± 2.6	88.8 ± 5.4
%Forward passes	57.0 ± 5.2	58.9 ± 6.8	68.8 ± 4.8	62.2 ± 4.5
%Forward pass success	87.0 ± 2.4	83.9 ± 5.4	86.4 ± 3.7	85.2 ± 5.6
Ball possessions	27.2 ± 3.4	26.5 ± 3.3	29.2 ± 3.2	26.0 ± 3.1
Passes Per Possession	3.9 ± 0.7	3.8 ± 0.8	3.6 ± 0.6	4.2 ± 0.8
Dribbles	23.5 ± 3.9	26.0 ± 5.6	26.0 ± 3.2	25.7 ± 3.3
Tackles	6.3 ± 2.5	4.7 ± 1.0	4.5 ± 2.1	3.7 ± 1.8
Shots	11.2 ± 2.3	10.5 ± 3.2	13.5 ± 3.3	12.2 ± 3.9
% Shots on Target	58.3± 14.4	62.4 ± 13.8	63.7±19.8	63.4±23.0
Goals	3.7 ± 1.9	2.3 ± 1.0	3.8 ± 1.8	3.3 ± 1.4
Lost Balls	10.5 ± 2.2	9.8 ± 1.7	11.5 ± 2.7	10.2 ± 2.1
Interceptions	11.5 ± 2.7	14.7 ± 2.3	14.2 ± 4.2	14.3 ± 4.4

BL = Baseline, AGS = After-game shuttle, IGS = In-game sprint and SM = Self-monitoring.

Chapter five: Discussion

This thesis presented data analysing the internal load, perception of load and technical output experienced by means of HRM, RPE and technical analysis for semi-professional soccer players during different interventions designed to increase SSG intensity. This section will present a detailed discussion of the results and explore possible reasoning for such findings within the current study. The initial section will address the aims of the investigation followed by a comparison of interventions across all games before an analysis of individual games. A separate examination of the interventions will be carried out to fully explore the results established to gain a comprehensive understanding of complex interactions. The chapter will close with recommendations and further advices applicable to this area of research.

5.1. Addressing the Aims of the Present Study

The primary aim of the current study was to determine if simple and practical strategies could be used to augment the internal training load through the use of interventions during 6 vs. 6 soccer games. The results recorded from the present study demonstrate that, within the restrictions of the experimental design, game intensity can be increased by utilising interventions during SSGs. Each intervention prescribed, resulted in a significant increase in the internal training load compared to BL, yet no significant differences were established between interventions (see figure 4.1). RPE values, indicating the player's perceptions of the overall load, typically reflected the HR results, establishing a significant main effect compared to BL, but no significant differences between interventions (see figure 4.3). Correlations between RPE and Yo-Yo IR2 test ranged from weak to strong and the majority of correlations demonstrated negative relationships (see table 4.3). The correlations indicate that players with the greatest physical capacities recorded the lowest mean %HR_{max} and perceived the games to be less strenuous.

A secondary aim of the present study was to assess the technical actions of each intervention in order for coaches to be aware of any implications on overall gameplay. A successful intervention should be able to increase the physiological measures while not being counterintuitive towards technical gameplay by causing a considerable decrease in actions. If considerable decreases were established, coaches may favour drills that specifically target technical, fitness and tactical components of soccer separately to ensure each are being trained to a high standard. The video replay analysis for this study revealed virtually all of the technical data variables for interventions to be comparable to BL values (see table 4.6). The only substantial difference occurred during the IGS intervention resulting in 11.8% more passes towards the opponent's goal in comparison to BL. A possible explanation for this is the IGS intervention reduced player numbers and at times produced moments of unbalanced teams, created where only one player across both teams were below 90%HR_{max} resulting in a temporary 6 vs. 5 situations. Teams are frequently trained to counter attack and exploit numerical advantages, which gives logical reasoning to the increased number of forward passes (Dellal et al. 2010). One team having a man advantage for a short time frame can increase urgency to attack the opponent’s goal by passing in a direct manner compared to patient build up play (Hill-Haas et al. 2010). The logic is a result of the probability of scoring decreasing as the duration of a possession cycle increases, largely due to the opposition having sufficient time to regain tactical defensive formation (Vogelbein et al. 2014, Charalampos et al. 2013, Almeida et al. 2014).

The final aim of the study was to access the practicality of each intervention. The study did not quantify practicality, but insight is given through the author’s experiences obtained during the study. In order for an intervention to be worthwhile, its must be relatively easy to use and have no detrimental effects to the overall game actions. The AGS intervention was relatively simple to set up and implement, as players maximum HR values could be pre-applied to the computer for live monitoring. This initial input meant minimum time was required maintaining the data feedback, before inspecting which players were below 90%HR_{max}. In contrast, the IGS intervention required continual monitoring of data, with markers placed using the software every 30 s to re-calculate the average intensity. The time and attention required for the IGS intervention could be seen as a limitation as it required more than one person to effectively perform. However, technological HR systems already exist that permit the use of software that can be set to automatically sound an alarm if an individual's average HR value drops below set a level. Consequently, there may need to be a sufficient number of coaches present to oversee the procedure for the IGS intervention to be practically applicable to training. Moreover, it would be recommended to use technology that supports individual target setting. This technology would hugely improve the practicality of the intervention, freeing up the user to closely monitor the SSG.

The SM intervention was practically the easiest, involving the least attention from the administrator. The only question over the SM intervention use would be long-term implications. It is unclear whether the main effect over BL intervention is exclusively because of the self-regulation or if any other mechanisms are influencing results. It is plausible that knowledge of performance increases effort levels. While these mechanisms do not strictly limit the intervention, longitudinal effects could be interesting to compare to the other interventions, which have direct influences on increasing internal load. The SM intervention could be particularly beneficial if it were reserved for sessions where live data computer monitoring was not practical or possible, such as heavy rain, technical issues or no battery power for the computer or HR base station. All the interventions can be classed as successful and practically applicable as all significantly increased %HR_{max} without decreasing technical actions. Each intervention has limitations and strengths, but varying the interventions and using them when the conditions are best suited may increase the practical application and potential benefits for the players as well as ease of use for coaches.

5.2. Comparison of Interventions across All Games

5.2.1. Heart Rate

Analysis of HR data demonstrated a significant difference between BL values and all other interventions for %HR_{max} (see figure 4.1). The results also established an effect size of $\eta_p^2 = 0.24$, meaning interventions had a large effect on measurable %HR_{max}. A plausible explanation for this is that the interventions increased the physiological demand of sessions and the player's cardiac system responded to the greater workload. Increasing the distance a player runs within the same timeframe will ultimately increase the average running speed exerted. Linear relationships have been established between exercise intensity and HR values; therefore, increasing the work rate should result in higher $\%HR_{max}$ readings (More et al. 2007). Comparing results across all games, BL displayed a mean value of $86.6\%HR_{max}$ while interventions AGS, IGS and SM recorded percentage increases of 3.5, 3.1 and $3.4\%HR_{max}$, respectively. The percentages above may seem minor, but relatively small percentage increases over longer durations of time may accumulate into greater gains through steady continual progression (Hoff et al. 2002) Especially after taking into consideration the high frequency soccer players typically performs SSGs in their career, which raises the potential improvements acquired through this method of training. Furthermore, it is unclear how a $3\%HR_{max}$ increase across training sessions will relate to both physical adaptations and game involvement over longitudinal studies. For example, a 3% increase in mean HR values may improve physiological measures (i.e., VO_{2max}) by smaller or larger percentage increments measured over longer periods of time. For example, Helgerud et al. (2001) separated soccer players into two groups where one performed HIIT consisting of four x 4 min at $90–95\%HR_{max}$, with a 3-min recovery in between, twice per week for 8 weeks, while the control group performed technical sessions and showed no significant changes in $VO2_{max}$. The HIIT group increased VO_{2max} levels from 58.1 ± 4.5 $mL \cdot kg^{-1} \cdot min^{-1}$ to 64.3 ± 3.9 $mL \cdot kg^{-1} \cdot min^{-1}$ and LT 47.8 ± 5.3 $mL \cdot kg^{-1} \cdot min^{-1}$ to 55.4 ± 4.1 $mL \cdot kg^{-1} \cdot min^{-1}$ and running economy was also improved by 6.7%. The physiological improvements found in the Helgerud et al. (2001) study also improved soccer performance by increasing distance covered during a match by 20%, increasing number of involvements with the ball by 24% and players performed double the number of sprints. In this instance, an increase of 6.2 $mL \cdot kg^{-1} \cdot min^{-1}$ or 10.7% of VO_{2max} related to more much larger percentages of variables integral to soccer performance

There is also evidence to suggest different HR intensities can be utilised to target particular energy systems often referred to as training zones (Robergs, Ghiasvand and Parker 2004, Helgerud et al 2001). The average $\%HR_{max}$ observed for interventions in the present study, could be substantial enough to tax the energy systems differently compared to BL, therefore produce distinct adaptations. Some studies are precise with values in regards to whether or not SSGs produce a high enough intensity in order for specific adaptations to occur (Rampinini et al. 2007). For example, Little and Williams (2006) disregard 5 vs. 5 games that produced and average intensity of 89.9%HR_{max} to increase maximal oxygen uptake but consider the response from 4 vs. 4 games of 90.2%HR_{max} to be appropriate. The cut off value of 90%$_{max}$ appears to be based on evidence showing this intensity to be optimal for improving VO_{2max}. While it may be true, to categorise a cut off value, such a precise figure could be unjust, as adaptions may occur to improve soccer specific endurance dependent on how well trained each player is (Clemente et al. 2012).

Mean %HR_{max} values provide insight for the average intensity across each intervention, but the unpredictable interval pattern of soccer depicts a HR signature that reflects the intermittent nature of the game. This means a greater breakdown of HR may be required to gain an awareness and understanding of player profiles. Furthermore, when devising or analysing training programs, not only is the overall intensity important, but the duration of time spent at specific intensities. Improving VO_{2max} is not only associated with high HR values, rather, enhanced development can require longer periods of exercise at high intensity (Dupont and Berthoin 2004).

5.2.2. Heart Rate Zones

Heart rate can be separated into zones and classed as different intensities due to the philological properties of the cardiac system. As exercise becomes more strenuous, working muscles require increased delivery of oxygen to meet the demands of elevated energy production (Dinenno and Kirby 2012). Consequently, the removal of the by-product carbon dioxide is required through transportation to the lungs for pulmonary gas exchange (Robergs, Ghiasvand and Parker 2004). The increased demand is partially met by increasing blood flow through increasing the cardiac output (a sum of the volume of blood ejected per heart beat multiplied by the frequency of beats per minute) (Dinenno and Kirby 2012). Stroke volume generally reaches maximum levels around 50-60% of maximal exercise level; therefore a greater frequency of BPM is required to meet the demand (Chatterjee et al. 2013). This means that high intensity actions for longer exercise durations result in an elevated HR response, supporting a linear relationship between HR and exercise.

A detailed assessment analysing the influence of interventions on HR was used through separating the percentage of time spent in specific HR zones. The separation was applied to illustrate a detailed replication of the intensity profile of each intervention. Distinctive zone separations can be seen in the literature for SSGs with authors typically separating percentages into 3, 4 or 5 HR zones, combined with variations of game format it makes direct comparisons with the present study challenging (Castanga et al. 2006, Jones and Drust 2007). For example Jones and Drust (2007) found 25% of playing time (2.5 min of a 10 min game) to be played above 85%HR_{max}. Analysis for the present study across all interventions results revealed 90% of game time to be spent above 80%HR_{max} and on average more than 50% of time spent above 90%HR_{max} (mean ± SD) 0.8 ± 1.9% (50-59%), 1.7 ± 1.8% (60-69%), 7.3 ± 10.7% (70-79%), 34.1 ± 12.3% (80-89%) and 56.0 ± 30.0% (90-100%). The main reason as to why disparities can be seen between the current study and that of Jones and Drust (2007) could be due to differences in game formats and the participants average age, resulting in the lower average game intensity for 4 vs. 4 and 8 vs. 8 (83% and 79% of HR_{max}). The participants of the study being youth soccer players could be critical, who may play at dissimilar playing intensities compared to adults as well as different physiological responses.

Larger standard deviations can be seen as zone percentage increases for both the present study and Castanga et al. (2006), which suggest greater variation for individual player HR zone profiles for higher intensity zones. The variations could be down to multiple factors such as player endurance, recovery rate as well as the different requirements and constraints of playing positions or style. Although the literature has widely investigated the differences between playing positions and found significant differences, one area, which appears to be neglected, are differences within the same position. Player behaviour, in terms of movement patterns or making runs off the ball could have substantial influences on the manner individuals perform similar positions. For example, two players may be regarded to play in the same position and have comparable fitness (i.e., VO_{2max} values), but display considerably different HR zone profiles. Once more, multiple reasons could be influential in determining player behaviour. Player 1 might be more attack minded who advances forward frequently, covering a greater distance within the same time frame and inevitably increasing workload. Due to a lack of research on the topic, it can only be speculated that differences in playing styles or coaching instructions could have substantial impact during SSGs.

The present study revealed significant differences between interventions for time spent in separate HR zones (see figure 4.2). BL produced significantly greater results in the initial HR zones (50 - 79%), ultimately spending less time in later zones in relation to other interventions. AGS, IGS and SM sessions recorded 14.4, 4.2 and 11.4% greater time in HR zone 90-100% compared with BL, respectively. The main explanation for this could be that the interventions increased high intensity running, which evokes a higher HR. The time spent in each HR zone was converted to a percentage. Therefore, any increase of percentage of time spent in a zone will inevitably result in a decrease in another zone(s) to equal 100%. The IGS intervention interestingly resulted in a significantly greater percentage of time spent at 80-89%HR_{max} compared to the AGS intervention. A reasonable explanation for this could be a result of the thematic differences between the two interventions. One intervention used smaller but more frequent sprints (IGS), while the other used longer shuttle runs (AGS). This could have resulted different physiological responses, as the IGS intervention may have not evoked as high a HR due to the reduced duration and more frequent recovery opportunities.

The HR zone 90-100% is of particular importance due to many regarding this intensity as ideal to create physiological adaptations relevant to soccer performance enhancement (Little and Williams 2006, Billat 2001, Helgerud et al. 2001, Hoff et al. 2002). Additionally, there are many variables that can influence HR, such as genetics, type of activity, duration and workload. However, during a short intermittent soccer game the duration and frequency of high intensity running will predominately be the primary factor responsible for producing a higher HR (Hill-Haas et al. 2011). BL recorded 48.5 ± 26.8% for time spent between 90-100%, while the AGS intervention resulted in a significantly greater value of 62.9 ± 27.5. The results of HR zone data suggest that interventions could be applied in order to target specific adaptations. For example, the AGS intervention recorded the greatest time above 90%HR_{max} meaning it could be particularly effective for targeting aerobic fitness or improving VO_{2max} (Helgerud et al 2001). Conversely, the IGS intervention recorded the greatest time at 80-89%HR_{max}, which has been shown to be an effective training range for increasing LT (Robergs, Ghiasvand and Parker 2004).

The separate HR zone values are of particular importance due to the esteem in modern soccer to possess the ability to perform repeated sprints, which some regard as the foremost physical factor for determining success and distinguishing playing level (Di Salvo et al. 2006). Having the capacity to out sprint an oppositional player can be advantageous, particularly during match winning situations where being first to the ball could result in a goal scoring opportunity when attacking or preventing a goal when defending. The results for percentage of time spent in different HR zones highlight the substantial variation in player profiles through the standard deviations yet mean HR values suggest similar results between players. Analyses of the HR data results indicate additional parameters outwith objective physiological markers may be needed for comprehensive monitoring (Aguiar et al. 2012).

5.2.3. Perceptual Responses

Research within SSGs suggests RPE to accurately reflect game intensity and assist the monitoring of psychobiological aspects as a global measure of internal perceptual load (Coutts et al. 2009). The overall mean RPE score for the present study was 6.6 ± 0.9 (range 4 – 9), which suggested that player's comprehensive perception of a session was typically between hard and very hard and range from somewhat hard to near maximal according to Borg's CR10 scale. BL recorded the lowest mean RPE value across all games (6.2 ± 0.7), approximately 8-10% lower than all other interventions (see figure 4.3). Variations in RPE scales used in the literature combined with many different SSG formats make comparison between studies challenging. Those that have applied the Borg CR-10 RPE scale have shown mean values to range between 7.0 - 7.7 (Coutts et al. 2009, Dellal et al. 2012). The mean RPE values of others show higher perceptual results in comparison to the present study. A primary factor for the reasoning as to why these studies recorded higher values could be related to the difference in game format sizes. Coutts et al. (2009) and Dellal et al. (2012) used fewer number of player games, as games as small as 3 vs. 3 were utilised. Smaller based games have been shown to have an increase in anaerobic actions that can cause intense feelings in the muscles, thereby increasing overall RPE. Although it is indeed possible that the players from the current study found the SSGs less strenuous, it is important to consider the limitations of using RPE. It is apparent that individuals could interpret the same physiological stress differently, dependent on their situational psychological state (Impellizzeri et al. 2004). Additionally, RPE protocols must be strictly adhered to and players need to be thoroughly educated as well as familiarised for purposes of reliability (Aguiar et al. 2012). These results therefore need to be interpreted with caution, as comparison between populations might be misleading due to the intrinsic nature of the group.

Soccer games require low intensity periods because continual exercise at such high intensities becomes unsustainable due to the manner in which energy is used and regenerated, meaning SSGs are performed at irregular intensities (Impellizzeri et al. 2004). Previous research has demonstrated that individual's recorded significantly higher RPE values during a 45 min intermittent protocol (15 ± 2) compared to steady state exercise (12 ± 1) where no significant differences were recorded for HR, oxygen consumption, sweat production rate or body temperature between the two conditions (Drust et al. 2000). Drust et al. (2000) suggest the reason as to why RPE is higher for the intermittent condition is largely due to different muscle fibre recruitment and energy provisions being met through an increase of anaerobic mechanisms. Moreover, much like BLa^-, it plausible that RPE is less of an overall global perceived measure of exertion across the whole game, rather, it could be largely influenced subconsciously by the intensity and actions that occur in the latter section of the game (Kilpatrick et al 2009).

Despite the possible limitations for RPE, studies have shown very strong correlations with HR during SSG sessions ($r = 0.85$, $P < 0.01$) resulting in RPE being considered as a valid indicator of global internal load for SSGs (Impellizzeri et al. 2004). The present study found mean values of RPE and some players recording values as low as 4, suggest there is a capacity for particular individuals to further exert themselves, but these players are potentially being constrained by the SSG arrangement. If so, this proposes the conjoined questions as to what level can SSGs be increased to through the use of modification/interventions that aim to reduce constraints, as well as, what impact does this have on the technical and tactical components of the game.

5.2.4. Tactical Actions

Teams commonly use SSGs as a multifaceted training method across all playing levels of soccer (Owen et al.2011). Interventions, which increase game intensity but considerably decrease playing actions through fatigue or distraction, may be questioned regarding efficacy and other training methods preferred. Using SSGs as a method to improve technical ability has been regarded as very successful for nations such as the Netherlands in competitive competitions (Aguiar et al. 2012). Lago-Peñas et al. (2011) and Collet (2013) agree that higher ranked teams have higher shooting and passing accuracy compared to lower level teams, while it has also been shown teams who finish higher in the league, perform greater number of passes and are better at retaining possession (Vogelbein et al. 2014). The aforementioned results can be associated with technical quality and any differences in the results can be compared to a typical game to monitor for any changes.

The present study found only one variable to show marked differences between technical actions observed during BL conditions and other interventions. The IGS intervention recorded over 10% more forward passes compared to BL, meaning the game involved a greater number of passes towards the opponents goal, rather than sideways or backwards. The difference in directional passing suggests particular interventions can influence SSG dynamics, which coaches may need to consider when implementing training programs. Interventions could be integrated into preparation for competitive matches depending on the opposition and tactical game plan. The IGS intervention could be specifically beneficial for preparing a team to counter attack and increase direct forward passing. The primary reasoning for observing the actions were to compare the technical actions of separate interventions within the current study, but looking at technical actions between other studies may give comparable insight.

Selected variables to best describe technical actions during SSGs appear to be subjective, with no universal protocol developed. Other studies range from looking simply at the total number of ball contacts (Jones and Drust 2007) to more comprehensive analysis covering passes, shots, blocks and tackles (Owen et al. 2014). A similar study, but using international level players, recorded a pass success percentage of 73.5 ±7.2% compared to 86.5 ± 4.4% of the present study (Dellal et al. 2012). Initially, these results might seem surprising, as pass success percentage is often a measure of player ability. The study by Dellal et al. (2012) used smaller game formats of 4 vs. 4 on a smaller pitch, which is likely to explain the reason for less successful pass completion rate due to the less passing opportunities, less time on the ball and high congestion increasing interceptions. Owen et al. (2014) investigated 3 x 5 min long games of 6 vs. 6 and recorded 170.0 ± 9.9 passes per session (15 min) compared to 101.5 ± 12.4 per game for the present study. Calculated into average passes per minute equates to 11 passes per min carried out by Owen et al. (2014) compared to 17 passes per min. A possible reasoning for this is that the present study used a population sample who are generally classed between amateur and semi-professional, while the study by Owen et al. (2014) used players from an elite team from the same country who play also play soccer for their represented national teams. The differences in playing levels are substantial and other studies have shown higher ranked teams to record a greater number of passes per game (Lago-Peñas et al. 2011, Collet 2013). However, during SSGs, higher ranked teams may be more organised, be better at tackling and press the opposition at a higher intensity, which could give players on the ball less time to locate a pass, providing some rationale to the difference in results observed.

A meaningful consideration is related to the physiological idea of a ‘ceiling effect’ in the same way that SSGs may also produce a relative maximum number of game actions. The frequency game actions occur could be depicted by an intricate combination of the quality of players, pitch dimensions, duration and player numbers. Generally, smaller game formats produce a greater frequency of technical actions per person, particularly for number of passes, dribbles and shots. Larger game formats have been shown to generate more headers, interceptions and longer passes as the pitch area influences game patterns (Owen et al. 2014, Dellal et al. 2012). Studies simply divide the total actions by the total number of players to gain insight into the average number of actions per player (Aguiar et al. 2012). A problem may arise as individual player variability may significantly fluctuate but can be hidden by consistent mean values. Furthermore, if total technical variables remain constant and individual players significantly increase playing actions; there could be a danger other players being deprived of the desired training stimulus as a consequence. If possible, future studies may focus on individual player analysis and track possible separate variations.

Although the other interventions did not record any substantial increases in technical actions, they can be regarded as successful as there were no sizeable decreases. Some have suggested that performing SSGs at high intensity (above 90%HRmax) is not sustainable, while this may be true for longer continual games; the present study and others have shown specifically designed formats with appropriate work:rest intervals can achieve high intensity. Moreover, coupled alongside the intensity argument, training at high intensity will hurry the onset of fatigue.

5.3. Evaluation of Separate Games

Separating games individually for analyses provides additional information about the results from this study and the ability to identify patterns. The HR results across separate games in the present study exhibit similar trends for all interventions, as the later games display higher mean values. A significant effect was also established form the data analysis, resulting in $\eta_p^2 = 0.08$, which translates into a medium effect size. Two phenomena may offer an explanation for the noticeable HR trends; 1) the intermission duration does not allow for sufficient time for HR to fully recover to resting values, therefore the proceeding game begins at a higher BPM (Koklu et al. 2011) and 2) the accumulation of fatigue from prior games induces a greater %HR_{max} (Impellizzeri et al 2005). This may be explained by SSGs involving repeated efforts of high intensity actions, which decrease creatine phosphate levels in the working muscles

(Glaister 2005). In turn, an augmented demand for ATP generation through aerobic energy pathways requires a greater oxygen supply. Increasing the cardiac output by increasing stroke frequency is one of the physiological mechanisms to assist in meeting the demand of oxygen (Dinenno and Kirby 2012). SSGs also contain periods of low intensity activity and game formats include a short break, but do not allow for a complete recovery. When games are played in this general interval format, it appears to create continual linear increases for HR values with the initial game being the lowest. The results of the BL intervention support the increase of game intensity as number of games increase (see figure 4.1).

Game 1 produced the greatest disparity between BL and all other interventions for mean %HR$_{max}$ with increases of 3.7, 5.0 and 5.6% for AGS, IGS and SM, respectively. This result is unsurprising as other studies have shown %HR$_{max}$ to be lowest after game 1 during a series of interval style games without interventions that target internal load (Kelly and Drust 2009, Rampinini et al. 2007, Koklu et al. 2011). Performing SSGs with no intervention may require a greater quantity of games being played to reach a desired intensity and the intensity of the initial game could be largely accountable. An investigation examining the influence that the number of games played has on game intensity across six games found BLa$^-$ to generally increase as game number increased, but %HR$_{max}$ typically can be seen to plateau or decrease after game 3 (Koklu et al. 2011). This may be explained by the physiological differences between the separate measure of HR and BLa$^-$ during specific game formats. HR follows a linear pattern in relation to exercise intensity and is more instantaneous in comparison to BLa$^-$. On the other hand, periods of low intensity during SSGs and the intermission aid in the removal of BLa$^-$, while the same periods of low intensity may lower HR it can be at a slower rate (Drust, Reilly and Cable 2000). The results obtained by Koklu (et al. 2011) may have practical implications when coaches increase the quantity of games in order to reach a relatively high intensity or training load. This approach might be detrimental to optimal practices due to the poor efficiency of training time as first two games may not provide a high enough intensity to target aerobic training zones, while the later games may see a drop in intensity due to a lack of energy in the muscles. Dellal et al. (2011) discovered with the on set of fatigue technical actions decrease as well as others finding a decrease in high intensity running actions (Bradley et al. 2011). Accumulating the results of others and the present study, game 1 appears to be arguably the most important game in a series in order to produce the highest intensity. Further importance can be added to sessions performed within a restricted time frame.

In the present study, game 2 witnessed similar disparities compared to BL to those seen in game 1 with increases of 4.8, 3.1 and 2.8% for AGS, IGS and SM, respectively. AGS posted the maximum mean value for any intervention across any game in this round (92.6%HR_{max} ± 3.3). Potential reasons for this and the results of other interventions will be explored later in the discussion. Analysis of game 3 observed BL to approach the intensity levels related to the other interventions. Although BL displayed considerably lower HR values after game 1, BL exhibited above average (for all interventions) increases between consecutive games. This could be a result of participants being further away from their maximum during game 1 of BL compared to other interventions. Therefore, players have a larger capacity for potential increases, creating greater opportunity to increase between games (Bangsbo 2008). Additionally, interventions integrated a premeditated intensity, where by they were created to bring as many players as possible to a desired intensity of 90%HR_{max} rather than pushing everyone to their maximum capacity. Potentially creating a combined influence through BL performing unimpeded from a lower initial intensity, thus producing steady linear increases and interventions reaching their desired intensity, consequently values begin to plateau.

5.4. Evaluation of Individual Interventions

5.4.1. Baseline Intervention

The BL intervention was utilised to represent a typical SSG to compare HR, RPE and technical data when additional interventions were applied. Although the present study is unique and modified interventions cannot be directly compared, the BL protocols were based on previous studies, where similar 6 vs. 6 SSGs were used. Other studies that utilised 6 vs. 6 formats found an average between 83-87%HR_{max}, reflecting the internal load for BL found in this study (Hill-Haas et al. 2009c, Katis and Kelis 2009, Rampinini et al. 2007). Katis and Kelis (2009) arguably used the most similar format, using the same number of players and pitch dimensions, but recorded a mean value of 83%HR_{max}, one of the lowest average values found in the literature for this layout. The difference in results could be a consequence of playing 10 games of 4-minutes durations. In comparison to the present study that equates to 33% shorter game time, yet accumulated duration of each session lasting 55% longer. It has been suggested players may apply a pacing effect when they aware of prolonged work loads, lowering over all game intensity due to energy conservation strategies (Carling and Bloomfield 2010). Additionally, SSGs can require approximately 1-minute for players to augment internal load to a true reflection of game intensity. Approximately 25% of the game time may have been allotted to increase players HR, compared to around 17% for a 6-minute game, which may substantially lower average results across each game.

In contrast, research on game duration by Fanchini et al. (2011) found a decrease in %HR_{max} between 4-minute and 6-minute SSGs (89.5 - 87.8%, respectively). The difference in results may have a physiological explanation as only 3 vs. 3 formats were tested. It has been well documented that fewer player games typically elicit greater RPE and BLa^- but %HR_{max} does not consistently mirror the perceptual load and blood concentrations during smaller formats (Jones and Drust 2007, Little and Williams 2007, Rampinini et al. 2007). Individuals are educated to summarise the global perceptual responses of all the body's feelings and responses where as HRM only reflects the cardiac system and fatigued state in response to the exercise (Céline et al. 2011). This is important to consider as games with fewer players have been reported to involve more actions per player, such as tackling, marking, sliding, and changes of direction (Dellal et al. 2012). The actions above may induce sizable damage to the working muscles and depend upon essential energy metabolism from the anaerobic system, increasing by-products that can accumulate to cause fatigue and intense feelings in the working muscles (Hill-Haas et al. 2008 and Hoff et al. 2002). Dellal et al. (2010) investigated the physiologic effects of directional changes in intermittent exercise in soccer players and found BLa^- and RPE to be significantly greater for the intermittent group compared to straight-line running, while HR remained relatively constant.

Correlations between total distance covered during Yo-Yo IR2 and HR plus RPE during BL conditions offer valuable insight into the game dynamics of how a player's endurance capacity influences internal and perceptual load. This study found no significant correlations for %HR_{max} and RPE, for individual game and mean analysis for BL intervention (see table 4.3). As the number of games played increased, correlations remained negative but did not reach significance (game 1. r = -0.11 and p = 0.76, game *2.* r = -0.36 and p = 0.30 and game 3. r = -0.25 and p = 0.44). The correlations fall between modest (0.1 to 0.3) and moderate (0.3 to 0.5) implying there is an indication of a relationship, but the ability to confidently assert an association is reduced given the low numbers of participants. Though these correlations are marginal, results provide some evidence and support claims that SSGs can evoke a ceiling effect on the players with highest VO_{2max} within the team (Hoff et al. 2002 and Wisloff et al. 2004). A ceiling effect can be further supported by examining individual data as the player who recorded the greatest score for the Yo-Yo IR2 test had the lowest average HR_{max} (72.3% ± 3.7) of any player, which was 12.3% less in comparison to the second lowest mean value and 14.7% below the team average. Player's who have greater endurance capacity are thought to be subjected to less physiological stress during BL conditions. Although this has not fully been tested, HR values are in agreement with Impellizzeri et al. (2005) who also discovered no significant correlations during SSGs. Their study may also have similar limitations as the present study as of the original 20 participants assigned to the SSG group, only 14 were analysed due to exclusions through injury, illness and a player transferring clubs.

The correlations between RPE values and Yo-Yo IR2 score for BL revealed (game 1. r = -0.05 and p = 0.89, game *2.* r = -0.33 and p = 0.35 and game 3. r = -0.32 and p = 0.38). Similarly to correlations between HR, all RPE correlations were negative and either scored weak or modest relationships and the population sample is too small to be conclusive. The increase from weak to modest correlations as game number increases suggest various possibilities and it would be unwise to take this value on its own as it is unclear whether; 1) players with poorer fitness capabilities perceive the games as harder as they progress, 2) players with greater endurance capabilities find the games less strenuous compared to the less fit players or 3) a combination of 1 and 2. Closer observations of the individual BL data indicate players who covered the greatest distance during the Yo-Yo IR2 test generally appear to have gradual linear increases in RPE or plateaus in values as game number increases, while players at the opposite end of the spectrum typically experience a sharper increases in RPE values between consecutive games. For example, the fittest player recorded RPE scores of 4, 5 and 6 compared to the least fit player of 4, 6 and 7 for BL games 1,2 and 3, respectively. Despite no significant correlations being discovered, it may be worthy to note these results because of the visible trend. While variables such as game duration and number can be designed around the endurance capabilities of the entire squad, variations in endurance capacity may warrant caution in SSGs with no interventions. The global perceptual results as well as physiological responses advocate the onset of fatigue appears to occur at different rates, with less capable players beginning to report greater differences in RPE values. The importance of these results may aid coaches in applying sessions that target overreaching but reduce the risk of overtraining. Also, emphasise the advantages of applying interventions that are designed to standardise the internal load across the team.

Regulating exercise intensity based on real-time data as a method of training is widely speculated about in SSGs research (Hill-Haas et al. 2007, Aguiar et al. 2012). Advances in technologies now permit live monitoring of team sports meaning auto-regulating soccer training is a possibility. Despite the potential advantages from autoregulation training, the literature contains relatively few studies examining the method and none utilise this for soccer. A reasonable explanation for this could perhaps be teams not publishing results for competitive reasons or many believe SSGs to already to be a form of auto-regulating exercise. The BL results from the current study warrants for interventions to be applied for an accumulation of reasons. Mean %HR_{max} values as low as 68.1% were recorded across a game and RPE scores of 4, suggesting opportunity for both physiological and perceptual exertion increases. A successful SSG session should also produce similar responses from the players but BL produced a 20%HR_{max} range across mean values (72.3 - 92.3%HR_{max}). Rampinini et al. (2007) investigated inter and intra participant variability for various different SSG formats and found the typical error expressed as a coefficient to range from 1.9 – 5.8% and 2.0 – 4.8%, respectively. Although these results can be considered to be more consistent, lower $\%HR_{max}$ mean values ranged from 83.8 – 85.1%, where as this study features evidence to suggest greater variation for individual player HR zone profiles for higher intensity HR zones (90-100% = 56.0 ± 30.0). Games played at overall higher intensity may not have equal work rate increases between players, rather, a disproportionate increase across players, thus increasing mean values but also the range and variability. Autoregulation training has the potential to simultaneously increase intensity as well as decrease variability by delivering a stimulus appropriate to the individual.

5.4.2. After Game Shuttle Intervention

The AGS intervention was designed to increase game intensity through various mechanisms and limit any possible technical decreases by applying the stimulus during intermissions of the session. The AGS intervention resulted in a significantly greater mean $\%HR_{max}$ recording the highest value of all interventions of 90.1 ± 3.5 $\%HR_{max}$ compared to the BL session 86.6 ± 3.3$\%HR_{max}$. It is reasonable to assume that more than one mechanism contributed to the overall increase in HR results, as there is evidence to support direct and indirect influences. The AGS intervention directly increased the volume of high intensity running through the additional shuttle sprint, which in turn, simultaneously reduced the duration of recovery. Increased HIR meant, plus decreased recovery means less opportunity for HR to return to resting values, proceeding game starts with a high BPM. Less time to reach higher HR values, therefore high average.

Insight into the indirect influences can be made apparent through the comparison of BL1 and AGS1. This comparison is possible as this data were recorded before the direct influence of the shuttle during the intermission. AGS displayed a 3.7% greater mean $\%HR_{max}$ across game 1 compared to equivalent game during BL conditions. The comparison provides a perspective into the AGS intervention having an effect on the anticipatory response to the possibility of an extra workload. Rational explanations for such increases may relate to each players motivational levels. It has been reported high levels of motivation will increase the likelihood a player will persevere during training, play with intensity and demonstrate more intense behaviour compared to an amotivated player (Vallerand 2004). Researchers commonly separate motivation into two general forms, intrinsic and extrinsic. Intrinsic motivation is within the individual and refers to participating in an activity for the self-satisfaction or gratification (Mageau and Vallerand 2003). A prominent reason some believe SSGs to be an integral area of soccer practice is due to the notion that the games are what soccer players enjoy most and raise levels of intrinsic motivation, thus increasing adherence and enjoyment. Extrinsic motivation involves external motives outwith the activity like fame, fortune and punishment avoidance (Vallerand 2004). As with many other measures, inter and intra-player variability exists for motivation, hence assuming player enthusiasm and determination levels are constant throughout the course of a season may be detrimental to optimal practices (smith 2003).

It is intuitively thought that the use of intense exercise as an external motivator for players who are deemed to be not working hard enough appears to be widespread among soccer coaches, yet it has not been systematically examined. The logic behind extrinsic motivators could be based on earlier studies displaying results where decrements in intrinsic motivation are associated with decreases in performance; therefore coaches may try to improve overall motivation levels by applying techniques to target external motivation rather than injecting intrinsic inspiration (Boggiano et al. 1993). While many warn of the negative impacts of punishment and exercise, the present study used this technique in a different form. Firstly, the participant samples of semi-professional soccer players are familiar with this concept of an expectation of high work rates during training sessions or they will receive supplementary fitness based drills. Secondly, in the literature, the negative aspect of punishment typically involves the removal or withholding of a positive stimulus. In contrast, the present study added an additional stimulus and the context in which the intervention was presented; certain individuals might have perceived it differently. For example, the interventions were presented stating players had to perform the session at above 90%HR_{max}, those who succeeded did not have to perform the shuttle run. By giving details in this manner, each individual were could interpret their own biggest motivational factor (i.e., ‘carrot or stick’ approach), rather than punishment alone.

The graph in Figure 1 shows a relatively sizeable increase in mean %HR$_{max}$ between AGS1 and AGS2 (3.8%), which was the greatest (positive or negative) percentage difference between consecutive games. Particular players who were below 90%HR$_{max}$ received an additional high intensity stimulus shuttle run during the intermission for AGS group, consequently increasing %HR$_{max}$ and reducing recovery time, which appears to have a combined outcome of increasing initial HR for the following game. The intensity decrease from AGS2-AGS3 (91.6 ± 3.3 – 90.8 ± 3.3) may be pertinent to the cut off point set out by the intervention. Once players have reached the required level (i.e., above 90%) the intervention is designed to not push the intensity further. During tests 1 and 2, seven players performed the shuttle run as a result of a below 90%HR$_{max}$ after AGS1 compared to three after AGS2; meaning fewer players had the coupled effect of added stimulus and reduced recovery (see table 4.4). The explanation of this can be aided by an analysis of individual %HR$_{max}$ across each game, where players can be placed in 1 of 3 classifications, those who were consistently below 90%HR$_{max}$ for all 3 games (performed a total of 3 shuttle runs), those who were consistently above 90%HR$_{max}$ (performed 0 shuttle runs) and those who fluctuated above and below 90%HR$_{max}$ (performed a total of 1-2 shuttle runs). It can be speculated the graph trend is predominantly influenced by the fluctuating group as a result of game 1 being below 90%HR$_{max}$, requiring the player to perform the shuttle run, assisting in an elevated HR above 90%HR$_{max}$ after game 2. The repercussion of the player not receiving the added stimulus and an extended recovery in comparison to the previous intermission permits for a greater recovery and lower %HR$_{max}$ across game 3. For example, %HR$_{max}$ across games 1, 2, and 3 for an individual fluctuating player = 88.0, 94.2 and 90.6%, respectively. These percentage increases followed by decreases are comparatively similar for those who were below 90%HR$_{max}$ after game 1 but above the cut off value after game 2. This phenomenon cannot fully rationalise all of the results, as it is highly plausible that other mechanisms are influencing player behaviours and ultimately their overall %HR$_{max}$.

Punishment as a form of motivation is associated with negative forms of coaching and been shown to decrease participation levels in longitudinal studies (Smith 2003). However, there is a difference between the environment used in previous studies and the context of the present study. The current study used soccer players who train on a regular basis and are accustomed to this form of concept. Others have investigated exercise adherence using largely sedentary populations or warned of the complication when using punishment and exercise with children. Punishment in the strict sense may create an aversive and unpleasant learning environment that is damaging to the intended goal. The present study informed the players that the runs were an added stimulus rather than a punishment and there may be game confinements that restrict players of a high endurance capacity.

Correlations between distance covered during the Yo-Yo IR2 and %HR_{max} for BL and AGS resulted in AGS recorded a similar pattern to BL but of greater negative values (see table 4.3). Interpreting the figures imply players of lower endurance capacity within the group may increase their work rate to a greater extent to avoid the punishment shuttle. It is equally possible all players increase their work rate but less fit players have greater physiological increases in relation to the increased load. Similarly, the punishment was standardised regardless of %HR_{max} or Yo-Yo IR2 score; therefore, the physiological response may also be dependent on endurance capacity. In hindsight, players of a high endurance capacity and/or players further away from the cut off value may require an additional stimulus, thus, each player may require a relative distance or target intensity in relation to their own data. Interventions may significantly elevate overall %HR_{max}, but do so in manner similar where players fatigue at different rates. The RPE results observed in table 4.3 for game 3 recorded a significant correlation of $r = -0.74$ ($p = 0.02$) meaning the global perceptual stimulus was relevant to individual endurance capacity. Closer inspection of the data reveal players with a higher endurance capacity have consistent RPE values or an initial increase in perceptual load followed by a plateau in values compared to less fit players typically recording linear increases.

5.4.3. In Game Sprint Intervention

Similar to AGS, the IGS intervention is also a form of autoregulation training, but with some thematic differences. Firstly, the IGS intervention used more frequent but shorter shuttle runs, which included one change of direction, compared to multiple changes during the AGS protocol. This is important as Drust et al. (2000) suggest that where separate conditions are matched for workload, the condition with greater number of accelerations and decelerations will be perceived to be more difficult by the players despite no significant physiological differences. Another major difference between the interventions was variations observed for the properties of the run set out by the interventions. Players performing shuttle run during the AGS intervention each completed equal run distance, recovery times and linear running. The IGS intervention could vary in distance depending on where the player was standing on the pitch from when they were called to perform the sprint. Also, the positional requirements of the player when re-joining the game may be influential on the sprint distance. For example, a striker may have to run a greater distance as they typically spend more time further away from where the marker was positioned (behind defending goal) and potentially return to the attacking zone of the pitch.

It could be argued that positioning the cone behind the defending goal is unfair and provides an unequal stimulus, which might be dependent on position. While this could be true, this protocol was decided on for a number of practical reasons. The marker was set out behind the defending goal to make it realistic of playing situations. Players are encouraged get behind the ball or be between the defending goal and the ball in order to prevent the opposition scoring and then regain defensive formation (Vogelbein et al. 2014). This movement pattern is similar to the run performed and re-entering the game when the player's team is not in possession. This could potentially target important qualities such as tactical shaping and communication, where the player and team have to quickly and effectively decide where the returning player is required (Charalampos et al. 201). Re-entering the pitch from a defensive position when the player's team is in possession encourages players to support attacking plays. If the marker were behind the attacking goal, when players re-enter the pitch they would be in an unrealistic offside position and encourage movement patterns that do not relate to competitive soccer. The original concept for the IGS intervention positioned the markers 10 yards from the mid point of the lateral pitch lines to reduce positional constraints. Markers positioned at the midway point could also be beneficial towards encouraging players to bend their run, or run in a curve pattern, which is an effective strategy to exploit teams playing a high defensive line for offside (Almeida et al. 2014). However, the training area was limited because of pitch sharing strategies from multiple teams, meaning the area was inadequate for this protocol. Although it was not tested, the author speculates that marker position could be influential on game dynamics and distances and position need to be considered should this concept be repeated or adapted. Furthermore, marker position could also be positioned to target specific aspects for tactical or strategic awareness that closely relate to full sized games.

Another difference between the AGS and IGS interventions is the latter targeted the player with the lowest %HR_{max} on each team rather than everyone below a cut off intensity for the whole group. Finally, the intervention temporarily reduced player numbers as the sprint was carried out during game time, which resulted in each player receiving the same recovery time during the intermission. The AGS intervention resulted in players performing shuttle runs during the intermission, subsequently providing a shorter passive rest period for those players compared to the players who did not perform the shuttle. Longer rest periods have been demonstrated to lower HR levels, meaning the subsequent game will begin at a lower HR value (KoKlu et al. 2011).

The objective of the intervention was to increase overall intensity and decrease variation, through consistently targeting the individual with the lowest %HR_{max} from each team every 30s. Those players who record the lowest intensity could be a result of positional constraints, the player not working hard enough or possess a greater endurance capacity in relation to the group. The complex combinations can be further convoluted through situational components that are less obvious to fully obtain (i.e., sleep, hydration, motivation, previous playing time and nutrition) (Hill-Haas et al. 2007). The results for IGS intervention produced a similar to trend to BL, displaying gradual linear increases but with less substantial increments amongst games (see figure 4.1). Mean increases between games for BL compared to IGS were 2.4% and 0.5% respectively;

while IGS recorded a significantly greater overall mean internal load by 3.4%HR_{max}.

Game 1 recorded a greater %HR_{max} value compared to BL, meaning less capacity to increase intensity and producing smaller increases between games (Bangsbo 2008). The results above are as expected and it is conceivable that game intensity is increased through direct and indirect methods. The IGS intervention directly pushed up the intensity of the players with the lowest %HR_{max}, while other player's intensity may increase indirectly through motivation to avoid the running or removal from the game. Additionally, the IGS intervention not only increased %HR_{max} compared to BL values, but recorded the lowest SD for HR (3.2) of any intervention across all 3 games. This is further supported by the correlations observed in table 4.3 where values decreased from -0.31 to – 0.13 for HR values and from -0.62 to 0.17 for RPE.

The IGS intervention temporally reduced player numbers as well as producing moments of unbalanced teams, resulting in momentarily 5 vs. 5 and 6 vs. 5 situations. Although there are discrepancies in the literature about the true influences of number of players, those who examined both 5 vs. 5 and 6 vs. 6 generally found the smaller number format to stimulate a greater internal load (Hill-Haas et al. 2009c, Little and Williams, 2006 and Rampinini et al. 2007). Some authors suggest that fewer based games require greater responsibility per player on game influence, thus, players are generally involved in more game actions and high intensity running (Jones and Durst 2007). Moreover, when pitch dimensions remain constant and player numbers are reduced; the area per player is increased, meaning each player may have to patrol a larger distance by increasing workload (Clemente et al. 2012). One study (Hill-Haas et al. 2010) investigated the influences of unbalanced teams in a 6 vs. 5 games for a fixed and a temporarily time through the use of a player who transferred between teams in possession. It is common training practice for creating under and overload situations as well as utilising games when total players equal an odd number. The researchers found games, which varied overload, had significantly greater RPE values. It is possible that teams with a player less automatically assume games are harder due to the numerical disadvantage, however, the authors speculate players may also be working harder to retrieve possession.

Another consideration is that the team with the numerical advantage have simultaneously increased the intensity to exploit the temporarily benefit of an extra player under the added time pressure. Considering the results of others, it is unsurprising that IGS intervention produced a significantly greater RPE value compared to BL intervention due to the temporarily reduction of player numbers and the maximal sprint performed by particular players (see figure 4.3). The results of RPE and HR values reflects the results from Hill-Haas et al. (2010) as they found greater increases in RPE compared to physiological responses.

Reduced players may also produce less opportunity to recover as games can require a greater necessity to be available to receive possession of the ball or close down the opposition (KoKlu et al. 2011). Aguiar et al. (2013) investigated a series of SSGs using increased player numbers 2 vs. 2 – 5 vs. 5 but keeping area:player number ratio constant. The researchers established significantly greater time spent below 75%HR_{max} for 4v4 and 5v5 compared to 3v3, supporting the smaller game have less recovery time. Compiling the information gained from fewer player based SSGs suggests these formats are less sustainable over greater durations in comparison to larger configured games. There appear to be a number of physiological explanations to suggest the unsustainability of SSGs with fewer players due to the increased frequency of anaerobic actions, which increase likelihood of muscle damage and blood lactate as well as decrease time spent during low intensity periods, resulting in less passive and active recovery periods that are vital to remove metabolic by products. These results emphasise the importance of planning sessions and the consideration of variables, such as total session duration, game durations, work:rest ratio, pitch dimensions, player numbers, game rules and conditions. The variation in results witnessed in the literature suggests the potential influences of variables are not yet fully known, or possibly unique to the participants used for testing. It would therefore be advantageous to both players and coaches to monitor game intensity to gain vital knowledge of their team, as there is evidence to suggest intensity to be situational and dependent on factors such as individual fitness capabilities.

Table 4.5 illustrates players according to Yo-Yo IR2 rank and the number of sprints each player performed per game. The player ranked number 1 is regarded as the player with the greatest endurance capacity and performed the greatest number of sprints across all games. A theory mentioned early involved SSGs being implicated by a 'ceiling effect', which players intensities are restricted by the constraints of the game (Hill-Haas et al 2011). In other words, the opposition, tactical priorities or positional demands depict many movements, which may ultimately limit the distance covered and therefore influence internal load. This theory is thought to have greater impact on the players with the uppermost VO_{2max} scores of the group (Buchheit et al 2009). However, in contrast, Hill-Haas et al. (2009) observed a weak but significant positive correlation between fitness level and exercise intensity during various SSGs ($_r$ = 0.26). The results of the above study suggest that players with a high fitness level exercise at a higher intensity during SSGs yet this study would support the notion that there are players unable to reach a relative high intensity through SSG alone. Therefore, future research is required to elucidate the possible relationships between fitness, skill and exercise intensity during SSGs. Furthermore, contradicting results observed in the literature as well as observations made during testing for this study have led the author to believe a far more complex relationship exists between individual intensity and VO_{2max}, but also incorporates player behaviour, motivation for training and previous positional education from coaches.

5.4.4. Self-Monitoring Intervention

The SM intervention is also a form of autoregulation training as players attempted to normalise training intensity to a pre-determined level. Although the SM intervention could be classed as self-regulation training, the literature uses the terms interchangeably or refers to self-regulations as an essential personality trait by which individuals attempt to govern their feelings, appetites, impulses, thoughts and task performances (Baumeister et al. 2006). This thesis will refer to self-regulation as the individual being responsible for regulating exercise intensity and focusing on task performances, while autoregulation will refer to regulation through adjusting intensity through the provisions of an external stimulus. To the author's knowledge, no study directly compares autoregulation and self-regulation whilst monitoring exercise intensity as much of the literature on this topic is in relation to weight management, exercise adherence and self-efficacy, particularly with sedentary populations.

Previous research has demonstrated that HR can be controlled in laboratory conditions on a treadmill by altering variables of speed or incline dependent on the live HR data (Su et al. 2007, Cheng et al., 2008a, Cheng et al. 2008b). But this setting has key differences compared to a soccer training environment. These studies directly influenced individual running speed, where as soccer players are largely in control of the direction and speed in which the run, unless they are being given direct instructions form the coach. Although coaches may try to encourage through positive feedback, it is not practically possible to instruct every player constantly throughout match play, and self-awareness becomes a key skill for the players. The results of the present study appear to suggest some players are capable of regulating the intensity they work at during SSGs. The SM intervention graph appears to display a more level trend than others and the only interventions to record a decrease between game 1 and game 2. Although the reduction is minimal (0.2%), it can be conjectured that the outcome of a relatively consistent graph is due to the players attempting to regulate their HR, and as a result SM1 recorded the highest %HRmax, therefore reducing the prospect of an increase. This requires further testing to be conclusive. A further possible reason for the self-monitoring session increasing %HR_{max} is it is commonly reported sports players to have a competitive mind-set (Gill and Dzewaltowski 1988). Players being informed of what percentage they are working may have led to an increase in effort being applied, through personal challenges to reach a highest percentage as possible. Also, players may gain a clear visual representation that it is physically possible to work harder and exert themselves further. The vast majority of studies investigating knowledge of performance have looked at skill acquisition meaning it is unclear the true impact live feedback of physiological results has on the players.

Although differences can be observed between the AGS and IGS intervention, they share an underlying theme that the primary purpose was to increase game intensity through direct measures of removing game constraints and increasing distance covered. The SM intervention relied on the self-regulation of players, which could be determined by social cognitive theory motivation. Individuals may have the desire to display a high work rate to demonstrate their capabilities and/or avoid exhibiting a poor performance (Roberts 2001). In soccer, this goal of action is examined with respect to perceived physical ability and may be dependent on their view of perceiving outcomes (Duda 2001). A task-oriented person seeks to improve their ability and the criteria for success are self-referenced. In contrast an ego-oriented person pursues to demonstrate their ability by being the best and out-performing others (Hodge et al. 2008).

Achievement goal orientations have also been employed to explain short-term positive affects in sport. For example, a positive association between a predominant task goal setting and enjoyment in sport is well documented in the literature (Duda et al. 1995, Fox et al. 1994). In turn, enjoyment can increase intrinsic motivation, which has been shown to increase effort levels and attendance of training. Further, although not directly empirically tested, a task orientation has been promoted as the means to facilitate long-term participation in sport and physical activity (Duda 2001). Those individuals who participate in sport over a long periods of time can be characterized as having a high level of sport commitment (Raedeke 1997) it would seem logical that a predominant task orientation should be associated with greater commitment to sport participation. However, this assumption is based on a larger scale where temporary declines in variables such as motivation could be overlooked, where as smaller day-to-day assessments could reveal substantial changes. There could be practical and performance implications based on these facts, as exclusively applying interventions based on self-regulation would require consistently high levels of commitment and enthusiasm, which may not be a reflection of reality. Additionally, using player attendance and commitment as alone measure of motivation could be questionable, which has also been demonstrated to fluctuate. The long-term application of the SM intervention is perhaps the biggest question regarding the practicality for the intervention. It is unclear if the main effect established is a short-term response from the players to a novel method of training, or if they can indeed be sustainable over time. Further longitudinal investigations could give insight into the matter and examine if the intervention was best reserved for occasions where direct intensity targeting interventions were not practical.

Chapter six: Limitations and Future Research

6.1. Study Limitations.

The results established by the present study should be interpreted cautiously for multiple reasons. Firstly, SSG intensity might be related to the properties of the group being tested and variation is plausible dependent on various factors that could be difficult to replicate. Game formats could be reproduced from this study, but variations in player fitness, age, tactical instructions and player motivation may all be integral in determining overall game intensity. Although the interventions were successful, following the methods precisely might be unproductive, rather, coaches may need to be dynamic and amend game formats or interventions to best suit the players throughout the team and the number in the squad. The low sample size may also be a limitation, particularly for statistical analysis where limited data results in low statistical power, meaning there is a reduced probability of detecting a true effect. Consequently, effect sizes may be overestimated, creating low reproducibility of results and unreliable correlations. It was not practically possible to increase the number of participants for the current study due to time constraints, lack of willing soccer clubs within the area and a limited population that could commit to the study given the competitive nature of soccer. The perception that engaging with research may alter a clubs preparation limited only one team participating in the study. This meant 14 participants from one club to be optimal due to the methodological format. Future studies would be encouraged to test a larger sample size or across multiple teams to provide a varied distribution and closer reflection of the population. This will aid in the generalisation and transfer of results for other studies to compare and duplicate as well as increase statistical power.

Another limitation of this study could be the usage of different team selection across the same intervention. The lack of each player performing a test and re-test meant reliability could not strictly be analysed, rather consistency was determined through testing for significance across tests 1 and 2. This technique was decided upon, as it required a shorter test window, where waiting for the same teams to be available is inherent with its own limitations. The testing timeframe may need to be considerably increased to wait for all players to be in attendance. This method could increase variations through adaptations in player's fitness levels due to the time and reduce the validity of results. Using different teams also meant that individual player analysis could not be analysed across multiple tests. The inclusion of individual player data could of tracked player variations in response to the intervention. This could of provided additional information where overall technical data remains constant, but there could be considerable fluctuations between players that mean values conceal. If the use of interventions is making individual players miss out the technical stimulus, the intervention no longer becomes practical and separate training methods may be preferred.

Logistical planning factors may also limit the practicality of the interventions. The study is designed for twelve players, including two goalkeepers, which may not always be the case for training attendance. Inconsistent attendance numbers could make planning difficult as it is unclear how the interventions would perform with alternative numbers in each team. Additionally, if player numbers vary, the game format should also change to suit the participants. With previous research displaying pitch area, game time, rest interval and the use of goalkeepers all to influence game intensity, interventions should be trialled during assorted game format combinations. The logistics of finances could also limit the use of interventions to teams without the financial resources to fund the use of HRM equipment, which can be relatively expensive for team sports.

SSGs are competitive by nature, increasing the possibility of injury through contact and collision (Hill-Haas et al. 2011). It is feasible to minimise incidence of injuries through modifying game rules, however, to the author's knowledge, there have been no investigations into the injury rate of SSGs in comparison to drill based exercises. A lack of prior research on methods to increase or regulate training in a soccer environment may have also limited the study. Prior research could of assisted in providing a foundation of knowledge and understanding in the area. As a result, an exploratory approach was taken rather than an explanatory when writing this thesis, highlighting the need for research to be expanded.

6.2. Future Research

Future research is required for SSGs in general as contradictions in the literature can be seen for results influencing game intensity. Variables, such as pitch area, rule modification and technical actions need to be systematically examined in studies where the researcher has total control. If possible, results should be as detailed as possible, expressing values per minute or per person to allow for comparison between separate formatted studies.

The present study presented an argument for the occurrence of a ceiling effect during SSGs involving the fittest players. Others have found correlations supporting this while some found the opposite, suggesting that players with the highest endurance capacity also have the highest work rate (Aguiar et al. 2012). There appears to be valid logic for both cases giving rise to the concept that a complex relationship exists between individual intensity and VO_{2max} that cannot be fully explained by fitness capabilities alone, but intricate permutations involving work rate, game constraints, positional constraints, tactical instructions and motivation.

Each intervention successfully increased responses compared to BL values, but interventions should strive to increase every player to a predetermined intensity, thus reducing variability. Based on the research and results, modifications can be suggested to further enhance the interventions. The shuttle run performed during the AGS intervention was the same for each player regardless of the Yo-Yo IR2 score or the proportion below $90\%HR_{max}$. A future suggestion could be to devise the shuttle run distance based on individual results (e.g., a player who scored highly on the Yo-Yo IR2 and was 20% below the cut off point may have to perform a greater distance shuttle compared to a player who scored poorly on the Yo-Yo IR2 but was only 2% below the cut off point). Similarly, the IGS intervention could perhaps have additional cones placed further away at 10, 20 and 30 yds intervals behind the goal, where players run to the nearest cone first but if called upon again, must run to the subsequent distance. During the present study, the IGS intervention notably witnessed the same players having to perform the run. Placing additional cones could be an attempt to reduce the same player making the run on consecutive occasions. Alternatively, the cones could be positioned at different locations to alter game dynamics and specific runs. The SM intervention displayed good potential but further testing to analyse the long-term implications to address unanswered questions. Coaches may feel the increase in playing intensity to be related to a novelty concept that could diminish off over time.

The results of the present study suggest that each type of intervention should be taken forward to longitudinal testing. Interventions could be compared to the physiological and technical data against SSGs without interventions and/or generic conditioning drills. This may greatly aid in the understanding of periodization for SSGs and when best to utilise interventions throughout the playing season. SSGs have potentially other benefits besides the concurrent training of technical, tactical and physical elements. It is speculated that SSGs can also improve decision-making and reactions, particularly specific to soccer that drill-based exercise may struggle to replicate. Further research is required to test these theories. Finally, the interventions of the present study evoked a high enough intensity, which other research suggests physiological adaptations may occur and increase endurance capacity. As players increase their fitness capabilities, SSG aspects of intensity may change, especially if players improve at different rates. Future studies may wish to perform fitness tests and monitor match involvements to access the practical application of SSGs with interventions over time.

Chapter seven: Conclusion

Lack of optimal game formats, inadequate resources to monitor training intensity and a shortage of conclusive research within SSGs are some of the barriers confronted by sports scientists, coaches and sports clubs when trying to improve training methods. The present study contributes knowledge and understanding towards SSGs as a method to simultaneously target multiple soccer elements and increase training efficiency. Meanwhile investigating the constraints SSGs may witness can give a rational for interventions to be applied and the impact interventions have on game play, in order to improve training methods.

Research has demonstrated better teams typically have higher fitness properties and generate more technical actions per game (Dellal et al. 2011b). Others have established physical improvements to improve soccer performance through increased game involvements and greater distances covered during matches (Helgerud et al. 2001). For SSGs to increase physical parameters, many believe the sessions must evoke a high intensity for adaptations to occur (Little and Willams 2007, Hill-Haas et al 2011c). Previous research on SSG is divided, as some found average intensity to be above 90%HR_{max}, while others recorded values as low as 79%HR_{max} (Little and Williams 2007, Dellal et al 2008). The results from the literature suggest SSG intensity could be dependent on the dynamics of the group and game format presented.

The results from the present study for BL are comparable to other investigations; displaying linear increases between games, relatively low mean values for perceptual and physiological responses but considerable variations, demonstrated by ranges and relatively large standard deviations (Koklu et al. 2012). Gathering the results of others and BL, there was rationale for the requirement of interventions to be applied to SSGs for this group of players. Interventions AGS, IGS and SM exposed players to a significantly greater %HR_{max} compared to BL and the results were mirrored by the RPE values. Evidence from correlations, individual HR data and the number of sprints performed provide evidence towards ceiling effects during SSGs, suggesting implications for those who have a greater endurance capacity in relation to the group. The results form others witnessing contrasting correlations where the fittest players also recorded higher work-rates suggest complex interactions may be taking place, further complicating SSGs (Aguiar et al. 2012).

Each intervention could be regarded as successful as technical data were comparatively similar for all interventions with the most substantial difference occurring for the percentage of forward passes played during IGS intervention. The interventions used could be most effective if used to meet the aims of the training session. The AGS intervention was easy to use and could be recommended to increase intensity when session objectives are to improve aerobic fitness. The IGS intervention was less practical and may require two or more operators or advanced software to operate effectively. Nonetheless, it could be utilised for LT training as well as preparing players for numerical under and overload situations, regaining tactical formation and improving communication for efficient organisation. The SM intervention proved to be the easiest to monitor and administer, but long-term implications or days when players lack motivation may require a more direct intervention. Self-regulation may be reserved for when other interventions are not possible due to adverse weather, technical issues or lack of coaches.

The present study has investigated innovative methods that present clear evidence to strongly suggest that the interventions could be beneficial to improve soccer performance. Each intervention may also produce specific intensities due to multiple direct and indirect mechanisms, which may further influence game dynamics and increase the complexity of the training response. All interventions used in the current study require further testing to more clearly assess whether they should routinely be used.

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Appendix 1

School of Health Sciences
School Research Review Group (SRRG)

Participant Information Sheet for Competent Adults (PISCA)

Generic Information	
SRRG Ref No:	SHS/SES/13/13
Title (short):	Small-Sided Games: Augmenting Training intensity
Date:	15/02/2013

Introduction:

My name is Hamish Munro and I am a Masters student at the Robert Gordon University, studying Sports and Exercise Science. This letter is an invitation to participate in my research project and will explain the study as well as other relevant information you may need to know should you volunteer.

The study:

The purpose of the study is to research possible methods that can increase a players work rate during small-sided football games (4v4, 5v5 etc.). This will be done through the use of heart rate monitors and simple question on how hard you feel you are working. The results will contribute to current research as well as aid coaches in providing training sessions that can increase player fitness levels while working with the ball. This has huge potential to be used across different age groups that maximise contact time with the ball as well as increase a player’s motivation.

You have been invited to participate in the study as you are contracted with Banks O’Dee Football Club, but your participation is completely voluntary. This study also aims to strengthen the relationship between Robert Gordon University/RGU: Sport and surrounding clubs, paving the way for future research. You are free to participate in the study if you currently play for the first team, are free from injury (permission given from the physio for full training), have no health concerns and sign a written consent form which further explains that you are free to withdraw from the study at any given time with no reason required. You are excluded from testing if you are injured (determined by club physio), are under 18, have a health concern(s) or are on medication that can influence the results.

Taking part:

The study has been designed with the consideration of your current training schedule and you will not have to commit to any additional training time or travel. Session will be held during normal training times and locations and will last approximately 45 minutes for each session. You will report to training as normal and will be given a heart rate monitor (a chest strap – provided for you at each session) and will be asked to answer simple questions on hard you feel you are working during 3 x 6 minute games of 6v6 with goalkeepers on a 30x40 yard pitch. One and a half minutes will be issued between each game. 9 sessions (total) will be performed. Firstly a maximal fitness test followed by three different interventions being performed twice as well as two games with no interventions. 1) You will be asked to monitor a wristwatch and try and raise your heart rate to a zone relevant to your own fitness capability. 2) Your heart rate will be monitored and if it drops below a set percentage (90%) of your maximum heart rate during each game, you well be temporarily pulled out of the game to perform a shuttle run. 3) Your heart rate will be monitored across each game and if it drops below a set percentage (90%) of your maximum heart rate, you will perform a shuttle run during the intermission. Two sessions will be performed with no interventions for a comparison. Each game will have no set conditions and will be any number of touches (all-in). Each session will be videoed by two digital cameras placed around the pitch for the analysis of each game to be performed. This will allow for a comparison of pass completions, and interceptions etc. After each session you will continue training as normal. Once 8 sessions are complete, you may be asked to take part of a small focus group (8 people).

Expenses and payment:

Expenses will be the usual agreement between you and the club for travel to training. No additional expenses or payment will be given nor required by you.

Advantages and disadvantages of taking part:

Due to the study being designed so closely with a typical training session in mind, there are no major advantages or disadvantages. If you agree to take part in the study you will be involved in 6v6 games during training, while if you do not want to be involved you may be part of a small group performing individual training this can be interpreted as you will.

Advantages:

- It is possible to provide you with a small report of how you performed throughout the study. How hard you were working throughout the games and technical summary can be issued on pass accuracy etc.

Disadvantages:

- Due to the nature of football there is always a risk of an injury, however we will provide you with an appropriate warm up and minimise any potential hazards wherever possible to reduce this possibility. Pitches will be screened for any objects before each session and the equipment will be tested throughout.

Confidentiality, data protection and anonymity:

- Confidentiality: All information collected will be confidential and available only to the student researcher and supervisor.
- Anonymity: It will not be possible to link individual results/data/findings back to named individuals. No names or other personal identifiers will be included in any report from this research.
- Data Protection: all data will be collected and stored within the requirements of the Data Protection Act (1998). Data will be stored on a password-protected computer, accessible only to the student researcher and supervisor.

What happens if there is a problem?

Please discuss any problems with the researcher or supervisor. Contact details are given at the bottom of this letter. If you have a complaint please send details of this to the convenor, School of Health Sciences Research Review Group, Robert Gordon University, Garthdee Road, Aberdeen AB10 7QG s.barnard@rgu.ac.uk or Mrs Elizabeth Hancock, Head of School of Health Sciences, Robert Gordon University, Garthdee Road, Aberdeen AB10 7QG l.hancock@rgu.ac.uk

What will happen to my research data?

- Your data will be destroyed at the end of the study. This means after the results have been analysed and a report has been submitted for marking (November 2013). The end of the study does not mean the end of the data collection period.
- A report will be written for assessment as part of the university degree and the findings may be further discussed in professional or academic journals and at conferences.
-

Assurance of research rigour:

- This research has been approved by the School Research Review Group at the School of Health Sciences, Robert Gordon University, Aberdeen. It is self-funded by the research student.

What happens now?

If after reading this information sheet you are interested in taking part in this research project please contact the researcher at the address/email/phone number below

Further information and contacts:

Researcher:	*Supervisor:*
Hamish Munro MRes Sports and Exercise Science School of Health Sciences Robert Gordon University Garthdee Road Aberdeen AB10 7QG Email: 0814757@rgu.ac.uk	Paul Swinton School of Health Sciences Robert Gordon University Garthdee Road Aberdeen AB10 7QG Email: p.swinton@rgu.ac.uk Tel: 01224 2633361

Appendix 2

Small-Sided Games Questionnaire

Name.. Date:.........................

Age:........... Date of Birth: DD/MM/YYYY

1. Are you currently permitted to participate in full training? (Permission from manager and physiotherapist)
Yes☐ No☐
If no, please state injury/reason and duration.

....

2. Have you ever had a heart attack or heart related disorder before?
Yes☐ No☐

3. Do you feel pain in your chest when you perform physical activity?
Yes☐ No☐

4. Do you have a bone or joint condition that could be made worse with a change in your physical activity?
Yes☐ No☐ Don't know☐ (If yes, please state.........................
....)

5. Are you currently taking any medication for high blood pressure or heart condition?
Yes☐ No☐
If yes, please state...

6. Are you currently being prescribed any other medication? If yes, please state...

7. Do you lose your balance because of dizziness or ever loose consciousness?
Yes☐ No☐

8a. Do you have diabetes?
Yes☐ No☐ Don't know☐
8b. If so, what type of diabetes?
Type 1☐ Type 2☐

9. Do you suffer from back pain?
Yes☐ No☐

10. Do you currently have any injuries?
Yes☐ No☐ (If yes, please state...
....)

11. Do you have exercise-induced asthma?
Yes☐ No☐

12. Do you know of any other reason to why you should NOT undertake physical activity?
Yes☐ No☐ (If yes, please state ....
....)

I agree I have answered the question to the best of my knowledge.

I know that I am not obliged to complete the test. I am free to stop the test at any point and for any reason.

Signed .... Date ....

Appendix 3

Consent Form

Study reference: SHS/ SES/2011/10
Title of project: Small-Sided Games: the Physiological and Technical effect of Interventions Designed to Augment Training Intensity.
Name of Researcher: Hamish Munro

1. *(Please initial box)* I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. ☐
3. I understand that individuals, from The Robert Gordon University, will look at data collected during the study where it is relevant to my taking part in this research. I give permission for these individuals to have access to the data. ☐
4. I understand that participation involves exercising at high to maximal physical capacity and I understand the implications of this which have been explained to me ☐

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I agree to take part in the above study.

Name of participant Date: DD/MM/YYYY
Signature
Name of person taking consent Date: DD/MM/YYYY
Signature