The effects of small sided game variation on hamstring strength

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“This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary’s University”

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After an intensive period of 12 months, writing this note of thank you is the finishing touch on my dissertation. It has been a period of intense learning for me, not only in the scientific arena, but also on a personal level. Writing this dissertation has had a big impact on me and I would like to take this opportunity to reflect on the people who have supported and helped me so much throughout this period.

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The effects of small sided game variation on hamstring strength

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Abstract

Soccer is a sport which induces fatigue. Fatigue results in a force decrement potentially exposing the muscle to injury. The purpose of this study was to determine the effects of small sided game (SSG) variations on hamstring torque in soccer players. 10 male semi-professional soccer players (age 23 ± 5 years; height 178 ± 7 cm; weight 73.4 ± 10.6 kg) were tested during the 2016-17 season. Two forms of game were designed for players to compete in during training, a 3 vs. 3 low velocity (LV) and 4 vs. 4 high velocity (HV) based game in an absolute playing area of 300 m^2 and 800 m^2 respectively. LV based games have a lower relative and absolute pitch area therefore restricting HV based running. The HV games have a higher relative and absolute pitch area therefore increasing HV based running. Games consisted of 6 x 4 min bouts with 90 s recovery in between. Physiological load such as distance covered (m) and heart rate (HR) were monitored by Global Positioning Systems (GPS), with hamstring torque measured pre and post training using the NordBord. A significant difference was found ($P<0.05$) between the LV and HV based SSG on peak hamstring force decrement (5.78 N and -13.62 N respectively). A significant difference was also found ($P<0.05$) between the LV and HV based SSG on mean hamstring force decrement (11.11 N and - 4.78 N respectively). HV based SSG induced a larger hamstring torque decrement in both peak and mean force production. Accelerations were related to (.328*, P<0.05) reduced hamstring torque. These results suggest if practitioners wish to train accelerations and induce hamstring fatigue, HV based SSG are considered most effective.

Key words: torque, fatigue, nordbord, StatSports, soccer

1. Introduction

Within team sports such as soccer and rugby, hamstring strain injuries are common, owing to the intermittent nature of performance and frequency of explosive movements, such as sprinting and jumping (Orchard & Seward, 2002; Woods, 2004). Soccer requires sustained high intensity intermittent exercise and sustaining this intensity for 90 minutes of match-play, causes the force generating capabilities of the muscles to deteriorate, with this being reflected in the decline of work towards the latter part of each half (Bangsbo, Iaia, & Krustrup, 2007; Mohr, Krustrup, & Bangsbo, 2005).

Fatigue is defined by the reduction in maximal force and power production as a direct result of exercise, resulting in a decreased level of performance (Rampinini et al., 2011). It is believed that combinations of peripheral and central factors are responsible for the degradation of performance during a team sports game (Waldron & Highton, 2014). Blood lactate accumulation has long been considered a cause of fatigue, along with the reduction in blood pH (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004), although the reliability of this assumption has been questioned due to the minimal rise in blood lactate recorded during matches of competitive soccer (Krustrup et al., 2006). The depletion of glycogen stores within single muscle fibres are associated with fatigue at the end of team sport matches (Krustrup et al., 2006). In a study by Sporis, Jukic, Ostojic, and Milanovic (2009), they identified that the average distance a player covered in a game of soccer was between 10-12 km but this also varied between positions. Central defenders covered less (10.63 km ± 0.89 km) and central midfielders ran further (12.03 km ± 0.63 km). With various activities occurring during a game, these findings support the notion that an isolated increase in blood or muscle lactate concentration is an unlikely explanation for acute muscle fatigue in athletes. Furthermore, it suggests that fatigue is multi factorial and various mechanisms can be a cause. The availability of energy substrates, during activities such as soccer, proves vital in supporting the running capacity of the athletes and therefore its effect on muscle fatigue and muscular strength. With hamstring musculature involved in locomotion, the depletion of glycogen stores within the muscle fibres could therefore reduce force capabilities and potentially expose the muscle to become strained.

In a study by Morgan and Oberlander (2001), hamstring strains accounted for 42% of all strain injuries recorded during competition in the US Soccer Major League. A study in the English Soccer leagues across a 2 year period, established approximately 12% of the 6030 injuries sustained during this period were in the hamstrings, with losses of approximately 30 days of action being incurred per incidence (Ekstrand, Hagglund, & Walden, 2011; Woods, 2004). The most concerning trait of hamstring strains is the exceptionally high rate of recurrence, particularly the re-injury resulting in more severe damage and more time being lost in competition than the original injury (Koulouris, Connell, Brukner, & Schneider-Kolsky, 2007). The accumulated time lost from competition is not only frustrating for the individual it also has a huge financial implication for the club. A study by Ekstrand, Hagglund, and Walden (2011b) estimated that hamstring injuries cost English Premier League clubs over £74 million every season, which is approximately £500,000 per injury, therefore further highlighting the need to reduce the occurrence of hamstring strains.

Numerous studies have examined risk factors for hamstring strains, with age, previous hamstring strains and a reduction in muscular strength appearing to be most common (Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2008; Woods, Hawkins, Hulse, & Hodson, 2003; Yeung, Cleves, Griffiths, & Nokes, 2016). One factor attributed to the high incidence of hamstring strains is reduced muscular strength caused by fatigue (O'Connor, Johnson, & Benson, 2015). In English soccer, over 47% of hamstring strains reported during competitive games were incurred during the final 15 min of each half (Hawkins & Fuller, 1999). The chronological configurations of injury during competitive games indicate that fatigue could be a factor, which could lead to a detrimental effect of strength within the hamstrings (Greig, 2008; Rampinini et al., 2011).

The utilisation of Electromyography (EMG) has been effective when studying the activation of the hamstrings throughout the gait cycle (Cleather & Brandon, 2007; Thelen, Chumanov, Sherry, & Heiderscheit, 2006). The EMG identified that hamstrings are silent at toe-off and become significantly more active during late swing phase, when the hip is extremely flexed and the knee is starting to extend (Wiemann & Tidow, 1995). The pattern of EMG activity proposes that the hamstrings function, due to their biarticular structure, is to eccentrically govern hip flexion and knee extension during the swing phase, whilst also being required to contract concentrically as a hip extensor during the stance phase of gait (Cleather & Brandon, 2007). Due to the horizontal force production needed concentrically during the acceleration phase and eccentric strength required during the late swing phase, the load placed upon on the hamstrings is vast (Cleather & Brandon, 2007).

Mohr, Krustrup, and Bangsbo (2005) recognised that the potential causes of fatigue during team sport competition are multifaceted, with the nature of the accumulated fatigue relating to the task being performed. Within a game of soccer, the amount of sprinting constitutes a total of <11% of the accumulative distance that a player runs (Mohr, Krustrup, & Bangsbo, 2003). A review by Stolen et al. (2005) suggested that an episode of sprinting occurs every 60-90 s, with each sprint lasting approximately 4 s. Around 90% of these sprints are >30 m and around 50% of these being >10 m, with the distance being dictated to by game situations (Bangsbo, 1994; Little & Williams, 2005). Positions of the athletes also dictate the frequency and speed of the sprints performed, with fullbacks and forward players being acknowledged to perform longer and more frequent sprints than the central midfield players and centre backs (Mohr et al., 2003).

Rahnama, Reilly, and Lees (2002) concluded injuries derived predominantly from strains to musculature caused by fatigue as a consequence of sprinting, change of direction (COD), jumping and landing. Due to the irregular and intermittent activity profile of soccer, physiological and mechanical load placed upon the hamstrings during a variety of tasks, should be acknowledged. English Premier League clubs utilise motion analysis technology, which is considered to be a valid measurement of mean velocity and reliable for the measurement of total distances covered during competition (Carling, Bloomfield, Nelsen, & Reilly, 2008; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009).

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Due to the restricted time available for fitness interventions in team sports such as soccer, the use of small-sided games (SSG) is frequently utilised. SSG are used to improve the technical abilities of players, as well as the development of aerobic capacity and sport specific movement patterns (Hill-Haas, Dawson, Coutts, & Rowsell, 2009; Rampinini et al., 2007). Despite the regularity of this type of training modality, no study to date has investigated the effects of SSG on hamstring muscle function. To ensure that SSG are considered effective as an intervention, an improved understanding of the related physiological responses such as muscular fatigue needs to be developed.

Within the literature, the type of SSG which allow for players to reach top speed are those with a greater absolute pitch area (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Hill-Haas, Dawson, Coutts, and Rowsell (2009) showed that as the number of players in SSG increase concurrently with the relative pitch area per player, the amount of distance travelled by the players above 18 $km.h^{-1}$ also increased. The choice of SSG variation chosen by the practitioner, in particular pitch size which affects LV and HV running, will result in different consequences to the athlete due to the different technical and physical demands placed upon them (Rampinini et al., 2007).

It is reported during an average 90 min game of soccer match play, players change activity on average every 4-5 s and perform approximately 1200 - 400 actions, with around 700 of these being COD (Bloomfield, Polman, & O'Donoghue, 2007). In comparison to straight line running, COD drills have reported increased lower limb muscle activation (Besier, Lloyd, Ackland, 2003). The amplified muscle activity in the quadriceps, hamstrings and gastrocnemius are thought to help maintain stabilisation of the knee joint during COD tasks in reaction to the rotation movements and greater valgus movements experienced (Hader, Mendez-Villanueva, Ahmaidi, Williams, & Buchheit, 2014). The hamstrings are considered to play a prominent role in providing stability to the knee joint, in particular when decelerating from a HV run (Friemert et al., 2005). An increase in semitendinosus activity is thought to be significant when compressing the medial compartment of the knee joint, thus limiting the excessive valgus load of the knee joint and resulting in a stress reduction on the anterior cruciate ligament (ACL; Zebis, Andersen, Bencke, Kjær, & Aagaard, 2009). The type of SSG which help to elicit COD are those with a lower absolute area and a reduced relative pitch area per player, such as 2 vs. 2 in an absolute area of 588 m^2 (Hill-Haas et al., 2009). This will encourage players to accelerate and decelerate quickly both in and out of possession of the ball.

The skill of jumping is considered an important attribute of football, in particular when a defender is clearing the ball or a striker scoring a goal (Paoli, Bianco, Palma, & Marcolin, 2012). MacKenzie, Lavers, and Wallace (2014) stated that the mean amount of force generated in a vertical jump (VJ) from a male athlete was over 1800 N, which increase the physical load upon the lower extremities therefore inducing muscular fatigue to the quadriceps and hamstring muscles. In the initial jump phase of a VJ, the athlete performs a quarter squat prior to a propulsive extension of the knee and hip joint through concentric contraction of the hamstrings, which enables the body to travel in a vertical trajectory (Farthing, 1998). During the landing phase of a VJ, the hamstrings are activated prior to landing, which is thought to counter the anterior translation of the tibia in relation to the femur that ensue just after landing to protect the ACL (O'Connor et al., 2015). The exact forces exerted by the muscles during landing are dictated to by activation patterns of the lower extremities and the maximum isometric (ISO) strength of muscles, in particular the hamstrings (O'Connor et al., 2015).

This study will therefore evaluate the impact of LV and HV based SSG on hamstring fatigue with particular reference to reducing injury occurrence. GPS will be utilised to investigate the relationships between hamstring fatigue and the motion analysis recorded from each session. Due to the role the hamstrings play isometrically to stabilise the knee during the landing phase, this study will assess ISO hamstring strength as a measure of induced fatigue pre and post SSG interventions. With hamstrings being required concentrically during the acceleration phase to produce horizontal propulsive force and during decelerations to stabilise the knee joint, this study will look to quantify the effect CODs and LV based work has on hamstring fatigue during SSG.

The hypothesis of this study is that a HV based SSG will induce greater fatigue in the hamstring in comparison to the LV based SSG. The second hypothesis is that hamstring strength is reduced through HV based SSG due to the number of accelerations a player performs during this session.

2. Methods

2.1 Participants

10 male semi-professional soccer players (age 23 ± 5 years; height 178 ± 7 cm; weight 73.4 ± 10.6 kg) agreed to participate in this study, which was approved by the Ethics Committee of St Mary's University Twickenham. Players completed a verbal medical screen to validate the inclusion criteria: (1) no injuries during the previous 2 months, (2) not to experience any lower limb muscular pain and (3) not taking any medication. All players were fully informed of the purpose, benefits and risks involved with participation of this project verbally and via a written sample information document. Written consent was collected from the players and the club for their testing data being used for research purposes.

2.2 Experimental Design

The LV based sessions included 3 vs. 3 SSG and were performed in an absolute area of 300 m^2 (20 m x 15 m) meaning the relative area per players was 50 m^2. The HV based sessions included 4 v. 4 SSG and were performed in an absolute area of 800 m^2 (40 m x 25 m) meaning the relative area per player was 100 m^2. Please see Figure 1 and 2 respectively for pitch dimensions. The duration of the games within each session was 4 min with 90 s rest in between. A total of 6 bouts were performed meaning a total of 24 min work was completed per session. The pitch size was measured out by using a 30 m measuring tape and was marked out by cones.

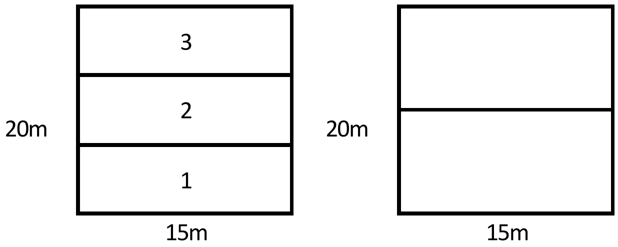

Figure 1. Low Velocity Based SSG Conditions

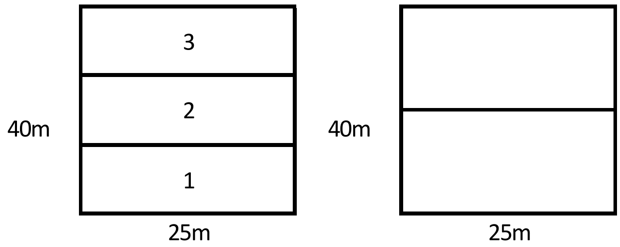

Figure 2. High Velocity Based SSG Conditions

The teams in each game were balanced based on the player's skill ranking to avoid mismatch of opposing teams. This was achieved through discussion with the management team and their opinions on player technical ability. Prior to each session a standardised warm up, 15 min in duration, was conducted following the RAMP protocol. All sessions had constraints which were utilised to increase session intensity and also provide the players with focus. The constraint for 3 of the 6 bouts was for a goal to stand all players must be in the attacking half. The constraint utilised for the other 3 bouts were point system based, depending on where the ball is won back from the opposing team. The pitch was divided into thirds, with 3 points being scored for winning the ball in the oppositions attacking third and then scoring, 2 points for the middle third and 1 point for winning back in your defensive third. Once a goal is scored, play was restarted by collecting a ball from your own goal therefore giving the opposition a chance to press. All constraints were applied in each session for an equal amount of time but were also randomised to keep the players focused on the task at hand. Intensity of the game was controlled by coaches and investigators by positioning themselves around the pitch with footballs to ensure one was available if the ball was to leave the designated area. All players were reminded verbally to keep themselves within the designated playing area.

2.3 Procedures

One week before data collection players performed one familiarisation session, which included use of all equipment that was used for testing. In total 4 sessions were completed every Thursday across a 4 week period, two being LV and 2 being HV based sessions. Sessions were completed on the same evening session at the same time. Players were instructed to eat no later than 1 hour prior to training commencing to ensure food had been digested and metabolised. Sessions were delivered in dry conditions and with players all wearing the same footwear in each session.

An ISO force test was performed prior and immediately following performance of the selected SSG. ISO force data was collected from a Nordbord (Vald Performance, Brisbane, Australia). This test was performed on both dominant and non-dominant limbs at 90° and 30° knee flexion (KF). These joint angles were specifically selected because the biceps femoris musculature has been shown to be maximally activated between 15° and 30° of KF, while the semi-membranosus and semitendinosus musculature were maximally activated between 90° and 105° KF (Onishi et al., 2002). Players positioned themselves on the Nordbord, placing knees on the pad, feet in the ankle straps and hands flat on the floor. The ankle position was to be checked to ensure the strap was in a completely vertical position to ensure effective data was collected. Player's hips and knees were flexed to relevant angle and measured by using a goniometer (Lafayette Instrument Company, USA). Knee position was recorded by making reference to the number on the Nordbord mat to keep testing reliable and to make future testing quicker to implement. Players were then instructed to pull their heels towards the ceiling therefore creating an ISO contraction against the ankle straps. The contraction was held for 3s and repeated three times at both 90° and 30° knee flexion, with the highest peak force (N) being recorded on the Nordbord Dashboard software. Data were classified in relation to dominant and non-dominant legs and also between the two different knee angles. A standardised verbal cue was provided during the contraction to keep them consistent. Immediately upon completion of each session, the ISO force test was again administered to ascertain the acute effects of the training session on the hamstrings.

2.4 Time Motion Characteristics

Player movements throughout each SSG were recorded using portable StatSports Apex GPS Units (10 Hz Augmented with a double consolation, Co. Down, Northern Ireland). Players were given an individual GPS unit to monitor physical and physiological load data such as distance covered (m) and HR during the session. Units were place inside a vest, positioned between the player's shoulder blades and used in conjunction with Polar Heart Rate monitors (T31 Coded), with each player being assigned their own individual vest and heart rate monitor strap during the entire testing period. For the purpose of data analysis, there were six speed zones selected based on players individual maximum speed (MS; Zone 1 (0-25% of MS); Zone 2 (25-50% MS); Zone 3 (50-75% of MS); Zone 4 (75-100% of MS); Zone 5 (100-125% of MS); Zone 6 (125%+ of MS). Individual speed zones were set based on MS achieved in a YoYo Intermittent Recovery Level 1 test (Bangsbo, Iaia, & Krustrup, 2008). Other variables which were collected were distance covered (m) in each speed zone, maximum speed ($km.h^{-1}$), total amount of accelerations (>1 ms^{-2}) and decelerations (>-1 ms^{-2}) performed and metabolic power (w/kg). The GPS data were later uploaded to the StatSports Apex software.

2.5 Reliability and Validity

The reliability of the StatSports Apex GPS Device (10Hz Augmented with a double consolation, Co. Down, Northern Ireland) for measuring sport specific movements was investigated during a pilot test. The protocol used was a YoYo Intermittent Recovery Level 1 test (Bangsbo et al., 2008) which was performed twice, at the same time and with 7 days recovery in between. Reliability was determined by comparing specific data from the units which were total distance (km), total of accelerations and total of decelerations. An Intra unit test of the GPS units was completed. The spreadsheet of Hopkins (2002) was also used to determine the change in the mean between trials, intraclass correlation coefficient (ICC) and the typical error of measurement, expressed as a coefficient of variation (CV %), calculating 95% confidence limits. The CV for total distance = 0.41%, ICC = 0.90 and 95% Confidence Intervals (CI) = -0.367, 0.997). The CV for total of accelerations = 4.34%, ICC = 0.37 and 95% CI = -0.895, 0.977). The CV for total decelerations = 2.83%, ICC = 0.81 and 95% CI = -0.60, 0.995).

The reliability of the Nordbord for measuring ISO hamstring force production was also investigated during a pilot test. The CV for ISO at 90º of left KF = 0.26%, ICC = 0.69 and 95% CI = 0.215, 0.898). The CV for ISO at 90º of right KF = 0.23%, ICC = 0.84 and 95% CI = 0.528, 0.956). The CV for ISO at 30º of left KF = 0.43%, ICC = 0.92 and 95% CI = 0.737, 0.975). The CV for ISO at 30º of right KF = 0.38%, ICC = 0.92 and 95% CI = 0.741, 0.976).

2.6 Statistical Analysis

Data are presented as mean ± standard deviations (mean ± s). A two-way ANOVA with repeated measures statistical test was performed to compare the two types of SSG and the reduction in ISO hamstring force from pre-to post training. The dependant variables were the hamstring torque and GPS data and the independent variables were the two types of SSG and the KF angle. A Pearson

Correlation Coefficient was conducted to evaluate the relationship between movement variables recorded from GPS units and hamstring torque differences pre-to post sessions. Pearson's r value >0.7 was considered low; 0.7–0.9 moderate; and <0.9 good for predicting relationships. Effect sizes were calculated according to the methods of Cohen (1988), where the difference between the means was divided by the pooled standard deviations. For the purpose of this research, 0.5–0.8 was considered a medium effect size and 0.8 and above a large effect size. The assumption of sphericity was explored and controlled for all variables. All statistical analysis were performed using the SPSS software and statistical significance was set at $P<0.05$.

Results

Hamstring Fatigue

An interaction was found between HV based SSG and peak hamstring force decrement, F (1, 156) = 5.431, p = .021. Mean scores of peak hamstring force decrement are shown in Figure 3. There was also an interaction found between HV based SSG in terms of mean hamstring force decrement, F (1, 156) = 4.750, p = .031. Mean scores of mean hamstring force decrement are shown in Figure 4.

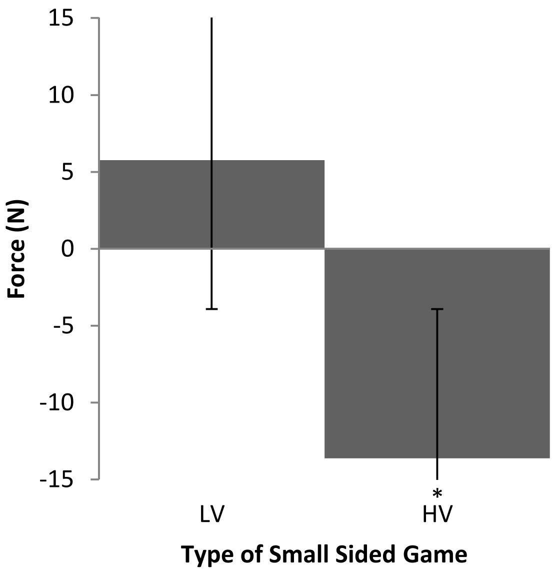

Figure 3. Comparison between both variations of SSG and peak decrement of hamstring force (mean ± SD). * Significant difference between low velocity and high velocity based SSG on peak hamstring force decrement pre to post intervention. *P<0.05*.

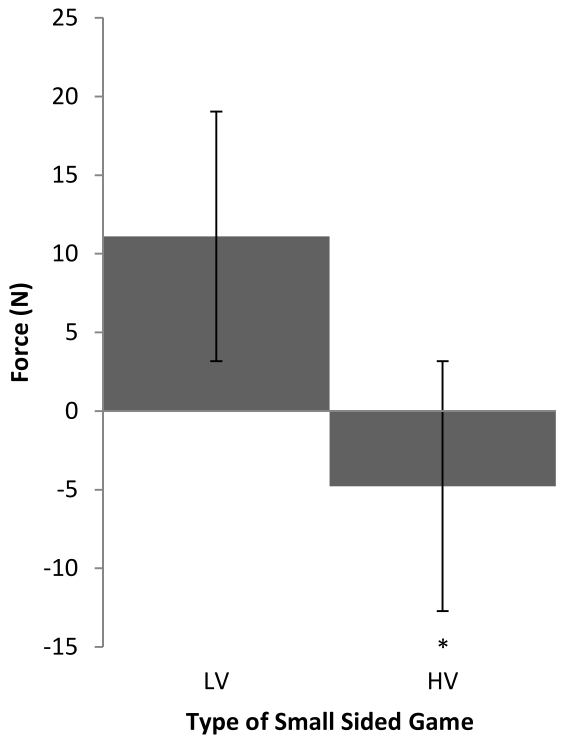

Figure 4. Comparison between both variations of SSG and mean decrement of hamstring force (mean ± SD). * Significant difference between low velocity and high velocity based SSG on mean hamstring force decrement pre to post intervention. *P<0.05*.

LV v HV SSG

A statistical difference was found between GPS metrics total distance covered (m), distance covered in zone 3-6 (m), MS achieved ($km.h^{-1}$), total amount of accelerations ($>1ms^{-2}$), total amount of decelerations ($>-1ms^{-2}$) and metabolic power (w/kg) accrued in the two types of SSG. No differences were found between distance covered in speed zone 1-2 (m) and maximum HR achieved in the session. Mean score values between the GPS metrics recorded in both types of SSG are shown in Table 1.

Table 1 Low Velocity v High Velocity Small Sided Games GPS Metrics (mean ± s).

Metric	3 v 3	4 v 4	*p*	ES
Total Distance (m)	2727.84 ± 316.16	3047.47 ± 289.69*	.000	1.50
Distance in Zone 1 (m)	783.78 ± 135.68	759.04 ± 141.94	.235	0.18
Distance in Zone 2 (m)	917.99 ± 126.08	917.89 ± 96.83	.294	0.00
Distance in Zone 3 (m)	674.61 ± 201.88	795.02 ± 187.67*	.000	0.62
Distance in Zone 4 (m)	280.50 ± 71.27	414.70 ± 92.58*	.000	1.62
Distance in Zone 5 (m)	67.24 ± 33.28	134.32 ± 42.59*	.000	1.76
Distance in Zone 6 (m)	3.72 ± 8.27	26.49 ± 25.88*	.000	1.19
Maximum Speed (km.h-1)	23.71 ± 1.73	26.13 ± 2.00*	.000	1.29
Total Accelerations (>1ms^{-2})	294.20 ± 39.90	276.30 ± 17.89*	.004	0.58
Total Decelerations (>-1ms^{-2})	273.10 ± 46.74	257.65 ± 22.17*	.048	0.42
Metabolic Power (w/kg)	292.55 ± 57.06	313.20 ± 51.90*	.003	0.38
Maximum HR	188.15 ± 28.21	194.2 ± 13.30*	.000	0.27

**P<0.05*

Correlation

A Pearson correlation analysis highlighted a relationship between amount of accelerations accumulated in the SSG and a decrease in peak hamstring force at a KF angle of 90º. No other significant correlations were found. All correlation scores can be found in Table 2.

Table 2 Correlation Matrix for GPS metrics and Hamstring fatigue (mean ± s).

Variable	Dis	LV	HV	MS	ACC	DEC	MP
PFKF90	.087	.138	-0.21	-0.25	.328*	.198	0.05
PFKF30	.010	.119	-.155	-0.80	.007	.007	.012
MFKF90	.029	.044	-.003	.007	.220	.097	-.021
MFKF30	.048	.136	-.100	-.061	-.019	.022	-.008

**P<0.05*

Note: PFKF (peak force at knee flexion angle), MFKF (mean force at knee flexion angle), Dis (distance), ACC (Accelerations), DEC (Decelerations), MP (Metabolic Power).

Discussion

The aim of the study was to determine which type of SSG, LV or HV based, elicited the greatest reduction in hamstring torque. The LV based sessions, which included 3 vs. 3 SSG, were performed in an absolute area of 300 m^2 with the relative area per players being 50 m^2. The HV based sessions were 4 vs. 4 and performed in an absolute area of 800 m^2 meaning the relative area per player was 100 m^2. The duration of each game was 4 min with 90 s rest in between. This process was repeated for a total of 6 bouts meaning a total of 24 min work was completed. The study also examined any correlations to hamstring torque reduction in relation to the GPS metrics acquired from the sessions.

There was a difference between the LV and HV based SSG when looking at peak force (PF) reduction of hamstring torque, with a higher amount of fatigue induced by the HV SSG. The study also found that a statistical difference in the mean force (MF) decrement of hamstring torque in the HV SSG. The 4 vs. 4 SSG had a higher absolute and relative pitch area per player meaning there was a greater amount of pitch space available for higher speed efforts.

The greater fatigue induced by HV based SSG were consistent with research by Rahnama, Reilly, Lees, and Graham-Smith, (2003), who stated the greater duration of time expended in the high intensity running, sprinting in particular, may produce a superior physiological cost and muscular requirement to match the additional load induced by the training stimulus. The authors study involved athletes performing a 90 min soccer-specific intermittent exercise protocol, incorporating a 15 min half-time intermission. This protocol was developed to provide fatiguing exercise equivalent to work load experienced in a game of soccer. The intervention was performed on a programmable motorized treadmill and consisted of the various intensities observed during soccer match-play (e.g. walking, jogging, running, sprinting). Muscle strength was measured before, during and immediately after exercise and was measured on an isokinetic dynamometer. The study investigated the strength ratios between knee extensors and knee flexors after the soccer-specific intermittent exercise protocol. The peak torque of the knee extensors and knee flexors was found to be greater before exercise, inferring that fatigue in both has occurred from the intervention.

A positive relationship was found between the number of accelerations and the change in hamstring PF at a KF of 90º. Onishi et al. (2002) reported that the semi-membranosus and semitendinosus muscles were maximally activated between 90° and 105° KF, whereas the biceps femoris was fully activated between 15° and 30° of KF. There is typically a knee flexor movement of greater magnitude during early stance phases of a sprint (Wild, 2011). The knee joint appears to be considerably more involved in concentric activity during the early stages of acceleration, which places greater physiological load upon the hamstrings (Bezodis, Kerwin, & Salo, 2008). Therefore due to the amount of accelerations performed, resulting in KF to be above 90º, it could be suggested that the current study's findings of peak torque reduction at a KF angle of 90º are consistent with the literature.

Total distance accumulated in sessions may be considered a poor indicator of global work rate in SSG formats (Hill-Haas et al., 2009). Hill-Haas et al. (2009) reported that there was no significant difference between 2 vs. 2, 4 vs. 4 and 6 vs. 6 SSG formats in terms of total distance covered, citing there could be additional factors such as number of players and opportunities to be directly involved with the ball. These findings contradict with the findings of this study, as total distance increase from 3 vs. 3 to 4 vs. 4 format. The main variance between the studies was although absolute pitch size increased with the number of players, this study also increased the relative pitch size per player. The increased number of players in the larger game format logically decreases the total number of technical actions (e.g. turning or dribbling with the ball) that each player executes. Due to the reduced technical involvement in the larger format, they are required to spend time working ‘‘off the ball’’ to create a passing opportunities therefore covering more ground. In the context of an increase in the absolute pitch area, this type of physical work may result in players completing an increased number of sustained higher speed runs in an attempt to lose their opponents.

In the present study, players travelled the greatest amount of total distance at LV (speed zones 1-2) during both variations of SSG. One explanation for the increased distance covered at LV is that players had more possession of the ball and consequently were required to reduce velocity to gain better control of the ball (Owen et al., 2004). However, this could contradict the findings regarding total distance and the larger format eliciting a greater response. In contrast to the 3 vs. 3 SSG format, the 4 vs. 4 format responses were accompanied by less distance travelled in the low speed zones and a higher amount of distance covered by HV. These results are consistent with previous literature (Aguiar, Botelho, Gonçalves, & Sampaio, 2013) and suggest that the 4 vs. 4 SSG training intervention used in this study, may be an effective method to achieve near MS running.

In this study, the MS increased with the larger SSG format. These findings are consistent with the literature (Hill-Haas et al., 2009) as the mean speed attained by players during the larger sided game increased. As previously mentioned, players are considered less likely to be involved with the ball in the larger format, therefore are required to spend more time trying to create space for their team mates and be in a position to receive the ball. However, the combination of a smaller pitch and fewer players in the 3 vs. 3 SSG may increase the total amount of technical actions each player performs. Closer marking by their opponents may also reduce sprint speed. This may reflect that a greater absolute pitch area has an increased amount of space available for MS efforts.

Deceleration during locomotion requires braking forces, which are produced predominantly by eccentric muscle actions (Hodgson, Akenhead, & Thomas, 2014). The athlete must absorb force, primarily through flexion of the ankle, knee, and hip placing eccentric demand on the quadriceps, hamstrings and gastrocnemius (Hewit, Cronin, Button, & Hume, 2011). An eccentric contraction is where a muscle is being forcibly lengthened while trying to shorten (Brockett, Morgan, Proske, & others, 2001). Muscular damage occurs when the muscle involved is lengthened beyond its optimum, causing impairment to the sarcomeres (Morgan & Talbot, 2002). The damage to the sarcomeres result in actin and myosin heads not able to slide over one another therefore reducing maximum force production capabilities (Morgan & Proske, 2004).

Further peripheral fatigue such as Excitation-Contraction coupling could also be considered a cause of muscular fatigue. Excitation-Contraction coupling is defined as the link to muscle excitation to calcium release from the sarcoplasmic reticulum (Allen, Kabbara & Westerblad, 2002). Allen (2004) suggested that the accumulation of lactate and cellular potassium, together with a lowering of pH, affects the excitability of the membrane. Repeated activation of the skeletal muscle causes various changes in its properties, with muscle strength decreasing with intense and frequent use, such as HV based running. Calcium release within the cell declines during the onset of fatigue, which has been shown to contribute to the reduction in force (Dugan and Frontera, 2000).

This present study demonstrated a significantly higher amount of decelerations were performed in the 3 vs. 3 format in comparison with the 4 vs. 4 format. These findings contradict that of Hodgson, Akenhead and Thomas (2014) as these authors found that as the absolute pitch size and number of players increased, so did the amount of accelerations and decelerations. A possible explanation for the difference could be that this current study did not include the use of goalkeepers, therefore encouraging players to not replicate positional play.

One variable associated with muscle fatigue is a reduction in energy substrates within individual muscle fibres (Krustrup et al., 2006). Therefore this study investigated the metabolic power demand (w/kg) placed upon the players. The study demonstrated a difference between 3 vs. 3 and 4 vs. 4 SSG where the 4 vs. 4 SSG elicited a higher metabolic demand. These findings are consistent with previous research by Gaudino, Alberti, and Iaia (2014) whereby an increase in high intense running and activities resulted in a higher metabolic expenditure when absolute pitch size increased and so did relative pitch are per player. Although the total amount of decelerations were greater in the 3 vs. 3 format, it could be suggested that the braking forces required in the 4 vs. 4 format from higher speed running, placed a greater physiological load on the players thereby causing more fatigue.

HR monitoring of players is considered an effective method for regulating exercise intensity (Reilly, Drust, & Clarke, 2008). The session intensity during this study in terms of max HR did not demonstrate a difference. These findings are consistent with some literature (Aroso et al., 2004; Sampaio et al., 2007) but not all (Little & Williams, 2006; Owen et al., 2004; Rampinini et al., 2006). The difference in results could be attributed to the variation in interventions utilised in the studies. The contradictory literature did not increase the relative pitch area per player in conjunction with the increase in the absolute area whereas the current study did. This allowed the players more opportunity to cover more distance at a higher speed which could be the cause of the perceived higher HR response in the 4 vs. 4 SSG format. SSGs comprise a combination of technical/tactical ability, decision making and physical exertion from the players; therefore it would seem that coexisting abilities may be required to achieve the desired exercise intensity for the session.

Consequently, it is plausible that less-skilled players may not be able to sustain the technical or tactical proficiency to achieve or maintain the required metabolic expenditure; therefore, training interventions may be counterproductive in terms of performance (Castagna, Belardinelli, & Abt, 2004). However, this has not been empirically tested during this study and future studies should examine the possibility that low technical skill ability limits the exercise intensity of individual players during SSGs.

This research appears to include some limitations. Primarily the sample size used was small therefore meaning the study being underpowered. A study of this magnitude ideally would require at least 20 participants, with a sample size calculation being performed using G Power software. This reduced sample size also had a direct impact on the types of SSG chosen, as the HV based SSG had to be restricted to 4 vs. 4 due to the reliability on the players attending and low sample number. The availability of the pitch size was also considered a limitation. Due to the club having youth team, reserve team and first team training on the same night, this caused a restriction on SSG pitch dimensions and variety of games which could have been performed.

For future research, a suggestion would be to do a test for quadriceps strength in conjunction with hamstring strength to look at ratio of quadriceps to hamstring. Current literature concludes a large coactivation of the quadriceps and hamstrings during isokinetic concentric knee extension (Kellis, & Baltzopoulos, 1997). Coactivation is defined as the simultaneous activation of agonist and antagonist muscle groups during voluntary contractions (Psek, & Cafarelli, 1993). It has been suggested that if the hamstrings become fatigued, the neural drive to the quadriceps will be reduced (Beltman, Sargeant, Ball, Maganaris, & De Haan, A, 2003). Consequently providing a safe deceleration and stability of the knee joint (Akima, Takahashi, Kuno, & Katsuta, 2004). This would highlight if hamstring torque and quadriceps torque reduced concurrently, especially in the multi directional nature of the SSG in comparison to the straight line treadmill based protocol.

Practical Applications

These findings can enable SCC to plan sessions within SSG in soccer. Due to the potential increased knee joint instability caused by reduced hamstring torque, utilising the 4 vs. 4 SSG during a busy time of the season could heighten the risk of injury due to less recovery time. The findings suggest that the HV based SSG would be better placed at the beginning of the training week and further away from match day due to the greater fatigue induced. Both LV and HV SSG would be most appropriate intervention if the SCC would be looking to develop accelerations due to the amount performed in both variations. If the physiological adaptation is HV running and looking to achieve MS, the SSG with the greater absolute area and relative area per player would be the most ideal training stimulus. Regarding using the intervention as a metabolic conditioning session, both variations of SSG elicited similar absolute values of energy expenditure which suggest both are similar in terms of effectiveness when looking to exert a conditioning session on the players.

Conclusion

In conclusion, HV based SSG elicit the greatest decrement in hamstring fatigue in comparison to LV SSG, both in PF and MF data. Also, as the number of accelerations performed in the session increases, it is likely to cause a greater reduction in hamstring torque.

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Participant Information Sheet

You are being invited to take part in a research study. It is important for me to allow you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish before deciding to participate. Please ask if there is anything that is not clear or if you would like more information. Thank you in advance for reading this:

What is the purpose and aim of our research?

Hamstring injuries are prevalent in soccer and cause players to lose many days of competition. The purpose of the study is to assess how much fatigue different types of sessions have on hamstring strength, which helps coaches understand demands of sessions on the players. This will then help with training load management thus reducing injury risk.

Why have I been invited?

You have been chosen because you are healthy athlete, who regularly undertakes exercise and is over the age of 18 and under the age of 40.

Who is organising the research?

The research is being organised by Glenn Donnelly (MSc Student), Dr Mark Waldron (Senior Lecturer Exercise Physiology) and Dr Stephen Patterson (Senior Lecturer Exercise Physiology).

What will happen to the results of the study?

The results will be given within a “summary of findings” document after the study is complete. You will only be given overall results and not the results of any other participant that took part. No further individuals or organisations will be given these findings.

Source of funding for the research

There are no external sources of funding for this study.

Contact for further information

Glenn Donnelly (145452@stmarys.ac.uk) - 07415394008

It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form and PAR-Q. You will be given copies of these. You are still free to withdraw at any time with no questions asked and no penalty.

Do I have to take part?

What will happen if you agree to take part?

You will be needed on a total of 6 occasions during a selected period of time. The visits will comprise, one familiarization session, four experimental sessions and one concluding session. Every session will take between 30 mins – 1 hour at the same time of day, across a 4-week period. During the familiarization session, you will be given the chance to practice the position and technique of the isometric hamstring test on the nordbord and also becoming familiar with use of GPS units. You will complete necessary questionnaires and consent forms. Any final questions that you might have in regards to the procedures can be asked here or throughout the rest of the study. During the four experimental trials, you will follow the procedure provided below.

Whether there are any special precautions you must take before, during or after taking part in the study

No. You will be assessed on normal training conditions under the instruction of the club.

On the day of the trial

The testing protocol will be the following:

You will arrive at the club ready for training at least 30 minutes before. You will have your hamstring strength measured on the nordbord prior to training. GPS will be attached to you as per normal training conditions. Upon completion of the training intervention, your hamstring strength will again be tested on both limbs via the nordbord. GPS units are then returned to me.

Are there any risks or side effects?

Any scientific investigate involving human participants carries an element of risk but due to less invasive nature of the study, very small risks are associated.

Agreement to participate in this research should not compromise your legal rights if something goes wrong

Research can carry unforeseen risks and we want you to be informed of your rights in the unlikely event that any harm should occur as a result of taking part in this study. Every care will be taken to ensure that your well-being and safety are not compromised during the course of the study. St Marys University also has insurance arrangements in place in the unlikely event that something does go wrong and you are harmed as a result of taking part in the research study.

What will happen to any information/data/samples that are collected from you?

Only the researchers will have access to the data collected during the study. However, your identity will not be revealed. All information which is collected about you during the course of the research will be kept strictly confidential. We will keep a record that you have taken part in the study but will not keep any other personal information about you. Professional standards of confidentiality will be adhered and the handling, processing, storage and destruction of data will be conducted in accordance with the Data Protection Act (1998).

Are there any benefits from taking part?

There are several benefits for participants to participate in the study. All the participants will gain useful information in terms of their health and fitness and, more generally, athletes may benefit from gaining further knowledge about the effects of different sized games on the hamstring strength.

How much time would I need to give up?

The total time commitment will be 6-8 hours over 4 weeks, distributed over 6 visits by myself to the club.

How your participation in the project will be kept confidential?

Your name and personal details will not be referred to within the study.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

St Mary's University Twickenham London

Consent Form

Name of Participant: ____

Title of the project: Effect of SSG on Hamstring Fatigue

Main investigator and contact details: Glenn Donnelly – 07415394008 – 145452@stmarys.ac.uk

Members of the research team: N/A

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)……………………………………………………………………………..

Signed………………….…………………   Date……………………………........

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: Effect of SSG on Hamstring Fatigue

I WISH TO WITHDRAW FROM THIS STUDY

Name: ____

Signed: ____________________________________   Date: __________________

St Mary's University Twickenham London

Approval Sheet

Name of applicant:	Glenn William Donnelly
Name of supervisor:	Mark Waldron
Programme of study:	Postgraduate Research
Title of project:	The impact of small sided games on hamstring fatigue in soccer players

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1 Approved at Level 1 Signature of supervisor (for student applications).. Date..
SECTION 2 Refer to School Ethics Representative for consideration at Level 2 or Level 3 Signature of supervisor: Colin Towey Date: 11/01/17
SECTION 3 To be completed by School Ethics Representative Approved at Level 2 Signature of School Ethics Representative.. Date..

SECTION 4

To be completed by School Ethics Representative. Level 3 consideration required byt the Ethics Sub-Committee (including all staff research involving human participants)

Signature of School Ethics Representative..

Date..

Level 3 approval – confirmation will be via correspondence from the Ethics Sub-Committee