Physiological, perceptual and time-motion characteristics of man marking in small-sided soccer games

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Abstract

Small-sided games (SSG) are a common training modality for soccer teams, and have been extensively researched in the literature. However, there are inconsistent findings regarding whether SSGs induce a sufficient intensity for optimal conditioning. Enforcing a man marking (MM) strategy during SSGs has been theorized to increase the intensity and running velocities of players. Currently, no study has quantified GPS-derived time-motion analysis data from MM SSGs. Hence, the purpose of this study was to compare the physiological, perceptual and time-motion characteristics of MM with non-man marking (NMM) in SSGs. Eight amateur players (mean age ± SD: 23.6 ± 3.3 years) participated in 2v2, 3v3 and 4v4 SSGs, with two repeats for NMM and MM for all three formats. Players were initially assessed for maximal aerobic speed, maximum heart rate (HR) and maximal sprint speed, with team allocation based upon results from initial testing and coach recommendations. Each session consisted of 4x4 min bouts, with 2 min passive recovery, during which players wore a HR monitor and GPS unit and reported their rate of perceived exertion (RPE).

Average percentage HR (%HR_{ave}) induced small to moderate effects with MM compared to NMM (ES = 0.22 to 0.65), however great inter-individual differences renders assumptions *unclear* for 3v3 and 4v4. Comparisons between MM formats indicated a decrease in %HR_{ave} with increased player numbers (%Δ = 1.6-3.5%; ES = 0.39 to 0.86). Bout comparisons (NMM vs MM and player numbers (MM only)) for time spent ≥90% HR_{max} were predominantly *unclear*.

Perceptual load increased with MM compared to NMM (%Δ = 6.7-17.6%; ES = 0.66 to 2.09), while increases in player numbers (MM only) reduced RPE scores (%Δ = 9.4-24.3%; ES = 1.14 to 3.61).

Time-motion characteristics revealed substantially greater total distance in MM irrespective of player number (%Δ = 6.8-14.7%; ES = 1.34 to 2.82). While only 3v3 MM elicited substantial differences compared to the NMM (%Δ = 21.2 ± 20.1; ES = 1.48 ± 1.27) for jogging (7-13 km/h), there were *very likely* increases in distances covered for both striding (13.1-17.8 km/h) (%Δ: 23.4-33.2; ES = 2.42 to 4.35), and high intensity running (HIR: 17.9-21 km/h) (%Δ: 47.3-104; ES = 0.91 to 1.68) for MM compared to NMM irrespective of player number. Comparing player numbers for striding revealed increased distances covered with increased player numbers (%Δ: 12.6-19.6; ES = 1.37 to 2.06), with similar findings identified for HIR (%Δ: 19.8-80.4; ES = 0.43 to 1.39).

Player number comparisons (MM only) for maximum and average metabolic load (P_{max} and P_{ave} respectively) revealed predominantly *unclear* differences, while a *very likely* decrease occurred with P_{max} and P_{ave} for MM implementation in 2v2 (ES = -1.21 ± 0.71) and 4v4 (ES = -0.95 ± 0.5) respectively.

In conclusion, this study demonstrates how MM substantially elevated perceptual load and distances covered when striding and running at high intensity regardless of player number. However, the lack of difference in internal load between MM and NMM, indicated by HR, suggests that SSGs with more players may not be prone to increased intensities.

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Attestation of authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Mr. Mats Aasgaard (MA)

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1.0 Introduction

Soccer is recognized as one of the most popular – if not *the* most popular – sport in the world, with people participating on various levels and across all ages (Stølen, Chamari, Castagna, & Wisløff, 2005). Elite level players predominantly find themselves playing in big European clubs/leagues, which further expand their marketing value and broadcasting opportunities to other continents around the world (Solberg & Turner, 2010). The global popularity inevitably initiates a desire among aspiring soccer players to emerge as top players, implying substantial amount of hours and years spent training in the attempt to reach the top level (Ericsson, 2008). Meanwhile, the top clubs aim tirelessly towards the goal of dominance on the field, consequently sparking an insatiable thirst to reveal optimal training strategies to achieve a competitive advantage (Williams, 2013).

The physical demands of soccer have been reported in detail in the literature (Boone, Vaeyens, Steyaert, Bossche, & Bourgois, 2012; Bradley et al., 2009; Hughes et al., 2012; Krustrup et al., 2006; Mohr, Krustrup, & Bangsbo, 2003), with a variety of physiological and physical requirements displayed throughout a full game (Stølen et al., 2005). Indeed, elite adult players may display aerobic capacity levels (VO_{2max}) up to 75 mL/kg/min and cover ~12km in a full game (Stølen et al., 2005), while youth players may display as much as 66.5 mL/kg/min (Chamari et al., 2005), and cover ~10.2km (Thatcher & Batterham, 2004). However, a major determinant of player level encompasses the anaerobic capacity (repeated sprint ability - RSA) as it has been found to discriminate between professional and amateur players (Impellizzeri et al., 2008; Rampinini et al., 2009), as well as between players of different age groups (Nikolaïdis, 2011). Thus, the ability to recover from intensive bouts of high intensity exercise highly determines the success of the team, as fatigue may constitute lost challenges and conceded goals (Jones et al., 2013).

Soccer itself furthermore requires the players to commit a change in activity every 4-6 seconds on average (Mohr et al., 2003), and engage in high-speed running (Abt & Lovell, 2009) while remaining highly agile (Sporis, Jukic, Milanovic, & Vucetic, 2010) and strong (Haugen, Tønnessen, & Seiler, 2013; Sander, Keiner, Wirth, & Schmidtbleicher, 2013). With multiple physiological and physical demands, conditioning for soccer players must be multifactorial, likely requiring separate exercises to tailor for various components of the game (Williams, 2013).

Aerobic capacity is of particular importance to soccer players, especially in relation to certain player positions, as midfielders and fullbacks cover greater distances compared to centre-backs and forwards (Boone et al., 2012; Dellal, Chamari, et al., 2011). The relationship between maximal oxygen uptake (VO_{2max}), player level and distance covered in a full game (Manolopoulos et al., 2012) further highlights the necessity to optimally condition for this particular physiological component to optimize performance (Helgerud, Engen, Wisloff, & Hoff, 2001; Hoff, Wisløff, Engen, Kemi, & Helgerud, 2002). The factors required to enhance VO_{2max} remain holistically identical irrespective of player level. For example, early studies by Helgerud et al. (2001) displayed elevated VO_{2max} levels (10.8%) among Norwegian junior elite soccer players following an 8 week study requiring participant engagement in 4-minute generic running intervals at 90-95% of heart rate maximum (HR_{max}), interspersed by 3-minute recovery consisting of light jog at 50-60% HR_{max}. The authors argue for a substantial workload on the heart to instigate changes in VO_{2max}, preferably in the excess of 90% HR_{max} (Helgerud et al., 2001). Additionally, a sport-specific soccer dribbling track with similar bout and rest durations displayed similar %HR_{max} levels (91.3%), furthermore suggesting that sport-specific interval training is a viable tool to enhance VO_{2max} for soccer players. Interestingly, Helgerud et al. (2007)

revealed superior effects for VO_{2max} following 4x4 minute intervals (3 x week for 8 weeks) for recreationally active people when compared to continuous and long-slow distance running, thus strengthening the argument for utilization of an intermittent approach to aerobic conditioning. Lastly, Helgerud, Rodas, Kemi, and Hoff (2011) utilized elite professional soccer players (with experience from the UEFA Champions League) to investigate the effect of concurrent 4x4 minute interval and strength training over 8 weeks (twice weekly), displaying an 8% and 51.7% increase in VO_{2max} and 1RM squat post intervention. Thus current research argues the usefulness of the 4x4 minute interval training to stimulate the cardiovascular system sufficiently to enhance VO_{2max} without concurrent decrements to strength gains, consequently elevating match performance and in-game success for individual players and teams.

While the abovementioned studies suggest that generic intermittent running and dribbling tracks are effective, an argument can be made towards tailoring aerobic conditioning while adhering to sport specific recommendations. To date, this has been achieved using small-sided games (SSGs) to induce physical load and imitate game-like situations (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011; Hoff et al., 2002; Reilly & Gilbourne, 2003). Indeed, SSGs have been widely incorporated in soccer as a viable training tool, with specific formats incorporated for various physiological and physical outcomes, as well as opportunities to condition for technical/tactical training (Hill-Haas et al., 2011).

With SSGs come an abundance of opportunities with regards to manipulation of game-play to achieve various effects. For example, previous literature has established fairly concise guidelines for optimizing aerobic fitness via SSGs (Casamichana & Castellano, 2010; Kelly & Drust, 2009; Koklu, Albayrak, Keysan, Alemdaroglu, & Dellal, 2013;

Rampinini et al., 2007). To achieve this intensity, multiple studies argue for less player numbers in SSGs to induce sufficient intensities similar to those required for enhanced aerobic capacity (Aguiar, Botelho, Gonçalves, & Sampaio, 2013; Bondarev, 2011; Brandes, Heitmann, & Müller, 2012; da Silva et al., 2011; Rampinini et al., 2007). Moreover, greater pitch sizes or relative individual pitch size (m^2) appear to result in elevated intensities, as players are required to cover greater distances at higher velocities (Casamichana & Castellano, 2010; Koklu et al., 2013; Owen, Twist, & Ford, 2004; Rampinini et al., 2007). Indeed, an 18-week SSGs training intervention (including performance tests at various stages) revealed a 7% increase in VO_{2max} for soccer players, as well as a 10% increase for lactate threshold (LT) (Impellizzeri et al., 2006).

Due to the variability of the sport, the manipulation of game components are highly influential on game performance and intensity level, with the influence of touch-limitations (Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011), goalkeeper inclusion (Köklü, Sert, Alemdaroğlu, & Arslan, 2015) and player number inequality between teams (Mallo & Navarro, 2008) generating alterations to technical, physiological and physical performance.

High-intensity running (HIR) and sprints occur frequently during a full game of soccer. Soccer-players spend approximately 18% of a full-game accelerating/decelerating (Akenhead, French, Thompson, & Hayes, 2014), with distances covered at velocities >19.8 km/h are identified to be in the excess of 900m for all outfield players (excluding central defenders) in the English Premier League (Bradley et al., 2009). Furthermore, the ability of players to conduct repeated sprints is highly dependent on player level, in spite of similar VO_{2max} levels between amateurs and professionals (Rampinini et al., 2009). The ability to instigate repeated sprints in SSG remains questionable – yet equally desirable – due to its in-game importance. Currently, only Owen, Wong, Paul, & Dellal (2012) have displayed significantly improved RSA times following a SSG intervention (in-season – 4 weeks), while two other studies revealed insufficient time spent running at high intensities in SSGs relative to full games (Casamichana, Castellano, & Castagna, 2012; Gabbett & Mulvey, 2008).

Man marking (MM) has been proposed as a suggestion for game-specific manipulation to instigate greater intensities and distances covered at greater velocities in SSGs (Gabbett & Mulvey, 2008). With MM emerges an increased requirement for players to sprint while defending, then recover, and eventually engage in another sprint to instigate an optimal counter-attack, as defending requires the constant tracking of an attacking opponent, while attacking aims towards avoiding the defenders in order to score goals (Gabbett & Mulvey, 2008).

To date, only three studies have investigated the physiological effects of MM in soccer SSG; utilizing players ≤16 years of age (Aroso, Rebelo, & Gomes-Pereira, 2004; Ngo et al., 2012; Sampaio et al., 2007) with inconsistent outcomes between studies. For example, Aroso et al. (2004) displayed evidence of elevated blood lactate levels (BLa^-) and time spent walking to increase for 2v2 MM compared to 2v2 non-man marking (NMM). Moreover, Sampaio et al. (2007) revealed no significant differences in $\%HR_{max}$ for MM vs NMM, although internal load obtained from perceptual measures (RPE) was higher for MM – both for 2v2 and 3v3 SSGs. Conversely, Ngo et al. (2012) revealed higher $\%HR_{max}$ for 3v3 MM compared to 3v3 NMM, with no significant difference in session-RPE between MM and NMM irrespective of game format.

What becomes apparent is the contradicting $\%HR_{max}$ result between studies, along with a lack of time-motion characteristics investigated in relation to MM in SSG. To date, no study on MM with an adult population has been conducted, and only Ngo et al. (2012) conducted repeated measures of each format to account for greater validity of the findings. Lastly, no study has investigated the effects of MM with different player numbers. Clearly, further research is required with older players and with time-motion metrics from GPS that are now commonly used in team sport research.

Study aims

- Determine the time-motion, physiological and perceptual effects of man marking vs non-man marking in SSG for amateur adult soccer players
- Determine the effects of man marking vs non-man marking in SSG in relation to various numbers of players.

2.0 Literature review

Small-sided games (SSGs) is a training method utilized for athlete conditioning, also known as game-based training (Buchheit et al., 2009; Gabbett, Jenkins, & Abernethy, 2009). In recent years there has been a significant increase in research conducted to identify various training opportunities within the domain of SSGs, with a systematic review published by Hill-Haas et al. (2011) presenting an overview of physiological applications. However, more than 30 studies, along with new theories and methodological advances within the SSG literature have emerged over the last 4-5 years, requiring an up-to-date review to highlight our current understanding and application.

Soccer remains multifactorial in its gameplay; hence manipulations of variables and components of the game are highly likely to influence each other. With major differences in the amount of research conducted on certain aspects of the game, the most influential and common game manipulations will be addressed initially in this review. Specific rule alterations will be discussed within the same section, while comparison to generic interval training, limitations and future research opportunities completes the review.

Firstly, the following review will consider the physiological responses to SSG and how manipulating SSGs may induce various adaptations and improvements in soccer players. Secondly, the review will discuss pitch size and player numbers, the most frequent variables manipulated in soccer SSG studies, and their impact on physiological and technical output. Game duration, recovery and verbal encouragement constitute the subsequent paragraphs, while a multi-segmented section on time-motion characteristics discuss the physical characteristics of SSGs. Furthermore, the review continues with a comparison between SSGs and generic interval training, while various rule alterations are subsequently discussed in relation to their impact on game intensity and physical outputs.

In addition, a section on perceptual responses to SSGs and associated format manipulations are discussed to highlight the psychological demand of the training modality, before a brief paragraph addresses periodization in association with SSGs. The review concludes with a section on SSGs and their associated limitations, followed by future applications and associated opportunities for future research into the field of soccer SSGs.

2.1 Physiological Components

Improvements in aerobic capacity is considered one of the main desirable outcomes from SSGs, as aerobic fitness is identified as a huge determinant of full-game performance as well as individual player level (Impellizzeri et al., 2006). Hence, the following three sections will address adaptations to determinants of aerobic capacity with soccer SSGs, predominantly heart rate, maximal oxygen uptake and lactate.

2.1.1 Heart Rate

It appears that sufficient stimuli of the cardiovascular system (>90% HR_{max} for 3-8 minutes), interspersed with low intensity breaks (≤70% HR_{max} for 2-3 minutes), is required to instigate a sufficient load on the heart to increase stroke volume (SV) and cardiac output (Q) (Stølen et al., 2005). While heart rate (HR) monitoring remains a valid and extensively used assessment method (Esposito et al., 2004), utilizing HR as the sole measurement of intensity in SSG have implications due to a high impact from the anaerobic system on intensity in SSGs with low player numbers (i.e. 2v2) (Little & Williams, 2007). Regardless, studies by Drust, Reilly, and Cable (2000) and Esposito et al. (2004) display valid use of the HR/VO_2 relationship in laboratory and sport-specific settings, implying the implementation of HR for monitoring and guiding training sessions intensities is valid. Thus, programming SSG to elicit ≥90% HR_{max} to induce stress on the oxygen utilization and transport systems, which subsequently may efficiently enhance maximal oxygen uptake (VO_{2max}), is warranted.

Köklü, Aşçi, Koçak, Alemdaroğlu, and Dündar (2011) argue for greater explosive movements in SSG as opposed to generic running – thus inducing greater anaerobic contribution – inevitably resulting in reduced HRs and a demand for recovery due to elevated lactate levels (La^-). da Silva et al. (2011) suggest how >85 HR_{max} intensity levels generate sufficient cardiovascular stimuli during SSGS to enhance aerobic fitness in soccer players. Moreover, several studies display intensities of ≥85% HR_{max} in combination with certain game variable manipulations (Casamichana & Castellano, 2010; Dellal, Owen, et al., 2012; Owen et al., 2004; Rampinini et al., 2007), while others again achieve ≥90% HR_{max} (Castellano, Casamichana, & Dellal, 2013; Dellal, Hill-Haas, et al., 2011; Dellal, Lago-Penas, Wong, & Chamari, 2011; Köklü et al., 2015). Indeed, Köklü, Ersöz, Alemdaroğlu, Aşç, and Özkan (2012) displayed the highest intensities (>90% HR_{max}) when 4v4 SSG teams were allocated based on the players' relative VO_{2max}, as opposed to technical or coaches subjective evaluation of players. Thus consideration into player allocation is advised for practitioners to ensure sufficient intensities. For further information regarding HR output in various SSGs, please refer to Table 2.

2.1.2 Maximal oxygen uptake (VO_{2max})

VO_{2max} in soccer players differs between elite and non-professional players, with elite soccer players capable of covering greater distances during full-games compared to non-elite (Mohr et al., 2003), likely due to greater aerobic fitness (Wisløff, Helgerud, & Hoff, 1998). VO_{2max} tend to increase significantly with ≥6 weeks of regular high-intensity training (≥2 x week) (Bacon, Carter, Ogle, & Joyner, 2013). Only a few studies have investigated the effect of SSG on VO_{2max} following weeks of regular conditioning, however as the ≥90% HR_{max} required intensity mimics that of intervals utilized in three different studies (Helgerud et al., 2001; Hoff et al., 2002; McMillan, Helgerud, Macdonald, & Hoff, 2005), it remains highly viable that SSG are capable of enhancing aerobic capacity to values similar to those of generic training. For example, Impellizzeri et al. (2006) revealed a significant improvement in VO_{2max} (7%) following an 14-weeks pre- and in-season intervention. Although this emphasizes the theoretical suggestion of improved aerobic capacity following SSGs, both Dellal, Varliette, Owen, Chirico, and Pialoux (2012) and Hill-Haas, Coutts, Rowsell, and Dawson (2009) failed to identify significant improvements for VO_{2max} for their respective studies. Due to methodological differences, this topic will be discussed further in section 2.7.

While SSGs certainly constitute a desirable approach to enhancing VO_{2max}, there are certain limitations to the training modality which require further attention. It is suggested that attaining sufficient intensities to elevate cardiac filling results in an enhancement in cardiac function (Helgerud et al., 2007), thus intensities close to SV must be attained (Lepretre, Koralsztein, & Billat, 2004). The combination of smaller pitch-sizes associated with SSG (Hill-Haas et al., 2011), increased concentric/eccentric activation of large muscle fibers/groups in acceleration/deceleration (Young, Benton, & Pryor, 2001), and a given time spent walking/light jogging imply rapid changes of direction and unstructured breaks throughout SSG bouts, thus inducing fluctuations in intensity (Buchheit & Laursen, 2013a). Hence, the variations in HRs obtained throughout bouts of SSG may be misleading in assuring optimal intensities for cardiovascular adaptations have been achieved (Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2013). While studies to date remain equivocal with regards to whether or not SSGs improves VO_{2max} – variations in research design, implementation of SSGs during various stages of the season, and player level/age implies a requirement for additional research.

2.1.3 Lactate

Lactate is recognized as the byproduct of anaerobic glycolysis, and its inclusion in research investigating soccer intensity is extensive. Blood lactate levels (Bla^-) of 2-14 $mmol^-$ post game (soccer) have been reported, with blood samples currently the most common measurement for lactate in soccer players (Krustrup et al., 2006; Stølen et al., 2005) as opposed to muscle sampling.

Although lactate levels fluctuate greatly in conjunction with specific energy demands throughout a game of soccer, and thus may impact measurements taken at various stages throughout training sessions or games (Krustrup et al., 2006), Rampinini et al. (2007) displayed greater Bla^- levels with decreasing number of players in SSGs (and subsequent alterations in pitch size), with values reaching as high as 10.1 ± 1.8 $mmol^-$. A similar relationship between player number and Bla^- values were observed in several studies (Ade, Harley, & Bradley, 2014; Brandes et al., 2012; Evangelos et al., 2012; Hill-Haas, Dawson, Coutts, & Rowsell, 2009). Interestingly, Dellal, Lago-Penas, et al. (2011) revealed higher Bla^- values for 4v4 free play (FP) SSGs among elite professional players when compared to touch limitations (1 + 2 touch). A second study by Dellal, Hill-Haas, et al. (2011) revealed higher Bla^- levels for amateur soccer players when compared to elite professional players, regardless of rule alterations (1-touch (1T), 2-touch (2T), FP).

Furthermore, the same study did not reveal an intragroup significant difference for Bla^- between rule alterations for SSG 4v4 for the elite professional players. Moreover, Hill-Haas, Dawson, et al. (2009) displayed higher average Bla^- levels for junior amateur soccer players when compared to elite professional players in a study by Dellal, Hill-Haas, et al. (2011). The abovementioned studies indicate a trend towards increased lactate levels with less player numbers, suggesting that increased involvement with the ball (less players) instigates elevated H^+ accumulation. Moreover, touch limitations appear to be less efficient in stimulating lactate production, while elite players accumulate decreased levels of lactate compared to amateurs – likely due to enhanced fitness levels.

A comparison between SSG (4v4) and friendly matches revealed higher levels of Bla^- for SSGs (Dellal, Owen, et al., 2012), likely due to higher intensities achieved during the training modality. The result may be explained by insufficient time to recover between repeated high intensity bouts, resulting in an inability of H^+ removal. Conversely, Rampinini et al. (2007) investigated the difference in SSGs with/without coach encouragement, displaying significantly higher Bla^- levels for SSGs with coach encouragement regardless of number of players (2v2 – 6v6).

Although the Bla^- levels reflect the accumulated La^- during repeated exercise of high intensity, it does not explicitly describe the muscle buffering capacity, as Mla^- and Bla^- buffering capacities differ greatly (Krustrup et al., 2006). A lack of research utilizing Mla^- may be considered a gap in the scientific research, as it constitutes a substantial part of anaerobic fitness (Buchheit & Laursen, 2013b). Moreover, the abovementioned studies that utilized Bla^- measurements remain inconsistent in the post SSG time-period with regards to drawing samples. Fluctuations in Bla^- ranges from 1 to 5 min post-exercise (Brandes et al., 2012; Dellal, Hill-Haas, et al., 2011; Dellal, Lago-Penas, et al., 2011; Evangelos et al., 2012; Hill-Haas, Dawson, et al., 2009; Rampinini et al., 2007), while one study did not specify the time at which they collected the samples (Ade et al., 2014). Additionally, two studies collected samples between bouts of SSG (Brandes et al., 2012; Dellal, Lago-Penas, et al., 2011), highlighting the alterations in Bla^- throughout a full session of SSG. With fluctuations in timing of sample collection, and Bla^- buffering capacity equaling approximately 0.25 $mmol \cdot L^{-1} \cdot min^{-1}$ (Krustrup et al., 2006), a total of 1 $mmol \cdot L^{-1}$ difference may occur between studies, which again may argue for less valid results.

2.2 Pitch dimensions in SSGs

A frequent topic for SSG research is the influence of pitch dimensions/sizes on physiological and technical responses in soccer. Pitch sizes may be altered in both absolute and relative terms, with relative pitch sizes calculated by dividing the total pitch area by player number.

2.2.1 Pitch dimensions in SSGs – physiological responses

Coaches may select to alter the size or the ratio of the pitch in SSGs to induce required responses in players. Multiple studies to date report a greater %HR among players when the pitch size is increased for a given player number (Aroso et al., 2004; Casamichana & Castellano, 2010; Koklu et al., 2013; Owen et al., 2004; Rampinini et al., 2007), with concomitant increases in BLa^- (Aroso et al., 2004; Rampinini et al., 2007). Moreover, greater work:rest ratios have been identified for large pitch sizes when compared to small, indicating that greater distances are covered at higher intensities throughout SSGs with increased absolute size (Casamichana & Castellano, 2010). As greater pitch sizes/m^2

requires players to remain in constant motion while both defending and attacking, a likely enhanced stimulation of the cardiovascular system occurs in response to the increased activity demand (Koklu et al., 2013). With BLa^- levels mirroring the increase in HR for greater pitch sizes, it is logical to attribute the findings to greater work:rest ratios, although this is not discussed in the above-mentioned studies. Indeed, as BLa^- is heavily linked with %HR (Buchheit & Laursen, 2013a), and greater pitch sizes induce higher mean and maximal sprint durations (Hill-Haas, Dawson, et al., 2009), BLa^- levels are likely to increase due to the enhanced physiological demand on the system.

Although several studies highlight a significant difference between pitch sizes for physiological responses, Kelly and Drust (2009) identified no significant HR differences for 4v4 SSGs (three different pitch sizes), while Tessitore, Meeusen, Piacentini, Demarie, and Capranica (2006) revealed greater HR_{max} and lactate levels for the smaller pitch in 6v6 SSG (Table 1). However, the intervention utilized a player number above recommendations for optimal intensity levels (≥4v4) (da Silva et al., 2011), thus explaining why the players spent most time at 150-170bpm (61-76% HR_{max}).

Table 1 - Summary of studies investigating the effects of pitch dimensions on physiological responses in soccer SSGs

Study	N	Age (gender)	Level	Mode	Format (rest)[a]	Pitch size (m^2)[b]	%HR_{max} (mean ± SD)	Bla$^-$ (mmol/L) [mean ± SD]	RPE (1-10 AU)[c] [mean ± SD)
Aroso et al. 2004	14	15 - 16 (m)	Nat	2v2	3x90s (90s)	30x20 (150)	84 ± 5	8.1 ± 2.7	16.2 ± 1.1[d]
				3v3	3x4 min (90s)	30x20 (100)	87 ± 3	4.9 ± 2.0	14.5 ± 1.7[d]
				4v4	3x6 min (90s)	30x20 (75)	79 ± 6	2.6 ± 1.7	13.3 ± 0.9[d]
						50x30 (188)		↑(N/A)	↑ (N/A)
Casamichana & Castellano, 2010	10	15.5 ± 0.5 (m)	Reg	5v5 + GK	1x8 min (5)	62x44 (272.8)	88.9 ± 3.9		6.7 ± 0.8
						50x35 (175)	88.5 ± 4.9		6.7 ± 0.8
						32x23 (73.6)	86.0 ± 5.8		5.7 ± 1.0
Kelly & Drust, 2009	10	18 ± 1 (m)	Pro	4v4 + GK	4x4 min (2)	30x20 (60)	91.0 ± 4.0		
						40x30 (120)	90.0 ± 4.0		
						50x40 (200)	89.0 ± 2.0		
Koklu et al. 2013	16	14.2 ± 0.6 (m)	Eli	3v3	4x3 min (2)	20x15 (50)	87.1 ± 1.6		5.2 ± 0.5
						25x18 (75)	89.0 ± 2.3		5.6 ± 0.5
						30x20 (100)	91.0 ± 2.5		6.1 ± 0.6
				4v4	4x4 min (2)	20x20 (50)	86.5 ± 4.0		4.4 ± 0.5
						30x20 (75)	88.9 ± 3.2		5.0 ± 0.4
						32x25 (100)	90.7 ± 3.0		5.3 ± 0.5
Owen et al. 2004[e]	N/A	17.5 ± 1.1[f]	Pro	1v1	1x3 min (12)	10x5 (25)	86		
						15x10 (75)	88		
						20x15 (150)	89		

				2v2		15x10 (38)	84.2		
						20x15 (75)	87.4		
						25x20 (125)	88.1		
				3v3		20x15 (50)	81.7		
						25x20 (83)	81.8		
						30x25(125)	84.8		
				4v4		25x20 (63)	72		
						30x25 (75)	78.5		
				5v5		30x25 (75)	75.7		
						35x30 (105)	79.5		
						40x35 (140)	80.2		
Rampinini et al. 2007	20	24.5 ± 4.1 (m)	Ama	3v3	3x4 min (3)	20x12 (40)	89.5 ± 2.9	6.0 ± 1.8	8.1 ± 0.6
						25x15 (63)	90.5 ± 2.3	6.3 ± 1.5	8.4 ± 0.4
						30x18 (90)	90.9 ± 2.0	6.5 ± 1.5	8.5 ± 0.4
				4v4		24x16 (48)	88.7 ± 2.0	5.3 ± 1.9	7.6 ± 0.5
						30x20 (75)	89.4 ± 1.8	5.5 ± 1.8	7.9 ± 0.5
						36x24 (108)	89.7 ± 1.8	6.0 ± 1.6	8.1 ± 0.5
				5v5		28x20 (56)	87.8 ± 3.6	5.2 ± 1.4	7.2 ± 0.9
						35x25 (88)	88.8 ± 3.1	5.0 ± 1.7	7.6 ± 0.6
						42x30 (126)	88.8 ± 2.3	5.8 ± 1.6	7.5 ± 0.6
				6v6		32x24 (64)	86.4 ± 2.0	4.5 ± 1.5	6.8 ± 0.6
						40x30 (100)	87.0 ± 2.4	5.0 ± 1.6	7.3 ± 0.7
						48x36 (144)	86.9 ± 2.4	4.8 ± 1.5	7.2 ± 0.8
Tessitore et al. 2006	12	21.7 ± 2.4 (m)	Reg	6v6	1x3 min (15)	30x40 (100)	70 ± 13		
					1x8 min (15)	30x40 (100)	76 ± 10		
					1x3 min (15)	50x40 (~167)	61 ± 13		
					1x8 min (15)	50x40 (~167)	70 ± 11		

a) Intervals and rest between bouts are in minutes unless otherwise specified (s = seconds)

b) Total pitch area divided by number of players

c) RPE is 1-10 unless otherwise stated

d) RPE is 6-20

e) HR values obtained from Hill-Haas et al. 2011

f) Gender not specified

Ama = amateur; **AU** = arbitrary units; **Bla-** = blood lactate concentration; **Eli** = elite; **GK** = goalkeeper; **HR** = heart rate; **%HR_{max} =** percentage of HR maximum; **mmol/L** = millimole per litre; **N** = number of participants; **Nat** = national; **NP** = neutral player; **Pro** = professional; **Reg** = regional; **RPE** = rating of perceived exertion; ↑ indicates increase

2.2.2 Pitch dimensions in SSGs – technical determinants

The link between pitch size and technical demands are of great interest due to the potential opportunity to condition for physiological and technical components simultaneously in a sport-specific setting. However, a lack of standardization of pitch sizes complicates training prescription, as only three studies to date have utilized the same absolute/relative pitch sizes (Akenhead et al., 2014; Hodgson, Akenhead, & Thomas, 2014; Kelly & Drust, 2009). This issue was identified by Fradua et al. (2013) who extrapolated individual playing areas from full games to optimally provide guidelines for SSG in relation to tactical training. The authors conclude that larger individual playing areas (90 m^2, range = 70–110m^2) are optimal for build-up and finishing play, while transition play require smaller individual playing areas (80 m2, range = 65–95m^2).

The majority of studies investigating technical actions in SSG fail to present numerical values for any findings, however current research indicates that particularly shots and tackles are more susceptible to pitch variations irrespective of player numbers (Hodgson et al., 2014; Kelly & Drust, 2009; Tessitore et al., 2006). Casamichana and Castellano (2010) reported similar findings for shots and tackles when pitch size was reduced, but also identified significant increases for a variety of other actions. Both relative (73.6 – 272.8 m^2) and absolute (32x23 – 62x44 m) pitch sizes were greater in the study by Casamichana and Castellano (2010) when compared to any of the other studies, potentially explaining the difference. Conversely, Kelly and Drust (2009) identified the highest amount of actions within the two first bouts of SSG (4 in total), with a gradual decrease for the final two bouts. As they only revealed a statistically significant change for shots and tackles with varying pitch sizes, they attribute the finding to enhanced levels of fatigue, rather than the impact of pitch size itself.

In general, it appears that a greater necessity to engage in actions more rapidly on smaller pitches (illustrated by the execution of passes and tackles more frequently) may explain a greater improvement in technical actions when compared to larger pitch sizes (Hodgson et al., 2014). Different playing positions may benefit from various pitch sizes differently, as a decrease in pitch size resulted in a reduction in interpersonal distance between attackers and defenders, ultimately leading to greater possession opportunities, but no significant difference in amount of shots or tackles (Vilar, Duarte, Silva, Chow, & Davids, 2014). The apparent differences between the findings by Casamichana and Castellano (2010) and Vilar et al. (2014) may be attributed to methodological differences, however the fluctuating findings and pitch dimensions utilized between studies imply a continuing requirement for additional research on the topic.

2.3 Player number in SSGs

Variations in player numbers are frequently conducted in SSG studies. The following two paragraphs aim to discuss the implications of varying the number of players on physiological and technical outputs.

2.3.1 Player number in SSGs – Physiological responses

The number of players per team fluctuates greatly between SSG studies. Although intensity requirements differ between studies, illustrated by ≥85% HR_{max} (da Silva et al., 2011) and ≥90% HR_{max} (Helgerud et al., 2001), it appears that reduced player numbers generate enhanced opportunities for physiological enhancements due to increased %HRs (Aguiar et al., 2013; Bondarev, 2011; Brandes et al., 2012; da Silva et al., 2011; Rampinini et al., 2007), with >4v4 SSGs recommended when lower-intensity training (technical/tactical) is desired (da Silva et al., 2011). The inclusion of less players allows every player to experience more time spent running with the ball, thus potentially explaining the increased physiological responses (Castellano et al., 2013; Köklü et al., 2011; Rampinini et al., 2007). Conversely, both Castellano et al. (2013) and Randers, Nielsen, Bangsbo, and Krustrup (2014) failed to identify a significant difference in HR and Bla^- between 3v3, 5v5 and 7v7 with constant pitch sizes (~$210m^2$ and $80m^2$ respectively). Careful consideration is advised however, as Castellano et al. (2013) utilized a single bout for each format, while Randers et al. (2014) implemented bouts of 12 minutes, which exceeds recommendations presented by Buchheit and Laursen (2013a), Helgerud et al. (2001) and Köklü et al. (2011).

Although research to date indicates lower player numbers for optimal physiological responses, two studies highlight how BLa^- appears to increase significantly with $\leq$ 2v2 (Aroso et al., 2004; Köklü et al., 2011). As SSG induce intensities at the anaerobic threshold, with a variety of explosive movements (sprints, tackles, jumps), sufficient time for recovery is required with this format (Köklü et al., 2011). A corollary of the increased demand on anaerobic energy contribution may propose $\leq$ 2v2 as a viable format to condition for anaerobic capacity (Brandes et al., 2012).

Theorized optimal intensity levels for aerobic capacity development (90-95% HR_{max}) (Helgerud et al., 2001) or ≥90% VO_{2max} (Buchheit & Laursen, 2013a), are not achieved in a substantial amount of soccer SSG studies, despite ≤4v4 formats utilized (Aroso et al., 2004; Castellano et al., 2013; da Silva et al., 2011; Hill-Haas, Coutts, Dawson, & Rowsell, 2010; Hill-Haas, Dawson, et al., 2009; Owen et al., 2004; Randers et al., 2014; Sampaio et al., 2007), however several findings are above 85% HR_{max} (Aroso et al., 2004; Brandes et al., 2012; da Silva et al., 2011; Köklü et al., 2011; Owen et al., 2004).

Furthermore, several studies presented in Table 2 failed to utilize the 4x4 minute format, either utilizing 1-2 sets per format (Castellano et al., 2013; Clemente, Wong, Martins, & Mendes, 2014; Sampaio et al., 2007), or less than 4 minutes per bout (Aroso et al., 2004; Köklü et al., 2011; Owen et al., 2004; Sampaio et al., 2007). Thus, methodological differences/discrepancies must be considered when interpreting current findings for player number manipulations, as fluctuations in research design may significantly impact intensities and provide suboptimal outcomes.

2.3.2 Player number in SSGs – technical alterations

The impact of player numbers on technical aspects of SSGs remains equivocal in research to date, however, there is a tendency for lower player numbers when conditioning for technical development in SSGs (Clemente et al., 2014; da Silva et al., 2011; Katis & Kellis, 2009; A. L. Owen, Wong, Paul, & Dellal, 2014). Additionally, consideration when interpreting results for technical variables in SSG research is advised, as only two studies to date have investigated the effect of player number numbers with absolute and/or relative pitch sizes (da Silva et al., 2011; A. L. Owen et al., 2014). Without an identical absolute/relative pitch size, its influence on gameplay may render interpretations of player number influence on technical outputs difficult.

Katis and Kellis (2009) highlight how intensity, ball contacts, dribbles, shots on goal and tackles increased with 3v3 as opposed to 6v6 ($p<0.05$, descriptive values n.a.), while Owen et al. (2014) revealed higher technical actions on average with 4v4 compared to 5v5-11v11 (i.e. *passes*: ES = 3.7, and *shots*: ES = 4.2 for 4v4 vs 9v9-11v11). More players on the field (and an increase in relative pitch size) likely equates to less pressure exerted on the players, thus the need to conduct a pass decreases as opposed to SSGs with less players (and concurrent decrease in pitch size) (Owen et al., 2014). Additionally, less players results in more shots, short passes, tackles and dribbles, as the inter-personal space and distance to goal is significantly shorter (da Silva et al., 2011; Katis & Kellis, 2009). Moreover, throughout a session of soccer SSGs (4 bouts) fatigue results in an overall gradual decrease in technical alterations irrespective of player number, however the magnitude of decrease is less with an increase in player number (numerical values n.a.) (Dellal, Drust, & Lago-Penas, 2012).

Specific technical tasks (i.e. long passes and headers) are more frequent in SSGs with greater player numbers (6v6 > 3v3) due to greater pitch dimensions, and greater opportunities to pass/clear the long balls through long passes/headers (Katis & Kellis, 2009). Indeed, findings presented by Owen, Wong, McKenna, and Dellal (2011) displayed significantly higher technical actions and ball contacts in a 9v9 when compared to a 3v3 (i.e. ES = 7.0 and 19.9 for dribbles and passes respectively). They further highlight how the different positions may benefit from different player numbers, with defenders requiring less distance covered during a full game, thus allowing technical actions to be the main focus. Consequently, the effect of player numbers is also largely dependent on a concurrent alteration in absolute and/or relative pitch size, which must be largely considered when implementing SSG for technical conditioning (Owen et al., 2014).

Table 2 - Summary of studies investigating the effects of player number on physiological responses in soccer SSGs

Study	N	Age (gender)	Level	Mode	Format (rest)[a]	Pitch size (m^2)[b]	%HR_{max} (mean ± SD)	Bla- (mmol/L) [mean ± SD]	RPE (CR6-20 AU)[c] [mean ± SD)
Aroso et al. 2004	14	15–16 (m)	Nat	2v2	3x90s (90 s)	30x20 (150)	84 ± 5	8.1 ± 2.7	16.2 ± 1.1
				3v3	3x4 (90s)	30x20 (100)	87 ± 3	4.9 ± 2.0	14.5 ± 1.7
				4v4	3x6 (90s)	30x20 (75)	79 ± 6	2.6 ± 1.7	13.3 ± 0.9
Brandes et al. 2012	17	14.9 ± 0.7 (m)	Eli	2v2	3x4 (90s)	28x21 (147)	93.3 ± 4.2	5.5 ± 2.4	
				3v3	3x5 (90s)	34x26 (147)	91.5 ± 3.3	4.3 ± 1.7	
				4v4	3x6 (90s)	40x30 (150)	89.7 ± 3.4	4.4 ± 1.9	
Castellano et al. 2013	14	21.3 ± 2.3 (m)	Semi-pro	3v3	1x6 (5)	43x30 (215)	83.4 ± 2.9		
				5v5		55x38 (209)	81.6 ± 3.3		
				7v7		64x46 (210)	83.2 ± 4.9		
Clemente et al. 2014[d]	10	26.4 ± 5.3 (m)	Ama	2v2	1x5 (3)	19x19 (~90)	83.38[1]		
				3v3		23x23 (~88)	81.98[1]		
				4v4		27x27 (~91)	83.61[1]		
da Silva et al. 2011	16	13.5 ± 0.7 (m)	N/A	3v3	3x4 (3)	30x30 (150)	89.8 ± 2		
				4v4		30x30 (112)	N/A		
				5v5		30x30 (90)	86.9 ± 3		
Hill-Haas et al. 2010	12	15.6 ± 0.8 (m)	N/A	3v3	1x24	37x28 (148)	82.3 ± 3.5	2.5 ± 0.7	16.3 ± 1.6

	16			4v4		37x28 (148)	83.1 ± 4.0	2.5 ± 0.9	14.6 ± 1.9
	8			floater		37x28 (148)	82.7 ± 3.0	2.3 ± 0.8	16.3 ± 1.5
	20			5v5		47x35 (149)	82.5 ± 5.0	2.5 ± 1.0	15.2 ± 1.0
	24			6v6		47x35 (149)	81.4 ± 5.1	2.6 ± 1.1	14.9 ± 0.9
	4			floater		47x35 (149)	82.5 ± 5.6	2.8 ± 0.2	16.3 ± 1.7
Koklu et al. 2011	16	15.7 ± 0.4 (m)	Eli	1v1	6x1 (2)	6x18 (54)	86.1 ± 4.2	9.4 ± 2.9	
				2v2	6x2 (2)	12x24 (72)	88.0 ± 4.9	8.0 ± 2.8	
				3v3	6x3 (2)	18x30 (90)	92.8 ± 4.1	7.5 ± 2.5	
				4v4	6x4 (2)	24x36 (108)	91.5 ± 3.6	7.2 ± 2.7	
Owen et al. 2004[e]	13	17.5 ± 1.1 (m)	Pro	1v1	1x3 (12)	15x10 (75)	88		
				2v2		15x10 (38)	84.2		
				1v1		20x15 (150)	89		
				2v2		20x15 (75)	87.4		
				3v3		20x15 (50)	81.7		
				2v2		25x20 (125)	88.1		
				3v3		25x20 (83)	81.8		
				4v4		25x20 (63)	72		
				4v4		30x25 (94)	78.5		
				5v5		30x25 (75)	75.7		
Randers et al. 2014	12	33.0 ± 6.4 (m)	Rec	3v3	4x12 (4)	15.5x31 (80)	84.1 ± 3.9	5.9 ± 2.9	4.7 ± 1.6[f]
				5v5		20x40 (80)	84.5 ± 5.0	5.9 ± 2.4	4.9 ± 2.1[f]
				7v7		23.5x47 (80)	82.8 ± 5.1	5.5 ± 2.9	4.6 ± 1.8[f]
Sampaio et al. 2007	8	15 (m)	Nat	2v2	2x90 (90s)	30x20 (150)	83.7 ± 1.4		15.5 ± 0.6
				3v3	2x3 (90s)	30x20 (100)	80.8 ± 1.7		15.8 ± 0.2

1) %HRR – percentage heart rate reserve
a) Intervals and rest between bouts are in minutes unless otherwise specified (s = seconds)
b) Total pitch area divided by number of players
c) RPE is CR 6-20 unless otherwise stated
d) Values from SSG with small goals only
e) HR values obtained from Hill-Haas et al. 2011
f) RPE is CR 1-10

AU = arbitrary units; **Bla-** = blood lactate concentration; **CR20** = category ratio 6-20 scale; **Eli** = elite; **HR** = heart rate%; **%HR_{max} =** percentage of heart rate maximum; **mmol/L** = millimole per litre; **N** = number of participants; **Nat** = national; **Pro** = professional; **Rec** = recreational; **RPE** = rating of perceived exertion

2.4 Game duration and recovery in SSGs

Game duration in SSGs predominantly relies on bout/rest lengths, with varying work:rest ratios. While the intensity during game-time fluctuates, the active/passive recovery intensities and duration remain unjustified in most research. Although work bouts of 3-5 minutes appear to be the commonly used duration for SSGs, research includes durations of 30 seconds (Ade et al., 2014) to 24 min (Hill-Haas, Coutts, Rowsell, & Dawson, 2008). Moreover, a great variety in structure of the amount of bouts utilized permeates current research, with as few as a single bout (Hill-Haas, Dawson, et al., 2009), compared to as many as 27 bouts (Casamichana et al., 2012). Similarly, differences exist for rest duration – mostly 2-5 min – with some studies incorporating breaks of 60s (Hill-Haas, Coutts, et al., 2009), to 12 min (Evangelos et al., 2012; Owen et al., 2004).

Fanchini et al. (2011) is the only study to date which reports the differences in exercise intensity and technical actions for SSGs when manipulating the bout duration (2, 4, 6 minutes), revealing a decrease in intensity for the longest bout duration (6 minutes), with no differences for technical actions. Interestingly, Hill-Haas, Rowsell, Dawson, and Coutts (2009) investigated the differences between continuous (1 x 24 min) and intermittent (4 x 6 min) prescription SSGs for 2v2, 4v4 and 6v6 (Hill-Haas, Rowsell, et al., 2009), with results indicating that both continuous and intermittent may be justified formats for in-season sport-specific aerobic conditioning, while greater distances covered at higher velocities (13-17.9 km/h) and number of sprints are favoured in the intermittent format. However, intensities below <90% HR_{max} imply debatable intensities for VO_{2max} improvements. Moreover, the intermittent format emerged as the superior modality in terms of distance covered at >13km/h, suggesting that the rest period (2 minutes) is sufficient for H^+ removal and PCr re-synthesis (Hill-Haas, Rowsell, et al., 2009). A later study by

Casamichana, Castellano, and Dellal (2013) describe differences between work:rest ratios, with findings of higher and more stable HR values for intermittent game formats (2x8 minutes, 4x4 minutes) as opposed to a continuous (1x16 minutes) format. The study also displayed greater distances covered during the intermittent format, especially for the 7-12.9 km/h speed zone in the third bout. The various modalities appear to suggest that both continuous and intermittent formats elicit sufficient intensities to instigate aerobic responses, however the intermittent format ranks superior when desiring greater distances covered at higher velocities throughout a session, consequently conditioning for moments of elevated intensity during a full game.

While three studies have provided research on bout duration, no studies have investigated rest duration in SSG, or passive (>50% HR_{max}) vs active (50-70% HR_{max}) recovery. In fact, only select studies highlight all three of the following; rest duration, rest classification (active vs passive) and rest intensity level in their studies (Chaouachi et al., 2014; Impellizzeri et al., 2006; Reilly & White, 2005), with the majority of studies predominantly excluding the intensity level and/or classification. Indeed, studies by (Gabbett & Mulvey, 2008; Gaudino, Alberti, & Iaia, 2014; Köklü, 2012) fail to display rest specification entirely.

In summary, practitioners may select to abide by recommendations by Buchheit and Laursen (2013a) who suggest that recovery intervals of 2-3 minutes should remain passive, while 3-4 minutes are encouraged for active breaks.

2.5 Verbal encouragement in SSGs

Verbal encouragement implementation in research studies are frequent (although its effect are seldom quantified), predominantly due to its positive effect on intensity (Rampinini et al., 2007), and prevention of pacing strategies (Sampson, Fullagar, & Gabbett, 2015). A greater effect for HR and BLa^- (ES = 0.668 and 0.976 respectively) were identified for various SSGs formats when verbal encouragement was implemented, which exceeds the effects for field dimensions and player number (Rampinini et al., 2007). Indeed, a study by Hoff et al. (2002) displayed insufficient intensity levels (value not reported) in SSG without complimentary encouragement and constructive instructions from the sideline.

Sampaio et al. (2007) revealed significant effects ($p \leq 0.05$) for RPE when introducing verbal motivation from the coach, however values remained insignificant for HR. Although this finding contradicts those of Rampinini et al. (2007), the verbal encouragement may induce a perceived load on the player which otherwise may not be achieved. For SSGs focused on achieving high intensities then verbal encouragement may be essential for optimizing training.

2.6 Time-motion characteristics in SSGs

Utilization of technical equipment allows for a substantial amount of data to be collected with respect to the movements of soccer players (Carling, Bloomfield, Nelsen, & Reilly, 2008). Nowadays, GPS tracking devices are capable of tracking movements in the horizontal and vertical plane, allowing for a time-efficient and easy approach for sports scientists to administer and analyze data (Carling et al., 2008).

2.6.1 Reliability/validity of GPS

Although GPS devices remain a highly desirable method of data collection, coaches should remain aware of their associated issues. Reliability and validity have been investigated in several studies (Akenhead et al., 2014; Coutts & Duffield, 2010; Edgecomb & Norton, 2006; Petersen, Pyne, Portus, & Dawson, 2009; Varley, Fairweather, & Aughey, 2012), with consistent reports acknowledging its justified use in sports. Indeed, typical error overestimation of values of 4.8±7.2% (classification not specified) (Edgecomb & Norton, 2006), deviation in total distance of -4.1 ± 4.6%, -2.0 ± 3.7% and 0.7 ± 0.6% (Coutts & Duffield, 2010) have been identified for various GPS trackers, with validity reported to highly correlate with actual distance travelled (*r* – 0.998) (Edgecomb & Norton, 2006). Lastly, the coefficient of variation (CV) appears to increase considerably with higher speed zones, as low-intensity activity (>14.4 km/h) experience CV = 2.3 – 5.8%, while high-intensity running (14.4-20 km/h) displays CV = 11.2-32.4%, and very high intensity running equates to CV values of 11.5 – 30.4% (Coutts & Duffield, 2010).

Units with lower sampling rates (1Hz, 5Hz) appears to inaccurately describe high velocity movements (>4 m/s) (Akenhead et al., 2014), while a minimum of 10 Hz appears to be required for movements in the 4-8 m/s interval (Varley et al., 2012). Additionally, the ability to connect with a sufficient amount of satellites highly impacts the accuracy of the data collected, and prevents most GPS systems from collecting data from indoor session (Hill-Haas et al., 2011). Finally, a 7% overestimation of total distance covered may impact the accuracy of the data, however this discrepancy has been considered acceptable in terms of relative technical error (Carling et al., 2008).

2.6.2 Running velocities during SSGs

While research to date on time-motion characteristics suggest that running velocities tend to increase with an increase in pitch sizes (Brandes et al., 2012; Hill-Haas, Dawson, et al., 2009; Hodgson et al., 2014; Owen et al., 2014), the utilization of constant player numbers while manipulating pitch sizes (absolute and/or relative) have been investigated in only two studies to date (Casamichana & Castellano, 2010; Hodgson et al., 2014). It appears that greater accelerations obtained with increased pitch sizes is likely to generate an increase in concentric muscle force through propulsive forces, while deceleration increases eccentric muscle forces (Hodgson et al., 2014). As greater acceleration/deceleration opportunities appears to occur in SSGs with increased player numbers/pitch sizes as opposed to full games (35% vs 18%), greater fatigue is likely to occur which potentially explains why this modality may rank supreme to generic interval training for full-game conditioning (Hodgson et al., 2014).

Conversely, the effects of player number on time-motion characteristics have been the topic of various studies (see Table 3), however the common increase in pitch size to accommodate greater player number implies its importance in velocity outputs. For example, Hill-Haas, Dawson, et al. (2009) revealed a higher mean sprint duration (↑0.57 – 1.19 sec) and distance (↑3.8 – 7.9m) with increased player numbers (2v2, 4v4, 6v6), highlighting the requirement to commit actions off the ball to create passing opportunities, furthermore ascribing the sprint increase to a greater absolute pitch size. In addition, Brandes et al. (2012) revealed greater mean sprint times with increased player numbers, while Castellano et al. (2013) displays increased distances covered at greater velocities with format enlargements from 3v3 to 7v7. While both of these studies maintained constant relative pitch sizes, the absolute pitch size increases with increased player numbers, thus providing players with opportunities to achieve greater velocities before the pitch ends. As full-game requires players to elicit high speed runs, and recover rapidly before engaging in high speed runs again; the pitch sizes associated with 4v4 (750m^2) and 5v5-8v8 (1840-3000m^2) provides insufficient space for players to engage in high speed runs (Owen et al., 2014). With SSGs limited ability to cater for accelerations to speed levels attainable in larger games – which furthermore largely coincides with greater inter-personal space – larger pitches generates greater space between opponents when pressuring for the ball, as well as making runs to achieve a pass (Owen et al., 2014).

Although it appears that an argument may be conducted for the implementation of larger pitch sizes and player numbers to instigate high speed running, Castellano and Casamichana (2013) displayed greater numbers of accelerations completed at >2.5 m/s^{-2} in SSG compared to full games, with the total number of accelerations identified in SSG likely to occur due to greater fatigue among players in full games. They argue that accelerations in small areas are a substantial part of the overall game, while sprint distance/duration may not be, thus quantifying them may assist in providing a holistic picture of the high-intensity running of the players (Castellano & Casamichana, 2013).

In summary, it appears that research to date remains equivocal with regards to opportunities within SSG to instigate high velocity running. While this may impact the usability of SSG as a conditioning option for in-game sprinting, coaches should be specific with regards to the SSGs format when prescribing for high velocity running.

Table 3 - Summary of studies investigating the effects of player number on time-motion characteristics in soccer SSGs

Study	N	Age (gender)	Level	Mode	Format (rest)[a]	Pitch size (m^2)[b]	Max[1]/mean[2] velocity (km/h)	Velocity interval distance (m)	Acc (m)	Dec (m)
Ade et al. 2014	16	17 ± 1 (m)	Eli	1v1	8x30s (2)	27x18 (243)		14.5-19.8: 25.6 ± 3.0 19.9-25.2: 5.6 ± 1.9 >25.5: 0.2 ± 0.5	>3m/s^2: 3.3 ± 0.5 2-3m/s^2: 4.8 ± 0.6	>3m/s^2: 3.3 ± 0.5 -2-3m/s^2: 3.0 ± 0.5
				2v2	8x60s (1)	27x18 (121)		14.5-19.8: 20.2 ± 5.5 19.9-25.2: 3.9 ± 2.2 >25.5: 0.1 ± 0.3	> 3m/s^2: 4.5 ± 1.3 2-3m/s2: 4.9 ± 0.7	>3m/s^2: 0.2 ± 0.4 -2-3m/s^2: 0.9 ± 0.8
Brandes et al. 2012[c]	17	14.9 ± 0.7 (m)	Eli	2v2	3x4 (90s)	28x21 (147)	6.5 ± 0.4[2]	14.0-17.2: 4.5 ± 1.3 17.2-26.8: 2.5 ± 1.2 ≥26.8: 0.0 ± 0.1		
				3v3	3x5 (90s)	34x26 (147)	7.0 ± 0.5[2]	14.0-17.2: 4.9 ± 1.2 17.2-26.8: 3.1 ± 1.2 ≥26.8: 0.1 ± 0.1		
				4v4	3x6 (90s)	40x30 (150)	7.1 ± 0.6[2]	14.0-17.2: 5.2 ± 1.1 17.2-26.8: 3.3 ± 1.4 ≥26.8: 0.1 ± 0.1		
Castellano et al. 2013[d]	14	21.3 ± 2.3 (m)	Semi-pro	3v3	1x6 (5)	43x30 (210)		13.0-17.9: 49 18.0 - 20.9: 12 ≥21.0: 1		
				5v5		55x38 (210)		13.0-17.9: 65 18.0 - 20.9: 17 ≥21.0: 7		

				7v7		64x46 (210)		13.0-17.9: 89 18.0 - 20.9: 23 ≥21.0: 14
Hill-Haas et al. 2010[e]	12	15.6 ± 0.8 (m)	N/A	3v3	1x24	37x28 (148)	106 ± 8	
	16			4v4		37x28 148)	100 ± 10	
	20			5v5		47x35 (149)	105 ± 13	
	24			6v6		47x35 (149)	105 ± 10	
Hill-Haas et al. 2009	16	16.3 ± 0.6 (m)	High	2v2	1x24	28x21 (147)		13 - 17.9: 411 ± 13
				4v4		40x30 (150)		13 - 17.9: 436 ± 15
				6v6		49x37 (151)		13 - 17.9: 442 ± 22
Koklu et al. 2015	16	16.5 ± 1.5 (m)	Eli	2v2 + GK	4x2 (2)	15x27 (101)		13.0-17.9: 122 ± 23.3 ≥18.0: 28.8 ± 17.6
				2v2 FP				13.0-17.9: 156 ± 44 ≥18.0: 34.3 ± 26.8
				3v3 + GK	4x3 min (2)	20x30 (100)		13.0-17.9: 175 ± 63.9 ≥18.0: 30.0 ± 17.6
				3v3 FP				13.0-17.9: 221 ± 72 ≥18: 49.2 ± 32.9
				4v4 + GK	4x4 (2)	25x32 (100)		13.0-17.9: 251 ± 93 ≥18.0: 50.9 ± 34.7

				4v4 FP				13.0-17.9: 352 ± 101 ≥18.0: 60.2 ± 49.3
Owen et al. 2014	16	27.6 ± 4.1 (m)	Eli	5v5	3x5 (3)	46x40 (184)	20.6 ± 0.8[2]	14.4-21.5: 185 ± 8 21.6-25.2: 5 ± 1 >25.3: 1 ± 1
				6v6		50x44 (183)	21.4 ± 0.4[2]	14.4-21.5: 190 ± 17 21.6-25.2: 8 ± 2 >25.3: 0 ± 0
				8v8		60x50 (188)	22.9 ± 0.3[2]	14.4-21.5: 168 ± 13 21.6-25.2: 12 ± 4 >25.3: 4 ± 1
Randers et al. 2014	12	33 ± 6.4 (m)	Rec + unt	3v3	4x12 (4)	15.5x31 (80)	21.1 ± 1.8[1]	13-20: 349 ± 145 >20: 13 ± 15
				5v5		20x40 (80)	20.8 ± 1.5[1]	13-20: 406 ± 134 >20: 20 ± 20
				7v7		23.5x47 (80)	20.5 ± 1.5[1]	13-20: 409 ± 165 >20: 16 ± 18

a) Intervals and rest between bouts are in minutes unless otherwise specified (s = seconds)

b) Total pitch area divided by number of players

c) Values for speed zones are in percentages

d) Distance covered are reported as meters per minute

e) Speed is reported as meters per minute

Acc = acceleration; **Dec** = deceleration; **Eli** = elite; **FP** = free play; **GK** = goalkeeper; **Int** = interval; **km/h** = kilometres per hour; **m/s^2** = meters per second; **N** = number of participants; **Rec** = recreational; S**emi-pro** = semiprofessional; **Unt** = untrained

2.6.3 Repeated sprint ability in SSGs

Repeated sprint ability may be defined as three consecutive sprints with <21 sec of recovery between sprints (Gabbett & Mulvey, 2008). While RSA has been identified as a determinant for level of play and performance (Stølen et al., 2005), recent findings by Gharbi, Dardouri, Haj-Sassi, Chamari, and Souissi (2015) argue for a major contribution of the aerobic system to facilitate PCr re-synthesis and H^+ removal from exercising muscles.

Current research on RSA utilize various speed zones (via GPS) to monitor the time spent and distance covered at various speeds (Casamichana et al., 2012; Dellal, Hill-Haas, et al., 2011), while one study incorporated video recording and purpose-built software for analysis (Gabbett & Mulvey, 2008). In fact, only one study (to date) has utilized a specific RSA test to measure pre- and post-intervention RSA changes in soccer players (Owen et al., 2012). Interestingly, the study utilizing a specific RSA test reported significant improvements (ES = 0.57, $p<0.05$) (Owen et al., 2012), while other studies deduce insufficient RSA stimuli due to lesser time spent running at high-intensities throughout SSGs relative to full games (Casamichana et al., 2012; Dellal, Hill-Haas, et al., 2011; Gabbett & Mulvey, 2008). In a study by Owen et al. (2012), both 10m and 20m sprint times improved (ES = 0.35 and 0.27 respectively) along with RSA. As it may be argued that RSA is a component of the game highly affected by both aerobic and anaerobic capacities (Owen et al., 2012), it may be more appropriate to measure its responses to SSG via a specific test, as opposed to comparing time spent at various speed zones.

While higher velocities may be achieved with greater pitch sizes, it is arguably problematic to achieve maximal speed with current pitch sizes frequently used in SSGs studies (Casamichana et al., 2012). Although Casamichana et al. (2012) identified greater repeated high intensity efforts (RHIE) in full games compared to SSGs, no significant difference were displayed for number of RHIEs, mean duration between efforts, and mean number of efforts per RHIE. As these variables remain similar between SSGs and FG – along with aerobic/anaerobic capacity hugely influencing the RHIE demand – a question emerges as to whether RSA indeed was improved (as it was not specifically measured).

With professional players spending more time at >13km/h and sprinting when compared to amateurs for SSG (Dellal, Hill-Haas, et al., 2011), it becomes obvious that RSA conditioning via SSGs is highly desirable for coaches of youth teams and those players attempting to make it onto the big scene. Moreover, elite team conditioners may seek to enhance RSA in their players without additional training, thus allowing for valuable training time spent on technical/tactical aspects.

2.6.4 Game format and rule alterations in SSGs

The SSG formats may significantly affect the velocity at which players run during. While an increase in player numbers with an associated increase in relative pitch size allow players to make use of the greater pitch size to cover greater distances at higher velocities (Brandes et al., 2012; Castellano et al., 2013; Hill-Haas, Dawson, et al., 2009), the amount of accelerations increase with lower player numbers (Gaudino, Alberti, et al., 2014). Indeed, this appears to occur mainly when a possession (POS) format is selected as opposed to goal scoring, due to a more multi-directional gameplay instead of the linear style associated with goals (Gaudino, Alberti, et al., 2014).

The intensity and distances covered at higher speeds may further be enhanced via limitations to the amount of touches, as a greater reliance is put upon the players to move the ball quickly (Dellal, Owen, et al., 2012). However, distance covered and time spent in various speed zones may fluctuate based on the performance/competitive level of the players when touch limitations are implemented, especially seen with players of greater technical/tactical skills or those accustomed to using 1-2 touch only (Casamichana, Suarez-Arrones, Castellano, & Román-Quintana, 2014).

Goalkeepers (GK) may also influence the physical outcome of a session due to increased demands to cover greater distances with small goals, as opposed to the potential of shooting from afar (Köklü et al., 2015). Similar increases in intensities and time spent in higher speed zones (>13km/h) were found for SSGs utilizing a fast paced game format (one team is informed to be losing), as opposed to a slow paced format (one team is in the lead), in combination with uneven player numbers (4v5 or 5v4) (Sampaio, Lago, Gonçalves, Maçãs, & Leite, 2014). Interestingly, Hill-Haas et al. (2010) reported insignificant time-motion differences for uneven player numbers for both 5v5 and 6v6, and the authors ascribe the lack of difference to increased pitch size negating the effect of the floater (one player always one the same team with those in possession of the ball), as well as the floater constituting a relatively less proportion of the total player number. This finding was not identified for 3v3 and 4v4, as increases in both physical and perceptual characteristics were found to increase with inequality in numbers (Hill-Haas et al., 2010).

Lastly, the influence of bout duration currently remains conflicting between studies, as Casamichana et al. (2014) revealed an increase in distance covered at high speed in the second bout (2x6 min) when 2T was implemented, as opposed to FP. Conversely, Casamichana et al. (2013) revealed greater distances covered for 0-4 minutes for three different formats (4x4 min, 2x8 min, 1x16 min), and a greater distance for 7-12.9 km/h was covered in first bout as opposed to the last bout (ES = 1.84).

2.7 Comparison between SSGs and generic training

To date, five valid and reliable studies have investigated the training effects of SSGs in comparison with general interval training (GIT), defined by Baechle and Earle (2008) as exercising at near VO_{2max} intensities for bouts of 30 seconds to five minutes, interspersed by rest periods of equal lengths to the work interval.

Studies to date remain equivocal on the aerobic improvements derived from SSGs. Early SSG studies by Reilly and White (2005) revealed insignificant improvements in both VO_{2max} as well as lactate threshold for both SSGs training and GIT for 6 weeks of in-season (nor any declines in aerobic fitness), thus allowing the authors to conclude that SSGs may constitute a valid replacement for GIT for maintenance of fitness levels during in-season. A similar result was identified in the latest study on GIT vs SSGs to date, which revealed equal effectiveness in maintaining aerobic fitness for the final 6 weeks of a soccer season, with additional preferences for SSGs as a training modality based on perceptual responses to training formats (ES = 1.86 ± 1.07) (Los Arcos et al., 2015). Additionally, Hill-Haas, Coutts, et al. (2009) utilized elite youth players (14.6 ± 0.9 years), displaying increased performance in the Yo-Yo Intermittent Recovery Test Level 1 (YYIRTL1) for both GIT and SSGs (3v3 – 7v7). However, VO_{2max}, sprint and RSA performance remained unaffected for both training regimens throughout the 7-week training period during pre-season, thus the findings align with the abovementioned studies.

Conversely, a thorough intervention conducted by Impellizzeri et al. (2006) displayed a 7%, 2% and 10% increase for VO_{2max}, running economy and LT following a 14 week pre- and in-season training regime for professional junior soccer players (age = 17.2 ± 0.8) with 3v3 – 5v5 SSGs (with touch limitations). Both Los Arcos et al. (2015) and Reilly and White (2005) implemented their respective interventions at stages throughout the season when players may have reached their maximum potential for aerobic capacity. Conversely, Hill-Haas, Coutts, et al. (2009) and Impellizzeri et al. (2006) conducted their interventions during pre-season, when a possible increase in $\%VO_{max}$ is expected in players due to their return from off-season (Hill-Haas, Coutts, et al., 2009). Additionally, multiple variables (for example: pitch size, player number, testing) may constitute differences between studies, and future research is required on GIT and SSG comparison for aerobic capacity improvements to enhance our current understanding.

Interval training with incorporated changes of directions (CODs) are different to GIT, as it incorporates 40-m shuttles, however these are believed to replicate the COD demands of full-games and result in greater amounts of accelerations/decelerations than linear GIT (Dellal, Varliette, et al., 2012). As in-season comparisons between SSGs and COD-interval training over 6 weeks generated similar responses in adult players with regards to performance in the 30-15 Intermittent Fitness Test ($30\text{-}15_{IFT}$) and a continuous aerobic test (vVameval) (Table 4), this may be considered supportive in utilizing SSGs to condition for aerobic and anaerobic components during in-season (Dellal, Varliette, et al., 2012). Similar findings are displayed by Chaouachi et al. (2014) for youth players (age = 14.2 ± 0.9) where a SSG group was compared to a COD group (mixed design) for a 6 week training intervention, revealing superior effects from SSGs for agility improvements (Reactive agility tests: SSG = ↑6.2%, COD = ↑4.2%). Conversely, the authors revealed superior improvements in sprint times and COD test (COD 15m) results for the COD group (↑6.7%) when compared to the SSGs group (↑5.1%), highlighting how specific COD exercises may be preferable to SSG for sprint and COD improvements. However, the limited amount of studies on COD and SSG comparisons suggest further research is warranted.

Table 4 - Summary of studies comparing interval training to soccer SSG

Study	N (T)[a]	Age (gender)	Level	Modality	Format (rest)[b]	Pitch size (m^2)[c]	MAS (km/h)	vVameval[1]/ 30-15$_{IFT}$[2]/ YYIRTL1[3]	ΔVO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)
Dellal et al. 2012	22 (6)	26.3 ± 4.7 (m)	Ama	SSG: 2v2, 1v1	2v2: 5x150s (2), 1v1: 5x90s (90 s)	2v2: 20x20 (100) 1v1: 15x10 (150)		↑6.6%[1] ↑5.1%[2]	
				IT: 40m shuttles	30s-30s, 15s-15s, 10s-10s			↑5.1%[1] ↑5.8%[2]	
Hill-Haas et al. 2009	25 (7)	14.6 ± 0.9 (m)	Eli	SSG: 2v2 - 7v7.	3x7 (1) - 3x13 (2)	15x20 - 60x40 (62.5 - 218)		↑254m[3]	
				IT: AP, CODS, PIH, RSA, SL, SP	Mixed designs (see original article)			↑387m[3]	
Impellizzeri et al. 2006	40 (14)	17.2 ± 0.8 (m)	Junior	SSG: 3v3 - 5v5.	4x4 (3)	3v3: 25x30 (146) 4v4: 40x50 (250) 5v5: N/A			↑4.1*, ↑%VO_{2max} at LT: 3.2*
				IT: Generic running at 90-95% HR_{max}	4x4 (3)				↑4.6*, ↑%VO_{2max} at LT: 3.6*

Los Arcos et al. 2015	17 (6)	15.5 ± 0.6 (m)	Eli	SSG: 4v4, 3v3	3x4 (3)	85m^2	16.9 ± 0.8 (↓0.4 ± 1.9)		
				IT: Generic running at 90-95% HR_{max}	3x4 (3)		17.1 ± 1 (↑1.7 ± 1.5)		
Reilly & White, 2004	18 (6)	18.2 ± 1.4 (m)	Pro	SSG: 5v5	6 x 4 (3)				↑0.1
				IT: Generic running at 85-90% HR_{max}	6 x 4 (3)				↑2.2

*p ≤ 0.05
a) Number of players, and training duration (weeks) of intervention in brackets
b) Rest between bouts are in minutes unless otherwise specified (s = seconds)
c) Total pitch area divided by number of players
2-3T = maximum of 2 or 3 touch allowed; **$30\text{-}15_{IFT}$** = 30-15 intermittent fitness test; **Ama** = amateur; **AP** = aerobic power; **Bla-** = blood lactate concentration; **CODS** = change of directions; **Eli** = elite; **FP** = freeplay; **HR** = heart rate; **$\%HR_{max}$ =** percentage of HR maximum; **IT** = interval training; **km/h** = kilometers per hour; **LT** = lactate threshold; **MAS** = maximal aerobic speed; **$ml{\cdot}kg^{-1}{\cdot}min^{-1}$** = milliliters per kilogram per minute; **N** = number of participants; **Pih** = prolonged intermittent high intensity interval; **Pro** = professional; **RSA** = repeated sprint ability; **SL =** speed ladder; **SP** = sprint training; **T** = weeks of training; **YYIRTL** = Yo-Yo intermittent recovery test level 1; **ΔVO_{2max}** = change in maximal oxygen uptake; **$\%VO_{2max}$** = percentage of maximal oxygen uptake; ↑ indicates increase

2.8 Rule alterations in SSGs

The following section aims to outline some of the findings identified in research manipulating one or several rules in SSGs. Only the most common rule alterations will be discussed in this review.

2.8.1 Touch limitations

The rule alterations predominantly investigated in the SSGs literature involve touch limitations, with a main focus on the difference between 1-touch (1T), 2-touch (2T) and free-play (FP).

A study by Casamichana et al. (2014) displayed how FP allowed players to achieve >80% HR_{max} within the first minute , while it appears touch limitations may cause a longer duration to achieve sufficient intensities, as players may need to adapt to the dynamics of the gameplay associated with touch restrains. Indeed, a greater decline in sprints and HIR have been found to occur from bout 1 to bout 4 (4x4 minutes) for 1T and 2T when compared to FP, although physiological responses remained the same (Dellal, Lago-Penas, et al., 2011). Moreover, a likely increase in lactate levels while decreasing muscle creatine phosphate (CrP) and pH values occur with touch-limitations, which again affect the technical qualities as amount of dribbles, duels ball contacts and duration of ball possession are reported to be higher in FP as opposed to 1T and 2T for international standard players (Dellal, Lago-Penas, et al., 2011). Additionally, the ability to conduct a successful pass decreases with fewer touches available; a finding which also separates elite players from amateurs, especially in combination with less players per team (Dellal, Hill-Haas, et al., 2011). In light of this, it appears that elite players possess greater anticipation and enhanced ability to shadow opponents, thus generating greater technical involvements; illustrated by increased number of duels (3v3 2T: *Int*: 28.2 ± 3.3, *Ama* = 23.2 ± 3.8) (Dellal, Hill-Haas, et al., 2011). The technical differences may be further discussed in relation to player position, as Dellal, Owen, et al. (2012) revealed a lower percentage for successful passes among centre backs (CB) for 1T and 2T, with fullbacks displaying the second lowest percentage. With CBs proven to complete significantly lower number of passes compared to midfielders and forwards (Dellal, Chamari, et al., 2011), the findings imply that 1T and 2T may be a viable option for enhancing the technical capabilities of players in these positions.

On a final note, implementing touch restrictions also appear to result in greater perceptual workloads among players (Aroso et al., 2004; Sampaio et al., 2007), although one study revealed insignificant differences in RPE with 1T and 2T compared to FP (Dellal, Lago-Penas, et al., 2011).

Consequently, inconsistent results have been identified in various studies, implying conflicting results and difficulties in highlighting a supreme modality for a specific stimulation (table 6). It appears that level of play and/or position highly influences the success of touch limitations in SSG, with a possible reduction in initial intensity level.

Table 5 - The effect of touch restrictions in soccer SSGs

Study	N	Age (gender)	Level	Modality	Format (rest)[a]	Pitch size (m^2)[b]	Rule	$\%HR_{max}$ (mean ± SD)	Bla- (mmol/L) [mean ± SD]	RPE (1-10 AU)[c] [mean ± SD]
Casamichana et al. 2014	12	22.7 ± 4.3 (m)	Semi-pro	6v6	2x6 (n.a.)	60x49 (245)	2T, FP	2T: 89.3 ± 3.1 FP: 90.4 ± 2.5		
Dellal, Lago-Penas et al. 2011	20	27.4 ± 1.5 (m)	Int	4v4	4x4 (3)	30x20 (75)	1T, 2T, FP	1T: 90.4 ± 2.7 2T: 89.7 + 3.2 FP: 86.8 ± 2.9	1T: 3.5 + 0.5 2T: 3.2 + 0.3 FP: 4.5 ± 0.3	1T: 8.9 ± 0.8 2T: 8.9 + 0.5 FP: 8.2 ± 0.9
Dellal, Hill-Haas et al. 2011[d]	40	**Int**: 27.4 ± 1.5 (m) **Ama**: 26.3 ± 2.2 (m)	Ama Int	2v2	4x2 (3)	20x15 (75)	1T, 2T, FP	INT 1T: 90.3 ± 2.6 2T: 90.1 + 2.2 FP: 86.8 ± 3.0 AMA 1T: 92.3 ± 2.5 2T: 91.5 + 2.4 FP: 91.6 ± 2.2	INT 1T: 3.9 ± 0.4 2T: 3.5 + 0.3 FP: 3.5 ± 0.2 AMA 1T: 5.0 ± 0.4 2T: 4.7 + 0.3 FP: 4.1 ± 0.3	INT 1T: 8.3 ± 0.7 2T: 7.8 + 0.6 FP: 7.7 ± 0.6 AMA 1T: 9.1 ± 0.8 2T: 8.4 + 0.7 FP: 8.0 ± 0.8
				3v3	4x3 (3)	25x18 (75)		INT 1T: 90.0 ± 2.4 2T: 89.4 + 2.7 FP: 89.6 ± 2.2 AMA 1T: 91.2 ± 2.6 2T: 90.0 + 2.8 FP: 89.5 ± 2.5	INT 1T: 3.6 ± 0.3 2T: 3.4 + 0.2 FP: 3.1 ± 0.3 AMA 1T: 4.6 ± 0.2 2T: 4.1 + 0.2 FP: 3.7 ± 0.3	INT 1T: 8.2 ± 0.7 2T: 7.9 + 0.7 FP: 7.5 ± 0.5 AMA 1T: 8.8 ± 0.4 2T: 7.9 + 0.8 FP: 7.7 ± 0.6

				4v4	4x4 (3)	30x20 (75)		INT 1T: 87.6 ± 2.5 2T: 85.6 + 3.0 FP: 84.7 ± 2.7 AMA 1T: 87.4 ± 2.3 2T: 86.6 + 1.9 FP: 85.1 ± 2.4	INT 1T: 3.0 ± 0.3 2T: 2.9 + 0.1 FP: 2.8 ± 0.2 AMA 1T: 3.5 ± 0.3 2T: 3.1 + 0.2 FP: 3.0 ± 0.2	INT 1T: 8.0 ± 0.7 2T: 7.9 + 0.8 FP: 7.3 ± 0.6 AMA 1T: 8.3 ± 0.6 2T: 8.1 + 0.6 FP: 7.6 ± 0.5
Dellal et al. 2012	40	25.3 ± 2.4 (m)	Int	4v4	4x4 (3)	30x20 (75)	1T, 2T, FP	CD 1T: 88.9 ± 2.9 2T: 87.1 + 3.3 FP: 85.9 ± 2.5 FB 1T: 87.4 ± 2.6 2T: 85.9 + 3.0 FP: 84.9 ± 2.9 CDM 1T: 86.3 ± 2.4 2T: 83.9 + 2.9 FP: 82.8 ± 3.0 WM 1T: 88.8 ± 2.3 2T: 86.6 + 3.1 FP: 86.5 ± 2.5 FW 1T: 88.9 ± 2.3 2T: 86.4 + 3.3 FP: 85.6 ± 2.6	CD 1T: 3.3 ± 0.4 2T: 3.2 + 0.2 FP: 3.1 ± 0.2 FB 1T: 3.0 ± 0.3 2T: 2.9 + 0.1 FP: 2.8 ± 0.2 CDM 1T: 3.0 ± 0.3 2T: 2.9 + 0.1 FP: 2.7 ± 0.1 WM 1T: 2.9 ± 0.2 2T: 2.8 + 0.1 FP: 2.7 ± 0.1 FW 1T: 2.8 ± 0.3 2T: 2.7 + 0.2 FP: 2.7 ± 0.2	CD 1T: 8.3 ± 0.6 2T: 8.2 + 0.6 FP: 7.7 ± 0.5 FB 1T: 7.9 ± 0.5 2T: 8.0 + 0.7 FP: 7.5 ± 0.5 CDM 1T: 8.0 ± 0.7 2T: 7.9 + 0.6 FP: 7.2 ± 0.5 WM 1T: 7.9 ± 0.9 2T: 7.8 + 1.0 FP: 7.1 ± 0.7 FW 1T: 79 ± 0.8 2T: 7.6 + 1.1 FP: 7.0 ± 0.8

Sampaio et al. 2007	8	15 (m)	Nat	2v2	2x90s (90s)	30x20 (150)	2T	81.2 ± 1.37		16.8 ± 0.51 (CR20)
				3v3	2x3 (90s)	30x20 (100)		80.8 ± 1.20		16.5 ± 0.46 (CR20)

a) Rest between bouts are in minutes unless otherwise specified (s = seconds)

b) Total pitch area divided by number of players

c) RPE is 1-10 unless otherwise stated

d) all values achieved in bout 4

1T = 1-touch; **2T** = 2-touch; **3T** = 3-touch; **Ama** = amateur level; **AU** = arbitrary units; **Bla-** = blood lactate concentration; **CD** = central defender; **CDM** = central defensive midfielder; **CR20** = category ratio 6-20 scale; **FB** = full-back; **FP** = freeplay; **FW** = forwards; **HR** = heart rate; **$\%HR_{max}$ =** percentage of HR maximum; **INT** = international; **mmol/L** = millimole per litre; **N** = number of participants; **Nat** = national; **RPE** = rating of perceived exertion; **Semi-pro** = semiprofessional; **WM** = wide midfielders

2.8.2 Goalkeeper inclusion

Only five studies to date have compared the physical outputs during SSGs with (SSG_{withGK}) and without ($SSG_{withoutGK}$) goalkeepers (GK). The implementation of a GK is likely to reduce the physiological load on the players as game tempo may decrease as a consequence of passes to the GK and shots on goal (Köklü et al., 2015). Additionally, players may attempt to re-organize defensively to protect the goal, which results in a decrease in tempo due to formation preferences (Mallo & Navarro, 2008). This reduction is furthermore found to reduce the overall average and maximal metabolic power of the players, implying that GKs should be excluded from the game if average higher intensities are desired (Gaudino, Alberti, et al., 2014).

It appears that elevated number of players (>5v5) do not elicit greater $\%HR_{max}$ values for $SSG_{withoutGK}$ when compared to SSG_{withGK} (Castellano et al., 2013; Dellal et al., 2008). Although this feature has currently not been addressed, it is likely that with increased number of players the influence of GKs decreases, as their relative participation in the game is reduced thus impacting the tempo to a lesser extent.

Physical outputs from utilizing GK in SSGs remain inconclusive, as Gaudino, Alberti, et al. (2014) reveals higher sprint speeds achieved with increased player numbers for SSG_{withGK}, yet accelerations/decelerations increased with a smaller SSG formats. Conversely, both Castellano et al. (2013) and Köklü et al. (2015) revealed lower sprint speed for $3v3_{withGK}$ and $7v7_{withGK}$, possibly due to a game format without GKs allowing the ball to stay in play longer, consequently resulting in higher velocities and TD (Köklü et al., 2015).

Table 6 - The effect of GK in soccer SSG

Study	N	Age (sex)	Level	Modality	Format (rest)[a]	Pitch size (m^2)[b]	$\%HR_{max}$ (mean ± SD)	Bla^- (mmol/L) [mean ± SD]	RPE (1-10 AU)[c] [mean ± SD]	Speed (km/h) [m][d]
Castellano et al. 2013	14	21.3 ± 2.3 (m)	Semi-pro	3v3		43x30 (215)	91.8 ± 2.8			13.0-17.9: 49 18.0-20.9: 12 ≥21.0: 1
				3v3 + GK			94.8 ± 3.7			13.0-17.9: 68 18.0-20.9: 13 ≥21.0: 1
				5v5		55x38 (209)	91.5 ± 3.5			13.0-17.9: 65 18.0-20.9: 17 ≥21.0: 7
				5v5 + GK			92.1 ± 4.0			13.0-17.9: 74 18.0-20.9: 19 ≥21.0: 8
				7v7		64x46 (210)	94.7 ± 5.9			13.0-17.9: 89 18.0-20.9: 23 ≥21.0: 14
				7v7 + GK			93.2 ± 4.4			13.0-17.9: 70 18.0-20.9: 14 ≥21.0: 7
Dellal et al. 2008	10	26 ± 2.9 (m)	Eli	8v8	4x4 (3)	60x45 (169)	71.7 ± 6.3 (%HRR)			
				8v8 + GK	2x10 (5)		80.3 ± 12.5 (%HRR)			
Gaudino et al. 2014	26	26 ± 5 (m)	Eli	5v5 POS	1x4	27x27 (73)				14.4-19.8: 30 ± 10 19.8-25.2: 1 ± 1 >25.2: 0 ± 0

				5v5 GK		30x30 (75)				14.4-19.8: 39 ± 15; 19.8-25.2: 3 ± 3; >25.2: 0 ± 0
				7v7 POS		37x37 (98)				14.4-19.8: 47 ± 16 19.8-25.2: 3 ± 3 >25.2: 0 ± 0
				7v7 GK		45x35 (98)				14.4-19.8: 47 ± 10 19.8-25.2: 10 ± 5 >25.2: 1 ± 1
				10v10 POS		52x52 (135)				14.4-19.8: 73 ± 20 19.8-25.2: 12 ± 7 >25.2: 0 ± 1
				10v10 GK		66x45 (135)				14.4-19.8: 57 ± 10 19.8-25.2: 16 ± 5 >25.2: 2 ± 2
Mallo & Navarro, 2008	10	18.4 ± 0.6 (m)	Eli	3v3 GK	1x5 (10)	33x20 (110)	88			
				3v3 POS			91			
Koklu et al. 2015	16	16.5 ± 1.5 (m)	N/A	2v2 + GK	4x2 (2)	15x27 (101)	86.0 ± 2.8	7.4 ± 1.9	6.0 ± 2.0	13-17.9: 122 ± 23.3 >18: 28.8 ± 17.6
				2v2			88.0 ± 2.9	8.4 ± 2.2	7.3 ± 1.4	13-17.9: 156 ± 44 >18: 34.3 ± 26.8
				3v3 + GK	4x3 (2)	20x30 (100)	86.9 ± 2.8	6.5 ± 1.9	4.6 ± 0.8	13-17.9: 175 ± 63.9 >18: 30 ± 17.6
				3v3			89.1 ± 2.6	7.3 ± 2.2	6.5 ± 1.4	13-17.9: 221 ± 72 >18: 49.2 ± 32.9

	4v4 + GK	4x4 (2)	25x32 (100)	88.7 ± 2.5	6.1 ± 1.3	5.1 ± 1.8	13-17.9: 251 ± 93 >18: 28.8 ± 17.6
	4v4			90.1 ± 2.7	6.9 ± 1.5	5.7 ± 1.6	13-17.9: 352 ± 101 >18: 60.2 ± 49.3

a) Intervals and rest between bouts are in minutes unless otherwise specified (s = seconds)

b) Total pitch area divided by number of players

c) RPE is 1-10 unless otherwise stated

d) All zones are km/h

AU = arbitrary units; **Bla$^-$** = blood lactate concentration; **Eli** = elite; **GK** = goalkeeper; **%HR$_{max}$ =** percentage of HR maximum; **%HRR** = percentage of heart rate reserve; **Km/h** = kilometers per hour; **mmol/L** = millimole per litre; **N** = number of participants; **POS** = possession play; **RPE** = rating of perceived exertion; **SD** = standard deviation; **Semi-pro** = semiprofessional;

Current research indicates greater opportunities for aerobic and physical conditioning for $SSG_{withoutGK}$, yet the inclusion of GK may be necessary for larger SSGs to instigate structure and balance within the team, furthermore providing the outfield players with a sense of defending/attacking and thus a greater full-game similarity (Hill-Haas et al., 2011). However, a possible imbalance in individual playing area on different areas of the field may occur in SSG_{withGK}, as the defense may push higher as they are not required to protect the goal (Fradua et al., 2013).

2.8.3 General rule and game format alterations

A large variety of rules may be implemented/manipulated in the game to induce or exaggerate a desired effect. Unfortunately, several variables are usually altered simultaneously – or implemented without an explanation and/or to mimic game-like situations – generating a difficult task to assess the impact of certain rules. For example, coach-administered SSGs with an offside rule were conducted in a 6v6 SSG in combination with the 'team across the halfway line-rule' and 2T (Hill-Haas, Coutts, et al., 2009), making it very hard to determine the effect of this rule on the gameplay.

Enforcing all players to run across the halfway line in order to score a valid goal have been extensively used in current literature (Brandes et al., 2012; Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2009; Hill-Haas, Coutts, et al., 2009; Hill-Haas, Dawson, et al., 2009; Katis & Kellis, 2009), yet no study to date have provided numerical values or specific research displaying the impact of this rule. Conversely, the addition of two or more neutral players in a separate area along the sidelines have occurred in four separate studies (Aroso et al., 2004; Clemente et al., 2014; Mallo & Navarro, 2008; Owen et al., 2004), with Mallo and Navarro (2008) arguing for less passing errors (without: 15.4

± 4.7%; with: 5.3 ± 2.9%) and increased attempts at long distance passes (values n.a.) with side-line players.

Some studies have incorporated the offside rule (Hill-Haas, Coutts, et al., 2009), controlling the ball over the end-line on the pitch; one goal and two goals for each team (Clemente et al., 2014), and man marking (MM) (Aroso et al., 2004; Ngo et al., 2012; Sampaio et al., 2007). With regards to the latter, MM has been proposed to enhance RSA in soccer players (Gabbett & Mulvey, 2008). Ngo et al. (2012) revealed a greater increase in HR for MM compared to non man-marking (NMM) (3v3 with small goals: ↑4.8%; 3v3 without goals: ↑4.4%) while RPE was only significantly higher for MM when goals were present (↑1.1). Conversely, Sampaio et al. (2007) displayed higher RPE values for MM compared to regular play (2v2 = ↑3.0; 3v3 = ↑2.1) for youth players, while Aroso et al. (2004) present findings of greater accumulation of BLa^- and more time spent walking with MM (values n.a.) in youth players as well.

In summary, rule-alterations are frequently utilized in SSG research, however their impact are seldom reported as the aim of a given study often lies elsewhere (e.g. player number, pitch dimensions).

2.9 Ratings of perceived exertion (RPE) in SSGs

Several articles utilize RPE to estimate the internal load on players during SSGs, with current research displaying an increase in RPE with decreased player numbers (Abrantes, Nunes, MaÇãs, Leite, & Sampaio, 2012; Beato, Bertinato, & Schena, 2014; Hill-Haas, Dawson, et al., 2009; Impellizzeri et al., 2006).

Casamichana and Castellano (2010) revealed an increase in RPE (↑1.0 AU) when both relative and absolute pitch sizes where increased in 5v5 SSGs. With a concomitant increase in physiological responses and work:rest ratios (Casamichana & Castellano, 2010) – as well as a validated use of RPE to indicate soccer SSGs intensity when compared with lactate and HR – one may argue that perceptual responses constitutes an important tool for monitoring global exercise intensity (Coutts et al., 2009).

Dellal, Owen, et al. (2012) and Sampaio et al. (2007) identified increases in perceived exertion with technical alterations; especially when the amount of touches decreased (↑RPE = 1T-2T > FP). More specifically, it appears that the technical challenges associated with touch limitations generate higher perceived SSG difficulty and thus higher RPE (Dellal, Owen, et al., 2012). Indeed, Beato et al. (2014) outline how technical actions decreased with 3v3 and 4v4 SSG progression (6x4 minutes) while RPE increased for indoor futsal players (↑21.5 and ↑21.1 respectively, CR100). Similar findings for RPE increases (↑0.4 - 0.7) with game progression was also identified by (Fanchini et al., 2011), however the length of the bouts did not significantly impact RPE scores.

As technical abilities in SSGs are viable indicators of player performance level (Dellal, Hill-Haas, et al., 2011), the abovementioned studies indicate that RPE may generate higher scores if rule alterations are implemented, and coaches should carefully monitor the perceived intensity of the players when implementing alterations to gameplay. Moreover, variables manipulated to generate greater physiological demand on the players consequently influences perceptual load (Abrantes et al., 2012; Casamichana & Castellano, 2010), and elevated physiological load coupled with decreased technical performance (Dellal, Lago-Penas, et al., 2011) suggest that RPE scores are highly susceptible to fluctuations.

2.10 SSGs and periodization

Periodized training has been recommended for team sport athletes to optimize the physiological stimuli and provide sufficient rest for the competitive season, as well as avoiding training status plateau and training dissatisfaction throughout the season (Gamble, 2006). Only Owen et al. (2012) have addressed the topic of periodization in SSGs to date. The authors conducted a 4-week mid-season SSG intervention resulting in improved RSA (~0.34s) and sprint performance (10m = 0.02s; 20m = 0.02s). The findings imply a justification for implementation of SSGs during in-season periods where the occurrence of games were non-existent (international break/reserve team break/poor weather conditions) (Owen et al., 2012), thus providing an option for coaches to condition their players utilizing SSGs during less intense season periods.

2.11 Limitations of SSG

While the improvement in physiological capacity is a highly desired outcome from SSGs, the ceiling of effect of VO_{2max} may occur in players already close to their maximal level (Buchheit & Laursen, 2013a), thus a smaller increase in VO_{2max} may be observed for fitter players (McMillan et al., 2005). Consequently, players with lower fitness levels may be prone to reduce the intensity level in SSGs, resulting in sub-optimal conditions for fitter players and large discrepancies in fitness improvements between players (Buchheit & Laursen, 2013a). Additionally, superior fitness among certain players may reduce the aerobic enhancement capacity of SSG, as players with advanced technical capabilities – or a combination of enhanced fitness and technical capabilities – may experience insufficient training stimulus from SSGs as their superior understanding of the game may allow for less effort exerted (Hill-Haas et al., 2011).

As outlined in section 2.6.3, SSGs remains highly questionable when desiring to enhance RSA capability of soccer players, however different methods to measure RSA ability implies a greater need to monitor this feature. Moreover, the physicality of soccer and the occurrence of numerous challenges that players are required to withstand (Stølen et al., 2005) imply a probability of sustaining an injury during gameplay. While rule-modifications may attempt to reduce this occurrence, the nature of the game does not allow for a complete elimination of this factor, thus players are always at risk while engaged in gameplay.

Logistic considerations associated with SSGs imply access to sufficient number of coaches to counteract pacing strategies (Sampaio et al., 2014) and monitor concurrent games (for large squads). In addition, amateur/recreational and/or teams in environmentally challenging weather-conditions may be forced to accommodate for challenging training surroundings.

The frequent utilization of >10 Hz equipment for time-motion data collection devices in current research, with poor reliability at high velocities, indicates a requirement for more advanced systems to monitor high velocity movements occurring in SSGs (Akenhead et al., 2014; Varley et al., 2012). With the current financial cost of GPS monitors, economic resources may financially restrain certain teams from acquiring these devices.

2.12 Future research

Elaborating and/or confirming previous findings are currently required to validate several studies within the literature, as demographic. Individual and/or team differences may impact the overall outcome. In example, research on pitch-size depicts fluctuations in individual playing areas that may be further investigated to enhance our understanding of its effectiveness when utilized in combination with player numbers, and/ or technical/tactical manipulations. SSG formats and rule alterations may only be restricted by the imagination of coaches and researchers, however current literature sees some studies stand alone in explaining certain variables (i.e. periodization). Indeed, physiological responses from man-marking in soccer SSG have been investigated by three studies, yet no study has currently investigated its effect on adult soccer players or associated time-motion characteristics.

Furthermore, periodization requires additional research to provide succinct and sufficient evidence of the optimal utilization of SSG during various stages of the season. To date, SSG research mostly occurs during pre/off-season, thus more research regarding in-season implementation would be worthwhile.

Unfortunately, very limited research has been conducted with female soccer players. Skill level among female soccer players may impact physiological and physical responses from SSGs with various game formats, as female soccer players may respond differently to exercise than their male counterparts (Katis, Amiridis, Kellis, & Lees, 2014). This may also lead to investigations on SSGs for females in relation to game demands, as increased research on female soccer over the last few years has elevated current knowledge on physical and physiological aspects of female soccer players (Datson et al., 2014).

Lastly, limited research has investigated the effect of SSG on agility/COD performance in soccer, with current studies solely utilizing adolescent males. While several studies have compared the effects on straight-line sprinting, research may aim to highlight the agility/COD component to enhance our understanding.

2.13 Conclusion

Research to date has initiated the process of revealing the effectiveness of SSG in soccer especially with regards to developing physical endurance. There has been much less attention paid to tactical and technical development using SSGs. Additionally, rule alterations in SSGs are diverse and used sporadically; predominantly utilized to instigate a response without scientific support.

In general, it appears that manipulation of specific variables, i.e. player number, pitch-size and rules may enhance a specific game component, thus providing a sport-specific setting where players may enjoy the conditioning aspects to a great(er) extent. However, the nature and versatility of the sport imply a continuing requirement for further research of SSGs to confirm/discard/reveal key aspects of the game.

3.0 Methods

3.1 Experimental design

This study investigated physiological and time-motion characteristics of MM and NMM in soccer SSG with amateur soccer players, varying in player number. SSGs were designed according to current research guidelines with parameters incorporated to account for current knowledge on physiological adaptations to the modality.

Preliminary testing were conducted over two days, two weeks prior to data collection with height and weight assessed measured upon arrival. Participants were assessed for HR_{max} and aerobic capacity by the $30\text{-}15_{IFT}$, as well as sprints between 0-40 meters.

Data collection was implemented mid-way through pre-season (early April 2015) to the early competitive season (May 2015). Players were ranked by the team coach based on their overall technical skills, while ranking of aerobic capacity was based on performance in the $30\text{-}15_{IFT}$. SSGs trainings occurred on the same pitch for the duration of the study, and no injuries occurred during the implementation of this study.

3.2 Participants

Eight amateur football players (age: 23.6 ± 3.3, height; 175.7 ± 8.6cm, weight: 75.5 ± 8.0kg, HR_{max}: 198.8 ± 8.0, $Speed_{max}$: 30.3 ± 1.2 km/h) volunteered to participate in the study. All players had a minimum of 5 years of soccer experience, and competed in the premier division of a local league. Training frequency of the squad during pre-season and in-season was 2-3 $d \cdot wk^{-1}$. All players were thoroughly informed about the aims, procedures and risks of the study (Appendix 2), and consented to the nature of the study by signing the

Participant consent form (Appendix 3) prior to an initial testing session and the following training intervention.

An ethical approval request was submitted to Auckland University of Technology Ethics Committee (AUTEC) in November 2014, and granted in February 2015 after one re-submission due to required alterations (Appendix 1).

3.3 Physical fitness testing

To establish baseline values and determine the fitness level of each player, testing sessions were conducted 2 weeks prior to data collection, with sprints and aerobic fitness tested on an indoor track & field track. Height and weight (Seca 876, German Healthcare Export Group, Germany) were registered prior to any physical exertion, and subjects were asked to refrain from drinking alcohol, or participating in strenuous physical activity for 48 hours prior to testing.

All players were tested in the evening to attenuate circadian differences, additionally aligning with the data collection (training sessions implemented in the evening). Players were divided into three groups, with two groups tested during the first day, and the remaining group tested on the second day.

3.3.1 Speed

The players engaged in a 10-minute warm-up procedure administered by the lead researcher. Light dynamic stretches, changes in directions, and gradual increase in intensity (50-90%) were implemented, with additional individual exercises included if desired by any participant.

Timing lights (Swift Performance Equipment, Lismore, Australia) were utilized to assess speed of players, with times measured at 5m, 10m, 20m, 30m and 40m. The intervals allowed for establishment of acceleration and peak speed of every player, further utilized for comparison with velocities obtained during SSGs. Due to limited amount of timing lights available, three sprints were conducted measuring times at 5m, 10m and 20m, before the lights were moved to 30m and 40m for another 3 attempts, bringing the total amount of sprints to 6. Every sprint was interspersed by a minimum of 3 minutes to allow for optimal rest between bouts (Frost, Cronin, & Levin, 2008).

To align with standardization recommendations outlined by (Cronin & Templeton, 2008), timing light height was set to the maximal height to avoid any differences between players. Furthermore, a split stance was enforced (individual player preferences for front leg incorporated) (Cronin, Green, Levin, Brughelli, & Frost, 2007), no rocking backwards to ensure equal starting position among all players (Frost et al., 2008), start position was set 50 centimeters behind the first timing light, and elimination of attempt was implemented if in breach of any of the standardization rules outlined by Cronin et al. (2007). Only the best result was recorded and utilized for future analysis.

3.3.2 Aerobic fitness

Maximal aerobic speed with CODs was assessed using the 30-15 Intermittent Fitness test (Buchheit, 2005; Buchheit, 2008). The test consists of 30-second shuttle runs interspersed with 15-second passive recovery bouts, where the initial speed is set at 8 km/h, and a \`beep' (announced from an iPod Classic – 7th generation, Apple, Cupertino, California, via loudspeakers – Logitech S715i 30-Pin, Lausanne, Switzerland) indicated the start/stop of each interval, with speed increasing by 0.5 km/h every 45 seconds. Participants were required to run back and forth over a shuttle distance of 40m, with a 3m zone located at both ends, as well as the centre, in which participants must find themselves when the audio signal occurs. The test ceased when the participant was unable to maintain the appropriate speed, or failed to reach the 3m zones on 3 consecutive `beeps'. The speed at the final completed stage was recorded as the maximal aerobic speed (Buchheit, 2008). Previous research on reliability of 30-15_{IFT} has seen an intraclass correlation coefficient (ICC) of 0.96 following two consecutive trials separated by 48 hours, with a typical error of 0.33 km/h, highlighting the tool's usefulness in assessing team sport players (Buchheit, 2005).

Heart rate monitors (Polar Team Sport System, Polar Electro Oy, Finland) were worn by participants throughout the test, and data was downloaded within 24 hours of testing from the Polar Team 2 software. The highest recorded HR value was utilized as HR_{peak} for subsequent data analysis and comparisons.

3.4 Small-sided games

A two-week familiarization process was implemented prior to any data collection, during which the participants adapted to the SSG training method, as well as wore appropriate gear for data collection (GPS units and HR monitors).

Every game was played at the same time of day (17:00-18:30) on natural grass, at the beginning of each training session, and only preceded by a 10-minute warm-up consisting of sport-specific drills with intensities of 50-90% HR_{peak}. Nutritional, hydration and activity status were assumed to be consistent, although not specifically measured, and access to fluids was granted ad libitum throughout each session. Each SSG game (2v2 MM, 2v2 NMM, 3v3 MM, 3v3 NMM, 4v4 MM and 4v4 NMM) was played on two separate occasions, with all SSGs executed in a random order, with a minimum of 48 hours recovery between each SSG. An abundance of soccer balls were distributed around the pitch to optimize efficient playing time, and small-goals (approximately 1 meter width, marked by cones) was implemented at each side. To optimize the equality between teams, players were allocated to each team based on their soccer skills (identified by the team manager with players ranked from 1-8: 1 = overall most skilled player, 8 = overall least skilled player), as well as test results from the initial testing session, with player allocation to a given team kept identical for each session.

Every SSG lasted for 22 minutes, comprising 4 bouts of 4 minute intervals interspersed with 2 minutes of passive recovery. The duration of interval and rest length was selected to abide by recommendations for optimal aerobic enhancements outlined in early studies by Helgerud et al. (2001). The selection of a passive recovery – as opposed to active – was implemented as per recommendations of passive (2-3 minute rests) vs active (3-5 minute rests) (Buchheit & Laursen, 2013a).

Verbal encouragement and constructive feedback were provided to counteract pacing strategies (Sampaio et al., 2014), and to optimize intensity levels throughout the entire session (Hoff et al., 2002; Rampinini et al., 2007).

Selection of pitch sizes for the various SSG formats was predicated on requirements for physiological adaptation and sufficient sport-specific technical/tactical stimulation. Consequently, averages of previously incorporated pitch dimensions in studies investigating the effects of pitch sizes were utilized (Casamichana & Castellano, 2010; Hodgson et al., 2014; Kelly & Drust, 2009; Koklu et al., 2013; Owen et al., 2004;

Rampinini et al., 2007), while simultaneously accounting for the technical/tactical requirements outlined by Fradua et al. (2013). Thus, the pitch sizes utilized in the current study were: 4v4 – 33.25m x 26m, 3v3 – 30m x 21m, and 2v2 – 20m x 20m, with relative m^2 sizes of $108.1m^2$, $105m^2$ and $100m^2$ respectively.

During all SSGs, each participant wore a 10 Hz GPS units (VX Sport 220, Visuallex Sport International, Wellington, New Zealand) incorporating a tri-axial accelerometer. The GPS device connected to HR equipment (Suunto Dual Comfort Heart Rate Belt, Vantaa, Finland) via short-range telemetry throughout each SSG session to allow for a single file of data. The same GPS device was used for repeated SSGs to reduce variability from potential inter-unit differences. The following metrics from the GPS, accelerometer and HR units were obtained: total distance, peak metabolic power, average metabolic power, average and maximum HR, time spent ≥90% HR_{peak} for the duration of each SSG session. Further analysis of time spent ≥90% HR_{peak} for individual bouts were conducted via available manipulations in the VX Sport software. Lastly, maximum and average speed were collected, along for distance covered at the following speed bands: 0-6.9 km/h (walking), 7-13 km/h (jogging), 13.1-17.8 km/h (striding), 17.9-21 km/h (High intensity running – HIR), >21 km/h (sprinting) which were generally consistent with previous soccer SSG literature (Casamichana et al., 2012; Casamichana et al., 2013; Castellano et al., 2013; Hill-Haas, Dawson, et al., 2009; Hill-Haas, Rowsell, et al., 2009; Köklü et al., 2015).

Rating of perceived exertion (RPE) was measured on a 1-10 CR (category ratio) scale after each SSG training session, due to its viable usability to assess training load in soccer players (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Rodríguez-Marroyo & Antoñan, 2015). Post-training RPE collection times were not specified as per current guidelines provided by (Fanchini, Ghielmetti, Coutts, Schena, & Impellizzeri, 2015).

3.5 Statistical analysis

Data from continuous variables were log-transformed to reduce bias to non-uniformity of error, furthermore analyzed in a post-only crossover spreadsheet (Hopkins, 2006). 90% confidence limits (CL) were implemented as the uncertainty of effects and as likelihoods of substantial change in the true value of the effect, in order to generate assumptions regarding true (population) values. Assumptions of true (populations) effects for small-sided games with various formats (including physiological, time-motion characteristics and perceptual responses) were conducted by the utilization of 90% confidence limits as the uncertainty of effects, and as likelihoods of substantial change in the true value of the effect. The assessment of smallest worthwhile effect of true (population) differences were analyzed with 0.2 standardized units (Δmean divided by inter-participant SD), furthermore expressed qualitatively and as percentages, with accompanying practical inferences (Hopkins, 2006). The 0.2 standardized unit follows Cohen's classifications for effect sizes (large = 0.8, medium = 0.5, small = 0.2), and are applied to both continuous and ordinal variables (Cohen, 1988). Classification of magnitudes of change are 0-5% (unclear), 5-25% (likely trivial), 25-75% (possibly positive/negative,), 75-95% (likely positive/negative), 95-99.5% (very likely positive/negative), ≥99.5% (most likely positive/negative).

4.0 Results

Descriptive statistics for physiological and perceptual responses are presented in Table 7, while descriptive statistics for physical responses are outlined in Table 10. The physiological and perceptual comparisons between NMM and MM responses are presented in Table 8, while a comparison between MM formats are presented in Table 9. Overviews of the physical responses to MM in comparison to NMM are presented in Table 11, while the MM comparisons are displayed in Table 12. Effect sizes, with respect to the smallest worthwhile change, are presented in Figures 1-8 for all comparisons.

4.1 Comparisons of physiological responses for MM vs NMM

The $\%HR_{peak}$ for 2v2 MM was *possibly* greater than 2v2 NMM ($\%\Delta = 0.7 \pm 1.6$, ES $= 0.24 \pm 0.45$), while *unclear* inferences were identified for 4v4 MM compared to 4v4 NMM (ES = -0.25 ± 0.78) and 3v3 MM compared to 3v3 NMM (ES = -0.25 ± 0.78) (Table 8, Figure 1). Conversely, increased player numbers elicited smaller differences between NMM and MM for $\%HR_{ave}$ (Table 8). Furthermore, *unclear* differences in $\%HR_{ave}$ for 3v3 MM (ES = 0.41 ± 0.73) and 4v4 MM (ES = 0.22 ± 0.77) were identified when compared to their respective NMM formats, while $\%HR_{ave}$ during 2v2 MM was *very likely* greater than 2v2 NMM ($\%\Delta = 2.7 \pm 1.7$, ES = 0.65 ± 0.41).

Differences between NMM and MM for total time spent ≥90% HR_{max} (T_{tot}) were *unclear* across all formats. Table 8 depicts how 2v2 MM and 3v3 MM generated increased T_{tot} compared to the respective NMM modalities (ES = 0.34 ± 0.55 and 0.1 ± 0.3 respectively), while 4v4 MM produced decreased T_{tot} compared to NMM (ES = 0.39 ±

0.71). A gradual decrease in Δ% in T_{tot} for MM compared to NMM occurred with an increase in players, although *unclear* inferences mirrors the small and unclear effects, predominantly due to large confidence limits (CLs) (Figure 1), as one player failed to reach ≥90% HR_{max} intensities.

A gradual increase in intensities ≥90% HR_{peak} occurred with progressions from B1 to B4 for both 2v2 MM and NMM. A comparison between the modalities revealed *unclear* inferences for B1 (ES = 0 ± 0.15), B3 (ES = 0.21 ± 0.82) and B4 (ES = 0.46 ± 0.69) when NMM was matched for MM, while time ≥90% HR_{peak} for 2v2 MM was *likely* greater than NMM in B2 (ES = 0.49 ± 0.61). Conversely, a comparison between 3v3 formats revealed *unclear* to *likely trivial* inferences for B1-B3 (ES = 0.01 to 0.13), however MM were *likely* greater for ≥90% HR_{peak} compared to NMM for B4 (ES = 0.6 ± 0.78). The 4v4 NMM format generated increased time ≥90% HR_{max} for B1 and B3 compared to MM (ES = -0.45 ± 0.54 and -0.47 ± 0.65 respectively), while B2 and B4 generated *likely trivial* differences between modalities (ES = -0.03 ± 0.22 and 0.05 ± 0.19 respectively).

A comparison between MM and NMM with regards to perceptual responses generated very large effects sizes for smaller formats, while 4v4 generated a moderate effect for MM. Indeed, MM are *very likely* to elevate perceptual responses for 2v2 and 3v3 when compared with NMM (%Δ: 16.4 ± 7.3% and 17.6 ± 15.7%; ES = 2.09 ± 0.86 and 1.77 ± 1.41 respectively), while 4v4 MM are *likely* to induce greater RPE responses compared to the 4v4 NMM (&Δ: 6.7 ± 6; ES = 0.66 ± 0.57).

Table 7 - Heart rate and perceptual responses during man marking (MM) and non-man marking (NMM) in soccer specific small-sided games, varying in player number (mean ±SD)

	2v2		3v3		4v4	
	NMM	MM	NMM	MM	NMM	MM
$\%HR_{peak}$	94.3 ± 3.1	95 ± 2	94.7 ± 1.8	95 ± 3.1	94.7 ± 2.6	93.9 ± 3.6
$\%HR_{ave}$	85.7 ± 2.8	88.1 ± 2	86.3 ± 2.2	87.8 ± 2.8	84.9 ± 3.6	85.7 ± 3.4
RPE	8.4 ± 0.5	9.75 ± 0.5	6.75 ± 0.7	7.9 ± 0.6	6.9 ± 0.8	7.4 ± 0.5
T_{tot} ≥90% HR_{max} (s)	307 ± 293	404 ± 276	308 ± 214	385 ± 220	314 ± 221	322 ± 270
T_{tot} ≥90% HR_{max} , B1 (s)	55.3 ± 45.1	73.3 ± 79	57.4 ± 60.3	64.3 ± 80.6	75.9 ± 60.5	51.3 ± 67.9
T_{tot} ≥90% HR_{max}, B2 (s)	63.8 ± 74.9	93.3 ± 86.1	83.8 ± 54.2	105 ± 61	61.8 ± 52	91.8 ± 68.3
T_{tot}≥90% HR_{max}, B3 (s)	89.8 ± 75	104 ± 70.8	81.2 ± 38.2	99.5 ± 49.8	108 ± 53.8	88.1 ± 65.8
T_{tot} ≥90% HR_{max}, B4 (s)	97.8 ± 102	133 ± 48.3	82.4 ± 78.1	116 ± 47	75.3 ± 66.6	91.4 ± 79.8

B = bout; $\mathbf{HR_{ave}}$ = average heart rate; **RPE** = ratings of perceived exertion; $\mathbf{T_{tot}}$ = total time; $\mathbf{\%HR_{ave}}$ = average percentage of maximum heart rate; $\mathbf{\%HR_{peak}}$ = peak percentage of maximum heart rate

Table 8 - Intra-format comparison of physiological and perceptual responses for NMM and MM (mean ± SD). %Δ represents an increase/decrease with MM implementation.

	2v2		**3v3**		**4v4**	
	%Δ	Inference	%Δ	Inference	%Δ	Inference
$\%HR_{peak}$	0.7 ± 1.6	Possibly positive	0.3 ± 2.4	Unclear	-0.8 ± 2.6	Likely positive
$\%HR_{ave}$	2.7 ± 1.7	Very likely positive	1.7 ± 3.1	Unclear	1 ± 3.4	Unclear
RPE	16.4 ± 7.3	Very likely positive	17.6 ± 15.7	Very likely positive	6.7 ± 6	Likely positive
T_{tot} ≥90% HR_{max} (s)	111 ± 317	Unclear	23.7 ± 87	Unclear	-57.4 ± 97	Unclear
T_{tot} >90% HR_{max}, B1 (s)	2.2 ± 76.2	Likely trivial	-50.4 ± 1690	Unclear	-87.1 ± 72.4	Likely negative
T_{tot} ≥90% HR_{max}, B2 (s)	398 ± 1619	Likely positive	3.3 ± 97.2	Very likely trivial	9.8 ± 96.9	Likely trivial
T_{tot} ≥90% HR_{max}, B3 (s)	54.4 ± 420	Unclear	30.3 ± 44.2	Likely trivial	-62.9 ± 68.8	Likely negative
T_{tot} ≥90% HR_{max}, B4 (s)	256 ± 1184	Unclear	267 ± 884	Likely positive	13.8 ± 63.1	Likely trivial

B = bout; **HR_{max}** = maximum heart rate; **MM** = man marking; **NMM** = non-man marking; **RPE** = ratings of perceived exertion; **T_{tot}** = total time; **%Δ** = percent change; **$\%HR_{ave}$** = average percentage of maximum heart rate; **$\%HR_{peak}$** = peak percentage of maximum heart rate

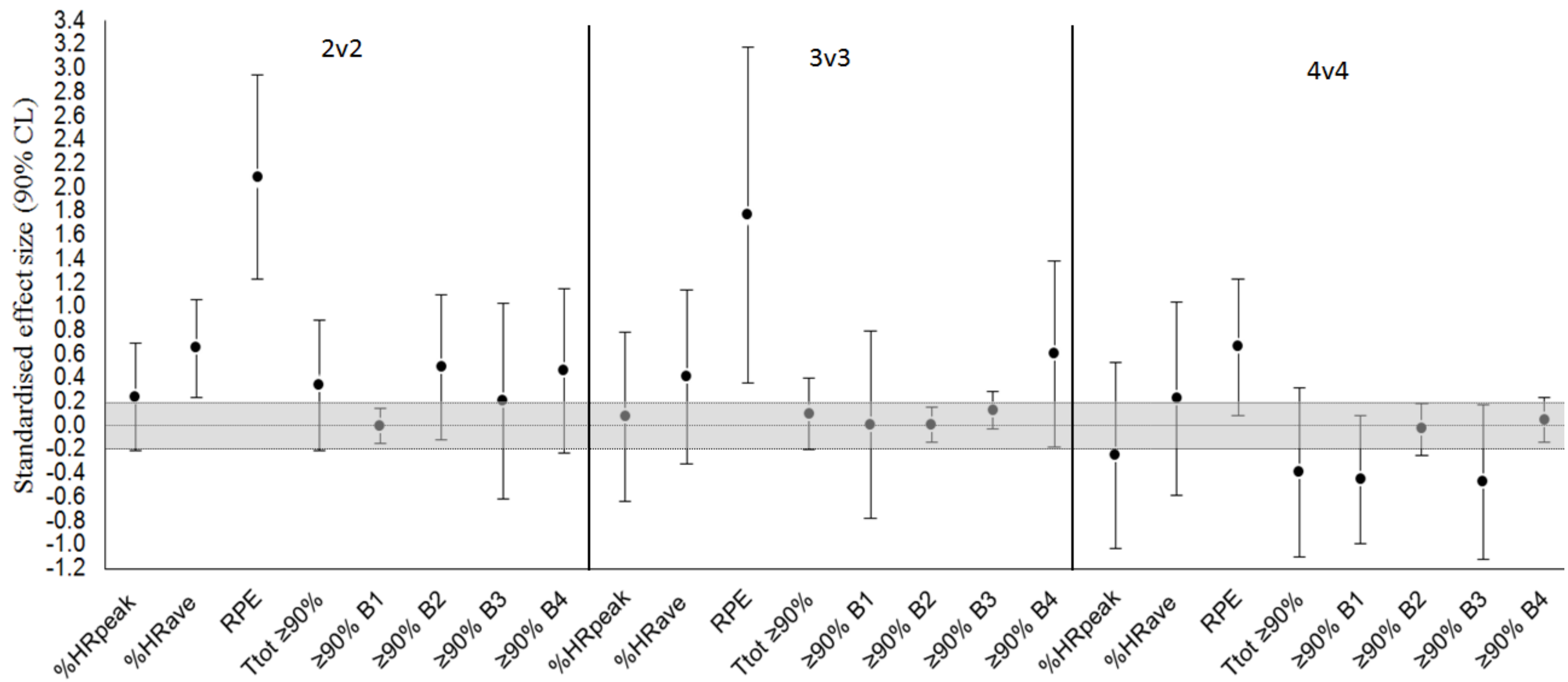

Figure 1 - Standardized effects for physiological and perceptual differences between formats: 2v2 non-man marking (NMM) vs man marking (MM) (left panel), 3v3 NMM vs MM (middle panel) and 4v4 NMM vs MM (right panel). Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

4.1 Comparisons of physiological and perceptual responses for player number

Table 9 reveals how increasing SSGs with 2 players generates a *likely negative* influence on $\%HR_{peak,}$ however 2v2 MM generated *unclear* inferences with regards to peak HR comparisons with 4v4 MM (%Δ: -2.1 ± 3.5, ES = -0.62 ± 1.06). Furthermore, format enlargements to 3v3 induced *likely* lower $\%HR_{ave}$, whereas a player number increase to 4v4 *very likely* decreased $\%HR_{ave}$ (%Δ: -3.5 ± 2.7%, ES = -0.86 ± 0.66). Conversely, a comparison between the two smallest formats (2v2MM vs 3v3 MM) displayed the smallest percentage change (%Δ = -1.6 ± 2.2), and subsequent negative small effects (ES = -0.39 ± 0.53), as depicted in Figure 2.

With regards to the T_{tot}, *unclear* inferences were revealed for both 4v4 MM comparisons, however the 2v2 and 3v3 comparison *possibly* decreased the time spent at ≥90% HR_{peak} with increased player numbers (%Δ: -29.6 ± 31.4, ES = -0.16 ± 0.2). The greatest difference in player numbers (2v2 MM vs 4v4 MM) revealed large effects (ES = -1.01 ± 1.84) for MM comparisons, while an increase from 3v3 MM to 4v4 MM is *likely* to reduce the overall time ≥90% HR_{peak} (%Δ: -79.9 ± 79.4, ES = -0.73 ± 0.95). Although moderate to large ES are depicted in Figure 2, the large CLs are predominantly responsible for the *unclear* to *possible* inference descriptions.

Table 9 depicts *unclear* and *trivial* differences for the majority of bout comparisons between 2v2 MM and both 3v3 MM and 4v4 MM (ES = -0.03 to 0.2). The effects of increasing player numbers were predominantly small to medium for 2v2 MM v 4v4 MM comparisons (ES = -0.37 to -0.74), as well as 3v3 MM and 4v4 MM comparisons (ES = -0.34 to -0.61). In contrast, comparisons between 2v2 MM and 3v3 MM were unclear for

B2-B4 (ES = -0.03 to -0.13) and small for B1 (ES = -0.2 ± 0.64). Increasing player numbers from 3v3 MM to 4v4 MM displayed moderate effects for B3 and B4 (ES = -0.61 ± 0.82 and -0.56 ± 0.71 respectively), with increases in player number *unclear* and *likely* to decrease time at ≥90% HR_{peak} respectively.

With respect to perceptual responses, increasing player numbers from 2v2 MM to 3v3 MM and 3v3 MM to 4v4 MM resulted in a *very likely* reduction in RPE (%Δ: -19.3 ± 11.7 and -9.4 ± 6.9; ES = -2.85 ± 1.84 and -1.14 ± 0.86 respectively). Furthermore, 2v2 MM resulted in *most likely* higher RPE responses than 4v4 MM (%Δ: -24.3 ± 6.4; ES = -3.61 ± 1.12).

Table 9 - Inter-format comparison of physiological and perceptual responses (mean ± SD). %Δ represents an increase/decrease with MM implementation.

	2v2 MM vs 3v3 MM		**2v2 MM vs 4v4 MM**		**3v3 MM vs 4v4 MM**	
	%Δ	Inference	%Δ	Inference	%Δ	Inference
RPE	-19.3 ± 11.7	Very likely negative	-24.3 ± 6.4	Most likely negative	-9.4 ± 6.9	Very likely negative
$\%HR_{peak}$	-1.4 ± 1	Likely negative	-2.1 ± 3.5	Unclear	-1.8 ± 2.2	Likely negative
$\%HR_{ave}$	-1.6 ± 2.2	Possibly negative	-3.5 ± 2.7	Likely negative	-3.4 ± 3.2	Likely negative
Total t ≥90% HR_{max}, (s)	-29.6 ± 31.4	Possibly negative	-89 ± 310	Unclear	-79.9 ± 79.4	Unclear
Total t ≥90% HR_{max}, B:1 (s)	-86.7 ± 146	Unclear	-81 ± 172	Unclear	-65.1 ± 203	Unclear
Total t ≥90% HR_{max}, B:2 (s)	-15.6 ± 219	Unclear	-78.5 ± 77	Likely negative	-67.9 ± 57	Possibly negative
Total t ≥90% HR_{max}, B:3 (s)	-16.1 ± 17.2	Very likely trivial	-78.9 ± 197	Unclear	-72.1 ± 74.9	Unclear
Total t ≥90% HR_{max}, B:4 (s)	-30.2 ± 14.2	Likely trivial	-87.1 ± 261	Unclear	-79.2 ± 73.9	Likely negative

B = bout; **HR_{max}** = maximum heart rate; **MM** = man-marking; **RPE** = ratings of perceived exertion; **T_{tot}** = total time; **%Δ** = percent change; **$\%HR_{ave}$** = average percentage of maximum heart rate; **$\%HR_{peak}$** = peak percentage of maximum heart rate

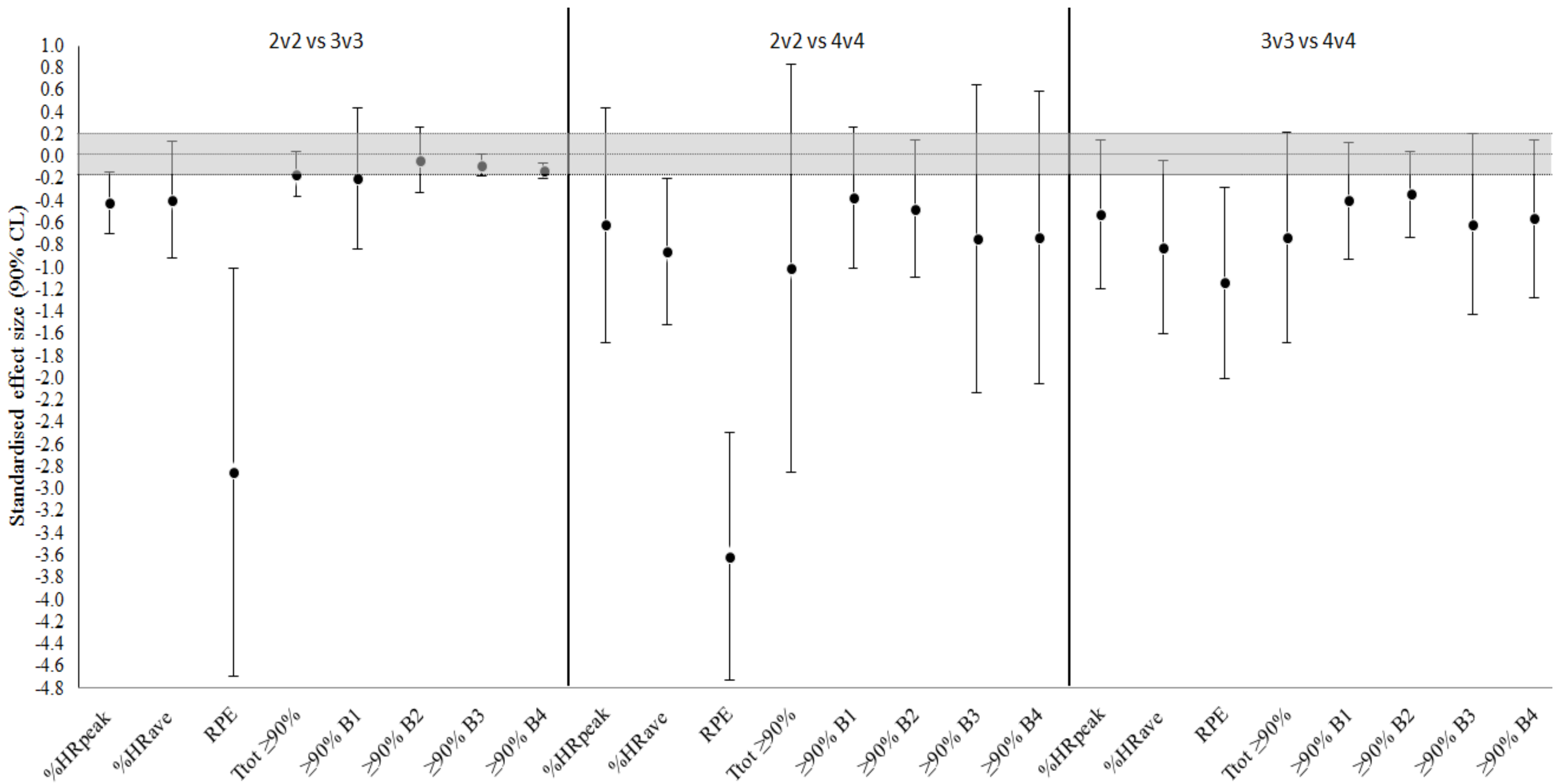

Figure 2 - Standardized effects for physiological and perceptual differences between formats: 2v2 man marking (MM) vs 3v3 MM (left panel), 2v2 MM vs 4v4 MM (middle panel) and 3v3 MM vs 4v4 MM (right panel). Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

4.3 Comparison of GPS-derived physical outputs between MM vs NMM

Total distance (TD) covered was *very likely* greater for MM when compared to NMM irrespective of player number, with 3v3 MM displaying as much as a 14.7 ± 10% increase compared to the NMM modality (ES = 2.82 ± 1.79). Consequently, player workload (m/min) revealed similar findings, as the MM modality generated a greater m/min than NMM, with very large effects identified across all formats (ES = 1.34 to 2.82).

While MM generated an *unclear* increase in peak speed ($Speed_{peak}$) compared to NMM for both 2v2 and 4v4 formats (ES = 0.83 ± 1.48 and 0.25 ± 0.87 respectively), the 3v3 format revealed a *very likely* increase for MM compared to NMM (%Δ = 5.9 ± 3.9, ES = 1.06 ± 0.69). Moreover, MM revealed a *very likely* increase for average speed ($Speed_{ave}$) compared to NMM for the 2v2 and 3v3 modalities (%Δ = 8.2 ± 6.8 and 14.8 ± 9.5, ES = 1.89 ± 1.51 and 3.3 ± 1.98 respectively), while an *unclear* inference occurred with 4v4 comparisons (ES = 1.06 ± 1.40).

Table 11 reveals how 2v2 MM and 3v3 MM elicited *unclear* decreases in TD at walking pace when matched with their respective NMM modalities (ES = -0.79 ± 1.16 and -0.61 ± 1.28 respectively). An *unclear* inference occurred for jogging for 2v2 modality comparisons, however 2v2 MM revealed how players *very likely* increased their TD at striding pace and HIR compared to NMM (ES = 3.31 ± 2.35 and 1.68 ± 0.81 respectively). Conversely, 3v3 MM induced *very likely* greater TD for jogging (%Δ = 21.2 ± 20.1, ES = 1.48 ± 1.27), striding (%Δ = 45.9 ± 31.2, ES = 4.35 ± 2.45) and HIR when compared to NMM (%Δ = 47.3 ± 39.2, ES = 0.91 ± 0.62), while the modality induced *possibly* greater DC while sprinting (>21 km/h, ES = 0.16 ± 0.18) (Table 11, Figure 4).

Table 10 - GPS-derived physical responses during MM and NMM, varying in player number (mean ± SD). %Δ represents an increase/decrease with MM implementation.

	2v2		3v3		4v4	
	NMM	MM	NMM	MM	NMM	MM
TD (m)	1689 ± 59.4	1834 ± 88.6	1586 ± 190	1811 ± 103	1759 ± 182	1874 ± 134
Work load (m/min)	105 ± 3.7	114 ± 5.5	99.1 ± 11.9	113 ± 6.5	110 ± 11.4	117 ± 8.4
$Speed_{max}$ (km/h)	21.7 ± 0.9	22.7 ± 1.7	22 ± 1.1	23.4 ± 1.5	23.2 ± 1.1	23.5 ± 1.8
$Speed_{ave}$ (km/h)	6.4 ± 0.2	6.9 ± 0.3	6 ± 0.7	6.8 ± 0.4	6.8 ± 0.8	7 ± 0.5
P_{max} (W)	443 ± 63.2	345 ± 59.6	336 ± 106	372 ± 76.4	318 ± 103	320 ± 69.4
P_{ave} (W)	11.3 ± 1.9	13.9 ± 1.1	14.3 ± 2.6	13.3 ± 1.5	15.1 ± 3.3	12.3 ± 2.3
Speed zones						
TD at 0-6.9 km/h (m)	681 ± 28	652 ± 50.4	687 ± 33.9	665 ± 49	669 ± 78.1	673 ± 52.4
TD at 7.0-13 km/h (m)	753 ± 69.7	818 ± 123	605 ± 154	726 ± 149	746 ± 183	736 ± 114
TD at 13.1-17.8 km/h (m)	219 ± 13.5	293 ± 40	218 ± 59.7	312 ± 55	264 ± 83.8	325 ± 85.1
TD at 17.9-21 km/h (m)	30.8 ± 8.3	62 ± 15.1	59.8 ± 35.1	81.3 ± 27.9	58.1 ± 27.5	106 ± 36.3
TD at >21 km/h (m)	3.5 ± 3.8	8.5 ± 6.8	15.2 ± 10.9	24 ± 19.2	18 ± 11.9	36 ± 18.1

km/h = kilometers per hour; **MM** = man marking; **m/min** = meters per minute; **NMM** = non-man marking; P_{ave} = average metabolic output; P_{peak} = peak metabolic output; **SD** = standard deviation; $Speed_{ave}$ = average speed; $Speed_{peak}$ = peak speed; **TD** = total distance; **W** = watts; **%Δ** = percent change

In contrast, the 4v4 MM format displayed *unclear* inferences for walking and jogging (ES = 0.15 ± 0.77 and 0.02 ± 0.56 respectively) when compared to NMM, while players appears to *very likely* increase their DC at striding with MM (%Δ = 23.4 ± 19.2, ES = 2.42 ± 1.79). HIR are *most likely* to increase with MM in the 4v4 format (%Δ = 83.7 ± 42.1, ES = 1.43 ± 0.53), while Table 11 reveals how distance covered while sprinting are *likely* greater for MM as well (ES = 0.3 ± 0.2).

Implementation of MM induced *unclear* inferences for maximal player load (peak metabolic power, P_{peak}) for 3v3 and 4v4 (ES = 0.62 ± 1.16 and 0.15 ± 1.12 respectively), while the defensive strategy is *very likely* to elicit a decrease in the 2v2 format (%Δ = -22.4 ± 11.7, ES = -1.21 ± 0.71).

Conversely, average player load (P_{ave}) are *likely* greater for MM than NMM for the 2v2 format (%Δ = 24.2 ± 28.6, ES = 1.02 ± 1.08), while *unclear* inferences for 3v3 MM were revealed (ES = -0.33 ± 0.82). Conversely, 4v4 MM generated a *likely* decrease in P_{ave} when compared to NMM (%Δ = -18.2 ± 8.6, ES = -0.95 ± 0.5).

Table 11 - Intra-format comparison of physical responses (NMM and MM, mean ± SD). %Δ represents an increase/decrease with MM implementation.

	2v2		**3v3**		**4v4**	
	%Δ	Inference	%Δ	Inference	%Δ	Inference
TD (m)	8.5 ± 7.4	Very likely positive	14.7 ± 10	Very likely positive	6.8 ± 4.7	Very likely positive
Work load (m/min)	8.5 ± 7.5	Very likely positive	14.8 ± 10	Very likely positive	6.7 ± 4.7	Very likely positive
P_{max} (W)	-22.4 ± 11.7	Very likely negative	13.9 ± 28.1	Unclear	3.2 ± 24.4	Unclear
P_{ave} (W)	24.2 ± 28.6	Likely positive	-6.8 ± 16.2	Unclear	-18.2 ± 8.6	Very likely negative
$Speed_{peak}$ (km/h)	4.6 ± 8.4	Unclear	5.9 ± 3.9	Very likely positive	1.4 ± 4.8	Unclear
$Speed_{ave}$ (km/h)	8.2 ± 6.8	Very likely positive	14.8 ± 9.5	Very likely positive	4.5 ± 6.1	Unclear
Speed zones						
TD at 0-6.9 km/h	-4.4 ± 6.3	Unclear	-3.4 ± 7	Unclear	0.9 ± 4.4	Unclear
TD at 7.0-13 km/h	8.1 ± 14.5	Unclear	21.2 ± 20.1	Very likely positive	0.2 ± 7.3	Unclear
TD at 13.1-17.8 km/h	33.2 ± 27.3	Very likely positive	45.9 ± 31.2	Very likely positive	23.4 ± 19.2	Very likely positive
TD at 17.8-21 km/h	104 ± 71.8	Very likely positive	47.3 ± 39.2	Very likely positive	83.7 ± 42.1	Most likely positive
TD at >21 km/h	116 ± 193	Possibly positive	51.7 ± 76.9	Possibly positive	120 ± 126	Likely positive

km/h = kilometers per hour; **MM** =man marking; **m/min** = meters per minute; **NMM** = non-man marking; P_{ave} = average metabolic output; P_{peak} = peak metabolic output; **SD** = standard deviation; $Speed_{ave}$ = average speed; $Speed_{peak}$ = peak speed; **TD** = total distance; **W/kgs** = watts; **%Δ** = percent change

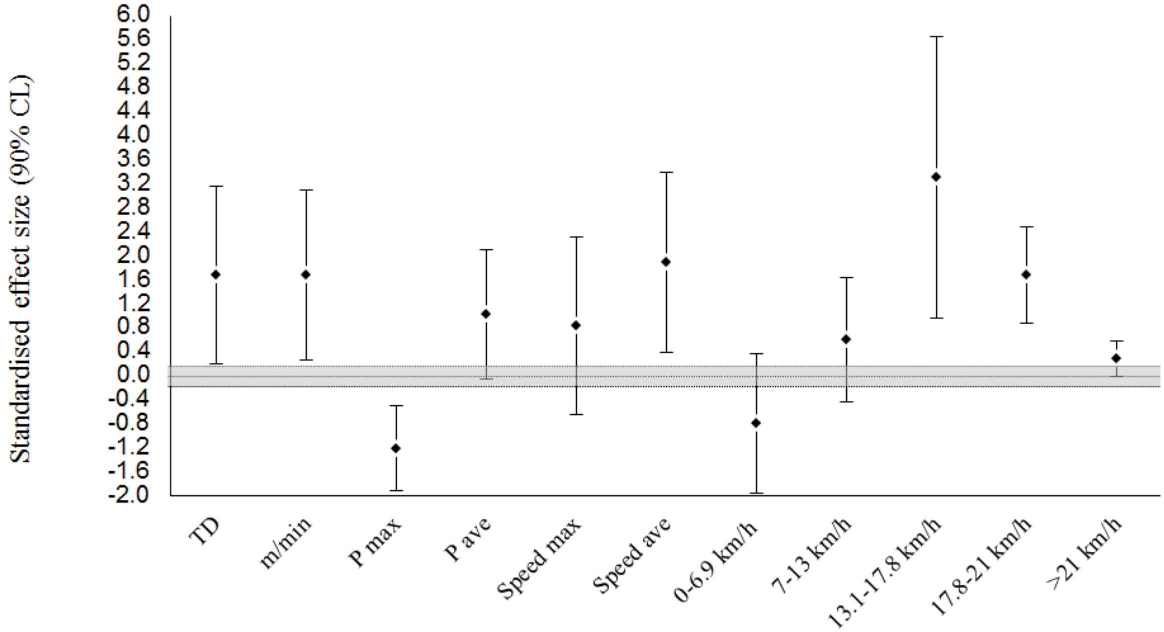

Figure 3 - Standardized effects for physical differences between 2v2 non-man marking (NMM) and 2v2 man marking (MM). Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

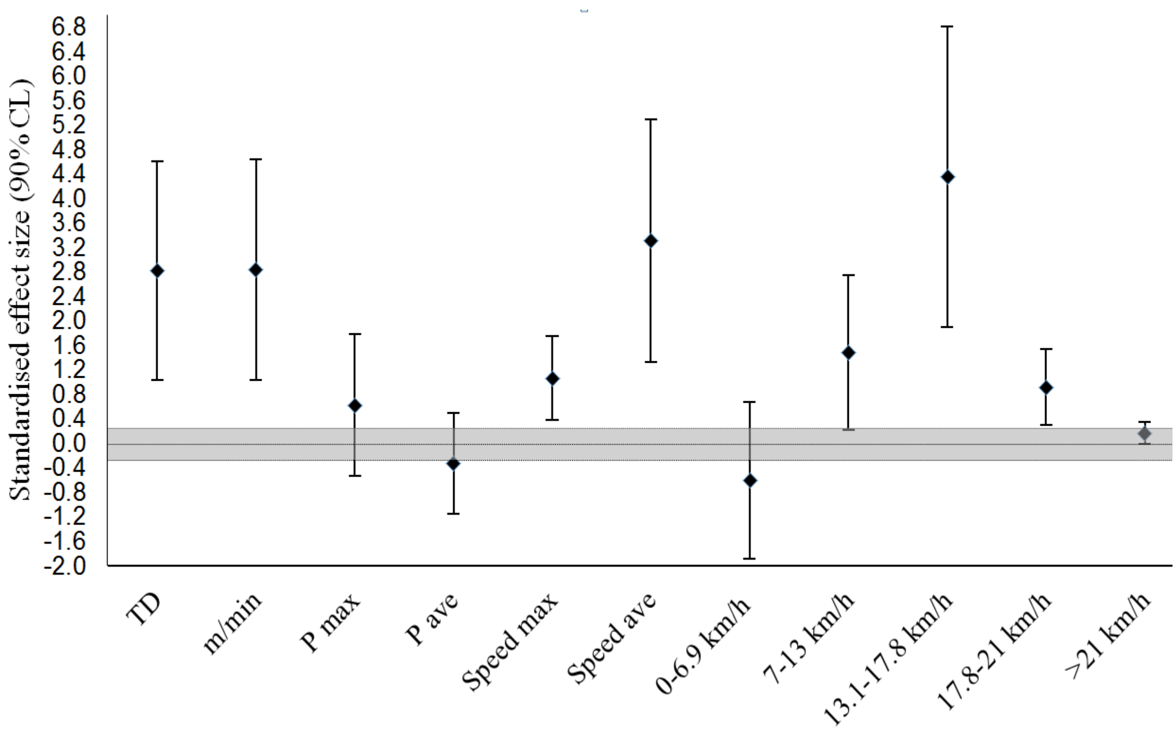

Figure 4 - Standardized effects for physical differences between 3v3 non-man marking (NMM) and 3v3 man marking (MM). Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

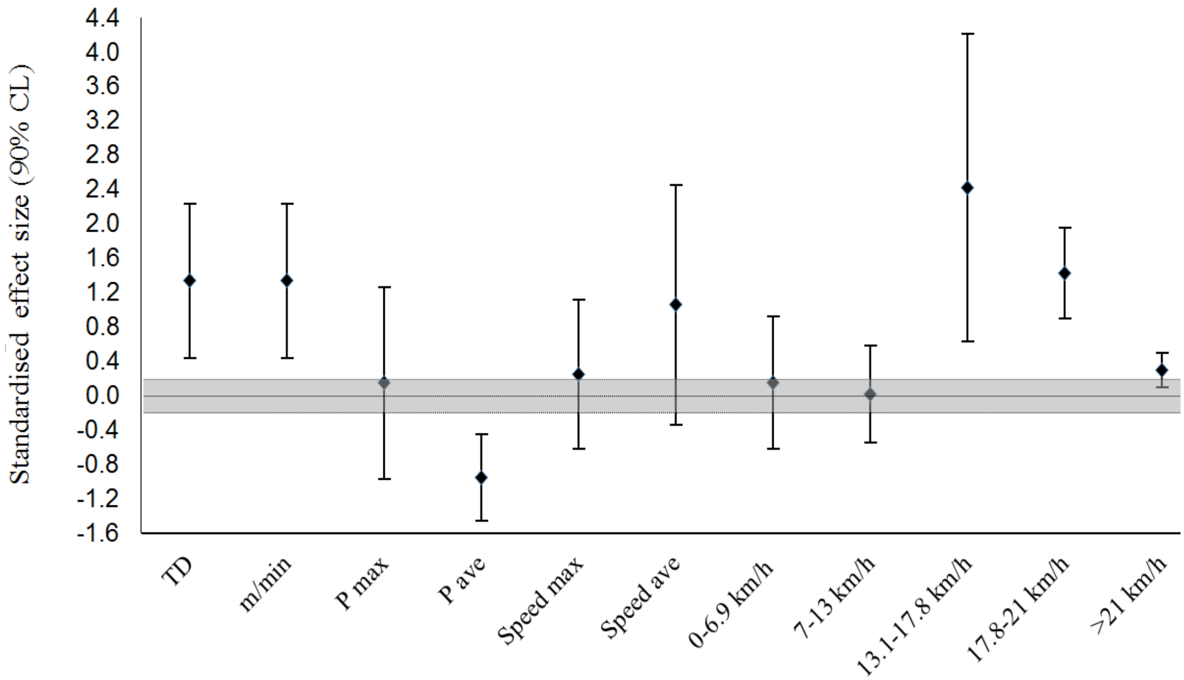

Figure 5 - Standardized effects for physical differences between 4v4 non-man marking (NMM) and 4v4 man marking (MM). Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

4.4 Physical characteristics with player number

Table 12 depicts how 4v4 MM *likely* and *very likely* generated an increase in TD and workload when compared to 2v2 MM (%Δ = 4.4 ± 3.2 (both) ES = 0.94 ± 1.07 and 0.95 ± 1.08 respectively) and 3v3 MM (ES = 0.89 ± 0.63 (both)). A 2v2 and 3v3 format comparison revealed *unclear* inferences for both TD and player load (ES = 0.33 ± 1.58 and 0.34 ± 1.59 respectively).

Man marking 2v2 produced *unclear* inferences when compared to 3v3 MM and 4v4 MM for $Speed_{peak}$ (ES = -0.17 ± 2.01 and 0.19 ± 1.58 respectively), while players were *likely* to reach a higher velocity in 4v4 MM as opposed to 3v3 MM (ES = 0.39 ± 0.45). Conversely, $Speed_{ave}$ were *likely* and *very likely* greater in 4v4 MM compared to 2v2 MM

(%Δ = 4.8 ± 5.4, ES = 1.13 ± 1.23) and 3v3 MM (%Δ = 4.3 ± 3.2, ES = 1 ± 1.74), as may be seen in Table 12 and Figures 7 and 8.

Walking and jogging revealed *unclear* inferences for all format comparisons. DC at striding and HIR were *likely* greater for 3v3 MM compared to 2v2 MM (%Δ = 14.1 ± 15.2 and 19.8 ± 19.3, ES = 1.52 ± 1.53 and 0.43 ± 0.38 respectively), while distance covered for the same speed zones were *very likely* greater in 4v4 MM compared to 2v2 MM (%Δ = 19.6 ± 13.7 and 80.4 ± 52.4, ES = 2.06 ± 1.32 and 1.39 ± 0.67 respectively). Although distance covered at striding velocity were *likely* greater in 4v4 MM than 3v3 MM (%Δ = 12.6 ± 12.2, ES = 1.37 ± 1.25), ground covered at HIR were *very likely* greater in the 4v4 MM format compared to 3v3 MM (%Δ = 43.3 ± 27.8, ES = 0.85 ± 0.45).

Despite small to moderate effects for 2v2 format comparisons and sprinting, Table 12 depicts *unclear* inferences, while large CLs portrayed in Figure 6 and 7 emphasizes the uncertainty of the results. However, DC while sprinting were *possibly* greater for 4v4 MM compared to 3v3 MM (ES = 0.23 ± 0.15).

P_{peak} comparisons with 2v2 MM revealed *unclear* inferences, however an increase in player number from 3v3MM to 4v4 MM are *likely* to decrease the peak metabolic output (%Δ = -10.6 ± 10.8, ES = -0.53 ± 0.57). Similarly, increasing player numbers from 2v2 MM to 3v3 MM will *possibly* decrease P_{ave} (ES = -0.33 ± 0.41), while 4v4 MM format comparisons produce *unclear* inferences.

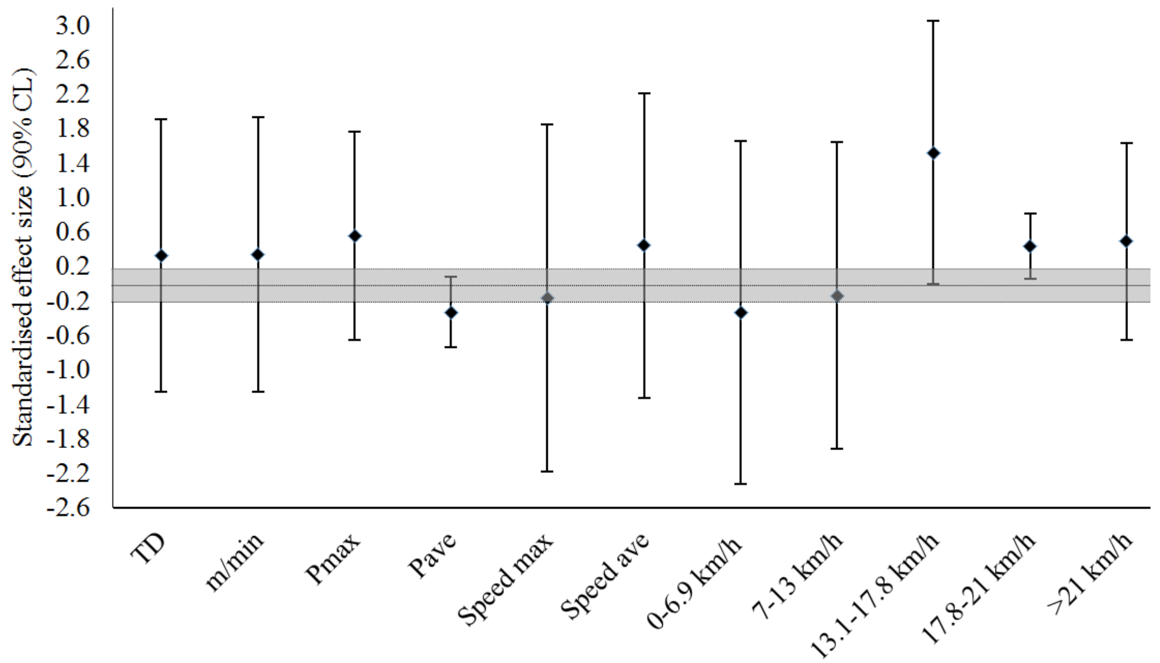

Figure 6 - Standardized effects for physical differences between 2v2 man marking (MM) and 3v3 MM. Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

Table 12 - Inter-format comparison of physical outputs (mean ± SD). %Δ represents an increase/decrease with MM implementation.

	2v2 vs 3v3		2v2 vs 4v4		3v3 vs 4v4	
	%Δ	Inference	%Δ	Inference	%Δ	Inference
TD (m)	1.6 ± 7.9	Unclear	4.7 ± 5.5	Likely positive	4.4 ± 3.2	Very likely positive
Work load (m/min)	1.6 ± 7.9	Unclear	4.7 ± 5.5	Likely positive	4.4 ± 3.2	Very likely positive
P_{peak} (W)	12.2 ± 28.8	Unclear	-3.4 ± 10.8	Unclear	-10.6 ± 10.8	Likely negative
P_{ave} (W)	-6.8 ± 8.1	Possibly negative	-6.4 ± 28	Unclear	-4.9 ± 19.3	Unclear
$Speed_{peak}$ (km/h)	-0.9 ± 10.8	Unclear	1.1 ± 8.6	Unclear	2.1 ± 2.5	Likely positive
$Speed_{ave}$ (km/h)	1.9 ± 7.6	Unclear	4.8 ± 5.4	Likely positive	4.3 ± 3.2	Very likely positive
Speed zones						
0-6.9 km/h (m)	-1.9 ± 11	Unclear	0.5 ± 7.8	Unclear	0.4 ± 4.1	Unclear
7-13 km/h (m)	-1.8 ± 23	Unclear	-4.6 ± 16.5	Unclear	0.9 ± 9.4	Unclear
13.1-17.8 km/h (m)	14.1 ± 15.2	Likely positive	19.6 ± 13.7	Very likely positive	12.6 ± 12.2	Likely positive
17.8-21 km/h (m)	19.8 ± 19.3	Likely positive	80.4 ± 52.4	Very likely positive	43.3 ± 27.8	Very likely positive
>21 km/h (m)	261 ± 3696	Unclear	684 ± 7392	Unclear	84.2 ± 72.8	Possibly positive

km/h = kilometers per hour; **MM** = man marking; **m/min** = meters per minute; $\boldsymbol{P_{ave}}$ = average metabolic output; $\boldsymbol{P_{peak}}$ = peak metabolic output; **SD** = standard deviation; $\mathbf{Speed_{ave}}$ = average speed; $\mathbf{Speed_{peak}}$ = peak speed **TD** = total distance; **W** = watts; **%Δ** = percent change

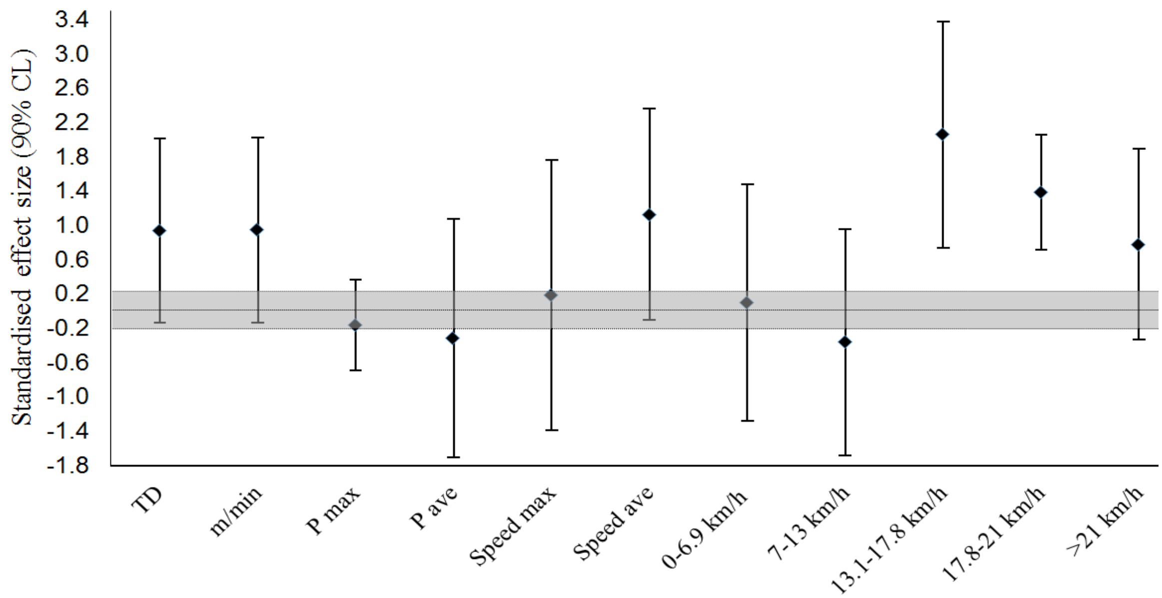

Figure 7 - Standardized effects for physical differences between 2v2 man marking (MM) and 4v4 MM. Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

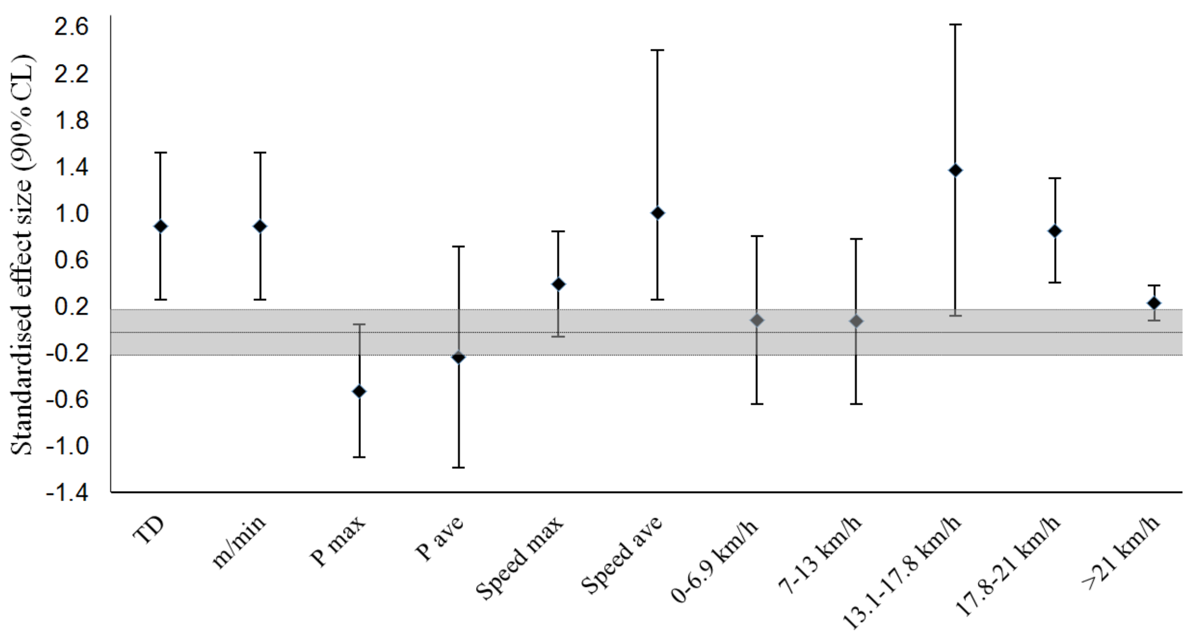

Figure 8 - Standardized effects for physical differences between 3v3 man marking (MM) and 4v4 MM. Error bars indicate 90% confidence limits. When 90% confidence limits overlapped the zero line (solid line), changes were deemed 'unclear'. The shaded area represents an unclear effect size.

5.0 Discussion

The aim of this study was to compare the physiological, perceptual and time-motion characteristics between MM and NMM game formats, varying in player number, during soccer-specific SSGs. While the physiological and time-motion characteristics of MM and NMM SSGs have been reported in previous studies involving youth/young players (Aroso et al., 2004; Ngo et al., 2012; Sampaio et al., 2007), no study to date has quantified and compared responses to MM and NMM SSG formats, and variations in player number in relation to MM with adult soccer players. The findings of this study indicated differences in key physiological, perceptual and physical outputs for MM and NMM SSG formats.

5.1 Physiological responses

5.1.1 NMM vs MM

The $\%HR_{ave}$ is a common metric in SSG studies to gain an insight into internal (physiological) player loads (Abrantes et al., 2012; Aroso et al., 2004; Casamichana & Castellano, 2010; Casamichana et al., 2013; Castellano et al., 2013; Dellal et al., 2008; Hill-Haas et al., 2008; Köklü et al., 2015). Quantification of cardiovascular demands during SSGs is of great importance, as it has been suggested that $\geq 90\% \ HR_{max}$ is required for optimal aerobic conditioning (Helgerud et al., 2001; Hoff et al., 2002). Similarly, da Silva et al. (2011) recommend a minimum requirement of 85% HR_{max} for aerobic enhancement. In the present study, we observed an increase in $\%HR_{ave}$ when MM was implemented in 2v2 SSGs, while unclear differences existed between 3v3 and 4v4 formats. Interestingly, players achieved intensities of $\geq 93.9\% \ HR_{peak}$, however the differences did not generate substantial effects compared to the NMM formats.

The magnitude of $\%HR_{ave}$ increases outlined in the current study are lower than those presented by Ngo et al. (2012), who revealed a large increase (4.4-4.8 $\%HR_{res}$) for 3v3 POS and small goal modalities with MM compared to NMM. Conversely, Sampaio et al. (2007) revealed insignificant differences for $\%HR_{max}$ between MM and NMM for 2v2 and 3v3 with youth soccer players, with $\%HR_{ave}$ of ≤80.8% for NMM and MM. However, several options exist with respect to manipulating the format of soccer SSGs. Dellal, Owen, et al. (2012) presented $\%HR_{max}$ of 84.7 ± 2.7 with free-play SSGs, while limiting players to one-touch induced a greater HR response (87.6 ± 2.5% HR_{max}), implying elevated game intensities with touch limitations. Conversely, Köklü et al. (2015) revealed a decrease in average $\%HR_{max}$ of 1.4-2% with GKs, while stopping the ball at opposing ends (as opposed to scoring with small-goals) elevated bpm (174 → 178) in a study by Halouani, Chtourou, Dellal, Chaouachi, and Chamari (2014). The results for $\%HR_{ave}$ comparisons between NMM and MM (1-2.7 $\%HR_{ave}$) in the current study depict minor elevations in %HRs for MM to a similar extent to the studies mentioned above. Hence, the *unclear* small effect identified for the 3v3 format (along with an increase in %Δ of 1.7 ± 3.1) in our study questions the viability of MM to increase intensities in soccer SSGs. This finding is supported by the study by Sampaio et al. (2007), but contradicts the findings of Ngo et al. (2012). Thus, further research is currently required on this topic to enhance our knowledge on the effect of MM in this format. Additionally, the 4v4 comparison revealed a small effect for the 1 ± 3.4% increase in $\%HR_{ave}$ for MM, rendering its effectiveness questionable with regards to intensity increase.

In contrast to the 3v3 MM and 4v4 MM formats, the 2v2 MM format revealed a 2.7 ± 1.7% increase and moderate effect for $\%HR_{ave}$ compared to 2v2 NMM, thus potentially rendering it more viable for implementation in SSGs if higher intensities are desired. Specifically, 2v2 requires players to constantly be involved in defensive/attacking components of the game, thus increasing HR due to greater energy requirements while handling the ball (Köklü et al., 2011). The limited player numbers associated with smaller SSGs are likely to generate instant attacker-defender roles, consequently less reliance on formation/tactical behaviours occur, while full-game dynamics and movements of defensive gameplay are predominantly pre-determined through tactical and formation philosophies (Taylor, Mellalieu, & James, 2005). Thus, intrinsic factors may see players habitually organize the team in SSGs according to pre-determined defensive strategies, while simultaneously maintaining defensive control over their allocated opponent. Indeed, observations throughout the 3v3 and 4v4 MM sessions suggest that forwards endeavored to occupy the attacking positions, while the defensively oriented players predominantly found themselves closer to their own goals. Whether to implement coaching strategies to account for this factor are questionable, as coaches may remain hesitant to alter a player's intrinsic behavior to avoid decrements in overall performance.

5.1.2 Player number and man-marking

Increased player numbers are likely to provide greater opportunities to recover between high intensity bouts as relative involvement with the ball decreases (Castellano et al., 2013; Köklü et al., 2011). However, while this may be true for NMM game formats, MM imparts, regardless of player number, a greater requirement to work *off the ball* to create space, avoid the defender (attacking) and shadow the attacker (defending) (Gabbett & Mulvey, 2008), thus potentially limiting the amount of recovery opportunities available to each player. Moreover, numerous accelerations/decelerations, enhanced by the MM characteristics, induce substantial demand on the energy systems in SSGs (Gaudino, Alberti, et al., 2014), with coach encouragement further contributing to the strenuous characteristics of SSGs (Rampinini et al., 2007). Comparisons between MM formats in our study revealed a large effect for decreased $\%HR_{ave}$ with an increase in player number from 2 to 4 per team, and thus refutes the abovementioned hypothesis presented by Gabbett and Mulvey (2008). Indeed, small to large effects for decreased $\%HR_{ave}$ with increased player numbers imply greater demand on each player with player number reductions, and thus align with current literature on format comparisons (Aguiar, Botelho, Lago, Maças, & Sampaio, 2012; Bondarev, 2011; da Silva et al., 2011).

With relative pitch sizes of 100-110m^2, the increase between formats may have been insignificant to elicit similar intensities between formats, as a large negative effect was identified for the comparison between 2v2 and 4v4 (see results, Figure 2). Additionally, our differences in Δ% for $\%HR_{ave}$ between modalities were identified when comparing either 2v2 MM or 3v3 MM with the 4v4 MM modality, as a 3.4-3.5% difference and a *likely negative* inference was revealed. Although this difference remains substantial, standard deviations of 2.7-3.2% further implies large fluctuations among players, likely due to a limited sample size. Conversely, Sampaio et al. (2007) revealed an identical $\%HR_{max}$ (80.8%) for 2v2 and 3v3 MM formats, but with substantially lower values than the current study (see Table 7, results). The lower intensity may be explained by their utilization of exercise bouts consisting of 90 seconds (2v2) and 3 minutes (3v3) with a rest period of 90 seconds (Sampaio et al., 2007), which is considerably less than the current study (4 min bouts, 2 min rest). An alternate study comparison is that of Brandes et al. (2012) who utilized similar game formats to ours, revealing a lower mean $\%HR_{max}$ (93.3 → 89.7%) with an increase in player number (2v2 → 3v3 → 4v4) and relatively constant pitch size (147-150 m^2). In spite of significantly greater relative pitch size utilized by (Brandes et al., 2012), the decrease in $\%HR_{max}$ aligns with the 1.6 – 3.5% decrease identified with increasing player numbers from 2v2 to either 3v3 or 4v4 in our SSG format comparison.

5.1.2 Total time and bout time >90% HR_{max}

Given the focus on attaining high enough intensities during SSGs to induce a worthwhile training adaptation, it is important to consider the time an athlete spends above the so called "critical threshold" of ~90% HR_{peak}, advocated by various authors (Helgerud et al., 2001; Impellizzeri et al., 2006; Rampinini et al., 2007). This may provide some quantifiable index of effective cardiovascular load. Required time spent at ≥90% HR_{max} in soccer SSGs remains undefined in the literature, however soccer SSGs are predominantly based on work:rest ratios developed by Helgerud et al. (2001) who further argued for 15 minutes above 90% HR_{max} (initial minute spent achieving sufficient intensities). In our study, 2v2 MM displayed the highest mean T_{tot} with 6 minutes and 44 seconds at sufficient intensities (42.1% of total game time), while the lowest time was revealed for 2v2 NMM and 3v3 NMM (32% of total game time), emphasizing the discussion on whether soccer SSGs are indeed capable of inducing sufficient intensities .

The 404 ± 276 seconds spent at sufficient intensities for 2v2 MM (42.1% of total time, highest across all formats) are significantly below those outlined by Helgerud et al. (2001) (15 minutes = 93.75%), while unclear to small effects and *unclear* inferences, as well as substantial SDs, for NMM and MM comparisons – in spite of large %Δ – reflect the individual responses to SSGs in the present study. For example, individual responses for total time spent >90% HR_{peak} in our current study ranged from 0 (81.2 $\%HR_{ave}$) to 716 seconds (90.9 $\%HR_{ave}$) for two different players in 4v4MM (not marking each other), in spite of our attempts to balance team selection based on common strategies applied in the literature (Casamichana & Castellano, 2010; Hill-Haas et al., 2010; Köklü et al., 2015). Buchheit and Laursen (2013a) highlight how individual differences in fitness level may greatly impact the overall intensity of the game. The discrepancies between players imply large fluctuations in inter-individual intensities, and possibly explain why the total time failed to mirror the intensities presented in a similar format by Kelly and Drust (2009), who depicts intensities of 89-91% HR_{max} for 4v4 with different pitch sizes. The observed short, and sometimes non-existent, amount of time spent ≥90% HR_{max} suggests SSGs might emerge as an ineffective strategy to enhance aerobic capacity for every player in a squad. For example, two players in the present study, ranked 7 and 8 for fitness based on the 30-15_{IFT}, displayed substantially elevated total time ≥90% HR_{max} for MM compared to NMM, while the fittest player failed to achieve similar intensities throughout a whole session of both 4v4 NMM and 4v4 MM (data not reported). Hence, players displaying superior fitness levels compared to others within a squad may be encouraged to engage in different training methods, while SSG MM may be used for those displaying insufficient aerobic capacities. Although this feature has not been investigated in literature, Köklü et al. (2012) generated >90% HR_{max} values with team allocation based on VO_{2max} uptake, as opposed to teams based on technical skills and/or coach subjective evaluation, furthermore highlighting the importance of individual aerobic fitness and its effect on other players in soccer SSGs.

The prolonged time to achieve sufficiently elevated HRs to enhance stroke volume (SV) and cardiac output (Q_{max}) (Macpherson, Hazell, Olver, Paterson, & Lemon, 2011) may assist in explaining the gradual increase in intensity with SSG bout-progression in two studies investigating responses to individual bouts during SSGs (Dellal, Lago-Penas, et al., 2011; Fanchini et al., 2011), as well as the current study. Fanchini et al. (2011) revealed an increase from 85.8 to 86.3% HR_{max} from bout 1 to bout 3 (3v3, 2-touch), while intensities increased from 88.9% HR_{max} in bout 1 to 89.9% HR_{max} in bout 3 when the first minute of each bout was excluded. Conversely, Dellal, Lago-Penas, et al. (2011) reported a gradual increase in intensities from B1 (82.7% HR_{max}) to B4 (86.8% HR_{max}). In our study, we display a gradual increase in total time at ≥90% HR_{max} for both NMM and MM during 2v2, which suggest a gradual increase in average intensity as the sessions progress, and coincides with findings from both Dellal, Lago-Penas, et al. (2011) and Fanchini et al. (2011). Conversely, the linear improvement with bout progression for time spent at intensities ≥90% HR_{max} identified in other studies is not supported in the present study with 3v3 and 4v4 MM game formats, as they depict greater time at ≥90% HR_{max} in B2 compared to B3. However, the decrease in intensity from B2 to B3 for 3v3 and 4v4 did not occur in 2v2, and Sampaio et al. (2014) highlights how players adjust their intensities and cognitive approach to SSGs with regards to rule implementation, format alterations and whether or not the team is winning or losing. The pacing strategies is poorly investigated in current literature on soccer SSGs, but the decrease in time ≥90% HR_{max} from bout to bout to for 3v3 and 4v4 may be due to a players' perceived increase in intensity for a certain bout. Thus, cognitive strategies may emerge among players, resulting in decreased intensity levels for the remainder of the bouts as the players may limit themselves from exhaustion in the initial stages of the session. A similar opportunity may not arise in 2v2 due to high involvement (Köklü et al., 2011), which may also be reflected in the very large effect for RPE for 2v2 compared to the larger formats.

While Fanchini et al. (2011) and Dellal, Lago-Penas, et al. (2011) remain the only other studies to investigate intensity fluctuations within bouts of SSG, their studies are limited to a sole format (3v3 and 4v4 respectively), rendering our comparison of player increases with bout progression unprecedented in the soccer SSG literature. The unclear effects revealed for 2v2 MM and 3v3 MM across all four bout comparisons do not align with results displayed by Castellano et al. (2013) and Katis and Kellis (2009) who displayed significant decreases in mean $\%HR_{max}$ with 2 and 3 player increase per team respectively (total game time), however the greater increase/decrease in player numbers outlined in these studies may explain the difference. Conversely, the large effect revealed for 2v2 and 4v4 comparison (MM only, Figure 2, results) in the current study may contribute to the argument for decreased intensities with increases in player number, however caution is advised due to substantial SDs and concurrent *unclear* inferences. Indeed, both 2v2-4v4 and 3v3-4v4 comparisons revealed small effects for B1 and 2, while B3 and 4 depicts moderate effects (Figure 2) for decreased intensities $\geq 90\%$ HR_{max}, potentially implying that MM instigates a greater effect as the session progresses. Whether this occurs due to abovementioned pacing strategies (Sampaio et al., 2014), or if players perceive their designated marker to display signs of fatigue (mentally boosting the players to step up their intensities to avoid their marker to a greater extent) remains a possible research topic for future studies. Another explanation may reside with the likelihood of players maintaining elevated HRs throughout the 2 minute breaks between B2 and B3, as well as B3 and B4 for formats with lower player numbers, thus time required to achieve $\geq 90\%$ HR_{max} intensities decrease towards the final stages of the session.

5.3 Ratings of perceived exertion

The elevated RPE scores identified for the MM modality across all formats implies that the adult players perceived MM games to be substantially harder than NMM games. Decreased opportunities to recover are reflected in the increased TD and $Speed_{ave}$ for MM modalities which are likely to increase RPE. Moreover, greater distances covered at higher velocities further implies greater energy contribution from the anaerobic energy systems (Buchheit & Laursen, 2013b), likely exceeding the lactate threshold and thus result in a greater sense of fatigue. Indeed, with 93.9%-95% HR_{peak} and 85.7-88% HR_{ave} identified across all MM formats, the lactate accumulation may have been substantial and further contributed to the perceived exertion. Unfortunately, we did not measure blood lactate to confirm this explanation.

Combining the increased distances covered at striding and HIR with greater work load may further explain the higher RPE ratings for the MM modality. Interestingly, the greatest difference between NMM and MM was identified for the 3v3 format (17.6 ± 15.7%), although the highest RPE output was identified for 2v2 MM. Arguably, 2v2 NMM was already generating strong indications of high perceptual demands (8.4 ± 0.5), with further evidence of high involvement due to limited player numbers suggesting that MM may indeed be a factor in the NMM modality. Regardless, our findings aligns with those of Sampaio et al. (2007) who identified significantly greater RPE scores for MM compared to NMM for 2v2 and 3v3 formats, while Ngo et al. (2012) identified 3v3 MM to significantly elevate perceived taxation compared to 3v3 NMM.

As elevated RPE values are linked with decreased player numbers (Abrantes et al., 2012; Hill-Haas, Dawson, et al., 2009; Impellizzeri et al., 2006), the current comparisons of game formats align with common perceptions in the literature, represented by a difference of 24.3 ± 6.4% between the 2v2 MM and 4v4 MM in our study. Indeed, our findings depict a strong effect for decreased player number in relation to perceptual responses across all format comparison. Fewer players often results in greater involvements with the ball, thereby enhancing energy expenditure due to more explosive movements (Köklü et al., 2011). Moreover, less players during SSGs indicates smaller pitch sizes and increased requirements to perform accelerations/decelerations with changes of directions, which further implies more concentric/eccentric muscle contractions (Hodgson et al., 2014), and metabolic demand (Gaudino, Alberti, et al., 2014). It appears that MM accentuates the existing knowledge of increased perceptual taxation with decreased player numbers, potentially mirrored in the physiological output (minor elevations in $\%HR_{ave}$), as well as certain physical results (metabolic power).

5.2 Physical characteristics

The major findings for physical output metrics derived from GPS were large effects (ES = 0.91 to 4.35) for MM compared to NMM for striding and HIR across all formats. Indeed, the increased distances discovered at paces between 13.1 and 21 km/h are accompanied by evidence for greater distances covered (DC) while sprinting, although walking appeared to favour the NMM format.

5.2.1 Total distance and work load

In the current study, MM displayed large effects for TD and workload (ES = 1.34 to 2.82 (both)) when compared to NMM across all player number formats. Indeed, a workload of 113-117 m/min identified across MM games exceeds the 108 m/min identified for FP by Hill-Haas et al. (2010), yet are well below the 135 – 155 m/min revealed for amateur players and 144 – 166 m/min identified for professionals by Dellal, Hill-Haas, et al. (2011) for 2v2, 3v3 and 4v4 games. Conversely, the 99.1-110 m/min identified across all NMM formats are well below the results displayed by Dellal, Hill-Haas, et al. (2011), however the latter utilized breaks of 3 min, as well as 2 and 3 bouts of 4 minute intervals for 2v2 and 3v3 respectively. Hence, the participants in the study by Dellal, Hill-Haas, et al. (2011) may possibly have covered greater distances at higher speed due to longer rest periods. In addition, the elevated results may also be a product of pacing effect, outlined by Sampaio et al. (2014), thus allowing the players to ‘expend more energy’ throughout 2v2 and 3v3 games and engage in runs of higher velocities due to decreased bout frequencies, inevitably elevating the workload observed throughout.

With a 100-110m^2 relative pitch size, opportunities to accelerate to higher velocities are permitted, allowing greater linear runs and utilization of individual speed to avoid defenders, as opposed to pitch sizes of smaller relative size (Gaudino, Alberti, et al., 2014). Logically, an increase in TD becomes the product of increased $Speed_{ave}$ for a given time, possibly due to elevated distance covered for striding and HIR in the current study, highlighting the ≥115m difference between NMM and MM identified across all formats. Greater opportunities for velocity increases without excessive CODs imply less concentric/eccentric muscle contractions (Gaudino et al., 2013; Osgnach, Poser, Bernardini, Rinaldo, & di Prampero, 2010), furthermore contributing to the greater TD outcome associated with larger formats. Köklü et al. (2015) revealed TD of 2154m with 4v4 FP for elite youth players, which exceeds the ~1874m identified for 4v4 MM in our study with amateur adult players. Conversely, Hodgson et al. (2014) revealed TD of 1941m with recreational players for 5v5 SSGs utilizing university level participants with medium (120m^2) and large (200m^2) pitch sizes, while the abovementioned Dellal, Hill-Haas, et al. (2011) study depicted TD of ~2664m for professionals and ~2420m for amateurs in 4v4. While our results resemble those of Hodgson et al. (2014) to a greater extent, the inferior TD revealed in our study when compared to Dellal, Hill-Haas, et al. (2011) and Köklü et al.

(2015) may simply be due to the inferior level of players utilized. Indeed, Dellal, Hill-Haas, et al. (2011) highlight a significant difference between amateurs and professionals for a variety of GPS metrics and physiological data, displaying elevated results for professionals across all variables investigated, hence emphasizing how player level discriminates significantly between full game performance.

5.2.2 Velocities

No other study has investigated the effect of MM on velocity outputs in SGGs to date, however the implementation of GPS units to investigate velocity changes are frequent in the soccer SSG literature (Ade et al., 2014; Casamichana & Castellano, 2010; Castellano & Casamichana, 2013; Dellal, Hill-Haas, et al., 2011; Gaudino, Alberti, et al., 2014; Hill-Haas et al., 2010; Hodgson et al., 2014). Köklü et al. (2015) revealed how the inclusion of GK appeared to decrease DC at higher velocities, while Dellal, Lago-Penas, et al. (2011) generated greater DC per bout (4) for HIR (13-17 km/h) and sprinting (>17 km/h) with 1T and 2T. Other common strategies enforce players to cross the halfway line to maintain high intensities, decrease time spent standing still/ recovering and create a defense/attack (tactical) approach. Dellal, Hill-Haas, et al. (2011) revealed greater DC with 1T, 2T and FP for professionals compared to amateurs for 2v2-4v4 SSGs, with increased DC for both zones with increased player numbers. Thus, rule alterations and format alterations greatly impact the intensity of the games, furthermore emphasized by the increased DC in the HIR and striding category in the current study. Indeed, a major finding in depicts how MM elevates the DC at striding pace and HIR substantially (≥23.4%, Table 5 in results) compared to NMM with large effect sizes (ES = ≥0.91, Figure 3-5 in results) across all comparisons. In light of theoretical proposals presented by Gabbett and Mulvey (2008) regarding MM implementation in soccer SSGs, the current finding appear to confirm the assumptions of increased running demands, with players engaged in greater demand of avoiding defenders to allow for goal-scoring opportunities or tracking forwards to prevent conceding goals. The increased DC at higher velocities, in combination with greater TD and $Speed_{ave,}$ is likely to induce greater physiological demand on the system, thus mimic particularly demanding phases of full games. Increased intensities across all formats in the current study, accompanied by substantially greater TD covered, may suggest that the defensive requirement forced players to instigate more runs at greater velocities to track opponents. Additionally, an 'inter-player competition' may have seen some players marking each other engaged in goal scoring competition, thus instigating greater velocities. This again would imply less tactical behaviours and formation strategies within the game, with a likely increase in challenges and increased turnovers over possession and attack/defensive work. Indeed, Ngo et al. (2012) reported greater frequencies of changes in offensive/defensive phases with MM (observations only), implying greater intensities highlighted by the increase in $\%HR_{res}$. Increased intensities would imply enhanced requirements to recover, however the increased DC at higher velocities accompanied less time spent walking or standing still, and may be explained by the requirement to mark an opponent when possession is lost. Furthermore, this finding also accompanies the substantially greater perceptive responses associated with MM, as the modality allowed for less DC at walking pace while simultaneously requiring runs at greater velocities and increased workloads (m/min).

Distance covered for sprints generated unclear to small effects (ES = 0.16 to 0.3), as well as *possibly positive* (2v2, 3v3) and *likely positive* (4v4) difference between all MM and NMM comparisons, likely due to elevated SDs. The opportunity to achieve near-maximum velocities are strongly linked with increased relative or absolute pitch sizes, proven to increase the DC covered at higher velocities in soccer SSGS (Brandes et al., 2012; Casamichana & Castellano, 2010; Castellano et al., 2013; Gaudino, Alberti, et al., 2014; Köklü et al., 2015), as limited total area may prevent players from reaching the later stages of acceleration and enter their sprint zone. Our findings of small to moderate effects (ES = 0.23 to 0.78) for increased player numbers suggest players are susceptible to cover greater distances at sprint speed with increased pitch sizes for MM, which aligns with suggestions presented by Brandes et al. (2012) and Castellano et al. (2013) who argued for increased opportunities to achieve greater velocities due to greater pitch length to accelerate towards top speed. Interestingly, 3v3 MM produced greater distance covered compared to 4v4 NMM at sprint velocities, suggesting that MM may be a potential tool to enhance greater velocities with smaller formats. This result failed to occur with 2v2 MM and 3v3 NMM comparisons, however a likely explanation resides with insufficient pitch length to allow for achievement of sprint velocities. Whether or not this result applies to larger formats remains currently unknown, however it poses an opportunity for future research.

5.2.3 Metabolic load

In conjunction with the utilization of workload presented by Casamichana and Castellano (2010), the player load (metabolic power) may provide an indication regarding the "true" physical output of the players. The metabolic demands of running are heavily influenced by the energy demands required during acceleration/deceleration (di Prampero et al., 2005; Osgnach et al., 2010), with soccer players heavily affected due to the intermittent nature of the sport, and the frequent changes of direction (Gaudino, Iaia, et al., 2014; Gaudino et al., 2013). Although maximal sprint speed is recognized as highly important to soccer performance (Haugen et al., 2013), both Gaudino, Alberti, et al. (2014) and Castellano and Casamichana (2013) highlight how acceleration may generate elevated importance in comparison, due to greater time spent accelerating as opposed to actual sprinting throughout a full-game. The large effects revealed for MM for P_{ave} (ES = 1.02 ± 1.08), identified for 2v2 in the current study, are in contrast to the negative effects (ES = -0.33 to -0.95) observed with the bigger formats. However, the values for both NMM and MM (15.1 W/kg and 12.3W/kg respectively) are similar with those observed for 5v5 by Gaudino, Alberti, et al. (2014) with elite English Premier League players (12.2 ± 1.7 W/kg). Interestingly, our study revealed a decrease in P_{ave} with an increase in player number for MM (Table 10, results), while an opposite effect was revealed for NMM. Gaudino, Alberti, et al. (2014) displayed findings of moderate accelerations and decelerations (2-3 m/s), as well as total number of changes in velocity to increase with decreased pitch sizes. These results imply the utilization of different physiological components associated with performance, which are not detectable with distance covered and velocities (Gaudino, Alberti, et al., 2014). In relation to the current study, it appears that NMM adheres to the suggestions presented by Gaudino, Alberti, et al. (2014), although MM revealed opposite effects which may be linked with less demands for acceleration/deceleration. Although not investigated in the current study, the explanation may be seen in conjunction with increased DC at greater velocities with MM, as the elevated velocities suggests a decreased occurrence for major changes in direction, and thus subsequent decreased requirement for acceleration/deceleration of high energy requirement. However, caution when interpreting these results are advised, as only a small effect was identified for format comparisons, while significant CIs imply large inter-individual differences.

Practical applications

The results of this study suggest that MM may be implemented to encourage adult players to cover greater distances at higher velocities, thus mimic phases of full games with high intensity/velocity demand. It appears that MM forces players to cover less distances at walking pace, subsequently limiting recovery and engaging players in more runs across the velocity range. Hence, MM may be implemented to optimize running throughout sessions of SSGs, minimize time spent at lower velocities, and instigate greater physical demand on the player via limited recovery opportunities. Furthermore, practitioners may select to use larger game formats to achieve increased DC at higher velocities, as our results displayed a substantial percentage increase in DC at higher velocities with larger game formats.

Despite increased DC at greater velocities for MM compared to NMM, this feature do not appears to impact $\%HR_{ave}$ greatly, as large fluctuations suggest soccer SSGs may remain questionable for aerobic fitness enhancement, irrespective of player number in the standard of players utilized in the current study. In combination with perceptual loads, coaches and practitioners should remain highly cautious of implementing MM as the intensity increases may not be sufficient to justify the excessive perceptual demand. Indeed, the perceptual load associated with this rule alteration far exceeds the NMM results, which again may influence player satisfaction with the training method, particularly for the smaller formats.

Limitations

It is acknowledged that there are limitations with the current study that may influence result interpretation and application. Firstly, the sample size utilized for the study (n = 8) was relatively low, likely resulting in substantial SDs and CIs when data was analyzed. Previous studies investigating the effects of MM have utilized 8-14 participants, however different statistical approaches have been utilized. While some caution is recommended when interpreting these results, to address this in our design we had players perform two repeats of each game format which would assist with certainty in our comparisons.

We adopted HR monitors only as a means of determining physiological responses to each format. To gain further insight, future studies should endeavor to incorporate, for example, Bla^- measurements to improve current knowledge on the physiological effects of MM in SSGs.

Thirdly, physical output data derived from GPS technology are subject to associated limitations with regards to reliability, especially at high running speeds (Akenhead et al., 2014; Edgecomb & Norton, 2006). In addition, the utilization of video analysis may provide further insight into the tactical effects lacking in the current study, as well as providing an overview of movement patterns and differences in player behavior with MM.

Lastly, the participants in the study were not elite players, thus findings may be applied to club-level players with moderate fitness.

Future directions

In our study, certain research opportunities emerged to allow for a better understanding of the influence MM has on soccer SSGs. Interestingly, 2v2 NMM and MM comparisons generated greater effects for average intensity ($\%HR_{ave}$) compared to similar comparisons for 3v3 and 4v4. In combination with conflicting results from previous research conducted by Ngo et al. (2012) and Sampaio et al. (2007), future research should endeavor to clarify the impact of MM on $\%HR_{ave}$ in soccer SSGs with various player numbers. The possibility of inducing greater $\%HR_{ave}$ in soccer SSG may consequently elevate the VO_{2max} of players, which is linked with an ability to cover greater distances during full games as well as discriminate between match performances (Rampinini et al., 2009; Stølen et al., 2005).

In addition, lactate, H^+, pH estimations and inter-bout comparison of intensity are likely to contribute to the overall understanding of MM effect in SSGs, while findings for player number comparisons for MM requires additional research to confirm/reject our findings. Indeed, future research on inter-bout intensity remains a topic for future research, as current knowledge are limited to single format information.

Our study remains the only to date with results regarding metrics from GPS with MM in soccer SSG. Thus, future studies should endeavor to replicate the time-motion investigation implemented in the current study, as well as investigate the effects of MM with larger games (5v5, 6v6 etc,) and different level of players (elite, professional, youth). Moreover, a comparison of technical outputs and player tactical behavior remains unstudied for MM and NMM, therefore video recording of SSGs in the future may extend our current understanding of the relationship between physical and technical demands of such SSGs when tactical rules/behavior are enforced.

Conclusions

In summary, MM invokes a greater perceptual load, as well as increase DC at greater velocities, though only minor differences existed in HR between MM and NMM. Physical outputs revealed a decrease in time spent walking (0.9-3.4%) with MM, while $Speed_{ave}$, striding and HIR increased with MM across all formats. Increased TD, DC for striding and HIR, as well as elevated $Speed_{ave}$ may allow coaches to condition for particularly demanding phases of full games, as well limit the recovery opportunities throughout SSG trainings. With respect to player number, greater metabolic demand was identified with lower player numbers, likely due to increased acceleration/deceleration demands and less recovery opportunities, which again may be reflected in the greater external load reported by players. Collectively, these findings will assist coaches and conditioners in manipulating soccer SSGs to instigate the required intensities and velocities during training.

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Appendices

Appendix 1 – Ethics documentation

A U T E C
S E C R E T A R I A T

13 February 2015
Andrew Kilding
Faculty of Health and Environmental Sciences

Dear Andrew

Re Ethics Application: **14/381 Physiological responses and time-motion characteristics of man marking in small sided soccer games.**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 12 February 2018.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 12 February 2018;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 12 February 2018 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Appendix 2 – Participant information sheet

Participant Information Sheet

15 November 2014

Physiological responses and time-motion characteristics of man-marking in small-sided games

Hi, my name is Mats Aasgaard and I would like to invite you to participate in my post-graduate research at AUT University, which aims to help coaches of football players design/plan effective training sessions using small sided games.

Please read this information and decide whether or not you would like to be involved in the project. You don't have to be involved, and you can stop being involved in the project at any time without any negative effects for yourself.

What is the purpose of this research?

The use of small sided games (SSG) is currently very popular with many professional and amateur football teams worldwide. SSG is the name used to describe any game with smaller teams than 11v11 (i.e. 3v3, 5v5, 7v7, 8v8) and is widely used by many football teams for fitness training and/or technical development. There is still a lot that we don't know about SSGs such as the most appropriate game format to enhance the endurance of the players. The main aim of this study is to look at the effect of man-marking on heart rate response and time spent accelerating and sprinting. This will be done by recording your physical performance during a variety of SSGs (3v3, 4v4, 5v5). The aim is to help your coaches to pick the most appropriate games to develop the team physically.

The results of the study may be published in scientific journals, but you will remain anonymous and your name will not appear in any papers seen by others.

What will happen in this research?

You will be required to attend an initial fitness testing session in which we will determine your maximum sprinting speed (MSS) and your predicted maximal oxygen uptake (VO_{2max}).

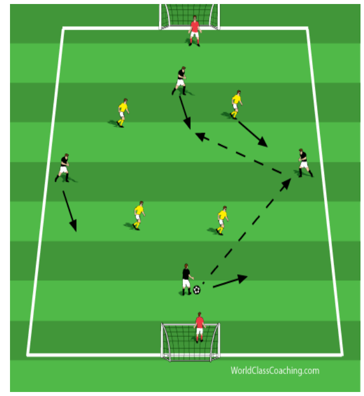
1. MSS: You will be required to sprint as fast you can between speed timing lights over a distance of 40m that will record your highest sprinting speed

2. VO_{2max}: You will be required to participate in a 30:15 test which consists of intermittent running between cones for 40m. 'Beeps' will signal the start and stop of each run, and you the test ends when you are too fatigued to continue. The test will allow us to measure your maximum heart rate and predicted VO_{2max}.

3. After the fitness testing, you will take part in two SSG sessions per week for a total duration of 6 weeks. All SSG sessions will have a focus on football fitness so you will be required to try as hard possible for the duration of the game. Every few minutes (see below) you will be given a short break to get your breath back and this will be repeated 4 times

A typical SSG session (60 minutes) to be used during the study is illustrated below:

Warm-up – 15 minutes



SSG – 24 minutes: 4×4 minute SSG (e.g. 4v4) with 2 minute recovery between each bout (i.e. 4×6 minute)

Bout 1 4mins → Bout 2 4mins → Bout 3 4mins → Bout 4 4mins

Injury prevention/functional strength circuit – 15 minutes

During all SSG sessions you will be required to wear a heart rate monitor around your chest. In addition, we will use state of the art player tracking technology (Catapult Innovations, Melbourne, Australia) (http://www.catapultsports.com) which is now used by many of the professional sports teams in the world. The GPS unit is extremely lightweight and fits snugly between your shoulder blades when wearing the Catapult neoprene vest (see Fig 1 below).

Figure 1. Images of GPS units worn by players during team sports.

In the very unlikely event that we notice anything unusual in your heart rate measurements, we will bring this to your attention and advise you to seek further medical attention.

What are the discomforts and risks?

There are no risks other than those you typically experience during football training and matches such as contact and non-contact injuries. We will minimise the chance of injury by providing sufficient warm ups prior to testing and SSGs. There may be slight discomfort with wearing the heart rate monitors and GPS for the first time but you will quickly get used to them and forget you are wearing them. Most top professionals clubs around the world wear similar equipment during their daily training sessions. They don't restrict your movement or hinder the way you play during the training sessions and matches.

What are the benefits from this project?

1. You will get to know about your different fitness scores (power, speed, agility and endurance).

2. We are able to benchmark some of your fitness scores against data from elite soccer players in Europe and the All Whites.

3. You will know how much distance you run in a match and SSGs compared to elite professional players and other young male players from around the world

4. By taking part in this project you are helping us to help your coach plan his sessions in the most efficient way to help you become a better football player.

How do I qualify for the study?

Any male soccer player (age 20-35) that has not suffered an injury within the last 3 months that will affect running performance is eligible for participation in the study. If you experience any illness, either acute or chronic, at the onset of the study, you may be excluded from participation.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

What compensation is available for participation?

You will be given a $15 petrol voucher to cover expenses associated with transport to AUT Millennium for fitness testing.

How will my privacy be protected?

All data collected from training sessions, matches and fitness testing will remain confidential. The only limitation to confidentiality of your identity is the required interaction with other soccer players. You can ask to see your own individual results if you wish. The research report may require a presentation of individual data. However, your identity will be protected by allocation of an identification number (i.e. ID001), and not your name. Some of the data collected during this study may be published in a scientific paper on behalf of AUT (Auckland University of Technology).

What opportunity do I have to consider this invitation?

Please take your time to decide if you would like to do the project. If you are happy to participate, fill in the consent form and return it to me by email: mats.aasgaard@gmail.com

Thank you for taking the time to read this information.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Andrew Kilding, Andrew.kilding@aut.ac.nz, Ph 921 999 ext. 7056

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Researcher Contact Details:

Mats Aasgaard, School of Sport and Recreation, AUT University, mats.aasgaard@gmail.com

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, SPRINZ, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056, Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 13.02.2015, AUTEC Reference number 14/381.

Appendix 3 – Consent form

Consent to Participation in Research

Project Title:	*Physiological responses and time-motion characteristics of man-marking in small-sided games*
Project Supervisors:	*Assoc Prof Andy Kilding*
Researcher:	*Mats Aasgaard*

- I have read and understood the information provided about this research project (Information Sheet dated 15 Nov, 2015). **Yes/No**
- I have had an opportunity to ask questions and to have them answered. **Yes/No**
- I am in good health and have currently (or within the last 3 months) not been suffering from any injury or illness that may impair my physical performance **Yes/No**
- I understand that the data collected from the testing sessions and the SSG sessions will be made available to the researchers only **Yes/No**
- I understand that my identity will not be revealed in any reports, and an identification number will be allocated for reference to individual results in the final report **Yes/No**
- I understand that the purpose of the study requires me to interact with other soccer players, thus limiting the confidentiality of my identity **Yes/No**
- I understand that only that only the named researchers (Andrew Kilding and Mats Aasgaard) will have access to information regarding the allocation of an identification number **Yes/No**
- I understand that I may withdraw from the project at any time, and any information that has been provided for this project may be withdrawn at any time prior to completion of data collection without being disadvantaged in any way. **Yes/No**
- I agree to allow the collected data to be used for research, including journal publications and post-graduate thesis **Yes/No**

Participant signature:____

Participant Name: ____

Date: ____

(If participant is under the age of 16 years please complete the parental/guardian consent)

Parent or Guardian name:____

Parent or Guardian signature:____

Participant's Contact Details: ____

Project Supervisor Contact Details:

Assoc Prof Andrew Kilding

High Performance Sport New Zealand

AUT|Millennium

17 Antares Place, Mairangi Bay, 0632

Ph: 921 9999 ext. 7056 Email: ***Andrew.kilding@aut.ac.nz***

Approved by the Auckland University of Technology Ethics Committee Date 13.02.2015

Appendix 4 – Player recruitment form

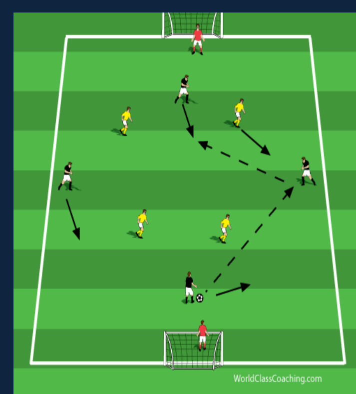
WANTED

Research Participants

Physiological responses and time-motion characteristics of man-marking in small-sided games

If you meet the following criteria:

- Male
- 20-35 years old
- Member of a football team
- Train at least twice/week



Then you may be eligible to take part in this study

We are investigating the benefits of different football small-sided games for fitness development

If you are interested please see contact details to get further information:

Primary Researcher
Mats Aasgaard, Ph 021 082 73134
mats.aasgaard@gmail.com

Supervisor
Dr Andrew Kilding, Ph (09) 921 9999 ext. 7056, andrew.kilding@aut.ac.nz

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

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AN INSTITUTE OF AUT UNIVERSITY