Science and Medicine in Football

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rsmf20

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To cite this article: Andrew N. Guard, Kenneth McMillan & Niall G. MacFarlane (2022) The influence of relative playing area and player numerical imbalance on physical and perceptual demands in soccer small-sided game formats, Science and Medicine in Football, 6:2, 221-227, DOI: 10.1080/24733938.2021.1939408

To link to this article: https://doi.org/10.1080/24733938.2021.1939408

Published online: 11 Jun 2021.

SCIENCE AND MEDICINE IN FOOTBALL
2022, VOL. 6, NO. 2, 221–227
https://doi.org/10.1080/24733938.2021.1939408

ORIGINAL PAPER

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The influence of relative playing area and player numerical imbalance on physical and perceptual demands in soccer small-sided game formats

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ABSTRACT

Purpose: This study aimed to examine physiological, mechanical and perceptual loading in small-sided games using different relative playing areas with balanced and unbalanced player numbers.
Methods: Data were collected in twelve elite youth male soccer players and included heart rate and standard time-motion outputs using commercial GPS.
Results: The data demonstrated higher cardiovascular, physical and perceptual demands with increasing pitch size (e.g. average HR was 88.7 vs. 86.7% HRmax with 8 vs. 2 high-intensity acceleration in medium vs. small pitch formats. The largest pitch format resulted in a greater accumulation of high-intensity distance (47 ± 30 m), higher peak velocity (25.2 ± 1.6 km.h−1) and a higher distance and frequency of accelerations (35 ± 9 m and 8 ± 3) compared with the smallest pitch (all $p < 0.01$). In unbalanced games, there was significantly greater average heart rate in the overloaded team (84.4 ± 4.9 vs. 80.4 ± 4.8% HRmax in 4 v. 6).
Conclusion: These data suggest that different game formats including numerical imbalance could be prescribed for squad management to target conditioning stimuli for specific players (e.g. to target a higher training load for players that do not get consistent match exposure).

ARTICLE HISTORY
Accepted 31 May 2021

KEYWORDS
GPS; small-sided games; overload; acceleration; training load; soccer

Introduction

Small-sided games (SSGs) are a common form of training used in soccer to elicit stimuli for technical and physical conditioning purposes. Their versatility makes them attractive to coaches through a myriad of variations with which to manipulate game format and subsequent intensity. Some of the most common variables employed have altered the number of players (Hill-Haas et al. 2009, 2010), use of goalkeepers (Castellano et al. 2013), bout duration (Fanchini et al. 2011) and both absolute and relative playing area (RPA) (Rampinini et al. 2007; Aguiar et al. 2013). Previous research has examined physiological (heart rate and blood lactate) and subjective responses to traditional SSG with goalkeepers, with some reporting higher physiological cost and rate of perceived exertion (RPE) found to be higher with smaller player numbers (Rampinini et al. 2007) and larger playing areas (Casamichana and Castellano 2010), although Kelly and Drust (2009) reported the opposite effect on heart rate with pitch size. Heart rate, however, has been questioned with regards to applicability to soccer training and match-play given the inherently intermittent movement pattern that comprises a significant anaerobic energy contribution (Achten and Jeukendrup 2003; Buchheit and Laursen 2013). To avoid any underestimation of physical intensity, work-rate may be further quantified with the use of global positioning systems (GPS), an area missing from earlier research (Rampinini et al. 2007). The use of GPS can help detail the frequency and magnitude of sport-specific actions that have not been included before. Initial research using this technology has emphasised the need for exercise over rest in SSG of greater RPA with a higher total distance covered (TDC) and at higher speeds (Casamichana and Castellano 2010).

Although a large body of literature has suggested significant cardiovascular strain in SSG with greater playing areas, it is unknown whether this is the case for mechanical loading indices. The physiological load of SSG has previously been described, but it may be proposed that these drills do not adequately simulate the movement demands of match-play in training, with specific reference to high-intensity efforts and higher magnitude accelerations and decelerations (Gabbett et al. 2009; Casamichana et al. 2012). To be able to repeatedly execute such actions are key physical requirements in soccer and form decisive changes in speed that are energetically taxing (Osgnach et al. 2009). As a result, the mechanical load on the musculoskeletal system may not significantly challenged as in match-play. The addition of acceleration data is absent from similar studies (Aguiar et al. 2013) may as provide vital information to this.

Other research comparing SSG with and without goalkeepers (possession) has found games without goalkeepers to be more physiologically and kinematically demanding in semi-professional players (Castellano et al. 2013). Higher heart rate responses were found with less player numbers, with running demands greater with more players in possession formats on the same RPA. It could therefore be said that there is potential to mix the training design of small group play, with modifications to the design enabling mediated physical stress, ensuring greater control over the training process. Hill-Haas et al. (2010) had also studied the effect of using a floater and uneven teams

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with different player numbers on the same relative pitch size, hoping to quantify the effect of imposed imbalances had on training outputs. No physiological differences were found, but perceptual responses were significantly higher in the overloaded team.

There is little research, however, surrounding the loading responses with these different formats, particularly in relation to acceleration behaviours (Aguiar et al. 2013). The different aims and underlying movement strategies employed by the players may tax physiological systems and/or the musculoskeletal system more significantly than others.

It was therefore the aim of this study to assess the loading and intensity of two different formats of SSG using the same player numbers. Building on previous research, the effect of RPA per player will be examined in traditional SSG conditions as well as an overload format of uneven teams, which may provide further information on how these types of activity can be manipulated to achieve greater physical or technical emphases. It was hypothesised that higher physiological load will be associated with traditional SSG with goalkeepers, while possession and overload drills will require a greater kinematic workload, specifically with overloaded teams who may also elicit a greater internal response.

Methods

Participants

Twelve elite youth male soccer players from the same squad were used for data collection for each SSG format (mean ± standard deviation; 18.0 ± 1.2 years, 182.1 ± 7.9 cm, 74.7 ± 6.3 kg, 194.3 ± 6 bpm; YoYoIR2 1338 ± 249 m). All players played at a club participating in the Scottish Youth Premier League and UEFA Youth League. Players also had a minimum of 2 years experience of full-time training and were accustomed to high-intensity interval training formats used in this study. The typical training week consisted of 3–4 field training sessions, 3 gym-based strength sessions, 1 competitive match and 1 recovery session. All players were familiar with heart rate and GPS equipment having worn them regularly in training prior to the study. Before data collection took place, all players completed the YoYo Intermittent Recovery Test Level 2 (YoYoIR2, Bangsbo et al., 2008) to determine their maximum heart rate (HR_{max}). This test was chosen as it had been used consistently by the players team, providing consistent, reliable results to be used in heart rate responses in training and match-play. Approval for the research study was given by the University of Glasgow ethics committee.

Procedures

Each of the SSG were performed at the same time each morning (10:30 am) on the same natural grass pitch in weather conditions between 10 and 15°C. They were also carried out in a random order following a standardised 20 min warm up and carried out at least twice, separated by a minimum of 7 days. Players were advised to maintain their normal nutritional intake prior to each training session, as recommended by the club dietician, with water available *ad libitum*. The SSGs were carried out as part of the players normal training. No tests to determine specific fatigue responses induced were performed. The independent variables were the game format, number of players per team and playing area, relative to player numbers, of each game format employed. In SSG of 6-a-side the key variable was that relative pitch size was increased by 25 m^2 each time for small, medium and large pitches, similar to the study by Rampinini et al. (2007). To compare different SSG formats and a subsequent change in available playing area per player, an 'overload' game of uneven teams of 6 v 4 was employed with a RPA was 84 m^2 and 126 m^2 per player in the team of 6 and team of 4, respectively. Each drill was performed as high-intensity aerobic interval training, with the overload format entailing shorter work and recovery durations given the uneven nature of the teams, total work time was still the same, however. It was not possible to record the time the ball was in play in each drill. The design of each SSG is outlined in Table 1.

External load measures

External load was recorded using a 5 Hz GPS (MinimaxX, Catapult Innovations, Scoresby, Australia) previously validated Portas et al. (2010) for use in monitoring soccer-specific movements. GPS units were positioned between the shoulder blades in a specially designed vest and switched on at least 15 min-prior to training to allow sufficient connection to a minimum of six satellites as recommended by Malone et al. (2017). Average available satellite coverage during sessions was 9 ± 1.1 with horizontal dilution of precision (HDOP) 0.71 on average. Data from GPS and accelerometer were analysed using Catapult Sprint software version 5.0.9.2. Velocity recorded was categorised into discrete thresholds and were similar to those used in previous studies of soccer time-motion analysis (Castellano, Blanco-Villasenor and Alvarez 2011); 0–11 $km{\cdot}h^{-1}$, 11–14 $km{\cdot}h^{-1}$, 14–17 $km{\cdot}h^{-1}$, 17–21 $km{\cdot}h^{-1}$, >21 $km{\cdot}h^{-1}$ (high-intensity), >24 $km{\cdot}h^{-1}$ (sprinting). TDC, frequency of efforts and percentage of time spent exercising at each of these intensities were recorded. GPS also provided frequency, and distance

Table 1. Drill design and conditions implemented of small-sided game formats employed. Table shows mean (standard deviation).

	SSGS	SSGM	SSGL	Overload (6 v 4)
Duration (min)	4 × 4	4 × 4	4 × 4	8 × 2
Recovery (min)	2	2	2	1.5
Pitch size (m)	40 × 30	45 × 34	49 × 37	23 × 23
Total area (m^2)	1200	1530	1813	529
Area per player (m^2)	100	127.5	151.1	52.9
Goalkeepers	Yes	Yes	Yes	No
Rules	2nd game 2 T, 3rd game 3 T	2nd game 2 T, 3rd game 3 T	2nd game 2 T, 3rd game 3 T	2nd game 2 T, 3rd game 3 T

2 T = two touch; 3 T = three touch, SSGS = small pitch, SSGM = medium pitch, SSGL = large pitch.

covered for accelerations and decelerations of different intensities; low 1–2 m·s^2, moderate 2–3 m·s^2, and high >2.78 m·s^2 and >3 m·s^2 (Aughey 2010; Aughey 2011; Hodgson et al. 2014).

Statistical analysis

Results are presented as mean ± standard deviation. Differences between dependent variables (distances, speeds, heart rate and subjective measures) were determined using one-way analysis of variance (ANOVA). Any differences between different game formats (SSG and overload) were determined using paired *t*-tests. Bonferroni post hoc tests were used to identify significant differences between parameters in each format. Pearson's correlations were performed between dependent variables of each SSG format. Significance was set at $p \le 0.05$. Analysis was carried out using IBM SPSS Inc. 19 for Windows (Chicago, IL, USA). Magnitude-based effects were also determined according to Cohen's *d*. Effect sizes were classified as small (0.2), moderate (0.5) and large (0.8) (Cohen 1988).

Results

Internal training load

The heart rate response (%HR$_{max}$ and TRIMP, calculated by multiplying the average exercise heart rate in beats per minute by the duration of exercise in minutes) was highest in SSG played on the medium (125 m^2) and large (150 m^2) pitch sizes for 6 v 6 compared to the total average in the overload game (Figure 1(b), $p < 0.05$, ES = 1.1 and ES = 0.7). No difference was found between SSG on different pitch sizes as well as the overload game for time spent in the highest heart rate zone ($p > 0.05$).

In the overload format, playing as the overloaded team of 4 produced the higher mean heart rate compared to the team of 6 ($p < 0.001$, ES = 0.8) as well as the amount of time spent above 90% HR$_{max}$ ($p < 0.01$, ES = 0.81), shown in Table 2.

External training load

Time-motion data for each SSG format is displayed in Table 3. Global work-rate in terms of meterage was significantly higher in SSGL (ES = 1.5 and ES = 1.1) and SSGM (ES = 2 and ES = 0.6) compared to both SSGS and overload ($p < 0.001$). This was also the case for total distance and distance covered at high-intensity (Figure 1(a), $p < 0.001$, ES = 1.1 and ES = 1.4), with SSGS consisting of a greater distance than overload ($p < 0.05$). In terms of mean exercise velocity, this was highest in SSGM and overload games compared to SSGS, $p < 0.05$ (ES = 1.1 and ES = 0.86). The peak velocity achieved was higher in SSGM (ES = 0.8) and SSGL (ES = 0.76) compared to SSGS ($p < 0.01$) as well as all 6-a-side SSG compared to the 6 v 4 overload game ($p < 0.001$). The work-to-rest ratio of activity under and above 11 km·h^{-1} was greatest on the medium (ES = 1.2) and large (ES = 2) pitch versus the small pitch size ($p < 0.001$), with SSGM also significantly higher than overload ($p < 0.05$, ES = 0.6).

When comparing the uneven teams used in the overload format, the team of 4 was found to have higher meterage, mean and peak velocities (ES = 3.5, ES = 3.9 and ES = 1.98) as well as a higher work-to-rest ratio compared to the team of 6 ($p < 0.001$ in each case, ES = 1.89). Acceleration data showed distance covered and efforts >2.78 m·s^2 and >3 m·s^2 were higher in SSGM and SSGL compared to the small pitch and overload games ($p < 0.001$). Deceleration distance >2.78 m·s^2 was greater in SSGL than overload ($p < 0.001$, ES = 1.5), SSGM and SSGS ($p < 0.05$, ES = 1.1 and ES = 1.6). The number of efforts, however, was more frequent in SSGM compared to SSGS and overload ($p < 0.001$, ES = 0.7 and ES = 1) and SSGL ($p < 0.05$, ES = 0.4). The highest decelerations >3 m·s^2 had a greater distance on the largest pitch compared to both the small and overload games ($p < 0.001$, ES = 0.8 and ES = 1.1) and medium pitch ($p < 0.05$, ES = 0.7). Again, efforts at this magnitude were more frequent on the medium size playing area versus overload ($p < 0.01$, ES = 1.3) and small 6 v 6 SSG ($p < 0.05$, ES = 1.3).

There were no differences between accelerations above 2.78 m·s^2 or 3 m·s^2 in either the team of 6 or team of 4 players ($p > 0.05$). However, significantly more distance was covered by the team of 4 decelerating >2.78 m·s^2 ($p < 0.001$, ES = 1.3) and more often ($p < 0.01$, ES = 1.9). This was also the case at an intensity above 3 m·s^2 for distance covered ($p < 0.01$) and efforts performed ($p < 0.05$) compared to the team of 6 players.

Peak accelerations were higher on medium and large playing areas compared to the small (ES = 2.8 and ES = 1.2) pitch and overload (ES = 4.5 and ES = 2.2) format ($p < 0.001$ for both). The highest decelerations were found to occur in the medium and large pitches also, greater than those achieved in the overload game ($p < 0.05$, ES = 1.4 for both). Peak acceleration in the SSG in this study was negatively correlated with mean velocity ($r = -0.52$) but positively correlated with peak velocity recorded ($r = 0.362$, $p < 0.001$). Decelerations were also positively correlated with peak velocity ($r = 0.240$, $p < 0.01$).

Subjective training load

Perceptual load was greater in SSGL and average in the overload format compared to SSGS ($p < 0.001$ and $p < 0.01$, ES = 0.9 for both). In the overload format, RPE was significantly higher in the team of 4 than that reported for the team of 6 ($p < 0.001$, ES = 3.1).

Discussion

The aim of this study was to examine any differences between physical outputs during SSG of equal numbers on increasing RPAs, and secondly to observe the effect of prescribing unequal or overloaded team formats that encountered differing RPAs as a result of an enforced imbalance in player numbers. The results found heightened physiological, mechanical and perceptual loads associated with SSG played with greater RPA at the players disposal. Furthermore, the method of employing unbalanced teams also induced a different game strategy and greater loading placed on players with numerical inferiority, with implications for training design and conditioning modes.

The main findings of this study were that the physiological, time-motion and perceptual loading responses of SSG in soccer differ according to the RPA available. In contrast to previous

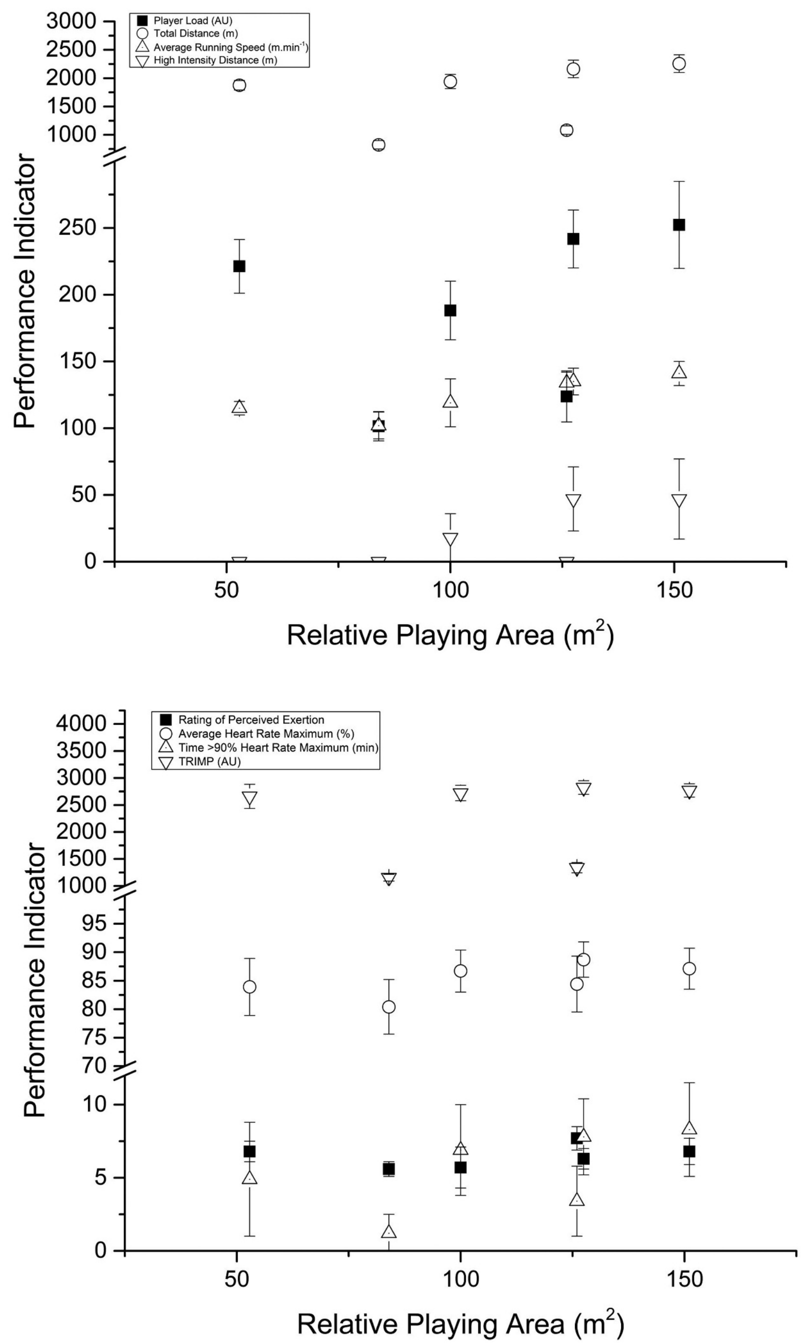

Figure 1. (a) Differences in total distance, high-intensity distance and meterage per minute; (b) heart rate TRIMP, percentage of maximum heart rate and time spent 80–90% HR_{max} and >90% HR_{max}.

research (Rampinini et al. 2007; Kelly and Drust 2009), this study found increased physiological and perceptual responses with larger areas. Furthermore, by progressively increasing the area per player, this study found a concomitant increase in accelerative load, particularly higher magnitude decelerations. This may have subsequent implications for mechanical loading with an environment more conducive to eccentric demands to promote adaptations to better withstand force. The use of numerical imbalance between teams may also serve to inflict greater loading responses influenced by a requirement for strategies of higher work-rate to regain possession.

The results of this study are similar to other SSG studies in soccer (Rampinini et al. 2007; Casamichana and Castellano 2010; Hodgson et al. 2014), higher heart rates were attained with the use of larger playing areas relative to the number of players (% maximum heart rate and time spend >90% HR_{max}), although SSGL was lower in this study in comparison (87.1% HR_{max})·

This increase in heart rate with available space may partly be explained by the resultant increase in average velocity and subsequent meterage in SSGL and SSGM, augmenting the higher work-to-rest ratios observed in these formats. Therefore, SSG on larger areas may be beneficial for providing a stimulus for aerobic conditioning compared to those on

Table 2. Internal LOAD responses of small-sided game formats. Data displayed as mean (standard deviation).

	SSGS	SSGM	SSGL	Overload (total drill)	Team 6	Team 4
RPA (m^2)	100	127.5	151.1	52.9	88	132
$\%HR_{max}$	86.7 (3.7)	88.7 (3.1) *a**	87.1 (3.6)	83.9 (4.9)	80.4 (4.8)	84.4 (4.9) *d***
Time >90% HR_{max} (min)	6.9 (3.1)	7.8 (2.6)	8.3 (3.2)	4.9 (3.9)	1.2 (1.3)	3.4 (2.4) *a***
TRIMP	2721 (143)	2822 (126) *a**	2769 (123)	2660 (225)	1153 (62)	1337 (95) *a***
RPE (AU)	5.7 (1.4)	6.3 (0.7)	6.8 (0.9) *b***	6.7 (0.7) *c**	5.6 (0.5)	7.7 (0.8) *d***

SSGS = small-sided game small pitch, SSGM = small-sided game medium pitch, SSGL = small-sided game large pitch, RPA = relative playing area, $\%HR_{max}$ = percentage of maximum heart rate, RPE = rating of perceived exertion, AU = arbitrary units.
[a]SSGM > Overload; [b]SSGL > SSGS; [c] Overload > SSGS; [d]Team 4 > Team 6 ($p < 0.05$, *$p < 0.01$, **$p < 0.001$).

smaller pitches, as heart rate intensity is close to that suggested to aid and V_{O2max} improvements (Helgerud et al. 2001). It is these cardiovascular adaptations that aid in the transport and utilisation of oxygen to fuel what is a predominantly aerobic sport, also enabling faster recovery kinetics from intense efforts, therefore delaying effects of fatigue (such a muscular acidosis with lactate accumulation, Bangsbo 1994). The same effect on work-rate in larger games was also found by Casamichana and Castellano (2010) on increasing relative pitch area in 5 v 5. As in the present study, various measures of motor-behaviour (total distance, high-intensity distance, peak speed and work-to-rest ratio) and perceptual load were also greater on larger playing areas. This may be more useful information on physical intensity, given the reported limitations on heart rate application to monitoring exercise in intensity in intermittent sports, such as soccer (Achten and Jeukendrup 2003).

The time-motion data would suggest a significantly higher requirement for 'working' behaviour (>11 $km{\cdot}h^{-1}$) despite maintaining the relative area at each player's disposal. The inclusion of this data highlights the important role GPS monitoring may play in further discriminating between SSGs with different constraints imposed. This is such as traditional measures of heart rate may not adequately illustrate this with the intermittent movement pattern limiting high stroke volume (Hoff et al. 2002). Furthermore, although average heart rate and meterage achieved in the current study are in excess of those previously reported for match-play (Bangsbo 1994; Bradley et al. 2009), the data in Figure 1(a) suggests that small-sided soccer training drills may not effectively reproduce key high-intensity actions associated with competitive matches (Gabbett et al. 2009; Casamichana et al. 2012). For example, the distance covered, and frequency of efforts performed for high-level accelerations and decelerations are not as feasible in these environments. This is largely due to area constraints where interactions are more likely with players, particularly in central areas therefore increasing average velocity to move away from opponents and find space (Fradua et al. 2013). Also, players may initiate forceful accelerations in these games but are quickly hindered by pitch boundaries. It has been put forward by Seifert et al. (2013) that player's movements may be a result of continual functional adaptation that derive from the game design in order to maximise success. Indeed, the dynamic environment of SSG's channel relationships and subsequent behaviour of each team and individual players (Vilar et al. 2014). This may help explain the larger standard deviations, particularly in SSGL, as well as the idea that some players may be more physically capable to produce the muscular forces needed to attain high threshold acceleration efforts. The observed higher work-rate and increased mean (and therefore starting) exercise velocity hinder any large changes in speed in SSG. This is especially true when space is quickly curtailed by pitch size, ensuring minimal high-intensity activity and lower peak speeds in comparison to match-play.

Table 3. External load outputs of small-sided game formats. Data displayed as mean (standard deviation).

	SSGS	SSGM	SSGL	Overload (total drill)	Team 6	Team 4
Total distance (m)	1941 (126)	2162 (155)	2256 (157)	1875 (83)	824 (74)	1083 (73)
Player load (AU)	188.2 (22.0)	241.8 (21.7) *b***, *d***	252.3 (32.6) *e***, *f***	221.3 (20.1)	101.5 (11.0)	123.8 (19.1) *i***
$m{\cdot}min^1$	119 (18)	135 (10) *b***, *d***	141 (9) *e***, *f***	115 (5)	102 (10)	134 (8) *i**
HID (m)	18 (18) *a*	47 (24) *b***, *d***	47 (30) *e***, *f***	0 (0)	0 (0)	0 (0)
Mean velocity ($km{\cdot}h^1$)	6.1 (0.9)	6.8 (0.3) *b*	6.5 (0.5)	6.7 (0.4) *h*	5.7 (0.6)	7.9 (0.5) *i***
Peak velocity ($km{\cdot}h^1$)	23.5 (2.3) *a***	25.2 (1.6) *b**, *d***	25.1 (1.9) *e**, *g***	16.4 (0.7)	15.6 (1.0)	17.4 (0.8) *i***
W:R (<11 $km{\cdot}h^1$)	0.3 (0.1)	0.5 (0.2) *b***, *d*	0.5 (0.1) *e***	0.4 (0.1)	0.3 (0.1)	0.6 (0.2) *i***
Accelerations >2.78 (m)	13 (5)	43 (9) *b***, *d* **	36 (16) *e***, *g***	7 (5)	3 (2)	4 (4)
Accelerations >2.78 (#)	3 (2)	10 (2) *b***, *d***	6 (3) *e***, *g***	2 (2)	1 (1)	1 (2)
Accelerations >3 (m)	10 (4)	35 (9) *b***, *d***	27 (16) *e***, *g***	2 (3)	1 (1)	2 (3)
Accelerations >3 (#)	2 (1)	8 (3) *b***, *c***, *d***	3 (2) *g**	1 (2)	1 (1)	1 (2)
Peak Acceleration (m/s2)	4.0 (0.4) *a*	5.0 (0.3) *b***, *d***	4.8 (0.8) *e**, *g***	3.4 (0.4)	2.8 (0.5)	3.0 (0.6)
Decelerations >2.78 (m)	3 (2)	7 (3)	17 (12) *e*, *f*, *g**	4 (4)	1 (1)	4 (3) *i***
Decelerations >2.78 (#)	4 (2)	6 (3) *b***, *d***, *c*	5 (2)	3 (3)	1 (1)	3 (3) *i**
Decelerations >3 (m)	4 (2)	5 (3)	13 (15) *e***, *g***, *f*	1 (1)	0 (0)	2 (2) *i**
Decelerations >3 (#)	2 (1)	5 (3) *d**, *b**	3 (2)	2 (1)	0 (0)	2 (2) *i*
Peak Deceleration (m/s^2)	4.3 (0.9)	4.5 (0.6) *d*	4.4 (0.5) *g*	3.7 (0.5)	2.8 (0.7)	3.1 (0.5) *i***

SSGS = small-sided game small pitch, SSGM = small-sided game medium pitch, SSGL = small-sided game large pitch, $m{\cdot}min^1$ = meterage per minute, # = frequency of efforts.
a SSGS > Overload; [b]SSGM > SSGS; [c]SSGM > SSGL; [d]SSGM > Overload; [e]SSGL > SSGS; [f] SSGL > SSGM;
[g]SSGL > Overload; [h] Overload > SSGS; [i]Team 4 > Team 6 ($p < 0.05$, *$p < 0.01$, **$p < 0.001$).

In addition to traditional SSGs of equal numbers, this study also compared the game strategy and subsequent responses of players performing with uneven teams in a possession format, which has not been demonstrated previously. One previous study has examined the effect of creating overload scenarios. Results showed that the overloaded team of 4 experiences significantly higher physiological and perceptual strain compared to the team of 6, contrasting with Hill-Haas et al. (2010) who found no differences. Although not measured by the previous study, time-motion analysis revealed meterage, mean velocity and work-to-rest ratio were also significantly higher in the overloaded team (p < 0.001). The higher exercise velocity and heart rate in the overloaded team is influenced by a different strategy than a conventional 6 v 6 SSG.

Instead, the numerically disadvantaged team works to press and close opponents down for the 2-min bout duration, working as a defensive unit to dictate their movements and limit passing options. Moreover, this team had to cover a relative area one-a-half times that of their opponents requiring continually high work-rates. The team of 6 on the other hand, experienced lower cardiovascular strain, where workload is more technical with a necessity to cover less relative space. Physiologically, there is therefore greater strain on the cardiovascular system when employing overloaded players with numerical disadvantage. In contrast to traditional SSGs of even team numbers, overload scenarios promote an opportunity to emphasise high work-rate (total distance) and Player Load (Figure 1(a)) in smaller RPAs and therefore a greater metabolic load (Figure 1(b)) in intense bouts. These specific forms of SSG format may then be used for conditioning purposes in the pre-season or in-season period for those player's not exposed to regular match-play and requiring greater training load and volume during the training week. This is particularly, relevant in this population of youth development players who are often required to join first team training sessions and may not have had the extent of match exposure of their senior counterparts.

The greater mechanical load and acceleration profile of the overloaded team may also result from higher average and peak speeds and frequent change of direction compared to the larger team, producing a degree of anaerobic as well as aerobic energy cost whilst trying to win possession back. The higher exercise velocity may also explain the lower peak acceleration values achieved in the overloaded team compared to those of the traditional 6 v 6 formats in this study. By changing the balance of teams in small-sided training games, the RPA required of the players differ greatly, ultimately determining game strategy and different outputs of training load. Employed in the overloaded team, such game formats may be appropriate for aerobically fitter players who have been suggested to benefit less from traditional SSGs due to a 'ceiling effect' from the intermittent nature preventing higher exercise intensities for fitness development (Hoff et al. 2002; Hill-Haas et al. 2011). For example, as shown in Figure 1 (b), the time spent above specific heart rate intensities (greater than 85 and 90% HR_{max}) in SSG formats with different RPAs may be pronounced, which contribute to cardiovascular adaptations (Helgerud et al. 2001). Training impulse (TRIMP) has also been previously described in scientific literature as a measure of physical effort with regards to external load and may reflect the selection of different SSG formats and the degree of internal load attained in each (Halson 2014). The introduction of an artificial sprint in the study of Hill–Haas increased peak speeds and high-intensity distance that are more typical of match-play and are not apparent in the present study. However, sampling at 1 Hz, the high-intensity running threshold in the earlier study was also lower than the present study which is more indicative of those used in match analysis (13 $km.h^{-1}$ vs. 21 $km.h^{-1}$). The overload game does not appear to be conducive to any high-speed activity which may also explain the absence of high-end deceleration efforts. These types of game may instead be associated with more frequent changes in direction at lower intensities that may not require as large a muscular force as match decelerations that occur cumulatively over distances of 900 m (Akenhead et al. 2013). Acceleration profiles may still constitute 'high-intensity' activity as they are energetically taxing despite low absolute speed (Varley et al. 2011). The higher RPE as an overloaded team compared to all other formats in this study would suggest there is still a degree of intensity in this format, however.

Conclusions

The main findings of this study indicate that increasing the relative area available to each player increases physiological, physical and perceptual responses. This may reflect the strategy of players to find space away from opponents to ensure more time for decision making and skill execution. In addition, a novel finding was highlighted in manipulating SSG to give teams of uneven numbers in a possession-based game significantly greater loading on the team with less players, despite being in smaller RPAs. As a result, this type of design may be prescribed by coaches to target players in need of further aerobic and muscular conditioning that accompany the context of the overloaded team's defensive role to press and close opponents down.

The results highlight the versatility of small-sided training formats and demonstrate the ability to moderate intensity and type of biological systems stressed for specific individuals through changes in relative space available and/or uneven teams which have not been explicitly compared in the literature. This may result from inherently different strategies implemented by players to create space, maintain or regain ball possession.

Coaches and conditioning staff may therefore use variables of RPA or indeed numerical imbalance to inform periodised training prescription with greater confidence depending on team and individual requirements. The use of inherently different formats of SSG may be necessary at times within the elite soccer training environment, though supplementary high-speed conditioning may also be warranted as a further conditioning and injury prevention stimulus.

Disclosure of potential conflicts of interest

No potential conflict of interest was reported by the author(s).

Funding

No funding is associated with this study.

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