ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2023; 30(**4**): 175-186
ISSN 2299-9590
DOI: 10.23829/TSS.2023.30.4-5

The effect of pitch dimensions and players' format on heart load and external load in semi-professional soccer players

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Abstract
Introduction. **Soccer players need to acquire high level of technical, tactical, and physical skills to be able to play at professional level. Changing the pitch size (while keeping the same format of play) causes variations in the relative area per player (calculated as the area of the pitch divided by the number of outpitch players involved in the game). This manipulation is one of the main concerns while using small-sided games (SSG), since different relative areas per player for the same format change the players' responses.** Aim of Study. **The present study is part of a doctoral thesis, the purpose of which was to investigate the internal and external load in semi-professional soccer players during SSGs with different numerical ratios and pitch dimensions.** Material and Methods. **The study sample included 16 semi-professional male soccer players, who played random 1v1, 2v2, 3v3 and 4v4 SSG without goalkeepers and with small goals on individual pitches of 1 : 150 m², 1 : 100 m², and 1 : 75 m² areas, respectively, for 8 weeks until the end of the season. GPS monitoring was used to record the elements of the internal and external loads during the whole training session. The level of significance was fixed at p 0.05.** Results. **The results indicate that training in different dimensions of pitches and with different players' format has a different effect on the internal and external load of soccer players.** Conclusions. **Numerical relationships and the player/space ratio affect the physiological responses of soccer players and should be taken into consideration by coaches for the best coaching design of technical, tactical, and physiological elements. The research findings will help coaches to choose the best training methods based on their training goals. Moreover, coaches in semi-professional teams now have consistent information to design and optimize their training time in mixing the technical and physical aspects.**

KEYWORDS: heart rate, soccer, physiological responses, GPS devices, small-sided games, internal and external load.

Received: 9 November 2023
Accepted: 21 November 2023

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Introduction

Soccer is classified as an intermittent exercise, in which the effort exerted depends on the dynamic of the game [3, 22, 26]. Small-sided games (SSG) are typically described as smaller versions of the formal game [10], with adjustments in the number of players (format) and the size of the pitch [25]. These games have been very popular and used in the last decade to improve the physiology of training sessions affecting game performance in team sports [10]. The potential of such modality for sports training has been of interest to many coaches as it simultaneously develops the players' physical, technical, and tactical performance. SSGs improve physical fitness while also increasing levels of enjoyment and competence [27]. Physical trainers prefer SSG and conditioned games [i.e., match-play with a reduced number of players [6] since: a) they enhance work on technical and tactical parameters [10], and b) they elicit high heart rate (HR) intensities (i.e. > 90% HR_{max}) [11] in the range of those reported to be functional in improving aerobic fitness in soccer players (i.e. 90–95% of HR_{max}) [10]. During the last decade, researchers have attempted to estimate the resulting training load. To a large extent, technological advancement has contributed to this progress. There are two types of training load evaluation methods: those that monitor the internal load and those that monitor the external load [4].

The predominant method, by which the external load is measured involves the use of GPS systems (Global Positioning System). GPS systems operate by tracking the position of soccer players using the data they receive from satellites. It has been proven that the higher the frequency (Hz), the more accurate the measurements. This particular recording system is used to measure the total distance travelled, the speed at which the distance is covered, as well as accelerations and decelerations during training.

Internal load, on the other hand, refers to the athletes' physiological response to the training stress. It is clear that internal load affects player adaptations [17]. Internal load is most accurately quantified by monitoring the HR, measuring lactate concentration, and using the rate of perceived exertion (RPE, CR-10, 6-20) [4].

In relation to physical conditioning, it has been suggested that SSGs may be a good alternative to classical physical conditioning in young soccer players to maintain or improve aerobic fitness, after pre-season and during the season. Hill-Hass et al. [8] showed that SSGs and generic training are equally effective in improving pre-season YYIRTL1 (i.e., Yo-Yo Intermittent Recovery Test Level 1) performance. Impellizeri et al. [13] observed that SSGs and aerobic intermittent training (IT) were also equally effective in aerobic fitness after pre-season and after 8 additional weeks of training. In turn, Reilly and White [26] reported that after a 6-week program during the competitive period the effects on aerobic capacity between SSG and IT were similar. Radzimiński et al. [23] found that in young soccer players SSG training was more effective in improving VO_{2max} than an IT protocol. The main findings of the studies indicate a greater internal load of soccer players (higher HR, RPE, lactate concentration) during small numerical relations (1v1, 3v3). Small numerical relations lead to a higher pace of play, but with a smaller overall distance travelled [20]. Nevertheless, Hoff et al. [12] reported that players with higher VO_{2max} tend to exercise at a lower percentage of VO_{2max} when participating in SSGs. Smaller formats have been found to increase HR responses, blood lactate concentration, and perceived exertion [10], as well as the frequency of ball contacts per player [19]. As far as the pitch dimension is concerned, the literature suggests that larger pitch dimensions increase the physiological responses and distance covered by players [1]. The effects of these task constraints have already been extensively studied [7, 10].

Furthermore, part of the research led to contradictory results. Köklü and Alemdarolu [15] reported a higher percentage of HR_{max} values in the 3v3 and 4v4 configurations compared to 2v2. However, Köklü [14] observed greater HR values during 3v3 compared to 2v2 and 4v4. Despite this observation, most studies revealed an inverse association between the number of players and internal load [5]. Extensive research has been conducted to investigate the effect of pitch size on external load. A study conducted on collegiate students found that larger relative pitch sizes (120 m^2/player and 200 m^2/player) resulted in increased distance covered as well as a higher number of decelerations and accelerations, when compared to smaller relative pitch sizes [11]. Furthermore, in a study conducted in youth under 17 (U-17) soccer players researchers observed considerably greater values of total distance and high intensity running with a relative pitch size of 175 and 273 m^2/player [2].

In addition, studies examining the external load of adults and young soccer players during the SSGs displayed that the comparison was challenging, as there are differences in the methodology and no relative values were reported that made the comparison between the variables possible [16,28]. However, where relative values were reported and comparisons were possible, researchers observed greater distance travelled per minute (m/min) as the number of players increased [5], while others noted greater distance travelled per minute (m/min) as the number of players decreased [20].

The purpose of this study was to investigate the internal and external load in semi-professional male soccer players during small-sided games with a different number of players (4v4, 3v3, 2v2, 1v1) and pitch size (150 m^2/player, 100 m^2/player, 75 m^2/player).

Material and Methods

Experimental design

The study was conducted over an 8-week period (April-May 2023); throughout the duration of the study there were no significant changes in environmental conditions, with average temperature of 19.9 °C and 63% humidity.

The training sessions were held on natural grass. Participants were instructed to abstain from any training stimulus for two days before the initial measurements. During the research period the participants did not engage in any other physical activity. For the next eight weeks the soccer players completed SSGs (4v4, 3v3, 2v2, 1v1 without goalkeepers and with only small goals) in a random sequence with relative pitch sizes of 150 m^2/player, 100 m^2/player, and 75 m^2/player. During SSGs the participants wore portable GPS (Polar Team Pro) tracking sensors to capture their internal and exterior loads. SSGs were conducted following a 15-minute standardized warm-up consisting of slow jogging, strolling locomotion, active stretching, progressive sprints, and accelerations. SSGs were followed by 5′ of recovery. Training sessions were performed at the same time in order to avoid the possible effects of the circadian rhythm on the variables. SSGs were followed by a 5-minute passive recovery period.

Participants

The study sample included 16 semi-professional male soccer players from the municipality of Katerini in Central Macedonia, Greece (mean ± SD: age = 18.36 ± 2.3 years and training age = 10.06 ± 2.2 years, height = 177.00 ± 4.2 cm, body mass = 69.75 ± 8.1 kg, body fat (%) = 22.64 ± 4.5%, 10 m sprint = 1.74 ± 0.08 s, sprint 40 m = 5.69 ± 0.43 s, VO_{2max} = 48.86 ± 4.21 $ml·kg^{-1}·min^{-1}$), who competed in the championship of E.P.S. Pieria, Greece and participated voluntarily in the study. Table 1 shows the participants' anthropometric and physical fitness parameters.

Inclusion criteria for participating in the study were the following: a) no musculoskeletal injuries over the last 4 months, b) abstention from any ergogenic supplement or medication for ≥4 months, c) 95% training and match compliance, and d) participation in all SSGs. All the players had played federation soccer for an average of 8 years before the study. Their training involved 4 sessions per week (each lasting 90 minutes) in addition to a competitive match. All the participants were notified of the research design and its requirements, as well as the potential benefits and risks, and they each gave their informed consent before participation. They were informed that they may withdraw from the study at any moment. The study was carried out in accordance with the rules of the Aristotle University of Thessaloniki's Ethical Committee (323/2023) and the revised Declaration of Helsinki.

Table 1. Anthropometric and performance characteristics

Variable	Mean (±SD)
Age (yrs)	18.36 (2.3)
Height (cm)	177 (4.2)
Weight (kg)	69.75 (8.1)
Body fat (%)	22.64 (4.5)
Sprint 10 m (s)	1.74 (0.08)
Sprint 40 m (s)	5.69 (0.43)
VO_{2max} ($ml·kg^{-1}·min^{-1}$)	48.86 (4.21)
Playing experience (yrs)	10.06 (2.2)

Procedure

Anthropometric measurements were carried out at the initial appointment. The participants then completed a 15-second warm-up followed by a 40-meter Maximal Sprint Test to define speed zones. Subsequently they underwent a Yo-Yo intermittent recovery test level 1 to determine their VO_{2max}. All the measurements were taken on natural grass at least 48 hours following a game. Players' movements throughout the following training sessions were tracked using portable GPS trackers. In this experimental design SSGs were conducted at 48-hour intervals. The equipment was thoroughly tested two weeks before the initial readings.

Anthropometric measurements

The participants' body mass and height were measured using an electronic digital weight scale and a height scale (Seca 220e, Seca, Hamburg, Germany). In the relevant evaluations these two measurements were accurate to 0.1 kg and 0.1 cm. The individuals were barefoot and wore only underpants throughout the measurements. A Lafayette skinfold caliber (Lafayette Instrument, Indiana, USA) was used to measure the thickness of the soccer players' hypodermic fat in four of their skinfolds (biceps, triceps, suprailiac, and subscapular) to estimate body fat. All skinfold measurements were taken on the right side of the body, and body fat (%) was estimated using Siri's algorithm [29].

Yo-Yo Intermitted Recovery Test Level 1

The YYIR1 consisted of two 20-meter intervals of running separated by regular 10-second rest breaks. Furthermore, a CD-ROM provided signals to control the speed. The player ran 20 meters forward, adjusting his speed to arrive at the 20-meter marker precisely at the moment of the signal. A turn was also made at the 20 m marker and the player sprinted back to the beginning

marker, which was to be reached at the next signal. The athlete then paused for 10 seconds to run slowly around the third marker, which was placed 5 meters behind him. He had to wait for the next signal at the marker.
The course was repeated until the player failed for two consecutive shuttle runs. When the start marker was not reached for the first time, a warning ("yellow card") was sent, and the test was cancelled at the second failure ("red card"). The last running interval completed by a player before being removed from the test was recorded, and the test result was reported as the overall running distance travelled in the test. The YYIR1 also began at a speed of 10 km/h. Afterwards, the speed was increased by 2 and 1 km/h in the next two speed levels, respectively. Following that, the speed was increased by 0.5 km/h at each speed level. The YYIR1 was maintained during the last 40 meters. The following equation was used to forecast the players' VO_{2max} based on their distance covered in the YYIR1: Prediction of VO_{2max} (ml/kg/min) = YYIR1 distance (m) 0.0084 + 36.4.

Speed evaluation
The sprint test was conducted using three pairs of photocells (Witty, Microgate, Bolzano, Italy) placed at three different points: the starting point at 10 m, and at the finish line (at 0 m, 10 m, and 40 m). Each pair of photocells served as a gate, through which the soccer players passed. The soccer players began their attempt from a standing stance, 0.3 meter behind the first gate. The photocells were placed around the height of the hip joint to detect torso movement rather than a false signal caused by upper limb movement. As the two efforts were completed in a circular format, recuperation time of more than 3 minutes was provided. The measurement–re-measurement tests had a coefficient of variation of 3.6%.

Internal load
Internal load was measured in real time using a Polar Team Pro (Kempele, Finland). The variables recorded during SSGs included HRmax, HR_{max}% and Cardio load. It needs to be stressed that in the present study only the variables that resulted from the calculation of the GPS were evaluated as internal load.

External load
External load was measured using the Global Positioning System (GPS, 10 Hz Polar Team Pro, Kempele, Finland). The variables recorded were total distance (TD), distance/min (m/min), number of sprints (>25 km/h), distance covered in five speed zones (Distance Speed: z1: 0.10-6.99 km/h; z2: 7.00-10.99 km/h; z3: 11.00-14.99 km/h; z4: 15.00-18.99 km/h; z5: >25.00 km/h), the total number of decelerations (NoDec –5.00-3.00,–2.99-–2.00, –1.99-–1.00 m/s²) and the total number of accelerations (NoAcc 1.00-1.99, 2.00-2.99, 3.00-5.00 m/s²).

The structure of SSGs
Table 2 shows the number of SSGs, their duration, interval rest durations, relative pitch size, and pitch dimensions. Furthermore, there was excess of reserved soccer balls throughout the pitch to replace the ball, assuring the necessary playing time. The soccer players were free to drink water during their breaks.

Statistical analysis
The IBM SPSS software (Statistics for Windows, version 25.0 Armonk, NY: IBM Corp.) was used to analyze the data. The data was presented as the means and standard deviations using descriptive statistics. The Shapiro-Wilk test was applied to determine the normality of the distributions. When normality was discovered, repeated measures of variance analysis (GLM Repeated Measures ANOVA) were used, followed by the post-hoc Bonferroni test when a statistically significant difference was discovered. A non-parametric Friedman test was carried out in the case of a non-normal distribution. The Wilcoxon signed-rank test was applied if there was a statistically significant difference between the samples. The statistical significance level was set at $p < 0.05$.

Table 2. Pitch sizes used for small-sided games

SSG	W	R	Small (S)	Medium (M)	Large (L)
1v1	4 × 1′	1′	1/75 m² 10 × 15 m	1/100 m² 20 × 10 m	1/150 m² 20 × 15 m
2v2	4 × 2′	2′	1/75 m² 20 × 15 m	1/100 m² 27 × 15 m	1/150 m² 30 × 20 m
3v3	4 × 3′	3′	1/75 m² 25 × 18 m	1/100 m² 30 × 20 m	1/150 m² 36 × 25 m
4v4	4 × 4′	4′	1/75 m² 30 × 20 m	1/100 m² 35 × 25 m	1/150 m² 40 × 30 m

Note: W – work; R – rest

Additionally, mediation analysis declares how a prognostic variable is related to an outcome variable, indicating that the relationship between two variables is affected by a third variable called the mediator. Direct and indirect effects emerge from mediation analysis. A direct effect is defined as the relation between the predictor variable and the outcome variable, while an indirect effect is considered the effect of the predictor on the outcome through the mediator.

Mediation analysis was applied in this study (JASP 16) to examine whether the dimensions of the pitch (the predictor) directly and/or indirectly affect performance in dependent variables. The ratio of players was considered as a mediator. The bootstrapping procedure was used in order to examine the significance of the indirect effect. Indirect effects were computed for each of the 1000 bootstrapped samples. Correlation analysis was conducted at the initial stage to examine prerequisites for mediation analysis; only highly significantly correlated variables were included into the mediation analysis.

Results

Anthropometric characteristics and the results from the fitness tests of the 16 participants are presented in Table 1 above. The mean scores and standard deviations of the examined variables for all the pitch dimensions are presented in Table 3.

Table 3. Means and standard deviations of all dependent variables in all pitch dimensions in all players' formats

	75 m^2			
	1v1	2v2	3v3	4v4
HR_{max}	187.17 (9.5)	178.4 (41.8)	163.2 (41.6)	179.4 (12.5)
HR_{max}%	94.2 (4.6)	89.6 (21)	81.8 (20)	90 (6.2)
Total distance	98.5 (17.3)	188.8 (52.9)	225.8 (85.3)	341.6 (89.6)
Distance/minute	94.1 (16.6)	93.8 (26.3)	74.8 (28.2)	85 (22.2)
Distance speed zone 1	39.6 (6.5)	71.4 (20.5)	115.2 (38.1)	160.2 (20.9)
Distance speed zone 2	30.5 (9.7)	60.9 (20.7)	58.6 (28.2)	96 (42.7)
Distance speed zone 3	17.6 (10.4)	39.5 (17.8)	37.8 (27.8)	60.5 (34.5)
Distance speed zone 4	10.7 (7.8)	16.9 (13)	13.9 (16)	24.9 (20.8)
Sprints	1.2 (1)	1.2 (1.1)	0.95 (0.94)	1.7 (1.5)
Number of decelerations (–5.00-–3.00)	0.64 (0.7)	0.91 (1.1)	0.38 (0.64)	1.15 (1.2)
Number of decelerations (–2.99-–2.00)	2.28 (1.5)	4.11 (2.2)	3.25 (2)	5.47 (3.1)
Number of decelerations (–1.99-–1.00)	5.56 (2.3)	11.25 (4.3)	12.7 (4.7)	19.4 (5.8)
Number of decelerations (–0.99-–0.50)	6 (2.2)	11.1 (4.6)	16.87 (5.7)	23.8 (6.1)
Number of accelerations (0.50-0.99)	5.75 (2.4)	10 (4.1)	16 (5.7)	20.52 (5.2)
Number of accelerations (1.00-1.99)	4.97 (1.7)	10.41 (3.9)	11.63 (4.8)	18.57 (6)
Number of accelerations (2.00-2.99)	2.19 (1.3)	4.53 (2.5)	3.83 (2.4)	6.83 (3.1)
Number of accelerations (3.00-5.00)	0.94 (0.88)	0.80 (0.9)	0.60 (0.7)	1.20 (1.1)
Training load	4.97 (1.3)	7.41 (2.6)	7.37 (2.5)	11.57 (2.5)
Cardio load	2.25 (0.9)	4.67 (1.8)	4.53 (1.8)	7.95 (2.3)
	100 m^2			
HR_{max}	184.6 (14.5)	182.6 (14.6)	162.8 (45.6)	164.4 (46.8)
HR_{max}%	92.65 (7.9)	91.65 (7.2)	81.82 (22.9)	82.60 (23.4)
Total distance	87.88 (25.4)	190.7 (55)	218.7 (84)	303.1 (119)

Distance/minute	86.37 (24.6)	92.6 (26.5)	72.67 (27.9)	75.30 (29.7)
Distance speed zone 1	38.14 (8.7)	74.06 (16)	113.7 (37.5)	154.7 (54.5)
Distance speed zone 2	28.75 (13.2)	51.19 (19.6)	55.35 (30.4)	79.47 (40.6)
Distance speed zone 3	14.46 (12.1)	37.77 (17.5)	35.25 (24.6)	50.63 (36.5)
Distance speed zone 4	6.60 (8.2)	27.62 (20.1)	14.15 (15.8)	18.25 (20.1)
Sprints	0.66 (0.7)	1.48 (1.2)	0.87 (1)	1.38 (1.1)
Number of accelerations (–5.00-–3.00)	0.40 (0.55)	0.88 (0.90)	0.45 (0.62)	0.82 (0.89)
Number of accelerations (–2.99-–2.00)	2.03 (1.5)	3.58 (2)	3.37 (2.5)	4.33 (2.8)
Number of accelerations (–1.99-–1.00)	5.09 (2.2)	9.44 (3.6)	11.70 (4.6)	17.03 (7)
Number of accelerations (–0.99-–0.50)	5.91 (2.4)	10.96 (4.5)	16.88 (6)	22.83 (8.2)
Number of decelerations (0.50-0.99)	6.23 (2.6)	11.12 (4.1)	15.73 (5.9)	20.42 (6.8)
Number of decelerations (1.00-1.99)	5.25 (2.3)	8.25 (3.2)	11.05 (4.8)	16.35 (7.2)
Number of decelerations (2.00-2.99)	1.62 (1.3)	3.67 (1.7)	3.33 (2.2)	4.92 (2.9)
Number of decelerations (3.00-5.00)	0.46 (0.63)	1.06 (0.97)	0.50 (0.74)	0.95 (1)
Training load	4.37 (1.2)	6.37 (1.9)	7.45 (2.6)	10.23 (3.9)
Cardio load	2.02 (0.93)	3.92 (1.5)	4.98 (2.1)	7.05 (3.2)
	150 m^2			
HR_{max}	186.2 (8.4)	188.1 (11.1)	185.7 (17.3)	189.5 (13.4)
HR_{max}%	93.52 (4)	94.45 (5.3)	93.28 (8.8)	95.17 (6.9)
Total distance	118.4 (20)	232.5 (37.7)	329.9 (71.4)	441.2 (82.3)
Distance/minute	116.4 (19.9)	114.1 (18.6)	104.5 (23.4)	109.9 (20.5)
Distance speed zone 1	35.17 (8.1)	72.92 (13)	126.45 (22.5)	158.3 (21.8)
Distance speed zone 2	38.08 (11.4)	67.62 (20.1)	91.28 (33.5)	125.70 (36.2)
Distance speed zone 3	25.07 (11.1)	54.80 (19.9)	68.70 (32.1)	98.98 (39.9)
Distance speed zone 4	20.02 (13.4)	36.63 (26.2)	40.02 (27)	57.66 (36.1)
Sprints	0.95 (0.85)	1.30 (1.1)	1.12 (1.1)	1.52 (1.2)
Number of accelerations (–5.00-–3.00)	0.77 (0.85)	0.90 (1.1)	1.08 (0.8)	1.42 (1.2)
Number of accelerations (–2.99-–2.00)	1.87 (1.2)	3.67 (1.7)	4.66 (2.6)	6.34 (2.8)
Number of accelerations (–1.99-–1.00)	5.02 (2.1)	10.88 (3.4)	14.50 (3.6)	18.73 (4.6)
Number of accelerations (–0.99-–0.50)	5.92 (2.1)	10.13 (2.8)	13.75 (4.3)	18.80 (4.6)
Number of decelerations (0.50-0.99)	5.12 (2.3)	9.85 (2.8)	14.67 (4.1)	19.6 (4.3)
Number of decelerations (1.00-1.99)	4.52 (2.1)	9.82 (3.2)	14 (4.3)	18.73 (5)
Number of decelerations (2.00-2.99)	2.05 (1.3)	4.38 (2)	4.77 (2.4)	6.44 (2.5)
Number of decelerations (3.00-5.00)	0.73 (0.07)	0.75 (0.08)	0.63 (0.08)	0.97 (0.09)
Training load	3.98 (1)	8.17 (1.6)	9.98 (3.3)	13.61 (3.9)
Cardio load	2.13 (0.05)	4.98 (1.4)	7.23 (2.7)	10.22 (3.1)

The above Table shows means and standard deviations of all variables assessed in the present study across all conditions – players' ratio and pitch dimensions.

Reviewing the results in detail, a significant difference emerged in the HR_{max} (F = 8,198, p < 0.001) and HR_{max}% (F = 8,222, p < 0.001) variables, with the dimensions of the pitch significantly affecting the maximum HR. The post-hoc Bonferroni test showed differences between the dimensions of the pitches. In particular, the 3v3 format at 75 m² resulted in significantly lower HR_{max} compared to 3v3 at 150 m² (I-J = –22,485, p < 0.001). Also, the 4v4 at 100 m² produced a significantly lower HR_{max}, compared to the 4v4 format at 150 m² (I-J = –25,144, p < 0.001).

For the HR_{max} and HR_{max}% variables no mediation analysis was performed, as the variables were not related to the independent variable, i.e. pitch dimensions (r = –0.029, p = 0.432; r = 0.028, p = 0.444 respectively).

The results showed differences for the total distance and distance/minute in each player variant (4v4, 3v3, 2v2, 1v1) between three different relative pitch sizes (150 m²/player, 100 m²/player, 75 m²/ player). Also, differences were observed between SSG formats in the same pitch size. These two variables were correlated highly significantly (p < 0.001) with the independent variable defined as the predictor, i.e. pitch dimensions. The mediation analysis revealed significant effects both directly (for total distance: z = 9,794, p < 0.001; for distance/minute: z = 3,436, p < 0.001) – the dimensions of the pitch have a significant effect on the total distance travelled but also on the distance per minute – and indirectly (for total distance z = 11,538, p < 0.001; for distance/minute z = –4,954, p < 0.001) the ratio of players mediated in the dimensions of the pitches. It is noted that for the last zone (5-25 km/h) no significant difference was found, as probably very few players reached the said speed. Post-hoc Bonferroni analyses shed light on significant differences in the ratio of players within the same dimensions of the pitch. In particular, the 4v4 format resulted in a longer distance travelled compared to the other three ratios in all the examined pitch dimensions (p < 0.001).

Closely reviewing the comparisons within the Zones, it appeared that in Speed Zone 1 (0.10-6.99 km/h) a significant difference (F = 204,711, p < 0.001) was found between the ratio of players and within the same dimensions. Typically, the 4v4 ratio always had a significantly greater distribution distance compared to the other three player ratios. Significant differences (F = 67,444, p < 0.001) were also observed in Zone 2 (7.00-10.99 km/h), where the proportion of players on the pitch appear to significantly differ statistically. In the small pitch of 75 m² the ratio 1v1 had a shorter distance travelled compared to the ratio 2v2 (I-J = –31.812, p < 0.001), which had a shorter distance travelled than the ratio 3v3 (I-J = –43.794, p < 0.001), with the ratio 4v4 having a greater distance travelled compared to the 3v3 ratio (I-J = 45.067, p < 0.001). The previous result was confirmed for the other two dimensions of the pitches. Regarding the comparison based on pitch dimensions, significant differences were recorded only in the 3v3 and 4v4 ratios in 150 m², which resulted in a greater distance travelled than the corresponding ratios in 75 m² (I-J = 32,615, p < 0.001 and I-J = 29,703, p < 0.001, respectively). For the middle pitch (100 m²) no significant differences were observed.

In Zone 3 (11.00-14.99 km/h) a difference was also observed between the ratio of players (F = 53.403, p < 0.001). In the 75 m² pitch the 1v1 variant had a shorter distance travelled compared to 2v2 (I-J = –21.891, p < 0.001), 3v3 (I-J = –20.225, p < 0.001) and 4v4 (I-J = –42.908, p < 0.001). Regarding pitch size comparisons there were significant differences in 3v3 ratios at 75 m² and 150 m² (I-J = –30.853, p < 0.001), while (I-J = –33.453, p < 0.001) for 100 m² compared to 150 m². For 4v4, it was compared to the smaller and large pitch (I-J = –38,451, p < 0.001) and (I-J = –48,35, p < 0.001) for medium and larger pitches. The same proportions of players in larger pitches recorded longer distances travelled.

For Zone 4 (15.00-24.99 km/h) significant differences (F = 32.494, p < 0.001) were recorded in the largest pitch, where the longest distances travelled for all the proportions of players were recorded; namely, 1v1 in the 150 m² pitch had a longer distance travelled compared to the 100 m² pitch, while the 2v2, 3v3 and 4v4 ratios in 150 m² had longer distances travelled compared to the same ratios in the 75 m² pitch. Regarding the in-pitch comparison, all the ratios differed significantly on the larger pitch, with 4v4 recording the longest distance travelled and 1v1 recording the shortest.

For the next dependent variable, i.e. sprints, it was observed that the independent variables – pitch dimensions and players' format – differentiate the mean scores of the measurements. However, due to the fact that the variable was not correlated with the independent variable of pitch dimensions (r = 0.048, p = 0.190) no mediation test could be performed.

In multiple post-hoc comparisons marginal differences were observed between the 3v3 and 4v4 ratios in the small pitch; namely, 4v4 displayed a higher number of sprints (I-J = 0.783, p = 0.008). In the middle pitch

(100 m^2), differences were recorded between 1v1 and 2v2 where the second ratio recorded more sprints (I-J = 0.819, p = 0.006). Additionally, there were differences between 1v1 compared to 4v4 (I-J = 0.722, p = 0.021) on the same pitch, with the latter displaying a higher number of sprints. It is emphasized that no significant difference was observed in the large pitch.

Regarding the dependent variable Decelerations, significant differences were observed ($p < 0.001$). In the mediation analysis that followed in order to investigate direct and indirect effects from the independent variables, significant direct effects of pitch dimensions were observed only at the two medium speeds (–2.99-–2.00, –1.99-–1.00 m/s^2) (z = 2.138, p = 0.033 and z = 2.478, p = 0.013, respectively), while indirect effects of pitch dimensions on decelerations were observed at all the four examined speeds (z = 3,021, p = 0.003 for –5.00-–3.00 m/s^2; z = 8,362, $p < 0.001$ for –2.99-–2.00 m/s^2; z = 11,507, $p < 0.001$ for –1.99-–1.00 m/s^2; z = 11,640, $p < 0.001$ for –0.99-–0.50 m/s^2).

In the Bonferroni multiple comparison test, speeds of –5.00-–3.00 m/s^2 resulted in more decelerations in the larger pitch compared to the other two, and only for the 3v3 and 4v4 ratios. In the next two –2.99-–2.00 m/s^2 and –1.99-–1.00 m/s^2, significant differences were observed within the same dimensions of the pitch between the proportions of the players. More specifically, 4v4 always displayed more decelerations compared to the other three proportions of players in all the pitch sizes. In the last zone –0.99-–0.50 m/s^2, there was also an increase in the number of decelerations as the number of players increased, with the 1v1 ratio recording the lowest number of decelerations in all the three pitch dimensions. It is worth noting at this point that comparing the dimensions of the pitches was also important. In detail, 3v3 and 4v4 on a 75 m^2 pitch displayed significantly more decelerations compared to 3v3 and 4v4 at 150 m^2 ($p < 0.001$).

To conclude, it seems that decelerations increase as the number of players increases and as the dimensions of the space decrease.

Regarding Accelerations, direct effects of space were observed in the first two speed zones (z = 4,293, $p < 0.001$ for 0.50-0.99 km/s^2 and z = 3,260, p = 0.001 for 1.00-1.99 m/s^2), while indirect effects of pitch dimensions occurred through the ratio of players in all the four speed zones.

Bonferroni post-hoc tests shed light mainly on differences between player ratios; the 1v1 variant resulted in fewer decelerations on all the three pitches compared to the other ratios, with 4v4 displaying the highest number of decelerations. The finding was confirmed in the other two speed zones (1.00-1.99 m/s^2, 2.00-2.99 m/s^2). However, specific variations were observed in the last speed zone (3.00-5.00 m/s^2). In particular, in the smaller pitch the ratio of 4v4 differed from the ratio of 3v3, while the medium (100 m^2) displayed the greatest differences. 4v4 differed from all other player ratios. In the smaller pitch 4v4 differed only from 3v3, while no differentiation occurred in the larger pitch.

The dependent variables training load and cardio load appeared to differ in the various measurements (F = 80.088, F = 91.161, respectively, with statistical significance $p < 0.001$). The mediation analysis showed direct significant effects of the predictor on both variables ($p < 0.001$) and indirect effects in the case of the player ratio ($p < 0.001$). In the Bonferroni post-hoc test significant differences were recorded in comparisons between the pitches as well as between the player ratios.

In detail, in the training load variable differences were observed for the player ratios within the pitch variant. The 4v4 ratio displayed the greatest load in all the pitch dimensions compared to the other proportions, with a lower load for the 1v1 ratio. In the proportions with more players, 3v3 and 4v4, differences were observed relative to the pitch dimensions. The 3v3 and 4v4 format in the larger 150 m^2 pitch had a higher load compared to the other two pitches. No significant differences were observed for the smaller proportions.

In the cardio load variable, differences also emerged between the pitches and the proportions of the players. In particular, the highest proportion of players recorded a higher cardio load compared to the other three ratios in all the pitches, with the 1v1 ratio recording the lowest heart load in all the pitch dimension variants. The proportions with a larger number of players, 3v3 and 4v4 on the

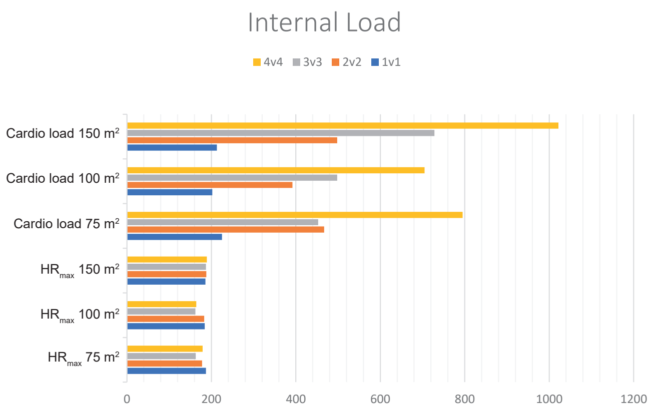

Figure 1. Internal load – cardio load, heart rate – on all pitch dimension variants for all players' formats

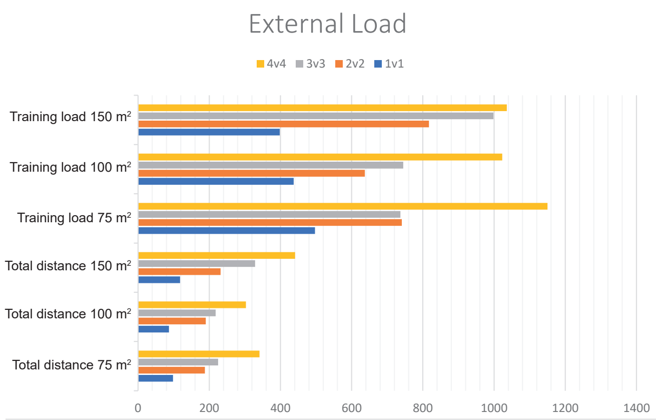

Figure 2. External load – training load, total distance – on all pitch dimension variants in all players' formats

150 m² pitch displayed a higher heart load compared to the two smaller pitches. Figure 1 displays the internal load (heart rate and cardio load) as recorded on all the pitches and in all the player ratios, while Figure 2 shows the external load (total distance and training load) in all the dimensions and in all the player proportions.

Discussion

The aim of the present study was to investigate the internal and external load on semi-professional soccer players during training in different pitch dimensions (75 m², 100 m², 150 m²) and different player ratios of 1v1, 2v2, 3v3, 4v4. For the internal load the variables calculated were the HR(specifically HR_{max} and HR_{max}%) and the heart load (cardio load). It is noted that the RPE was not evaluated in this study, as only objective assessments were used from the application of GPS. On the other hand, for the external load total distance, distance/minute, accelerations, decelerations, sprints and training load were calculated. The analyses shed light on different relations between the size of the pitches and the proportion of players having a different effect on the load experienced by soccer players. Important results are discussed in aggregate for internal and external load, respectively.

Internal load

The analyses conducted for the internal load showed that it is significantly affected by the dimensions of the pitch. The 150 m² pitch contributed to a greater internal load. In fact, in the cardio load variable the effect of the pitch dimension is immediate. This finding was not confirmed for the maximum HR. Regarding the player ratios, heart load appeared to have a significant indirect effect and to vary based on them. Typically, 3v3 and 4v4 recorded a greater heart load compared to 1v1 and 2v2. On the other hand, HR only varies for the large proportions of 3v3 and 4v4 players and only for the large and small 75 m² pitch compared to 150 m². It was already suggested by previous studies that the increase of pitch dimensions with a constant number of players can lead to an increase in HR [2, 11, 24]. Furthermore, in a study carried out on amateur players researchers observed higher values of % HR_{max} during SSGs with larger dimensions [21]. This is probably due to the fact that players have to cover longer distances with greater intensity [24]. In particular, players covered more distance from defense to attack [25]. The above findings are confirmed by a study by Casamichana and Castellano [2], which shows that reducing the dimensions of the pitch decreases the intensity of SSGs. In addition, it has been suggested that the increase in the number of players during SSGs provides more recovery time due to decreased active participation in the game. It was evident that during smaller sized matches, soccer players reached higher HR values [9]. On the other hand, the training load was shown to be both directly influenced by the dimensions of the pitch and indirectly by the proportion of players. In conclusion, SSGs with a larger number of players have a greater training load, as do those in a larger pitch dimension.

External load

The factors that constitute the external load – total distance and distance/minute – seemed to be influenced both by the larger dimensions of the pitch and by the larger proportions of players. An increase in the distance that needed to be covered was shown with an increase in the relative pitch size during all the game formats. This probably occurred due to the fact that the soccer players had the opportunity to cover longer distance/min as a result of greater available space [2].
After analyzing the data of five speed zones during the 4v4, 3v3, 2v2 and 1v1 formats with three different relative pitch sizes, it appeared that the ratio of players seemed to affect the distance travelled per minute, with the 4v4 format covering longer distances. In the first zone the dimensions of the pitch had no effect on the dependent variable. In speed zones 2 and 3 there was an increase in the covered distance with an increase of relative pitch size and an increase in the players' format. Greater covered distances were observed in 150 m² with more players. In speed zone 4 the covered distance was greater with a relative pitch size of 150 m²/player compared with that of 75 m²/player during the 3v3 and 4v4 format. In addition, there is a greater borrowed

distance on the pitches with more players. The 4v4 format consistently recorded the longest distances travelled compared to the other player ratios, with the 1v1 format recording the shortest. Similar results on the effect of pitch dimensions on speed zones had already been discussed by other researchers [28].

As far as the number of Sprints is concerned, what seemed to have an indirect effect is the proportion of players while there was no significant difference in the size of the pitches. The finding so far contradicts the existing literature, which claims that the number of Sprints is influenced by the size of the pitch [9].

Regarding the total number of decelerations, a greater number of decelerations (–5.00-–3.99 m/s^2) was recorded in the 3v3 format on a 150 m^2 pitch compared to the smaller 75 m^2 pitch, as well as in the 4v4 format on a 150 m^2 pitch compared to a 100 m^2 pitch. Therefore, it is evident that the number of decelerations is connected with an increase in available space [11]. Concerning the total number of decelerations (–3.00-–2.99 m/s^2), it appeared that the highest proportion of players recorded more decelerations with a greater difference in the larger 150 m^2 pitch. In the next zone (–2.00-–1.99 m/s^2) it was clearly demonstrated that the ratio of players affects the number of decelerations, with the least decelerations recorded in the 1v1 format and the most in the 4v4. In the last zone (–1.00-–0.99 m/s^2) it was also shown that the smaller proportion of players recorded a lower number of decelerations. Additionally, significant differences occurred in the 3v3 and 4v4 format at 75 m^2 compared to 150 m^2, where smaller pitches recorded a higher number of decelerations.

Regarding the results recorded on acceleration in the first three zones (0.50-0.99, 1.00-1.99, 2.00-2.99 m/s^2), there was a significant variation within the same pitch dimensions regarding the ratio of players. The 4v4 format consistently recorded the highest accelerations and the 1v1 recorded the lowest. The size of the pitches did not seem to make any difference in the number of accelerations. In the last zone (3.00-5.00 m/s^2) differences were recorded only in the 100 m^2 pitch. In particular, the 4v4 format recorded a higher number of accelerations compared to 1v1 and 3v3. The 2v2 format recorded more accelerations compared to 1v1. In the small pitch only the 4v4 format recorded more accelerations compared to the 3v3 format, while no significant differentiation was recorded in the large 150 m^2 pitch. Regarding the literature review, while there are some studies that typically evaluate the accelerations of athletes in team sports, they do not present results regarding the effect of the numerical ratio on them [18].

Conclusions

In summary, the purpose of this study was to investigate the importance of the players' ratio and the pitch dimensions for the internal and external burden experienced by semi-professional players during football training via small-sided games. What has emerged from the statistical analyses is that the higher proportions of players have a significant impact on the cardio load, the training load and the total distance. In contrast, the smaller pitches have a significant impact on the number of decelerations and accelerations, while they also affect the total number of sprints. The results of the study could by applied in the football training plan of semi-professional teams, with the aim of maximizing training results.

Limitations of the study and further research

A limitation of the study may be connected with the sample size; thus, in a future study data could be obtained from more football teams from the same division. In addition, it is important to evaluate other load factors such as lactic acid and subjective fatigue. The study could be carried out in another time phase, for example at the beginning of the league in order to set light on possible changes compared to the end of the season results. Moreover, it would be important in a subsequent design of the study to predict and evaluate the mental and psychological impact of football players in SSG. Furthermore, it would be important in further research to adopt the theoretical framework of reserve HR as a formula for an inter-individual comparison between football players.

Acknowledgments

The authors would like to thank the soccer players and the coaches for their participation in the present study. In addition, the authors thank the President of the soccer team, Mr. Papadopoulos Charalambos, for his support in the endeavor.

Conflict of Interest

The authors declare no conflict of interest.

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