ORIGINAL ARTICLE

Small-sided games (ssg) internal and external load on different pitch sizes in young elite women football players

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ABSTRACT

The present study aimed to assess and compare the internal and external training loads experienced by elite young female football players during small-sided games (SSGs) conducted on two different pitch sizes. Eight athletes (age: 19.6 ± 3.7 years) from a top-tier Greek women's football team participated in two training sessions and one official match. GPS tracking and heart rate monitoring were used to collect data on total distance, speed zones, sprint count, maximum speed, and heart rate distribution across five intensity zones. Two SSG formats (4v4) were implemented: one on a 20×30 m pitch (75 m²/player) and one on a 30×40 m pitch (150 m²/player), each consisting of four 4-minute bouts with 2-minute passive recovery. The results revealed no significant differences in internal load (heart rate responses) between the two pitch sizes. However, external load metrics varied notably: the smaller pitch induced more frequent accelerations and decelerations ($p < .05$), while the larger pitch resulted in longer total distances and more sprints ($p < .05$). These findings highlight the influence of pitch size on movement demands, with smaller areas favouring anaerobic, change-of-direction actions and larger areas promoting mostly aerobic and high-speed activities. The study emphasizes the effectiveness of SSGs in conditioning programs and supports their role in developing both aerobic and anaerobic fitness within realistic game contexts. The application of GPS technology enabled precise workload quantification, offering valuable insights for individualized training design. Importantly, this research addresses a gap in the literature regarding elite young women footballers, providing practical guidance for coaches aiming to optimize performance and minimize injury risk through targeted SSG configurations.
Keywords: Performance analysis, GPS tracking, Small-Sided Games (SSG), Young women's football.

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INTRODUCTION

The aggressive development of technology is allowing the football community to better analyse training and thus make it more effective. At the top level, attention to detail, in addition to the planning and execution of training sessions, is what sets teams apart and makes them stand out. The use of GPS devices (Global Position System) is of great concern to the technical staff of the teams to monitor the players' performance during either training or a match. In this way, people are well trained in the use of these devices, draw useful information about the physiological demands of the training or one of its parts, and later inform the coaches.

More specifically, at the high level and mainly in men footballers many studies refer to the recording of data from GPS devices to monitor the training load received by the players through the training units (and more often reference is made to the components of these competitive games) and the competitions involved (Gómez-Carmona et al., 2018). The GPS devices give useful information about heart rate, speed, total distance, as well as their changes during the tracking time. This information allows for improving the quality of training and makes it easier for the coaches to achieve their goals for each training session by regulating the intensity and the load of every training. However, researchers are paying attention to acceleration and deceleration to reach useful conclusions about the player's performance (Hodgson et al., 2013). These devices give a lot of data to analyse and draw important results.

An important chapter of football is injuries. Many researchers have started working on how GPS monitoring can help teams to prevent injuries. A lot of them mention that it is worth paying attention to players' internal loads over time to prevent injuries (Ehrmann et al., 2016; Ravé et al., 2020), but the variables of these devices are also useful for controlling the player's return to train or to play (Franchini et al., 2018). Common studies about youth leagues refer to the relationship between the training load and injury prevention. After a systematic review of research using GPS tracking during the training sessions and the official games at youth academies, the researchers concluded that, from continuous monitoring of training load, there is a possibility to prevent injuries and also control their fitness level (Ravé et al., 2020). Nowadays, reality-based learning concerns most coaches to build the training protocol. So, for this reason, coaches are trying to simulate players with training exercises similar to the real game. Researchers have found that SSGs (Small-Sided Games) with different pitch sizes could be used for this kind of training (Hill-Haas et al., 2011). Based on this idea some researchers tried to track and match the player's load during official or not championship games and training sessions (Casamichana et al., 2012). These game formats are easy to fix and fit into the training goal and this is the reason they are usually used. Coaches can easily plan to improve the fitness level of the player's performance as SSG can, as generally agreed, help increase the aerobic and anaerobic levels. It is important to mention that the rules coaches could set are the facts which are controlling the purpose of those games during the training (Aguiar et al., 2013).

Most researchers are working on men's football development. The knowledge about women's football is poor, especially about the SSGs and GPS tracking. However, there is some research which is referring to physical responses during the training sessions. (Mara et al., 2016). From this research, there are no significant differences between men's and women's physical responses during the SSGs but it's clear for both men and women that these games can improve their aerobic-anaerobic levels (Mara et al., 2016). FIFA is trying to improve the football game for women with a lot of projects and activities. This movement to be successful must be supported by appropriate knowledge. There are many investigations of women's football teams in Europe, but there are very few in Greece. To diminish this disadvantage, this article investigates the variables from GPS in the champion team of the 1st League of Women's Football in Greece.

This research highlights the integration of technology, specifically GPS tracking systems, in analysing Small-Sided Games (SSGs) and their impact on young female football players. The use of advanced tracking technology provides detailed insights into the physiological demands of training, enabling coaches to refine their methods for improved performance and injury prevention. Given the limited research on SSGs in women's football, especially among young athletes, this study aims to bridge the gap by offering data-driven insights that can help optimize training strategies and contribute to the sport's overall development.

MATERIAL AND METHODS

Participants

The experiment involved eight (8) players who participated throughout the official competitive match, with an average age of 19.6 ± 3.7 years, height of 162.2 ± 4.5 cm, body weight of 57.4 ± 4 kg, and body fat percentage of 19.06 ± 2.1%. All the athletes participated in six (6) training sessions and one match during the study. The match, which took place during the experimental phase, was part of the top division of the Greek women's football league, and data was recorded from the same team and the same players. All testing procedures were explained to participants before the start of the study, and they all participated voluntarily. Written informed consent was signed by all participants before any testing procedure. The study was approved by our university's Institutional Review Board (approval number EH 28/2020) and was conducted according to the Declaration of Helsinki.

Measures

For the execution of the experiment and based on existing literature (Hill-Haas et al., 2011), two different dimensions of the competitive playing area were selected. The measurements were made on separate days for each selected playing space. The recordings were conducted at the same time of day and at the same time during the training session and on the same day in two consecutive weeks. The training parameters were recorded using the Global Positioning System (GPS) from POLAR. The selection of players was based on their positions on the field. Specifically, two wide defenders, two defensive midfielders, two attacking midfielders, and two wide attackers were selected. Furthermore, the teams were divided based on player positions to form a 4v4 setup. For each team, one defender, two midfielders, and one attacker were chosen. This team distribution followed existing literature to establish a correlation between the playing areas and match conditions (one player from each line). The GPS devices were placed on the eight players, using bands, before the warm-up. The athletes participated normally in the team's warm-up session and, once physically ready, took part in the competitive games prepared during the warm-up period.

GPS variables

Using the POLAR devices, the necessary variables were recorded. The total distance (in meters), maximum heart rate, and game time in the five different heart rate zones were recorded. (Zone 1 = 50%-59%, Zone 2 = 60%-69%, Zone 3 = 70%-79%, Zone 4 = 80%-89%, and Zone 5 = 90%-100%). Additionally, the distance each player ran about her speed was categorized into five zones, the total number of sprints (with speeds above 19 km/h), and the maximum speed reached by each player. (Zone 1 = 3-6.99 km/h, Zone 2 = 7-10.99 km/h, Zone 3 = 11-14.99 km/h, Zone 4 = 15-18.99 km/h, Zone 5 = 19+ km/h).

Competitive games

According to existing literature, the first competitive game took place in a 20x30 meter space, with a total area of 600 square meters and a player-to-area ratio of 75 square meters per player. The second game took place one week later in a 30x40 meter space, totalling 1200 square meters, with a player-to-area ratio of 150 square meters per player. The duration of each game was four (4) minutes with four (4) repetitions and a two

(2) minute recovery time between them. The total duration of the experiment, including breaks, was twenty-two (22) minutes. During the games, efforts were made to maintain the rhythm. To achieve this, balls were placed in the corners of the square, and whenever the ball was lost, the trainer kicked one of the outside balls inside the playing area immediately. There were no restrictions in the game rules regarding passing or the number of ball touches. This allowed the players to play free football, simulating more realistic match conditions. After the completion of the competitive square process, the GPS devices were removed from the players before the end of their overall training session. After the final four-minute period, the players followed the coach's training plan, which involved a full-field competitive game.

Procedures

The purpose of the study is to record and compare the training parameters of competitive games during the training session in spaces of different dimensions. The recordings were made at a sports centre for football in Thessaloniki, Greece. The experiment was completed over a span of seven days, with data being recorded during two team training sessions, one week apart.

Analysis

Designed for statistical analyses, descriptive statistics were initially used to summarize the anthropometric characteristics, highlighting the mean, standard deviation, minimum, and maximum values. Additionally, the test of normality to assess whether our variables followed a normal distribution was conducted. Specifically, the researchers applied the Shapiro-Wilk test due to the sample size, using a significance level of $p < .05$. For variables that followed a normal distribution, an independent samples t-test to examine mean differences between the number of attempts and the variables under investigation was employed. For variables that did not follow a normal distribution, the researchers used the non-parametric Kruskal-Wallis test.

RESULTS

The sample consisted of eight (8) players from the team, those who played most of the championship games. Tables 1 and 2 present the anthropometric and physiological characteristics of the players.

Table 1. Anthropometric characteristics of players.

	N	Minimum	Maximum	Mean ± Std. Deviation
Height (cm)*	8	157.00	169.00	162.12 ± 4.54
Weight (kg)*	8	52.00	63.70	57.42 ± 4.02
Age (y)*	8	16.00	27.00	19.62 ± 3.70
Body fat (%)*	8	16.20	23.11	19.06 ± 2.13
Valid N (listwise)	8			

*Note. *A normality test of the value distribution was conducted using the Shapiro-Wilk test.*

Table 2. Physiological characteristics of players.

	Group (Number of attempts)	N	Mean ± Std. Deviation	Std. Error Mean
HR/min [bpm]	1.00	8	109.37 ± 8.89	3.14
	2.00	8	107.00 ± 12.88	4.55
HR avg/min [bpm]	1.00	8	159.87 ± 4.67	1.65
	2.00	8	162.00 ± 8.07	2.85
HR max/min [bpm]	1.00	8	183.00 ± 7.87	2.78
	2.00	8	183.62 ± 8.21	2.90
HR [%]	1.00	8	55.25 ± 4.49	1.58
	2.00	8	54.12 ± 6.42	2.27

HR avg [%]	1.00	8	81.00 ± 2.50	0.88
	2.00	8	81.62 ± 4.10	1.45
HR max [%]	1.00	8	92.50 ± 4.95	1.75
	2.00	8	92.62 ± 4.10	1.45
Time in HR zone 1 (50 - 59 %)	1.00	8	0.77 ± 0.86	0.30
	2.00	8	1.04 ± 0.97	0.34
Time in HR zone 2 (60 - 69 %)	1.00	8	3.23 ± 0.44	0.15
	2.00	8	2.94 ± 0.72	0.25
Time in HR zone 3 (70 - 79 %)	1.00	8	3.01 ± 1.37	0.48
	2.00	8	2.50 ± 0.80	0.28
Time in HR zone 4 (80 - 89 %)	1.00	8	10.80±2.32	0.82
	2.00	8	9.29±4.87	1.72
Time in HR zone 5 (90 - 100 %)	1.00	8	3.84±3.41	1.20
	2.00	8	6.16±5.87	2.07

According to the test results, all variables show normal distribution ($p > .05$) except for the variables: a) maximum HR (%), b) time in zone HR 2, c) time in HR zone 3, d) time in HR zone 5 ($p < .05$) e) distance in speed zone 4, f) time in power zone 2 ($p < .05$) (Table 3).

Table 3. Tests of Normality.

Variable	Shapiro-Wilk Statistic	df	Sig
Height	.902	7	.343
Weight	.923	7	.492
Age	.867	7	.175
Fat	.915	7	.433
HR at Rest [bpm]	.914	7	.427
Mean HR [bpm]	.891	7	.280
Max HR [bpm]	.940	7	.636
HR [%]	.966	7	.864
Mean HR [%]	.852	7	.127
Max HR [%]	.871	7	.189
Time in HR Zone 1 (50 - 59%)	.870	7	.184
Time in HR Zone 2 (60 - 69%)	.690	7	**.003**
Time in HR Zone 3 (70 - 79%)	.738	7	**.010**
Time in HR Zone 4 (80 - 89%)	.924	7	.499
Time in HR Zone 5 (90 - 100%)	.799	7	**.040**
Total Distance [m]	.964	7	.849
Distance/Minute [m/min]	.960	7	.817
Max Speed [km/h]	.967	7	.879
Mean Speed [km/h]	.959	7	.810
Sprints	.835	7	.089
Distance in Speed Zone 1 (3.00 - 6.99 km/h)	.933	7	.581
Distance in Speed Zone 2 (7.00 - 10.99 km/h)	.931	7	.563
Distance in Speed Zone 3 (11.00 - 14.99 km/h)	.906	7	.371
Distance in Speed Zone 4 (15.00 - 18.99 km/h)	.798	7	**.039**
Distance in Speed Zone 5 (19.00+ km/h)	.888	7	.266
Training Load Score	.956	7	.782
Cardio Load	.991	7	.994
Recovery Time [h]	.971	7	.902
Calories [kcal]	.914	7	.426
Number of Decelerations (-50.00 to -3.00 m/s²)	.979	7	.956

Number of Decelerations (-2.99 to -2.00 m/s²)	.947	7	.704
Number of Decelerations (-1.99 to -1.00 m/s²)	.882	7	.236
Number of Decelerations (-0.99 to -0.50 m/s²)	.915	7	.432
Number of Accelerations (0.50 to 0.99 m/s²)	.868	7	.178
Number of Accelerations (1.00 to 1.99 m/s²)	.937	7	.610
Number of Accelerations (2.00 to 2.99 m/s²)	.849	7	.120
Number of Accelerations (3.00 to 50.00 m/s²)	.912	7	.409
Time in Power Zone 1 (70 - 84%)	.973	7	.919
Time in Power Zone 2 (85 - 99%)	.661	7	**.001**
Time in Power Zone 3 (100 - 129%)	.831	7	.082
Time in Power Zone 4 (130 - 179%)	.845	7	.112
Time in Power Zone 5 (180 - 800%)	.984	7	.978
Muscle Load in Zone 1 (70 - 84%)	.920	7	.471
Muscle Load in Zone 2 (85 - 99%)	.825	7	.071
Muscle Load in Zone 3 (100 - 129%)	.990	7	.994
Muscle Load in Zone 4 (130 - 179%)	.944	7	.679
Muscle Load in Zone 5 (180 - 800%)	.926	7	.521
Total Muscle Load	.923	7	.492

T-test results for independent samples

A T-test for independent samples was performed for the variables that followed the normal distribution. The results showed statistically significant differences between the two conditions of SSGs ($p < .05$). Specifically, there was a statistically significant difference between the two different conditions of SSGs and total distance with t(14) = -5.546, $p < .001$, MD = -347. Moreover, statistically significant differences were observed between the two different conditions of SSGs and distance with t(14) = -5.228, $p < .001$, MD = -14.5. Statistically significant differences were also shown between the two different conditions of SSGs and max speed with t(14) = -2.629, $p < .05$, MD = -2.43. Furthermore, statistically significant differences were observed between the two different conditions of SSGs and average speed with t(14) = -4.870, $p < .001$, MD = -.86. Statistically significant differences were also shown between the two different conditions of SSGs and distance in speed zone 2 with t(14) = -2.771, $p < .05$, MD = -111.13. Statistically significant differences were also shown between the two different conditions of SSGs and distance in speed zones 3, 4, and 5 with t(14) = -4.418, $p < .01$, MD = -204.88, t(14) = -5.884, $p < .001$, MD = -103.63 and t(7.9) = -3.299, $p < .05$, MD = -17, respectively. Statistically significant differences were also shown between the two different conditions of SSGs and time in power zone 1, 3, 4, 5 with t(14) = -2.804, $p < .05$, MD = .31, t(14) = -2.553, $p < .05$, MD = -45, t(9.5) = -3.249, $p < .01$, MD = -.47 and t(8.5) = -2.466, $p < .05$, MD = -.32, respectively. Finally, statistically significant differences were shown between the two different conditions of SSGs and muscle load in power zone 1, 2, 3, 4, 5 and muscle load, with t(14) = -4.615, $p < .001$, MD = -4.25, t(14) = -3.809, $p < .01$, MD = -4, t(14) = -3.706, $p < .01$, MD = -7, t(14) = -3.848, $p < .01$, MD = -8.63, t(14) = -2.741, $p < .05$, MD = -10.63 and t(14) = -5.600, $p < .001$, MD = -32.38, respectively. This information is shown in Table 4.

For the variables that showed non-normal distribution, the Kruskal-Wallis Test was performed. The results showed statistically significant differences between the number of attempts and distance in speed zone 4 (metres), with H(1) = 11.294, $p < .001$. Moreover, there was also a statistically significant difference between the number of attempts and time in power zone 2, with H(1) = 7.225, $p < .01$. There was not a statistically significant difference for time in HR zone 2, time in HR zone 3, and time in HR zone 5. This information is represented in Table 5.

Table 4. T-test for independent samples.

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Total distance [m]	Equal variances assumed	0.016	.901	-5.546	14	.000	-347.000	62.56425
	Equal variances not assumed			-5.546	13.261	.000	-347.000	62.56425
Distance/min [m/min]	Equal variances assumed	0.004	.949	-5.228	14	.000	-14.5000	2.77344
	Equal variances not assumed			-5.228	13.427	.000	-14.5000	2.77344
Max speed [km/h]	Equal variances assumed	0.701	.417	-2.629	14	.020	-2.42500	.92241
	Equal variances not assumed			-2.629	13.187	.021	-2.42500	.92241
Avg speed [km/h]	Equal variances assumed	0.033	.858	-4.870	14	.000	-.87500	.17966
	Equal variances not assumed			-4.870	13.600	.000	-.87500	.17966
Distance in speed zone 2 [metres] (7.00 - 10.99 km/h)	Equal variances assumed	4.130	.062	-2.771	14	.015	-111.12500	40.10797
	Equal variances not assumed			-2.771	10.268	.019	-111.12500	40.10797
Distance in speed zone 3 [metres] (11.00 - 14.99 km/h)	Equal variances assumed	0.102	.754	-4.418	14	.001	-204.87500	46.36816
	Equal variances not assumed			-4.418	12.863	.001	-204.87500	46.36816
Distance in speed zone 4 [metres] (15.00 - 18.99 km/h)	Equal variances assumed	0.665	.429	-5.884	14	.000	-103.62500	17.61258
	Equal variances not assumed			-5.884	11.713	.000	-103.62500	17.61258
Distance in speed zone 5 [metres] (19.00- km/h)	Equal variances assumed	14.500	.002	-3.299	14	.005	-17.00000	5.15302
	Equal variances not assumed			-3.299	7.893	.011	-17.00000	5.15302
Time in power zone 1 (70 - 84 %)	Equal variances assumed	3.016	.104	-2.804	14	.014	-.30875	.11012
	Equal variances not assumed			-2.804	10.770	.017	-.30875	.11012
Time in power zone 3 (100 - 129 %)	Equal variances assumed	2.816	.115	-2.553	14	.023	-.44500	.17432
	Equal variances not assumed			-2.553	13.030	.024	-.44500	.17432
Time in power zone 4 (130 - 179 %)	Equal variances assumed	32.394	.000	-3.249	14	.006	-.47000	.14467
	Equal variances not assumed			-3.249	9.467	.009	-.47000	.14467
Time in power zone 5 (180 - 800 %)	Equal variances assumed	8.392	.012	-2.466	14	.027	-.32375	.13128
	Equal variances not assumed			-2.466	8.503	.037	-.32375	.13128
Muscle load in power zone 1 (70 - 84 %)	Equal variances assumed	0.206	.657	-4.615	14	.000	-4.25000	.92099
	Equal variances not assumed			-4.615	13.659	.000	-4.25000	.92099
Muscle load in power zone 2 (85 - 99 %)	Equal variances assumed	0.000	1.000	-3.809	14	.002	-4.00000	1.05009
	Equal variances not assumed			-3.809	13.869	.002	-4.00000	1.05009
Muscle load in power zone 3 (100 - 129 %)	Equal variances assumed	0.148	.706	-3.706	14	.002	-7.00000	1.88864
	Equal variances not assumed			-3.706	13.650	.002	-7.00000	1.88864
Muscle load in power zone 4 (130 - 179 %)	Equal variances assumed	1.242	.284	-3.848	14	.002	-8.62500	2.24155
	Equal variances not assumed			-3.848	12.691	.002	-8.62500	2.24155
Muscle load in power zone 5 (180 - 800 %)	Equal variances assumed	2.365	.146	-2.741	14	.016	-10.62500	3.87615
	Equal variances not assumed			-2.741	11.352	.019	-10.62500	3.87615
Muscle load	Equal variances assumed	0.550	.471	-5.600	14	.000	-32.37500	5.78078
	Equal variances not assumed			-5.600	12.617	.000	-32.37500	5.78078

Table 5. Kruskal Wallis Test for independent samples [a,b].

	Distance in speed zone 4 [metres] (15.00 - 18.99 km/h)	Time in power zone 2 (85 - 99 %)
Kruskal-Wallis H	11.294	7.225
df	1	1
Asymp. Sig.	<.001	.007

Note. a. Kruskal Wallis Test. b. Grouping Variable: number of attempts.

DISCUSSION

The present study revealed significant differences between the two SSG conditions across a range of performance and physiological variables. Independent samples t-tests indicated that players covered significantly less total distance and distance under one condition compared to the other. Additionally, significant reductions were observed in maximum and average speed. Distances covered in speed zones 2, 3, 4, and 5 were also significantly lower, indicating a general decline in high-intensity activity. Significant differences were further noted in time spent in power zones 1, 3, 4, and 5, suggesting changes in the physical demands associated with each condition. Muscle load also varied significantly between conditions across all five power zones, with notable reductions in total muscle load. The Kruskal-Wallis test also identified significant effects of the number of attempts on distance covered in speed zone 4 and time in power zone 2, while no significant differences were found for time spent in HR zones 2, 3, and 5. These findings highlight that different SSG configurations can lead to markedly different physical and physiological demands, with implications for training load management and session design in team sports.

The findings of this study provide valuable insights into the physiological demands and performance variations of elite female football players under different Small-Sided Games (SSG) conditions. The results indicate that there were no statistically significant differences in heart rate indicators between the two pitch sizes, suggesting that the intensity level remained relatively stable. However, the variations in total distance covered, acceleration, and deceleration patterns highlight the impact of pitch size on external load variables.

In line with previous research (Mara et al., 2016). The data confirm that smaller playing areas (20x30m) demand more frequent changes in direction and explosive movements, leading to increased accelerations and decelerations. This aligns with the notion that reduced space promotes higher intensity through shorter but more frequent high-intensity actions. Conversely, the larger pitch (30x40m) resulted in a higher number of sprints and greater total distance covered, which may be attributed to the increased space available for movement and the necessity to cover larger distances to maintain positional structure. These findings reinforce the importance of pitch size selection in training design, depending on the desired physical outcomes (Köklü eta al., 2013; Nunes et al., 2021).

The use of GPS tracking technology in this study has provided precise and quantifiable data on player workload, allowing for a more comprehensive analysis of training intensity. The ability to monitor internal (heart rate zones) and external (distance, speed, and acceleration) loads enables coaches to optimize training sessions by balancing workload and recovery. Importantly, the findings contribute to the limited body of knowledge on GPS applications in elite women's football, where research remains significantly less developed compared to men's football (Mara et al., 2016; Scott et al., 2020; Castellano et al., 2013; Halouani et al., 2014).

Another critical aspect highlighted by this study is the role of SSGs in conditioning programs. The findings confirm that SSGs serve as an effective training method for improving both aerobic and anaerobic fitness while maintaining game-specific movement patterns. The ability to simulate match intensity while manipulating pitch dimensions offers coaches a valuable tool for player development. Furthermore, as FIFA and other organizations strive to enhance the competitive level of women's football, research-based training methods such as those investigated here will be crucial for improving player performance and reducing injury risks (Hill-Haas et al., 2011; Aguiar et al., 2013; Castellano et al., 2013).

One of the key contributions of this study is its focus on elite young female players, a demographic often underrepresented in sports science research. From a motor development perspective, training young athletes using structured SSGs and GPS monitoring allows for optimal neuromuscular adaptation, coordination enhancement, and progressive workload management (Beenham et al., 2017). This not only improves performance but also contributes to long-term athletic development, reducing the risk of overuse injuries and ensuring sustained growth in the sport (Ehrmann et al., 2016; Ravé et al., 2020). By analysing the training load of top-level female athletes, this study helps bridge the knowledge gap and offers practical insights for clubs and national teams looking to optimize training regimens for female players. Given that most existing studies focus on men's football, these findings provide a necessary foundation for developing sex-specific training recommendations (Martínez-Lagunas et al., 2014; Strauss et al., 2019; López-Fernández et al., 2017).

Future research should further explore the interaction between different SSG formats and player performance, incorporating additional metrics such as muscle oxygenation and neuromuscular fatigue. Video-based motion analysis could complement GPS data to provide deeper insights into technical and tactical adaptations during SSGs. Additionally, expanding the sample size and including players from different competitive levels would enhance the generalizability of these findings.

CONCLUSIONS

In conclusion, this study reinforces the value of GPS technology in assessing training demands and highlights the significance of pitch size in structuring SSGs. Focusing on elite young female players, it contributes to the growing body of research aimed at improving women's football through data-driven training methodologies. These insights can be directly applied to coaching strategies, helping to enhance player development, optimize performance, and reduce injury risks in elite young women's football.

AUTHOR CONTRIBUTIONS

All authors contributed significantly to the final version of this manuscript and to the interpretation of the results. P. C.: literature review, data collection, and manuscript writing, E. S.: conceptualization, study design, statistical analysis support, supervision, as well as assisted in manuscript preparation, A.L.: contributed to methodology design, data interpretation, and critical revision of the manuscript, as well as assisted in manuscript preparation, G. S.: statistical analysis support, data organization, data analysis, and drafting of specific sections, I. T.: technical support, data processing, and contribution to the discussion and conclusions. All authors have read and agreed to the published version of the manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors. The experiments comply with the current laws of the country in which they were performed.

REFERENCES

Aguiar, M. V., Botelho, G. M., Gonçalves, B. S., & Sampaio, J. E. (2013). Physiological responses and activity profiles of football small-sided games. The Journal of Strength & Conditioning Research, 27(5), 1287-1294. https://doi.org/10.1519/JSC.0b013e318267a35c

Beenham, M., Barron, D. J., Fry, J., Hurst, H. H., Figueirdo, A., & Atkins, S. (2017). A comparison of GPS workload demands in match play and small-sided games by the positional role in youth soccer. Journal of human kinetics, 57, 129. https://doi.org/10.1515/hukin-2017-0054

Casamichana, D., Castellano, J., & Castagna, C. (2012). Comparing the physical demands of friendly matches and small-sided games in semiprofessional soccer players. The Journal of Strength & Conditioning Research, 26(3), 837-843. https://doi.org/10.1519/JSC.0b013e31822a61cf

Castellano, J., Casamichana, D., & Dellal, A. (2013). Influence of game format and number of players on heart rate responses and physical demands in small-sided soccer games. The Journal of Strength & Conditioning Research, 27(5), 1295-1303. https://doi.org/10.1519/JSC.0b013e318267a5d1

Ehrmann, F. E., Duncan, C. S., Sindhusake, D., Franzsen, W. N., & Greene, D. A. (2016). GPS and injury prevention in professional soccer. The Journal of Strength & Conditioning Research, 30(2), 360-367. https://doi.org/10.1519/JSC.0000000000001093

Francini, L., Rampinini, E., Bosio, A., Connolly, D., Carlomagno, D., & Castagna, C. (2019). Association between match activity, endurance levels and maturity in youth football players. International journal of sports medicine, 40(09), 576-584. https://doi.org/10.1055/a-0938-5431

Gómez-Carmona, C. D., Gamonales, J. M., Pino-Ortega, J., & Ibáñez, S. J. (2018). Comparative analysis of load profile between small-sided games and official matches in youth soccer players. Sports, 6(4), 173. https://doi.org/10.3390/sports6040173

Halouani, J., Chtourou, H., Gabbett, T., Chaouachi, A., & Chamari, K. (2014). Small-sided games in team sports training: a brief review. The journal of strength & conditioning research, 28(12), 3594-3618. https://doi.org/10.1519/JSC.0000000000000564

Hill-Haas, S. V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: a systematic review. Sports medicine, 41, 199-220. https://doi.org/10.2165/11539740-000000000-00000

Hodgson, C., Akenhead, R., & Thomas, K. (201). Time-motion analysis of acceleration demands of 4v4 small-sided soccer games played on different pitch sizes. Human movement science, 33, 25-32. https://doi.org/10.1016/j.humov.2013.12.002

Köklü, Y., Albayrak, M., Keysan, H., Alemdaroğlu, U., & Dellal, A. (2013). Improvement of the physical conditioning of young soccer players by playing small-sided games on different pitch size-special reference to physiological responses. Kinesiology, 45(1.), 41-47.

López-Fernández, J., Sánchez-Sánchez, J., Gallardo, L., & García-Unanue, J. (2017). Metabolic power of female footballers in various small-sided games with different pitch surfaces and sizes. Sports, 5(2), 24. https://doi.org/10.3390/sports5020024

Mara, J. K., Thompson, K. G., & Pumpa, K. L. (2016). Physical and physiological characteristics of various-sided games in elite women's soccer. International journal of sports physiology and performance, 11(7), 953-958. https://doi.org/10.1123/IJSPP.2015-0087

Martínez-Lagunas, V., Niessen, M., & Hartmann, U. (2014). Women's football: Player characteristics and demands of the game. Journal of Sport and Health Science, 3(4), 258-272. https://doi.org/10.1016/j.jshs.2014.10.001

Nunes, N. A., Goncalves, B., Coutinho, D., Nakamura, F. Y., & Travassos, B. (2021). How playing area dimension and number of players constrain football performance during unbalanced ball possession games. International Journal of Sports Science & Coaching, 16(2), 334-343. https://doi.org/10.1177/1747954120966416

Ravé, G., Granacher, U., Boullosa, D., Hackney, A. C., & Zouhal, H. (2020). How to use global positioning systems (GPS) data to monitor training load in the "real world" of elite soccer. Frontiers in physiology, 11, 944. https://doi.org/10.3389/fphys.2020.00944

Scott, D., Haigh, J., & Lovell, R. (2020). Physical characteristics and match performances in women's international versus domestic-level football players: a 2-year, league-wide study. Science and medicine in football, 4(3), 211-215. https://doi.org/10.1080/24733938.2020.1745265

Strauss, A., Sparks, M., & Pienaar, C. (2019). The use of GPS analysis to quantify the internal and external match demands of semi-elite level female soccer players during a tournament. Journal of sports science & medicine, 18(1), 73.