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Physiological responses, fatigue and perception of female soccer players in small-sided games with different pitch size and sport surfaces

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ABSTRACT: The aim of this research was to evaluate the influence of game surface and pitch size on the physiological responses, jump performance and perceptions of sub-elite female soccer players playing four-a-side games. Sixteen sub-elite female soccer players were divided into four groups of four players each. Three small-sided games (SSGs; pitch size: 400 m^2, 600 m^2 and 800 m^2) were played on three surfaces (dirt [DT], artificial turf [AT] and natural grass [NG]). Players' heart rate (HR) was monitored during each game. Before and after each SSG, participants performed two counter-movement jumps (CMJs) and answered a questionnaire based on visual analogue scales (VASs) to indicate their perception of the effort required on each surface. DT obtained lower outputs for most variables. In the SSG 600 mean HR was higher on NG than AT (+3.31 $\%HR_{max}$; $p = 0.029$), but players' overall satisfaction with both surfaces was similar ($p>0.05$). The SSG 400 received the lowest ratings for most variables, whereas the SSG 600 resulted in higher mean HR than SSG 800 [NG (+9.14 b.p.m.; $p = 0.001$); AT (+7.32 b.p.m.; $p = 0.014$)]. No surface differences in CMJ performance were found. In conclusion, a higher internal load can be achieved on NG, whereas DT is not recommended for playing soccer. Moreover, the internal load on players in SSGs can be controlled by manipulating pitch size, but over-large pitches may entail a reduction in the physiological profile of female soccer players.

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INTRODUCTION

The strong growth in female soccer in recent years, with over 1.2 million federative licenses already granted in Europe alone [1], is matched by increasing scientific interest in this sport [2-8]. Several studies have described the physical and physiological demands of female soccer matches at different levels [7-9], evidencing that the competitive demands of female soccer are different from those of the male game and so the training methods may not be the same [2, 3, 7].

Because soccer is a sport involving an intermittent burst of activity, performance is heavily dependent on high-intensity actions such as jumps, kicks and sprints. However, such actions impose high metabolic demands and lead to acute fatigue [3, 10-12]. The ability of players to execute these actions throughout a game depends on fitness factors such as their VO_{2max}, muscular tone or maximum heart rate (HR_{max}) [3, 11].

Currently, small-sided games (SSGs) are increasingly used in training because they reproduce the technical, tactical and even physical demands of soccer matches [13-16], whilst allowing players to increase their fitness regardless of age or gender [5, 17, 18]. It is possible, however, that female SSGs do not provide sufficient external load to replicate the physical demands of soccer matches [4]. It is likely that some SSGs do not make sufficient physiological demands on some female players [19], bearing in mind that players' mean and peak heart rate (HR) should reach 81–87% and 97–98% respectively of their individual HRmax to reproduce the physiological demands of matches [20].

Research on male soccer has demonstrated that the physiological responses of players in SSGs are affected by several external factors, such as the length of the game, rest period, number of players, pitch dimensions, presence or absence of keepers or goalposts, number of touches or the game surface [16, 18, 21-23]. However, the physiological responses of female soccer players during SSGs has only been investigated relative to the number of players [6]; so further analysis is required to discover how external variables affect the physiological profile of female soccer players during SSGs.

Among all these variables, pitch size is considered a key factor in soccer because, in matches, players usually have to face game situations in a reduced space [24, 25]. Nonetheless, the importance of the pitch size in SSGs also reflects the fact that it may influence game intensity and hence manipulations of pitch size may be used to adjust training loads [26, 27]. The influence of pitch size on the physiological demands of SSGs has only been studied in men and there is no clear consensus on what the relationships are. Casamichana and Castellano [28] and Rampinini et al. [15] reported that players' physiological responses improve when the pitch size increases, suggesting that the physiological demands of SSGs increase with pitch size. However, Kelly and Drust [23] did not find this pattern in the physiological responses of professional soccer players, although the technical patterns of these players did change with the pitch size. One could conclude from these findings that the influence of pitch size on the physiological responses of soccer players in SSGs is mediated or moderated by other variables, such as competitive level or game format; this would imply that the effects of pitch size should not be investigated in isolation [27]. Similarly, findings based on research on male soccer should not be assumed to generalise to female soccer; so separate research is required to determine how pitch size should be manipulated to regulate the intensity of female SSGs [29].

On the other hand, research into the intensity of SSGs has paid scant attention to the potential impact of the surface on which games are played. Only Brito et al. [21] have studied the influence of the sports surface in SSGs, but they compared artificial turf with two surfaces that are not used for eleven-a-side soccer (sand and asphalt). Professional soccer has traditionally been played on natural grass, whilst dirt pitches are widely used in amateur soccer due to the low number of uses per week and its maintenance costs. However, the newest artificial turf systems are now widely used in soccer because they provide similar mechanical properties to natural grass [30].

The latest comparative studies have demonstrated that the injury rate, sprint performance and recovery time are similar on artificial turf systems and natural grass [31-33]. Moreover, it seems that playing on artificial turf does not alter the pattern of changes in heart rate and blood lactate relative to playing on natural grass [31, 34, 35], although most of this research involved standardised tests performed without a ball. It remains possible, therefore, that alterations in game style according to the surface (i.e. more short passes and lower tackles on turf than on natural grass) [36] may decisively influence the physiological responses of soccer players during SSGs. It follows that there is a need for more research into how the playing surface influences players' physiological responses during real games, including SSGs. This is especially important in female soccer as artificial turf is more prevalent in professional and sub-elite tournaments, being even used for the 2015 FIFA Women's World Cup [37].

To address these gaps in the literature, the aim of this research was to evaluate the influence of game surface and pitch size on the physiological responses, fatigue and perceptions of sub-elite female soccer players in small-sided games of four-a-side. On the basis of previous research, we hypothesised that players' physiological responses would be affected by the game surface and would be more marked in SSGs played on larger pitches.

MATERIALS AND METHODS

Experimental Design

Prior to the main interventions players performed a Yo-Yo Intermittent Endurance Test Level 2 to determine their maximum heart rate (HR max) [38, 39]. The total distance achieved in the test was recorded (777.1 ± 159.98 m). Heart rate (HR) was monitored using a pulsometer (Polar Team System, Kempele, Finland) attached to the participant's chest.

The study was conducted over four consecutive weeks (2 days per week). Three different SSG conditions (Table I) were repeated twice on each of the three chosen surfaces, dirt (DT; uniform and dry dirt), artificial turf (AT; fibre: monofilament of polyethylene, 60 mm in height; infill: 20 $kg \cdot m^{-2}$ of styrene-butadiene rubber and quartz sand with 0.3–0.8 granulometry) and natural grass (NG; grass height: 25 mm) to yield 96 observations. The three surfaces had the same orientation (north-south) and altitude (770 m above sea level). All tests were conducted under similar weather conditions (dry; 20-24.5ºC; 22-30% relative humidity), as the mechanical properties of sports surfaces are affected by meteorological conditions [40]. The tests were also conducted at the player's regular training time (19:00 to 21:00) in order to reduce the possible influence of circadian rhythms [41]. Before the test session, players completed a familiarisation session to get used to both the heart rate monitors and the SSG included in the study.

TABLE 1. SSG characteristics

	Game duration (min)	Duration of the recovery between SSG	Pitch area (m)	Pitch total area (m^2)	Pitch ratio per player (m^2)
SSG 400	4	10	20 x 20 m	400 m^2	50 m^2
SSG 600	4	10	24.5 x 24.5 m	600 m^2	75 m^2
SSG 800	4	10	28.3 x 28.3 m	800 m^2	100 m^2

SSG: Small Sided Game

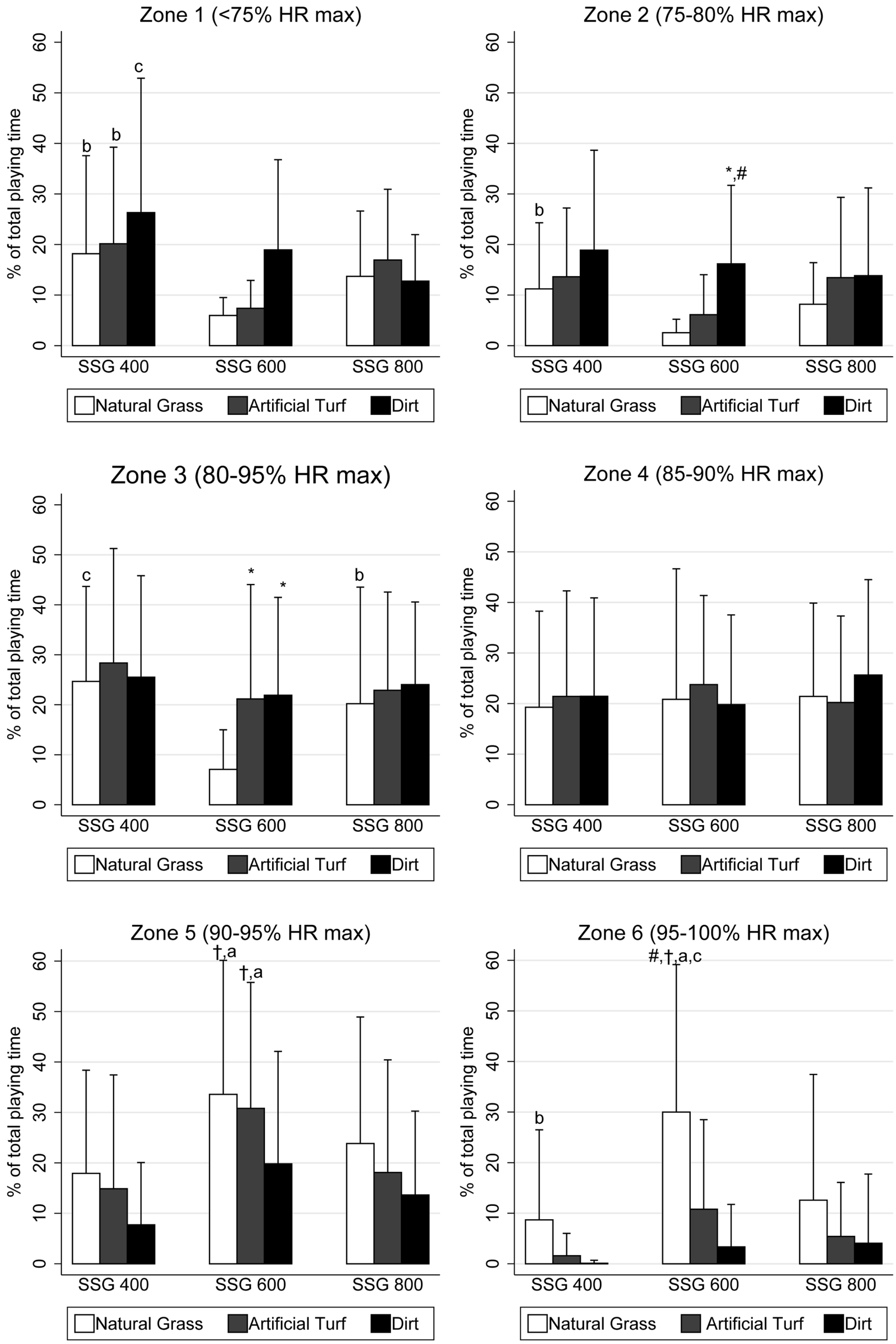

FIG. 1. Physiological responses on the three surfaces and in three SSGs
Significant differences ($p<0.05$): Natural grass = *; Artificial turf = #; Dirt = †
Significant differences ($p<0.05$): SSG 400 = a; SSG 600 = b; SSG 800 = c

Sample Characteristics

Sixteen women from the same Spanish Second Division team participated in the study (19.56 ± 1.97 years; 57.74 ± 4.89 kg; 161.57 ± 5.83 cm; 24.93 ± 4.1% body fat). All participants had been playing soccer on artificial turf and natural grass for at least 5 years (5.81 ± 0.75 years) and practised for two hours, three days a week as well as playing a weekly competitive game. None of the participants reported any cardiopulmonary disease or took medications during the study and all confirmed that they had passed the medical examination required to play soccer.

The participating club, coaches and players were informed about the possible risks of taking part in this study. All players provided written informed consent to participate. The study was approved by the local Clinical Research Ethical Committee in accordance with the Declaration of Helsinki.

Experimental Protocol

Players were asked to rest for 72 hours before each test session. During this period, they were asked to avoid exhausting activity and to maintain the same eating habits. They were asked to use the same soccer boots (with rubber studs) for all test sessions.

The order of the SSGs and surfaces was randomly determined so that every test day participants played one sort of SSG (small, medium or large) on each surface. At the start of each test day, participants carried out a standardised warm-up consisting of 5 minutes of running, 5 minutes of joint mobility and three 30 m sprints of increasing intensity [41].

Four-a-side SSGs. Coaches divided the players into four teams of four players matched with respect to level. Each team played three different four-a-side games on each surface (Table 1). We used four-a-side games rather than the five-a-side games favoured by Mara et al. [6] because this format is widely used in research [15], and there has already been some research on four-a-side female soccer games [26, 29]. We also considered the findings of Zubillaga et al. [25] when designing our SSGs. They demonstrated that the individual player area in matches ranges from 77.91 ± 32.72 m^2 to 96.19 ± 22.66 m^2. Moreover, the length to width ratio ranges from 1:1 to 1:1.3 [24, 25].

Teams and match format remained the same throughout the whole investigation. The objective was to maintain ball possession for as much time as possible; so, neither goalposts nor keepers were included in the SSGs. We chose this option because possession SSGs appear to be more intense than those with goal-keepers [27, 42]. Coaches encouraged the players during the whole study and balls were replaced when they went outside the pitch to maximise the playing time. Finally, to ensure maximum recovery between SSGs the players performed 10 min of active recovery work (low-intensity ball-passing exercises and three incremental sprints at the end of the recovery time).

Physiological responses and internal load. Physiological variables were recorded using HR monitors (Polar Team System, Kempele, Finland). HRmax was determined for each player in the Yo-Yo Intermittent Endurance Test Level 2. Taking this value as a reference the peak heart rate (HR peak) and the average heart rate (HR mean) in both beats-per-minute (b.p.m.) and percentage of the individual maximum heart rate (% HR_{max}) were calculated. The physiological responses were assessed establishing six zones of intensity (all in % HR_{max}: <75; 75-80; 80-85; 85-90; 90-95; >95%) [43]. All activity at over 85% HR_{max} was also recorded as HR High Intensity.

Vertical jumping. Players performed two countermovement jumps (CMJ) before and after each SSG. During jumps, players kept their hands on their hips so that their performance was not influenced by arm movement. Jumps were recorded using an infrared system (Optojump Next, Microgate, Bolzano, Italy), and data from the best jump were used in statistical analyses. The maximum jump height in cm and the coefficient of variation after SSG were analysed.

Visual analogue scales. Perceptions of effort, fatigue and the difficulty of executing specific technical actions on each surface were assessed using a series of 100 mm visual analogue scales (VASs) where 0 represented 'nothing, hard/tired/comfortable' and 100 'very, hard/tired/comfortable'. Data were registered in arbitrary units (a.u.) and players completed the questionnaire immediately following each SSG.

The questionnaire consisted of twelve questions adapted from previous research on sports surfaces [21, 36, 41]: "How would you classify the effort you made during this session?" (VAS1); "How tired are you at this moment?" (VAS2); "How difficult did you find it to make a precise pass?" (VAS3); "How fast was the ball speed after a pass?" (VAS4); "How difficult did you find it to control the ball?" (VAS5); "How difficult did you find it to dodge an opponent?" (VAS6); "How difficult did you find it to perform changes of direction?" (VAS7); "How easy did you find it to do a tackle?" (VAS8); "How easy did you find dribbling?" (VAS9) "How easy was it to run without the ball?" (VAS10); "How well did the ball rebound?" (VAS11); "In general, how did you feel during this session on this surface?" (VAS12).

Statistical Analysis

Results are presented as means and standard deviations (±SD). The Kolmogorov-Smirnov test and Levene's statistic were used to verify the normality of the data and the homogeneity of variance. The comparisons between results of the physiological variables were developed through two-way ANOVA (surface x game situation) tests. The results collected for the jump variables before and after the different game situations on all surfaces were analysed by the same method using the percentage change. Interactions were assessed using post hoc pairwise Bonferroni tests. Confidence intervals (95% CI) were calculated to indicate the magnitude of change. Effect size (ES) was calculated and classified using Cohen's criteria [44] and defined as follows: trivial <0.19; small 0.2–0.49; medium 0.5–0.79; large >0.8. Data were analysed with the statistical software SPSS v 20.0. The level of significance was set at $p<0.05$.

RESULTS

Physiological Responses

Table 2 shows the physiological responses of the players in the different SSG and surfaces. The HR mean and HR peak in the SSG 400 and SSG 600 were higher on natural grass than on dirt ($p < 0.05$). Moreover, in the SSG 600, the natural grass also had higher outcomes than artificial turf for HR mean [+3.31 $\%HR_{max}$; $p = 0.029$; ES: 0.856; CI: 0.49–12.87]; HR mean [+6.68 b.p.m.; $p = 0.012$; ES: 0.838; CI: 0.58–6.04]; and HR High Intensity [+19.07 %; $p = 0.041$; ES: 0.934; CI: 0.54–37.59].

On the other hand, the main differences among SSGs were found for dirt since the values of the SSG 400 were lower ($p < 0.05$) than the SSG 600 and SSG 800 ones for HR mean (%HRmax and b.p.m.), and HR peak (%HRmax). Nonetheless, the SSG 600 also had higher outcomes than the SSG 800 for HR mean [NG (+9.14 b.p.m.; $p = 0.001$; ES: 1.014; CI: 3.11–15.18); AT (+7.32 b.p.m.; $p = 0.014$; ES: 0.850; CI: 1.13–13.51)] and HR High Intensity [NG (+26.60 %; $p = 0.001$; ES: 1.174; CI: 8.54–44.67); AT (+21.63 %; $p > 0.001$; ES: 0.727; CI: 3.11–40.16)].

TABLE 2. Physiological responses in the three surfaces and the three SSG.

	Natural Grass (NG) (*)			Artificial Turf (AT) (#)			Dirt (DT) (†)		
	SGG 400 (a)	SSG 600 (b)	SSG 800 (c)	SGG 400 (a)	SSG 600 (b)	SSG 800 (c)	SGG 400 (a)	SSG 600 (b)	SSG 800 (c)
HR mean ($\%HR_{max}$)	84.11 (5.80) [†]	89.88 (3.56) [#,†]	84.92 (6.06)	81.15 (5,52)	86.57 (4,17) [†,a]	82.40 (5,27)	79.18 (4.88)	82.45 (5.30) [a]	82,90 (4.41) [a]
HR mean (b.p.m.)	169.39 (12.11) [†]	178.43 (6.48) [#,†, a,c]	169.29 (11.55)	163.74 (10.92)	171.75 (8.44) [†,a, c]	164.43 (9.74)	160.07 (8.83)	164.03 (12.17) [a]	165.54 (8.67) [a]
HR peak ($\%HR_{max}$)	92.58 (4.46) [†]	95.47 (3.64) [†]	92.77 (4.57)	89.32 (5.38)	92.88 (4.11) [a]	90.30 (7.92)	86,93 (5.89)	91,22 (5.60) [a]	91,51 (4.37) [a]
HR peak (b.p.m)	186.40 (8.86) [†]	189.56 (7.43) [†]	184.97 (8.95)	180.17 (9.87)	184.31 (8.98)	180.13 (14.91)	175.71 (10.52)	181.46 (12.87) [a]	182.79 (9.53)
HR High Intensity (t [%])>85% HR_{max})	45.89 (34.28)	84.43 (12.68) [#,†,a,c]	57.83 (32.64)	37.89 (34.73)	65.36 (28.14) [†,a,c]	43.73 (31.36)	29.27 (28.13)	42.97 (32.45)	43.34 (30.16)

[*, #, †] Significant differences with the surface indicated ($p<0.05$)

[a,b,c] Significant differences with the SSG indicated ($p<0.05$)

NG=Natural Grass; AT=Artificial Turf; GR=Ground.

SSG400=Small Sided Game 400; SSG 600= Small Sided Game 600; SSG 800=Small Sided Game 800

TABLE 3. Differences between the high pre CMJ and the high post CMJ

	Natural Grass (NG)			Artificial Turf (AT)			Dirt (DT)		
	SGG 400	SSG 600	SSG 800	SGG 400	SSG 600	SSG 800	SGG 400	SSG 600	SSG 800
High Pre CMJ (m)	23.23 (3.43)	23.69 (4.11)	23.73 (3.38)	23.72 (3.89)	24.27 (4.08)	23.07 (3.72)	24.60 (3.89)	23.12 (4.84)	22.29 (3.50)
High Post CMJ (m)	24.09 (3.81)	24.56 (4.09)	24.45 (3.13)	24.39 (3.90)	24.93 (4.04)	24.13 (3.55)	25.47 (4.19)	23.76 (4.85)	23.00 (3.58)
Coefficient of variation	3.57 (4.42)[*]	3.84 (3.70)[*]	3.35 (5.23) [†]	2.99 (4.70) [†]	2.90 (3.24)[*]	4.83 (5.10)[*]	3.49 (4.00)[*]	2.99 (4.72) [†]	3.32 (5.09) [†]

* = $p<0.001$

† = $p<0.01$

Figure 1 displays the internal load in terms of the percentage of time that players spent in each of the six zones of intensity established. The main differences among surfaces were found in the SSG 600. Thus, in this SSG, players spent significantly more time in Zone 5 on natural grass than on dirt (+13.77 %; p = 0.048; ES: 0.564; CI: 0.08–16.35), while in Zone 6 the outcomes were higher on natural grass than on artificial turf (+19.21 %; p < 0.001; ES: 0.819; CI: 8.76–29.66) and dirt (+26.65 %; p < 0.001; ES: 1.420; CI: 16.11–37.20).

On the other hand, the main differences among pitch sizes were found on natural grass. Hence, players spent significantly more time in Zone 5 in the SSG 600 than the SSG 400 (+16.65 %; p = 0.016; ES: 0.666; CI: 2.21–29.10); while in Zone 6 the SSG 600 had higher outcomes than the SSG 400 (+21.32 %; p < 0.001; ES: 0.908; CI: 10.97–31.68) and the SSG 800 (+17.43 %; p < 0.001; ES: 0.645; CI: 7.24–27.62).

Countermovement Jump

The coefficients of variation for the CMJ jumps (Table 3) were similar on all three surfaces and for all three pitch sizes (p > 0.05). However, in descriptive terms mean post-game CMJs were always higher than mean pre-game CMJs.

TABLE 4. Post-session Visual Analogue Scale (VAS) results according to the three surfaces and the three SSG.

	Natural Grass (NG) (*)			Artificial Turf (AT) (#)			Dirt (DT) (†)		
	SGG 400 (a)	**SSG 600 (b)**	**SSG 800 (c)**	**SGG 400 (a)**	**SSG 600 (b)**	**SSG 800 (c)**	**SGG 400 (a)**	**SSG 600 (b)**	**SSG 800 (c)**
VAS1: Perceived exertion (a.u.)	42.17 (18.81)	51.34 (16.92)	45.81 (17.10)	41.86 (16.04)	47.14 (15.40)	40.19 (15.83)	52.64 (20.84)	49.00 (19.53)	52.47 (19.66)$^{\#}$
VAS2: Level of fatigue (a.u.)	42.73 (17.48)	51.31 (18.50)	48.53 (14.38)	42.66 (15.97)	48.14 (16.03)	44.16 (15.88)	47.63 (22.61)	49.04 (18.30)	49.88 (16.33)
VAS3: Difficulty for making a precise pass (a.u.)	41.70 (16.18)	39.06 (18.71)	39.31 (11.93)	37.03 (14.05)	38.55 (16.50)	36.94 (11.84) †	66.41 (13.16)$^{*,\#}$	63.86 (18.30) $^{*,\#}$	63.72 (16.71) $^{*,\#}$
VAS4: Ball speed after a pass (a.u.)	63.60 (11.52) $^{\#,\dagger}$	60.56 (21.55) †	63.09 (11.90) $^{\#,\dagger}$	50.34 (14.81) †	52.24 (20.13)	47.34 (15.69)	36.63 (21.36)	44.07 (24.59)	50.81 (16.40) ^{a}
VAS5: Difficulty to control the ball (a.u.)	42.00 (15.68)	44.81 (19.33)	37.34 (10.95)	38.00 (13.60)	39.86 (15.77)	36.44 (9.80)	63.07 (18.17) $^{*,\#}$	65.07 (16.52) $^{*,\#}$	64.59 (13.42) $^{*,\#}$
VAS6: Difficulty for a dodge (a.u.)	45.30 (16.78) $^{\#}$	46.03 (19.37)	37.41 (12.29)	34.76 (12.28)	38.59 (18.26)	35.97 (10.82)	62.78 (16.10) $^{*,\#}$	65.86 (15.56) $^{*,\#}$	65.50 (12.23) $^{*,\#}$
VAS7: Difficulty for changes of direction (a.u.)	41.70 (15.10)	41.31 (17.84)	38.93 (11.58)	37.10 (11.56)	38.34 (19.20)	36.00 (10.39) †	66.11 (12.49) $^{*,\#}$	65.14 (14.40) $^{*,\#}$	63.06 (12.23) $^{*,\#}$
VAS8: Amenity for a tackle (a.u.)	60.50 (17.56) $^{\#,\dagger}$	57.50 (22.49) $^{\#,\dagger}$	62.06 (13.23) $^{\#,\dagger}$	46.80 (18.12) †	38.52 (22.84)	42.91 (16.81) †	27.15 (22.26)	26.18 (21.85)	27.59 (18.25)
VAS9: Amenity when dribbling the ball (a.u.)	60.50 (15.36) †	60.28 (17.75) †	64.44 (8.87) †	57.90 (16.58) †	56.31 (16.86) †	62.66 (8.05) †	38.89 (24.87)^{b}	27.21 (16.61)	31.06 (12.83)
VAS10: Amenity when running without the ball (a.u.)	61.50 (18.65) †	60.28 (18.38) †	64.44 (14.71) †	58.87 (17.48) †	56.34 (16.87) †	56.09 (12.80) †	40.59 (23.44)	33.64 (14.93)	35.88 (13.91)
VAS11: Ball rebound quality (a.u.)	57.37 (10.99) †	66.88 (17.22) ^{†,a,c}	61.78 (11.65) †	59.86 (16.75) †	55.55 (21.76) †	56.78 (14.56) †	25.19 (12.36)	21.36 (16.97)	24.56 (11.15)
VAS12: General perception of the surface (a.u.)	69.10 (10.82) †	68.06 (13.41) †	67.06 (10.25) †	64.14 (12.97) †	66.24 (16.31) †	61.25 (11.77) †	43.25 (22.63)^{b}	32.93 (20.48)	39.81 (18.08)

$^{*,\#,\dagger}$ Significant differences with the surface indicated (p<0.05)

^{a,b,c} Significant differences with the SSG indicated (p<0.05)

NG=Natural Grass; AT=Artificial Turf; GR=Ground.

SSG400=Small Sided Game 400; SSG 600= Small sided Game 600; SSG 800=Small Sided Game 800

VAS=Visual Analogue Scale

a.u.= arbitrary units

Visual Analogue Scale

Table 4 presents the players' perceptions of twelve specific variables. At all pitch sizes dirt obtained significantly lower results than the other two surfaces for most of the variables for the three SSGs (400, 600 and 800 m^2), indicating that players found it a less suitable playing surface. The main difference between natural grass and artificial turf was observed in VAS8, where players considered the natural grass more suitable for doing a tackle than artificial turf [SSG 400 (+18.98 a.u.; $p = 0.001$; ES: 0.768; CI: 7.00–30.96); SSG 600 (+19.16 a.u.; $p < 0.001$; ES: 0.837; CI: 7.47–30.84); SSG 800 (+13.71 a.u.; $p = 0.021$; ES: 1.257; CI: 1.54–25.88)].

DISCUSSION

Small-sided games are a suitable way of improving soccer-specific aerobic fitness despite the difficulty of controlling work intensity [6, 21, 27, 28]. This study analysed the physiological profile and perceptions of fatigue and exertion in sub-elite female soccer players in different-sized SSGs played on three distinct surfaces: natural grass, artificial turf, and dirt. The analyses revealed that both surface and pitch size affected the physiological performance and perceptions of sub-elite female soccer players. The greatest physiological response to games was observed in the SSG 600 played on natural grass. Therefore, when planning training sessions coaches must take into account several variables that influence players' responses [27].

The findings of this research are in line with those of Jastrzebski et al. [29], who suggested that SSGs stimulate the cardiovascular system in both genders, as HR_{peak} and HR_{mean} of participants in this study were over 90% and 80% of individual HR_{max} except on dirt [6, 13, 22, 28]. However, several studies that analysed the physiological responses of female soccer players during SSGs and real matches defined the HR_{max} as the highest HR_{peak} in the game [20, 45]; hence we cannot compare our results directly, owing to this difference in methodology.

Regarding the pitch size of SSGs, some authors have assessed the most common reduced spaces in matches either in male or female soccer players. They reported that area per player ranges from 78.97 ± 15.05 m^2 to 93.87 ± 16.25 m^2 in men [24] and from 77.91 ± 32.72 m^2 to 96.19 ± 22.66 m^2 in women [25]. The pitch sizes chosen for this study are in line with the recommendation of these authors; with the area per player being lower than 110 m^2 per player (SSG 400 = 50 m^2 per player; SSG 600 = 75 m^2 per player; SSG 800 = 100 m^2 per player). Nevertheless, most studies that have compared pitches of different sizes have included pitches yielding up to 200 m^2 per player [23, 28].

Previous studies in men have shown that playing on bigger pitches increases the physiological responses of soccer players [15, 27, 28], probably because smaller pitches led to shorter effective playing time than the large pitches [28]. Our findings in female soccer players corroborate the research on men, as we found that female players had a lower internal load (HR_{mean} as b.p.m and HR High Intensity) on small pitches (SSG 400) than when playing on medium (SSG 600) or large pitches (SSG 800). However, unlike these studies, we found that female players playing on natural grass and artificial turf had smaller heart rate responses (HR_{mean} as b.p.m and HR High Intensity) when playing on large pitches rather than medium pitches. In the literature, not all published studies have reported differences in players' physiological responses when the pitch size increases [23], but our research is the first to report that physiological responses were greater on medium-sized pitches than large pitches. We believe that the large pitch used in our study was so big that retaining possession of the ball was not a challenge and so there were fewer disputes over possessions when playing on the large pitch. In future, it would be helpful to record ball possession patterns in order to confirm this hypothesis.

One of the most important findings of this research is that the total time over 85% of players' HR_{max} was greater on the SSG 600 (26.26% on natural grass and 21.63% on artificial turf) than on the SSG 800. This suggests that coaches should take care when selecting the pitch size for SSGs as playing on a large pitch may reduce the internal load on players. Nevertheless, one must consider that it may have influenced our results and may make it difficult to compare our findings with those of other studies, for instance, players' age and gender [10, 28], the absence of goalkeeper [27], the number of players [6], the pitch sizes selected [25] and the players' level [13]. Our findings should, therefore, be interpreted with care.

On the other hand, this research proves that the game surface also influences players' physiological responses during SSGs. These findings are not new since, for instance, Brito et al. [21] reported that physiological responses of amateur soccer players in five-a-side games varied according to whether they were playing on asphalt, sand or artificial turf; however, neither sand nor asphalt are soccer-specific surfaces. The reduced physiological responses of players on dirt are probably due to the fact that this surface is harder than natural grass and artificial turf [41]. This suggests that dirt is not suitable for playing soccer, which indeed was stated by players through the VAS questionnaire. Players perceived surface-ball and surface-player interactions to be worse on dirt than on the other surfaces, and this may have had a negative impact on game intensity [36]. To some extent, these results were expected, because dirt surfaces are being replaced by artificial turf systems [30] and international bodies such as FIFA no longer support the use of dirt as a playing surface.

Regarding the remaining surfaces, the latest comparative studies suggest that soccer players have similar physiological responses on artificial turf systems and natural grass surfaces [31, 34], but they were carried out using a soccer-simulation protocol that does not include the use of the ball. Like Anderson et al. [36], our participants found it easier to perform tackles on natural grass, whereas they perceived the ball speed as faster on artificial turf. These results suggest that the higher HR_{mean} and HR High Intensity on the natural grass during the SSG 600 were influenced by the different game patterns associated with each surface [36]. Nevertheless, it remains more likely that these results primarily reflect the differences in the mechanical properties of each surface. Previous studies have demonstrated that the mechanical properties of artificial turf systems vary widely and that these differences also affect the physical and physiological responses of soccer players [41]. It seems that softer surfaces increase the heart rate responses of soccer players [41], so the greater internal load found on the SSG 600 played on natural grass may be due to this surface having a higher force reduction than the artificial turf system [34]. This may also explain why, when playing the SSG 400, players found it easier to dodge opponents on artificial turf than on natural grass, as harder surfaces are associated with higher running speed and faster turn times [41]. However, these interpretations are offered somewhat cautiously, as we did not assess the mechanical properties of the three surfaces used in the study [34]. Besides, players' overall satisfaction rating was similar for artificial turf and natural grass.

Finally, like Brito et al. [21], we found that the playing surface did not affect the deterioration of the CMJ performance after the SSG. However, unlike other studies, players jumped higher after the activity than before [21, 41]. This could be because each SSG only lasted 4 minutes. Likewise, the lack of differences in players' perceived fatigue following games on each type of pitch might explain why the CMJ was not sensitive to either play surface or pitch size.

As demonstrated by this study, playing surface and pitch size are both extrinsic variables that coaches should consider when designing SSGs, as both variables affect female soccer players' physiological responses. It should be remembered, however, that we did not assess the mechanical properties of the surfaces used in our research, nor did we evaluate total possession time or the number of possessions per team in each SSG. Future research should include these variables, as they could explain the differences in players' responses. Likewise, it is important to be cautious when comparing our results with those of previous studies, given the dearth of research on SSGs in female soccer and the differences between our method of analysing HR responses and those used in other studies with women.

CONCLUSIONS

Pitch size can be used to manipulate the internal load of SSGs as big pitches provoke greater heart rate responses than smaller ones. However, coaches should bear in mind that playing on very large pitches may reduce the internal load on female soccer players.

On the other hand, it is recommended not to play soccer on dirt surfaces because surface-player and surface-ball interactions on this surface are rated poorly by soccer players. Moreover, playing on dirt also elicits smaller heart rate responses than playing on other surfaces. Finally, female players reported similar satisfaction with the artificial turf systems and the natural grass surfaces. However, playing on a natural grass surface elicited greater heart rate responses in the SSGs, suggesting that a higher internal load can be achieved on natural grass than on artificial turf.

Disclosure statement

The authors report no conflicts of interest.

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