Efectos del tamaño de juego y la configuración de la serie sobre las respuestas mecánicas y fatiga inducida por diferentes juegos reducidos en fútbol

Effects of pitch size and set configuration on mechanical responses and fatigue induced by different small-sided games in soccer

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Abstract

Introduction: Physical match actions are simulated through modified games. Pitch size and set configuration seems to influence the physical responses during small-sided games.
Objective: The aim of the present study is to analyze the effects of pitch size and set configuration during small-sided games.
Methodology: Fourteen young male field soccer players performed three small-sided games, involving 7 vs. 7 + 2 goalkeepers: 3 x 8 min with 5 min of rest between sets on a 68 x 40 m pitch (194 m^2); same pitch area but 6 x 4 min with 2 min of rest (194 m^2); and 6 x 4 min with 2 min of rest on a 40 x 34 m pitch (97 m^2). Vertical jump, kick velocity and sprint were assessed to examine the residual fatigue before and after each small-sided game.
Results: Larger pitch sizes showed significantly higher physical demands. Shorter bouts demanded greater distances at high intensity than longer bouts. A significant SSG x time interaction was observed for 10-m sprint time (P = 0.04), where a greater impairment was observed after completing 6 x 4 min (194 m^2).
Discussion: Higher external loads have been observed during games on larger pitches. A 4 min bout was provided as the optimal physical training stimulus.
Conclusions: Larger pitch sizes and shorter bout durations are higher-demand games than smaller pitch sizes and longer bouts. Sprint performance is impaired after completing every small-sided game, especially acceleration capacity after completing modified games involving larger pitch areas and shorter bout durations.

Keywords

Bout duration; external load; physical performance; relative area; residual fatigue; team sports.

Resumen

Introducción: Las acciones físicas de partido son simuladas a través de juegos modificados. El tamaño del campo y la configuración de la serie parecen influir las respuestas físicas durante los juegos reducidos.
Objetivo: El objetivo del presente estudio fue analizar los efectos del tamaño del campo y la configuración de la serie durante los juegos reducidos sobre la carga externa y la fatiga residual.
Metodología: Catorce jóvenes jugadores masculinos de fútbol de campo realizaron tres juegos reducidos, involucrando 7 vs. 7 + 2 porteros: 3 x 8 min con 5 min de descanso entre series en un campo de 68 x 40 m (194 m^2); misma zona de campo, pero 6 x 4 min con 2 min de descanso (194 m^2); y 6 x 4 min con 2 min de descanso en un terreno de 40 x 34 m (97 m^2). El salto vertical, la velocidad de golpeo y el esprint fueron evaluados para examinar la fatiga residual antes y después de cada juego reducido.
Resultados: Terrenos de mayor tamaño mostraron una exigencia física significativamente mayor. Una interacción significativa SSG x tiempo fue observada para el tiempo del sprint en 10-m (P = 0.04), donde se observó un mayor deterioro tras completar 6 x 4 min (194 m^2).
Discusión: Mayores valores de carga externa han sido observados en los juegos con terrenos de mayor tamaño. Una serie de 4 min fue propuesta como estímulo óptimo de entrenamiento físico.
Conclusiones: Los tamaños de juego más grandes y la duración de la serie más cortos resultaron en juegos de mayor demanda física que las dimensiones más pequeñas y series más largas. El rendimiento del esprint disminuyó después de completar cada juego reducido, especialmente la capacidad de aceleración que implicaban áreas de juego más grandes y duraciones de la serie más cortas.

Palabras clave

Duración de la serie; carga externa; área relativa; fatiga residual; rendimiento físico; deportes de equipo.

Introduction

Soccer trainings have traditionally tried to simulate the physical match actions through modified games played in smaller areas and less player´s number (SSGs) (Clemente et al., 2019; Riboli et al., 2023). Several training variables should be considered when designing SSGs (Hill-Haas et al., 2011). Pitch size seems to influence the physical demands induced during SSGs. Specifically, modified-sided games conducted on larger areas (LSG) result in greater workloads (Casamichana & Castellano, 2010) than smaller dimensions, which evoke greater numbers of accelerations/decelerations (Castellano et al., 2015; Hodgson et al., 2014) but less distance covered at high speed (Casamichana & Castellano, 2010). Furthermore, previous research has found that greater relative areas (i.e. the total pitch area divided by the total number of players) let players cover greater total distances (TD) and greater distances at medium-to-high velocities (13.00–21.00 km·h-1) (Castillo et al., 2019; Santos et al., 2022). Another training variable is bout duration (Fanchini et al., 2011). Bout duration combined with scheduled rest periods is used to determine work:rest ratios. In this regard, few studies have examined the effect of bout duration on SSGs intensity but in none of them the work:rest ratio was equalized across different protocols. Fanchini et al. (2011) reported a decrease in heart rate between 4 min and 6 min SSGs bout durations, with no significant differences between 2 min and 4 min. In this regard, Koklu et al. (2017) observed that shorter bouts (6x2 min) allowed players to cover greater distances at moderate-intensity running as well as a greater total distance compared to longer bouts (2x6 min) or continuous (1x12 min) SSGs. Castillo et al. (2019) also reported that longer bouts (4x6 min) induced a decrease in total distance covered in the last bouts in SSGs played on a larger pitch area (i.e 200 m2), while shorter bouts (6x4 min) resulted in lower distances covered at high velocities. Likewise, these authors observed that physical demands remained constant throughout bouts in SSGs played on a smaller pitch (i.e 100 m2), independently of format. These limitations result in a lack of consistency in the design of SSGs to elicit the desired physical and physiological responses.

Nowadays, global positioning system (GPS) technology is increasingly used in team sports to provide a comprehensive analysis of player performance (Cummins et al., 2013). The data recorded by these devices are converted into a multitude of variables (Buchheit et al., 2010). Despite providing all these data, time-motion throughout SSGs display high variability, especially in the higher-speed zones (Hill-Haas et al., 2011). This characteristic may hamper the interpretation of levels of fatigue induced during SSGs activities. Therefore, in order to provide better knowledge about the actual level of fatigue (i.e., acute fitness impairment) induced during SSGs it is necessary to use other accurate and reliable methods typically used for fatigue monitoring. In this regard, sprint velocity and countermovement jump (CMJ) height are considered good markers of fatigue (Claudino et al., 2017; Jimenez-Reyes et al., 2016). Although, there are other variables as the ratio of flight time to contraction time (FT:CT) which has been suggested to be more sensitive to variations in load (Rowell et al., 2018). In this sense, it has reported close relationships between impairments in CMJ height and running speed and blood lactate and ammonia concentrations during typical running sprint sessions (Jimenez-Reyes et al., 2019). Furthermore, Andersson et al. (2008) reported a decreased jumping height immediately after an elite female soccer game, as well as a decrease in all parameters of a neuromuscular nature. In addition, fatigue development may also impair kick velocity (KV) throughout matches or specific soccer training. Therefore, it would be of interest to examine the residual fatigue following SSGs training using tests employed to monitoring physical performance in soccer, such as running sprint, CMJ or KV. Despite the relevance of SSGs variables such as pitch size and bout duration in players' physical and physiological responses, to date, there is limited scientifically based evidence relating to the magnitude of fatigue when manipulating the above-mentioned variables. Therefore, the aim of the present study is to analyze the effects of pitch size and bout duration on physical demands and mechanical fatigue in young soccer players. Our hypothesis is that larger relative pitch areas and longer sets would result in higher impairments in time-motion characteristics and physical abilities.

Method

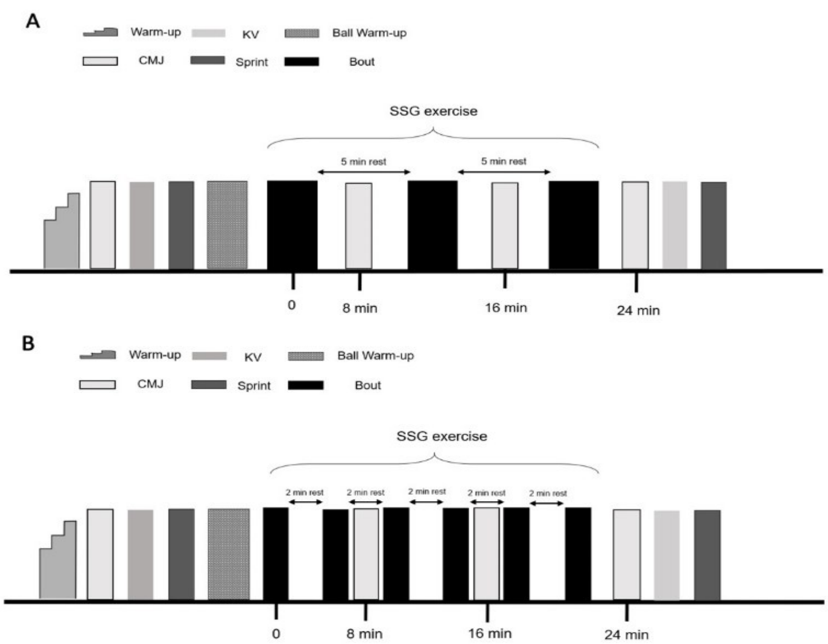
Participants

A total of 14 trained young male soccer players (mean ± standard deviation (SD); age 17.1 ± 0.6 years; height: 177.5 ± 6.1 cm; body mass: 64.2 ± 8.0 kg) participated in the study. Subjects belonged to the same college team and competed in the U-18 British Local League Division. Players reporting to be free from taking drugs or medications known to influence physical performance. Once informed about the purpose, procedures, and potential risks of the investigation, parents´ players gave their voluntary consent to participate. The present investigation was approved by the College´s Ethics Committee.

Procedure

A cross-sectional experimental design was used to examine the effects of pitch area and set configuration during SSGs (7 vs. 7 + 2 GK) on running demands and mechanical fatigue in young soccer players. Goalkeepers (GK) were not included in the study. The investigation consisted of 3 different SSGs, one per session, with at least 48 h rest between them. The total duration of each SSGs was 24 min (Figure 1), performed in the following formats: 3 x 8 min with a large pitch (LSG8; 68 x 40 m) with 5 min rest between sets; 6 x 4 min with a large pitch (LSG4; 68 x 40 m) with 2 min rest between sets; and 6 x 4 min with a small pitch (SSG4; 40 x 34 m) with 2 min rest between sets. For this analysis, 3 time periods of 8 min (1 bout of 8 min for LSG8 and 2 bouts of 4 min for SSG4 and LSG4: accumulated 1-2; 3-4 and 5-6 bouts) were compared for different pitch sizes (LSG4 vs SSG4) and bout durations (LSG8 vs LSG4). Before (Pre-test) and after (Post-test) each session, CMJ, KV and 20-m sprint were assessed, in that order.

Figure 1 Timeline schedule for the fitness tests conducted after each small-sided game (SSG). CMJ: countermovement jump; KV: kick velocity; Sprint: 20 m sprint.



Measures

Running demands were monitored using a GPS unit capturing data at 5 Hz (GPSports SPI Elite System, Canberra, Australia). Variables selected for analysis were: 1) total distance covered (TD), 2) low-intensity running (LIR; running speed < 13.0 km·h−1), 3) high-intensity running (HIR; running speed from 13.1 to 16 km·h−1), 4) very high-intensity running (VHIR; running speed from 16.1 to 19 km·h−1) and 5) sprinting distance (Sprinting; running speed > 19.1 km·h−1), mean velocity (Vmean), maximal velocity (Vmax) (Suarez-Arrones et al., 2015) and numbers of accelerations and decelerations above 2 m·s-2 (Hodgson et al., 2014).

Before fitness test, players performed a standardized warm-up which consisted of 5 min jogging, two 20 m running accelerations and 5 progressive submaximal jumps. Jump height was calculated to the nearest 0.1 cm from flight time measured with an infrared timing system (OptojumpNext; Microgate, Bolzano, Italy). Subjects completed 2 maximal CMJs, with 20 s rest between each jump, with their hands on their hips (without arm swing); the best of these jumps was recorded (CMJ best). After the CMJ test, players executed the KV test. Two maximal instep kicks with the dominant leg with a 3 m approach run were performed, aiming at a square target measuring 2 m and located in the middle of a goal (7.32 m × 2.44 m). There was a rest interval of 1 min between kicks. From the 2 trials, the highest ball velocity was selected for further analysis. The speed of each kick was measured using a radar device (Stalker Sport, Applied Concepts Inc, Texas, USA), which was placed 1 m behind the ball. As a warm-up, two submaximal kicks were performed. The kick test was performed at Pre- and Post-SSGs. After the SSGs, only one kick was performed in order to respect the timeline schedule and avoid accumulated fatigue affecting the following test (i.e. running sprint test). Finally, players performed the sprint test. Two 20 m sprints were performed on an outdoor field of artificial grass, separated by a 2 min rest. Sprint times were measured using photocell timing gates (Witty, Microgate, Bolzano, Italy), which were placed at 0, 10 and 20 m. A standing start with the lead-off foot placed 1 m behind the first timing gate was used. The warm-up protocol consisted of two 20 m running accelerations at 80% and 90% of perceived effort, and one 10 m sprint at 100% effort. At Post-SSGs, only one sprint was performed.

Data analysis

Descriptive statistics are presented as mean ± SD. The normal distribution of the results was tested using the Shapiro-Wilk test, and statistical parametric techniques were performed. Paired sample t-test was used to compare the difference of physical load accumulated between the pitch size formats (LSG4 vs SSG4) and bout durations (LSG8 vs LSG4). A 2 (pitch size) x 2 (bout duration) x 3 (time) repeated measures ANOVA test with Bonferroni's post hoc adjustments was also used to compare the time-motion characteristics among different pitch sizes (LSG4 vs SSG4) and bout durations (LSG8 vs LSG4) throughout the SSGs-format. Fitness data were analyzed using a 2 (pitch size) x 2 (bout duration) x 2 (time) factorial analysis of covariance (ANCOVA, with baseline values as covariate) for CMJ, KV and sprint with Bonferroni's post-hoc comparisons. Effect sizes (ES) with 95% confidence intervals (CIs) were calculated using pooled SD. Threshold values for Cohen's ES were >0.2 (small), <0.6 (moderate) and >1.2 (large) (Cohen, 1992). The statistical analysis was performed using SPSS 22.0 (SPSS, Chicago, IL, USA).

Results

Running demands for the different SSGs formats are shown in Table 1. No significant differences were found in any variable analyzed between LSG8 and LSG4 (P range: 0.10 to 0.55), except to VHIR which was higher for SSG4 than LSG8 (P = 0.01). Regarding to pitch size, LSG4 resulted significantly higher than SSG4 in all variables (P range: 0.00 to 0.02) excluding Acc (P= 0.50).

Table 1. Time-motion characteristics during the 3 modified-sided game formats.

Variable	LSG8	LSG4	SSG4
TD (m)	2626.6 ± 180.0	2709.1 ± 227.9	2251.6 ± 155.5[2]
LIR (m)	2156.6 ± 173.8	2113.3 ± 198.1	2019.6 ± 160.3[2]
HIR (m)	251.2 ± 61.5	294.7 ± 67.6	149.5 ± 43.8[2]
VHIR (m)	118.1 ± 45.3	163.9 ± 46.5[1]	54.5 ± 32.7[2]
Sprinting (m)	94.9 ± 60.4	125.3 ± 69.1	18.1 ± 22.9[2]
V_{mean} (m/min)	109.1 ± 7.5	113.0 ± 9.5	93.9 ± 6.5[2]
V_{max} (km/h)	25.6 ± 1.8	25.2 ± 2.1	21.4 ± 1.9[2]
Acc (n)	33.1 ± 7.5	36.1 ± 8.4	34.4 ± 12.6
Dec (n)	29.7 ± 7.9	31.4 ± 6.2	26.1 ± 9.2[2]

Data are expressed as mean ± standard deviation. N = 14. LSG8: 3 x 8 min with 5 min of rest between sets in 68 x 40 m pitch (194 m^2); LSG4: 6 x 4 min with 2 min of rest between sets in 68 x 40 m pitch (194 m^2); and SSG4: 6 x 4 min with 2 min of rest in 40 x 34 m pitch (97 m^2).; TD: total distance covered; LIR: distance covered at low-intensity running; HIR: distance covered at high-intensity running; VHIR: distance covered at very high-intensity running; Sprinting: sprinting distance; V_{mean}: average velocity during SSG; V_{max}: maximum velocity achieved during SSG; Acc: number of accelerations; Dec: number of decelerations.
[1] indicates significant differences between different bout durations (LSG8 vs LSG4) ($p < 0.05$); [2] indicates significant differences between different pitch sizes (LSG4 vs SSG4) ($p < 0.05$).

The change in running demands throughout the different SSGs is displayed in Table 2. A significant bout duration x time interaction was observed for TD (P = 0.01), LIR (P = 0.02) and Vmean (P = 0.01). It was also observed a significant "time" effect for bout duration in TD (P = 0.00), LIR (P = 0.00), Vmean (P = 0.00), Vmax (P = 0.01) and Sprinting (P = 0.02). Lower LIR values during the first bout (P = 0.00) in LSG4 respect to LSG8 and higher TD, HIR, VHIR and Vmean values during second bout (P range: 0.00 to 0.02) were found for LSG4 compared to LSG8. Moreover, LSG8 showed significant impairments in the second (P range: 0.00 to 0.02) and the third bout (P range: 0.00 to 0.04) for TD, LIR and Vmean, while LSG4 only showed significant decreases during the third bout (P range: 0.01 to 0.04) compared to first bout. On the other hand, significant pitch size x time interactions were found for TD and Vmean (P = 0.03; 0.04). There was also a significant "time" effect for TD (P = 0.04), LIR (P = 0.01), Vmean (P = 0.04) and Vmax (P = 0.00) for pitch size factor. Higher TD, HIR, VHIR, Sprinting, Vmean, and Vmax (P = 0.00) were observed for LSG4 compared to SSG4 for all bouts and only in the first bout for Dec (P = 0.04). SSG4 kept the TD and Vmean values constant throughout all bouts (P = 1.00) while LSG4 showed significant decreases during the third bout respect to the first (P = 0.04; 0.04) and second bout (P = 0.01; 0.00). However, no significant differences were observed for the number of accelerations and decelerations among bouts in any format (P>0.05).

Table 2. Evolution of time-motion characteristics across the different modified-sided games completed for 8 min periods (1 bout of 8 min for LSG8 and 2 bouts of 4 min for SSG4 and LSG4).

	LSG8			LSG4			SSG4		
Bout	1	2	3	1	2	3	1	2	3
TD (m) #¶§¥	932.2 ± 71.1	839.4 ± 64.5[*]	854.9 ± 72.5[*]	919.1 ± 79.7	932.2 ± 99.4[1]	857.8 ± 74.1[*††]	761.0 ± 41.0[2]	749.2 ± 74.0[2]	741.5 ± 71.4[2]
LIR (m) #§¥	768.7 ± 58.5	701.5 ± 78.9[*]	686.4 ± 51.9[*]	717.5 ± 61.8[1]	726.4 ± 85.4	669.4 ± 65.1[*†]	692.8 ± 52.8	673.3 ± 57.9[2]	653.5 ± 57.1[*]
HIR (m)	90.7 ± 29.0	70.6 ± 25.4	89.8 ± 34.1	104.7 ± 29.8	98.4 ± 22.5[1]	91.6 ± 29.9	48.2 ± 19.8[2]	52.5 ± 26.5[2]	48.8 ± 21.2[2]
VHIR (m)	43.8 ± 21.9	33.8 ± 14.5	40.5 ± 19.8	60.0 ± 19.9	51.1 ± 16.4[1]	52.8 ± 31.0	15.5 ± 14.4[2]	16.5 ± 9.8[2]	22.5 ± 18.3[2]
Sprinting (m) §	27.0 ± 23.7	31.5 ± 36.4	36.5 ± 18.1	32.8 ± 26.8	52.4 ± 32.6	40.1 ± 22.8	1.5 ± 2.0[2]	3.2 ± 3.5[2]	13.5 ± 21.8[2]
V_{mean} (m·min^{-1}) #¶§¥	115.4 ± 8.8	105.0 ± 8.0[*]	106.9 ± 9.1[*]	114.9 ± 10.0	116.5 ± 12.4[1]	107.2 ± 9.3[*††]	95.1 ± 5.1[2]	93.7 ± 9.4[2]	92.7 ± 8.9[2]
V_{max} (km·h^{-1}) §¥	22.2 ± 3.0	22.7 ± 3.8	24.8 ± 1.5	23.6 ± 2.9	24.2 ± 2.3	24.4 ± 2.4	18.4 ± 1.7[2]	19.7 ± 1.8[2]	20.2 ± 2.9[2]
Acc (n)	13.0 ± 2.6	10.1 ± 2.5	9.2 ± 4.7	12.5 ± 3.1	11.1 ± 3.5	12.2 ± 3.7	11.7 ± 5.6	11.8 ± 5.6	11.0 ± 3.5
Dec (n)	11.0 ± 3.8	8.8 ± 2.5	9.9 ± 3.8	11.4 ± 3.1	9.7 ± 3.2	10.3 ± 3.9	9.0 ± 3.3[2]	8.6 ± 4.2	8.6 ± 4.5

Data are expressed as mean ± standard deviation. N = 14. LSG8: 3 x 8 min with 5 min of rest between sets in 68 x 40 m pitch (194 m^2); LSG4: 6 x 4 min with 2 min of rest between sets in 68 x 40 m pitch (194 m^2); and SSG4: 6 x 4 min with 2 min of rest in 40 x 34 m pitch (97 m^2); TD: total distance covered; LIR: distance covered at low-intensity running; HIR: distance covered at high-intensity running; VHIR: distance covered at very high-intensity running; Sprinting: sprinting distance; AV: average velocity during SSG; V_{max}: maximum velocity achieved during SSG; Acc: number of accelerations; Dec: number of decelerations. # indicates significant bout x time interaction ($p < 0.05$). ¶ indicates significant pitch size x time interaction ($p < 0.05$). § indicates significant bout "time" effect ($p < 0.01$). ¥ indicates significant pitch "time" effect ($p < 0.05$). [1] indicates significant differences with LSG8 ($p < 0.05$); [2] indicates significant differences with LSG4 ($p < 0.05$). [*] indicates significant differences with respect to the first bout ($p < 0.05$); † indicates significant differences with respect to the second bout ($p < 0.05$). †† indicates significant differences with respect to the second bout ($p < 0.01$).

In relation to physical fitness changes, a significant difference was observed for T10 (P = 0.03) between LSG8 and LSG4 (Figure 2). No significant differences between LSG8 and LSG4 were observed for the rest of fitness parameters analyzed (CMJ: P = 0.36, KV: P = 0.73, T20 P = 0.50, and T10-20: P = 0.70), either between LSG4 and SSG4 in any fitness variable (CMJ: P = 0.36, KV: P = 0.47, T10 P = 0.12, T20 P = 0.76, and T10-20: P = 0.67). With regard to intra-comparisons, no significant differences were found for CMJ height (P>0.05) and small (ES = LSG8: -0.16 [-0.40, 0.09], LSG4: -0.10 [-0.27, 0.07] and SSG4: -0.06 [-0.22, 0.1]) after any SSG-format (Figure 2). Nevertheless, a significant small impairment was observed in KV (P = 0.04; ES = -0.54 [-0.09, -0.99] after SSG4 (Figure 2). Regarding sprint-related variables, moderate to large (T10-20 and T20; ES = 0.6-1.50 [0.35-2.25]) and significant impairments (P range: 0.00 to 0.01) were found after the three SSG formats, while a significant small worsening in T10 (P <0.01; ES = 0.29 [-0.14, 0.71]) was observed after LSG4 (Figure 3).

Figure 2. Changes in countermovement jump height during the different small-sided games (SSG) and changes in kick velocity (KV) before and after the SSG. Data are expressed as mean ± standard deviation. N = 14. LSG8: 3 x 8 min with 5 min of rest between sets in 68 x 40 m pitch (194 m^2); LSG4: 6 x 4 min with 2 min of rest between sets in 68 x 40 m pitch (194 m^2); and SSG4: 6 x 4 min with 2 min of rest in 40 x 34 m pitch (97 m^2).

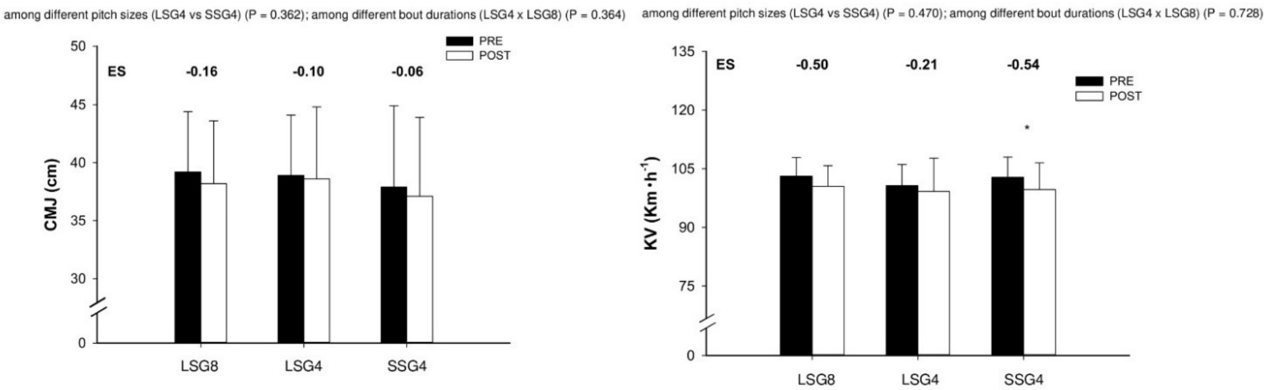
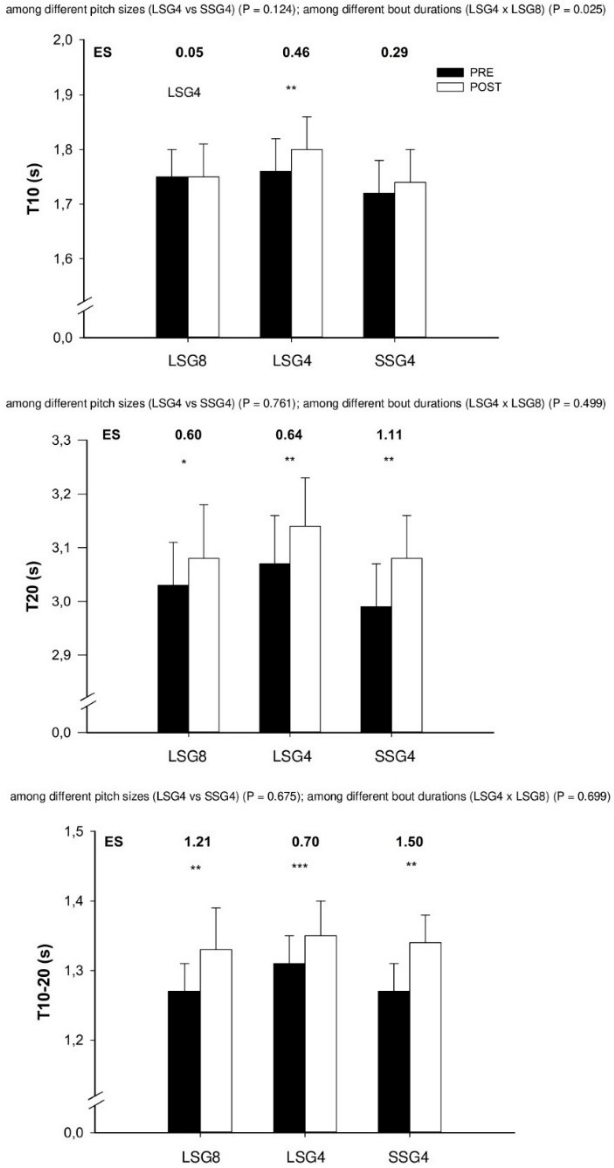


Figure 3. Changes in sprint performance before and after the different small-sided games (SSG). A) Split sprint time for 0-10 m; B) Split sprint time for 10-20 m, C) Sprint time for 0-20 m. Data are expressed as mean ± standard deviation. N = 14. LSG8: 3 x 8 min with 5 min of rest between sets on a 68 x 40 m pitch (194 m^2); LSG4: 6 x 4 min with 2 min of rest between sets on a 68 x 40 m pitch (194 m^2); and SSG4: 6 x 4 min with 2 min of rest on a 40 x 34 m pitch (97 m^2). Significant differences with respect to the baseline values: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. ES: within-protocol effect size from pre- to post-exercise (negative values indicate an increase in sprint time, i.e. impaired sprint performance).



Discussion

To our knowledge, this is the first study to examine the effects of pitch size and bout duration on physical demands and mechanical fatigue in young soccer players. An important aspect of this research was the equalized of work:rest ratio of bout duration between protocols. Firstly, larger pitch sizes (i.e., LSG4) resulted in greater external load than smaller pitch sizes (i.e., SSG4). Secondly, shorter bouts (LSG4) resulted in longer VHIR than longer bouts played on similar pitch areas (LSG8). Lastly, although CMJ height was not altered after any SSG format, KV was affected after SSGs involving smaller pitch-sizes (SSG4) and a generalized worsening in running sprint was observed after completing the SSGs tasks. Interestingly, a greater impairment in sprint acceleration was observed after completing the SSGs involving shorter bout durations (LSG4). Therefore, pitch size and bout duration should be considered when coaches design SSGs to adjust training loads, since they determine the influence of game demands and residual fatigue on acceleration performance.

Pitch size is an editable variable in the design of SSGs. In agreement with previous studies (Buchheit et al., 2012; Castillo et al., 2019; Hill-Haas et al., 2011; Hodgson et al., 2014; Rampinini et al., 2007), our findings indicate that pitch size in SSGs influences game intensity, since when SSGs are played on larger pitches (LSG4) greater external load (TD, LIR, HIR, VHIR, sprinting, V_{mean} and V_{max}) are imposed compared to smaller pitch areas (SSG4). In this regard, it has already been reported that young soccer players cover higher TD, higher HIR, VHIR and attain greater V_{max} during SSGs played on larger pitch areas (Casamichana & Castellano, 2010; Castellano et al., 2015). This behavior has also been observed in professional soccer players (Sangnier et al., 2019). Higher pitch areas maintaining a similar number of players imply greater individual interaction space (194 vs. 97 m2 per player for LSG vs. SSG, respectively). Thus, it could be suggested that larger areas allow to cover high-speed distances and opens the possibility of attaining higher velocities during sprinting (Rampinini et al., 2007). In addition, the higher physical demands for larger pitch areas were maintained through the entire training session (Table 2). However, a decrease in TD and V_{mean} was observed in the last set for larger pitch sizes (LSG4), while the SSG involving a smaller pitch area (SSG4) kept the TD and V_{mean} values constant throughout all bouts. In agreement with our findings, it has been reported that an increase in LIR and a decrease in HIR throughout different bouts of SSGs is characteristic of larger pitch sizes (Campos-Vázquez et al., 2017). As with the rest of the mechanical parameters, the number of decelerations was lower for the smaller pitch area (SSG4) compared to the larger pitch area (LSG4). Thus, the larger the pitch, the greater the maximum speed achieved and, as a consequence, the more possibilities players have to engage in high deceleration actions. This is in line with Hodgson et al. (2014), who reported that larger relative areas resulted in greater distances covered during acceleration and deceleration movements than smaller pitches.

With regard to bout duration, shorter sets allowed players to cover greater high-velocity distances (i.e., VHIR) than longer bouts with similar pitch sizes (197 m2 per player, LSG4 vs. LSG8). In addition, longer bouts (LSG8) resulted in impairments in TD and V_{mean} in the second and the third bouts while shorter bouts (LSG4) only evoked decreases in the third bout (i.e., the last 8 minutes). These findings may indicate that an 8-minute bout may be too long to keep covering great distances during later bouts while shorter sets allow players to better maintain their performance during the entire training session, although these findings could be influenced by the different bout distributions and duration of rest between SSGs format (3x8 min with 5min of rest and 6x4 min with 2 min of rest). The effects of bout duration during SSGs in soccer were originally examined by Fanchini et al. (2011) who reported that an increase in bout duration from 4 to 6 min produced a decrease in heart rate, although no significant differences were observed between bout durations of 2 and 4 min. Therefore, these authors (Fanchini et al., 2011) suggested that 4 min bouts provided the optimal physical training stimulus. However, it should be noted that the total work time was not equalized between protocols (6, 12 and 18 min), which could have influenced the findings. Later, Koklu et al. (2017) reported that shorter bout durations (6x2 min) allowed players to cover greater total distance and greater distances at moderate velocity than longer bout durations (2x6 min or 1x12 min). However, although these authors (Koklu et al., 2017) kept the total work duration constant (i.e., 12 min) across protocols, the work:rest ratio was not equalized. Likewise, Castillo et al. (2019) reported that longer bouts (4x6 min) induced a decrease in total distance covered while shorter bouts (6x4 min) resulted in a lower distance covered between protocols. It should be highlighted that both protocols were performed with the same rest period between sets (i.e. 2 min). Therefore, the higher game demands observed during shorter bout durations may be due to the lower work:rest ratio experienced in these protocols. This aspect was controlled in the present study.

Although SSGs are a suitable tool for improving specific soccer fitness (Kunz et al., 2019), they have some drawbacks in controlling work intensity (Clemente et al., 2020; Halouani et al., 2014). As a result, in order to examine the effects of residual fatigue from SSGs on physical performance, it is necessary to combine time-motion analyses with the accurate and reliable methods typically used for fatigue monitoring (Hodgson et al., 2014). Our results showed no significant decreases in CMJ height after any SSGs format, but these findings could be affected by do not provide kinetic variables that could be more sensitive to find performance changes after different conditions (Cormack et al., 2008; Rowell et al., 2018). KV was impaired after SSGs format with smaller pitch size and shorter bout duration (i.e., SSG4) as well as sprint performance after the completion of each SSGs, mainly after SSGs formats characterized by larger pitch areas and shorter bout durations (i.e., LSG4). These findings could be explained by the higher physical demands, especially the greater high-velocity distances (i.e., VHIR), attained during SSGs with larger pitch areas and shorter bouts (LSG4). In agreement with our findings Castillo et al. (2019) reported significant impairments in sprint performance after 4x6 min and 6x4 min in a space of 100 m^2, while horizontal jump performance remained unaltered. By contrast, Rebelo et al. (2016) observed a decrease in CMJ height after two SSGs formats (4 vs. 4 + GK two sets of 3 × 6 min, relative area: 176 m^2 per player, and 8 vs. 8 + GK: 2 × 18 min, relative area: 285 m^2 per player). Likewise, sprint ability decreased only after the 4-a-sided format (Rebelo et al., 2016). However, the fact that different numbers of players, bout durations, total work, work:rest ratio, pitch area, and relative area were employed in each SSGs format hampers comparison with our findings.

These findings have important practical applications in the design and periodization of training sessions, suggesting that shorter bout durations will tend to increase external loads, especially high-velocity actions, via the more frequent rest periods associated with shorter bouts, although similar total work and rest time will be accumulated for all protocols.

The current study had several limitations, which should be considered. Physiological measures as heart rate or blood lactate responses were not measured to provide markers of internal training load along with the external load (GPS parameters). In addition, technical actions such as tackles, winning the ball from an opponent and pass completion rates were not collected during the SSGs. This could be an area for future research. The sample size consisted of young soccer players; as a consequence, the effects observed among SSG-formats analyzed could be different in top-level players.

Conclusions

In conclusion, larger pitch sizes and shorter bout durations resulted in greater demand on players than games including smaller pitch sizes and longer bouts. CMJ height and KV were not affected after any SSGs format; however, sprint performance was impaired after completing every SSGs task, especially acceleration capacity after completing SSGs involving larger pitch areas and shorter bout durations (e.g. LSG4).

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