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Physiological and physical responses according to the game surface in a soccer simulation protocol

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Abstract

Purpose: Recent studies have shown that soccer player's responses are similar on natural grass (NG) and artificial turf (AT), but they did not control the mechanical properties of these surfaces. This work aimed to analyse the influence of the game surface on amateur soccer player's physical and physiological responses using a soccer simulation protocol (SSP). **Methods**: Sixteen amateur players performed three bouts of the SSP on AT and NG. The mechanical properties of both surfaces were recorded. The order of surfaces was randomly established for each participant. Physiological responses of players were assessed before and after the six-repeated sprints test existing at the midpoint of each bout. Fatigue (% Best; % Diff) and general variables (total time; best time, mean time; maximum speed) for both the repeated sprint test and the agility tests (nonlinear actions at maximum speed) incorporated into the SSP were also analysed. **Results**: The two surfaces displayed different mechanical properties. Physical responses were found similar for both surfaces (p>0.05) before and after the repeated sprint test. There were no surface differences in sprint times or fatigue variables for the repeated sprint test (p>0.05). The agility test was faster on AT than on NG in bout 1 (average speed [+1.17 Km/h; p=0.037]; agility test cut time [-0.31 s; p=0.027] and best time [-0.52 s; p=0.042]). **Conclusions**: The differences in the mechanical properties of the two surfaces are not sufficient to cause differences in the physiological and physical responses of soccer players, although they may affect turns and cuts.

Keywords: Exercise Performance; Motion Analysis; Physical Performance; Sport; Training

Introduction

In recent years the third generation artificial turf (AT) systems have become an alternative to natural grass (NG) surfaces, mainly due to the standardisation of AT systems under the aegis of international bodies such as the Fédération Internationale de Football Association (FIFA) and the European Committee for Standardisation (CEN).[1-3] However, soccer players still consider AT more physically demanding than NG.[4,5] The latest comparative studies have shown that soccer players' fatigue, sprint times, and recovery are similar on the two surfaces.[6-8] Nevertheless, these findings cannot be widespread due to the wide variation in the mechanical properties of AT systems reported by previous works.[9-11] Thus, soccer players seem to run faster and perform more high-intensity actions on harder surfaces whilst the softer systems are associated with a greater physiological responses.[3,11]

Most studies have used standardised tests to compare surfaces because they have lower variance than soccer matches. This is true of the soccer simulation protocol (SSP) and the soccer-specific aerobic field test (SAFT90) which attempt to replicate the physiological and physical demands of real matches.[7,12] Authors such as Stone et al.[8] recommend the SSP because it includes a repeated sprint test halfway through each of the six bouts and nonlinear sprint actions at maximum speed (agility tests). The latest comparative studies, suggest that players' performance is similar on AT and NG,[6-8] although it has been reported slight surface-interaction in the recovery time after the SAFT90 and better sprint performance on AT during the SSP.[7,8] Hughes et al. found that players' sprint times and agility performance were similar on NG and AT,[6] whereas Stone et al. reported that creatine kinase levels in blood and perception of muscle soreness were similar for the two surfaces immediately after the SSP and, 24 and 48 hours post-test.[8] These studies also found that physiological responses and blood lactate accumulation were similar for NG and AT.[6,8] Together, these studies suggest that although there may be some surface-specific effects, one would expect players' responses to be similar on both types of surfaces.[6-8]

To the best of our knowledge, the studies that have the SSP to compare AT and NG have only analysed the mean times for each series of sprints and have not looked at the times for individual sprints.[6,8] Moreover, these studies did not analyse the effects of the repeated sprint test on soccer players' physiological responses or performance in the second half of each bout. It is possible therefore that there are interactions (surface x time) with respect to these SSP variables during the SSP. For these reasons, the aim of this research was to analyse the influence of the game surface on amateur soccer player's physical and physiological responses using the SSP. Previous studies used AT systems that complied with FIFA standards,[6,8] but they did not report the mechanical properties of the surfaces used despite that the mechanical properties of AT systems are highly variable. Consequently, we expect to add further information about how the players' responses are influenced by the game surface. On the other hand, several authors have reported a high diversity in the mechanical properties of AT systems.[3,11] For that reason, we hypothesised that the mechanical differences between NG and AT would affect the physical patterns of players during the SSP, but not their physiological responses.

Methods

Subjects

Sixteen amateur soccer players (22.17 ± 3.43 years; 177.12 ± 5.24 cm; 69.16 ± 4.55 kg) with more than 10 years of experience of playing soccer (13.57 ± 1.85 years) were recruited for this study. All volunteers presented the medical examination required to play soccer and they did not reported any cardiopulmonary pathology or other diseases. They did not take any medication during the study. All players were informed about the possible risks of participating in this study, and provided written informed consent before the beginning of the study. In accordance with the latest version of the Helsinki Declaration, this research was approved by the ethics committee of Toledo.

Design

A NG surface (25 mm high; certified as high quality by two independent gardeners) and an AT system (fibre: monofilament of polyethene of 60 mm of height; infill: 20 kg/m^2 of Styrene-Butadiene Rubber and quartz sand with 0.3–0.8 mm of granulometry) were used in this study. The mechanical properties of both surfaces were assessed as in previous studies.[10,11] Shock absorption (%), vertical deformation (mm), and energy return (%) were recorded using an Advanced Artificial Athlete (Labosport, Le Mans, France), the FIFA-certified equipment for assessing these variables.[2] Each variable was measured three times in each of five zones on each surface (Figure 1), but only the last two measurements from each zone were used in the statistical analysis.

*** Figure 1 near here***

Prior to the main test players completed a yo-yo test of intermittent recovery level 1.[13] Maximum heart rate (HR_{max}) was recorded from a heart rate monitor attached to the volunteers' chest (Polar Team System, Kempele, Finland).[11] Players also completed a familiarisation session to allow them to get used to the procedures and equipment used in this research. In the main test players completed three bouts of the SSP on the NG surface and three further bouts on the AT system, [8,12] because previous authors have demonstrated that 45 min of playing time is sufficient to detect differences between surfaces.[11,14] Test order was randomised so that eight players did their first trial on AT and the remaining eight on NG. The two trials were separated by a 72-h recovery period.

All tests were performed at training time to avoid the results being affected by circadian rhythm and in dry conditions (temperature: 18 Cº ± 3ºC; relative humidity: 25% ± 5%; wind speed: 0.0-0.5 m/s). Players agreed to keep a resting time of rest for 72 h before each trial (no vigorous or exhausting activity) and to maintain the same diet throughout the test period. Finally, all volunteers agreed to use the same type of footwear on both surfaces. The selected shoes had rubber cleats of a non-aggressive design in order to minimise traction effects (Munich Mundial® multiground, 25 cylindric rubber cleats).

Methodology

Players performed a standardised warm-up consisting of 5 min of continuous running, 5 min of articulation mobility and three sprints at increasing intensity before completing the SSP.

Soccer-simulation protocol (SSP). Players completed the first half of the SSP, which consists of three 16-min bouts with 3 min of rest between bouts[8,12]. Each bout consists of eight cycles and one repeated sprint test (6 × 15 m sprints departing every 18 s) block between cycles 4 and 5 (Figure 2) structured as follows:

- 3 × 20 m at a walking pace of 1.43 m s−1
- 1 × sprint-agility run at maximal intensity (20 s for sprint and recovery)
- 3 × 20 m at a running speed of 2.5 m s−1
- 3 × 20 m at a running speed of 4.0 m s−1

*** Figure 2 near here***

Physiological indicators and speed performance of SSP. The maximum speed and average speed (km/h) in each bout of the SSP were recorded through a global positioning device (GPS; HPU, GPSports, Australia). Using individual HR_{max} as a reference, we also calculated the peak heart rate (HR_{peak}) and mean heart rate (HR_{mean}) in both beats per minute (bpm) and as a percentage of the maximum heart rate (%HR_{max}). The percentage of total time that players spent at over 85% of their HR_{max} was recorded as HR-high intensity (%). These values were recorded for the three bouts, dividing them as pre-values (the four cycles before the repeated sprint test) and post-values (the four cycles after the repeated sprint test).

Repeated sprint test variables. Maximum speed in each sprint of the rerepeated sprint test was measured through a GPS (HPU, GPSports, Australia) attached to the back of the players 15 min before the beginning of each test. The total time that participants took to complete each sprint of 15 m was recorded through two pairs of photocells (Witty, Microgate, Bolzano, Italy). The best time, the average time, the total time, the percentage decrease (% Best) and the difference between the best and the worst sprint of each repeated sprint test (% Diff) were also recorded.

Agility test variables. The total time (s) for each agility test was recorded through the two pairs of photocells, the total time (s) of each agility test was registered. We also recorded the average time (s) for the three sections of the agility test (S-AR 15 m sprint time [first 15 m of the agility test]; S-AR turn time [next 10 m of the agility test, includes the 180º turn]; and S-AR cut time [last 17 m of the agility test, includes a 73º change of direction]) and the average speed (km/h) of each agility test. The GPS devices were also used to record the maximum speed achieve on each agility test. Finally, the best time, average time, total time, percentage decrease (% Best) and the difference between the best and the worst agility test (% Diff) were also calculated for the pre- and post-sprint phases of each bout.

Statistical analysis

The statistical analysis was carried out through the SPSS v. 21.0 was used to carry out the statistical analyses. Results are presented as mean ± standard deviation. The normality of the distribution of variables and homogeneity of variance was checked using the Kolmogorov–Smirnov test and Levene's statistic. A two-way (surface x bout) ANOVA was used to assess differences between surfaces and bouts for all variables. Interactions were assessed using post hoc pairwise Bonferroni tests. The magnitude of changes was quantified by calculating 95% confidence intervals (CIs). Effect sizes (ES) were also calculated and defined as follows: null: <0.3; mild: 0.3–0.5; moderate: 0.5–0.7; strong: 0.7–0.9; and very strong: 0.9–1.0.[15] The level of significance was set at $p < 0.05$.

Results

Mechanical properties of surfaces

The NG surface was softer (higher shock absorption) (+6.10 %; *p*=0.07; ES: 0.54; CI: 1.81–10.40) values, whereas the AT system displayed greater vertical deformation (+1.48 mm; *p*<0.01; ES: 2.07; CI: 0.94–2.02) and was more rigid (greater energy return) (+14.62 %; *p*<0.01; ES: 3.25; CI: 10.85–18.38).

Physiological indicators and speed performance of SSP

The physiological responses and maximum and average speeds of players on both surfaces are displayed in Table 1. Data are divided into pre- and post-sprints values. Mean heart rate was higher (as $\%HR_{max}$) in the post-sprint phase (after the repeated sprint test) on both surfaces: AT [bout 1 (+7.59 $\%HR_{max}$; *p*<0.001; ES: 1.465; CI: 4.13–11.05); bout 2 (+4.11 $\%HR_{max}$; *p*=0.017; ES: 0.849; CI: 0.75–7.46); bout 3 (+8.24 $\%HR_{max}$; *p*=0.036; ES: 0.786; CI: 0.30–8.71)] and NG [bout 1 (+8.24 $\%HR_{max}$; *p*<0.001; ES: 1.946; CI: 4.76–11.69); bout 2 (+8.24 $\%HR_{max}$; *p*<0.001; ES: 1.328; CI: 4.76–11.69); bout 3 (+4.25 $\%HR_{max}$; *p*=0.048; ES: 0.967; CI: 0.44–8.46)]. Also, on NG some significant differences in HR_{mean} among bouts were found before the repeated sprint test (bout 3>1; +11.9 b.p.m.; *p*=0.006; ES: 1.434; CI: 0.77–43.76).

*** Table 1 near here***

The total time for the six sprints in the repeated sprint test was similar for both surfaces and in all bouts (Table 2). There were also no differences (*p*>0.05) between bouts or surfaces for the variables total time, best time, meantime, maximum speed, % Best and % Diff for the repeated sprint tests (Figure 3).

*** Table 2 near here***

*** Figure 3 near here***

Table 3 presents all results pertaining to the agility test. In pre-sprint phase (before the repeated sprint test) of bout 1, players presented greater time on NG than AT for the agility test 2 (+0.60 s; *p*=0.018; ES: 1.034; CI: 0.11–1.10), S-AR turn time (+0.31 s; *p*=0.027; ES: 1.016; CI: 0.04–0.58), and best time (+0.52 s; *p*=0.042; ES: 0.867; CI: 0.02–1.02). Moreover, the average speed of the agility test in bout 1 during the pre-sprint phase was higher on AT than NG (+1.17 Km/h; *p*=0.037; ES: 0.807; CI: 0.07–2.26).

*** Table 3 near here***

Discussion

The use the SSP to assess the influence of the playing surface on players' responses is not new,[6,8] but previous studies did not assess the mechanical properties of the surfaces or analysed this influence on each component of the SSP.
This research found that the fatigue response in the second half of each bout and the time for the repeated sprint tests were similar on AT and NG. Although most of the agility test variables were similar on the two surfaces, times were quicker and speeds higher on AT in some components of the agility test. Many of the previous studies used AT systems that met FIFA standards so it is likely that these surfaces were of higher quality than the one used in this study which did not meet this standard for shock absorption.[6,8] Sánchez-Sánchez et al. have reported that players run faster and display lower physiological responses on more rigid AT systems (systems that offer less shock absorption).[3,11] Therefore, AT systems cannot be treated as a homogeneous group.[10] The differences among AT systems are evident from published values for shock absorption (31.45% ± 6.24 to 70.30% ± 61.47),[9,10] vertical deformation (3.43 mm ± 0.43 to 7.34 mm ± 60.43) [10,11] and energy return (32.66% ± 3.17 to 50.50% ± 2.19).[11,16]

Analysis of the physiological load on players before and after each repeated sprint test showed similar responses to those obtained in matches and small-sided games: HR_{mean} over 80% of HR_{max} and HR_{peak} over 90% of HR_{max}.[11,14] However, the increase in HR_{mean} after the repeated sprint test suggests that players experienced greater energy and physiological demands in the second half of each bout.[11,14,17] On the other hand, the lack of surface difference in either before or after the repeated sprint test indicates that playing soccer on AT entails similar physiological effects and internal load to playing on NG.[6] It is remarkable that on NG players presented a greater increase in HR_{mean} and HR high intensity (total time over 85% of HR_{max}) between bout 1 and the other bouts; yet no differences between surfaces were found. These results suggest that the physiological activation of soccer players is slightly influenced by the surface. However, the general lack of differences between surfaces indicates that these alterations are probably due to the players' running technique or prior adaptation to each surface.[18] A previous study of different AT systems reported differences of up to 20% in shock absorption among artificial turf systems, finding that HR_{peak} is higher on those systems with greater damping capacity (greater shock absorption).[11] This suggests that the 6.10% difference between the shock absorption of the two surfaces used in this study was probably not high enough to affect player's physiological responses. The lack of differences between AT and NG with respect to HR_{mean} and HR_{peak} in this and previous studies suggests that both surfaces elicit similar physiological responses,[6,8] although perceived effort may be higher on AT than on NG.[4] Nevertheless, the variability of AT systems together with the low shock absorption of the AT system used in this study means that caution must be exercised in comparing our findings with those of others.[11]

Several studies have found that sprint times are slower on surfaces with higher shock absorption and lower energy return,[3,11,14] probably due to lower surface contact times.[19] On this basis, one would expect to see some differences in the sprint times between the surfaces used in this study as the AT system had lower shock absorption than the NG surface; however, in line with other studies, no such differences were found.[6,8,20] In our study, the AT system was only 6.10% harder than the NG surface, whilst Sánchez-

Sánchez et al. reported differences of up to 21.76% in shock absorption between the softer AT system and the harder one.[3] Thus, players' performance in linear sprints appears to be similar on AT and NG, [6,20] despite the differences in their mechanical properties. There were no surface difference in the fatigue variables for the repeated sprint test (% Best and % Diff) and the general variables for the repeated sprint test (total time, best time, mean time and maximum speed). Although soccer players may perceive running to be more effortful on AT than on NG,[4] the findings of this study suggest that AT systems are not more demanding in this sense. We conclude that the differences in the mechanical properties between of AT and NG surfaces were not high enough to cause differences in the players' physical responses.[11,14] It also indicates that dependence on creatine phosphate is similar in these two surfaces,[11,14] as other studies that included surfaces with higher shock absorption, such as sand, did find differences in energy costs among surfaces.[21] Nonetheless, one must consider that our findings can be influenced by the lower capacity of the AT system selected for this study.

The main finding of this research is that there are some differences in agility performance on NG and AT, despite the general lack of difference in physical and physiological responses. These findings may reflect differences in the biomechanics of players in turning cutting movements probably due to lower muscle-sinew efficiency on NG.[8,19,22] It appears likely that the differences between surfaces with respect to shock absorption and energy return were not high enough to cause differences in physiological responses, although they were sufficient to affect turning performance.[9,11] It is probable that the two surfaces also have different rotational traction capacity, but we did not measure this. Previous research suggest that rotational traction capacity and energy return are the most important mechanical determinants of performance in sprints including turns,[3,11] so both these variables should be measured in future research. Unlike Hughes et al.,[6] who reported higher performance in 180º turns on NG than on AT, but in line with Gains et al.,[20] this research found that peak turns were faster on AT. This suggests that players' contact time in turns is lower when they run on a synthetic surface.[3,8,19] This study suggests that performance of actions requiring high agility will be better on AT systems than on NG, provided that the AT surfaces offer a higher energy return.[11] However, as the differences in agility only occurred in the first bout of the SSP, it is possible that the surface effect are too weak to be taken into account by coaches. Finally, another important finding of this work is that the increased physiological activation observed after the repeated sprint test did not affect performance on the agility test and linear sprints. This indicates that the agility test imposed similar external load before and after the repeated sprint test.[17]

Practical Applications

Our findings on in linear and non-linear sprints are consistent with earlier research in which the mechanical properties of the test surfaces were not assessed. [6-8,20] The study provides clear evidence that the differences in shock absorption and energy return between AT and NG may not be high enough to affect linear sprint times or the physiological response to repeated linear sprints, but may be sufficient to affect high-intensity turning and cutting movements. However, these differences in turning and cutting performance may not be great enough to be taken into account in training or matches. For that reason, more research that analyses the mechanical properties of the surfaces are required. [11,23]

An AT system with a low shock absorption was used in this study and so our findings cannot be generalised to other AT systems with greater shock absorption. We consider that the mechanical properties of a surface are more important factors in sporting performance than its category (artificial or natural turf). The findings of this research may have been influenced by the nature of the sample which was made up of amateur players who will have been less able to perform the repetitive sprint tests and the agility tests at high speeds than professional players. In addition our, volunteers only completed three SSP bouts instead of the six bouts that are standard for this test.[12] On the other hand, the protocol used in this study is not affected by surface differences in game characteristics existing in the real matches (i.e. fewer sliding tackles and more short passes on AT).[4]

Conclusion

There may be small differences in agility performance on AT and NG even when there are no surface-related differences in other physical or physiological variables. We only observed such difference in the first SSP bout, so they may not be important enough to warrant consideration by coaches. These findings suggest that the mechanical properties of sports surfaces are more important than their category and so future studies of surfaces should include information about the mechanical properties of the sports surfaces.

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Figures

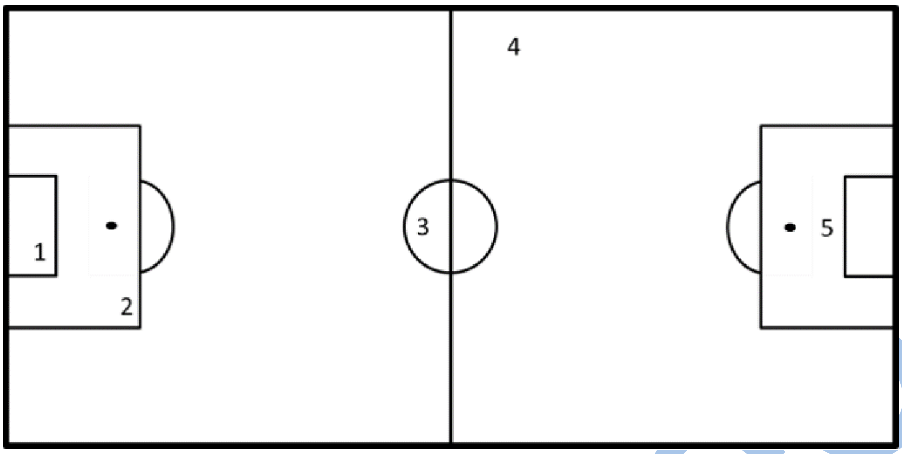

Figure 1. Zones to assess the sport surfaces

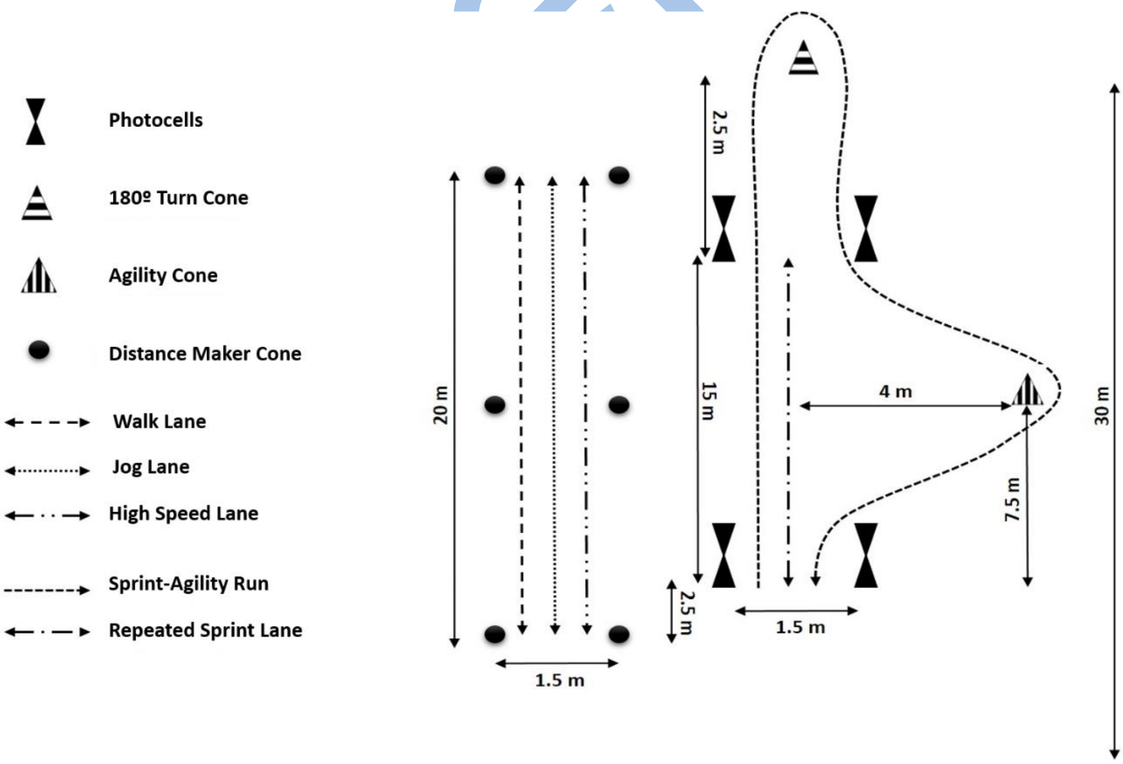

Figure 2. Soccer-simulation protocol (SSP)

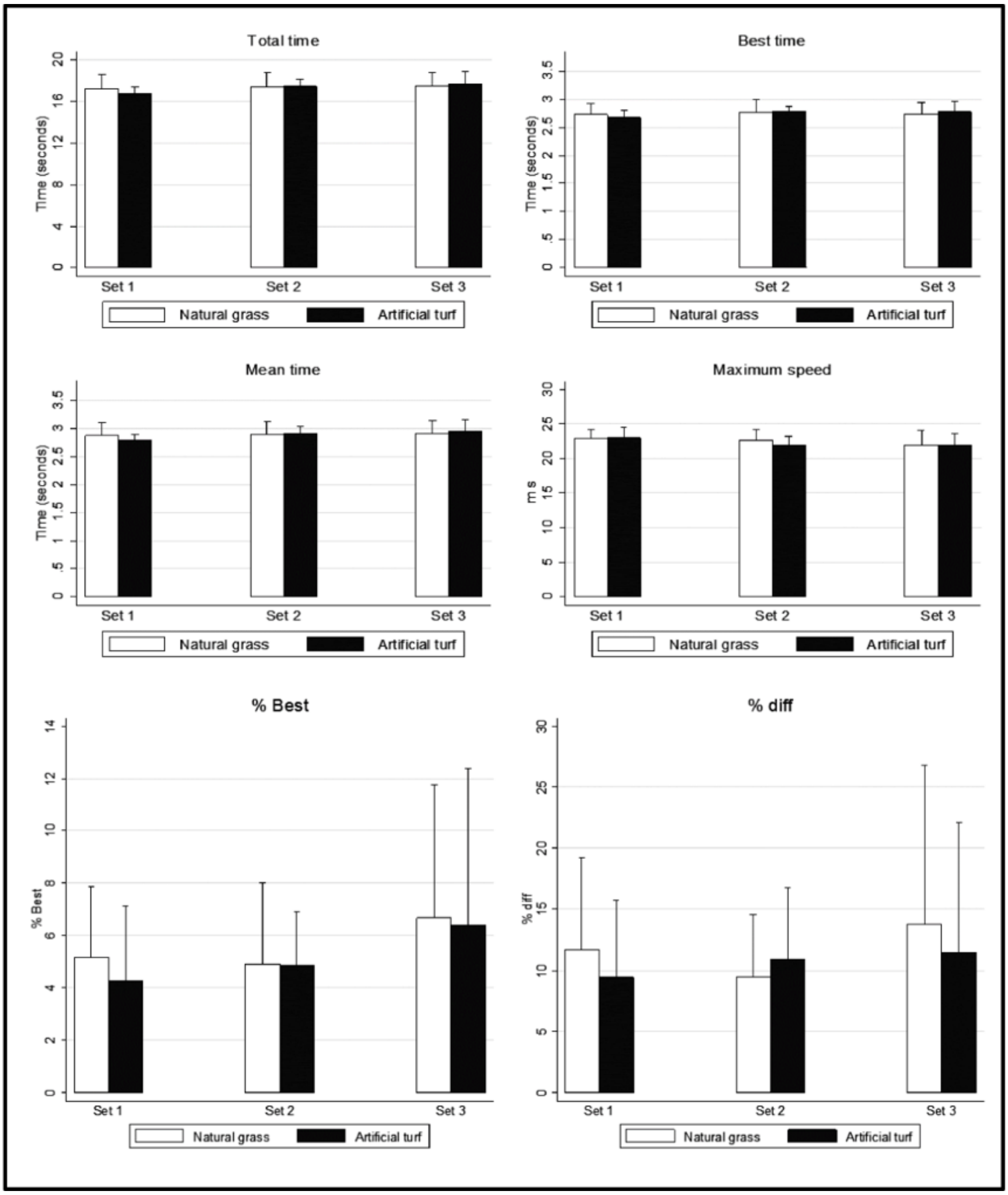

Figure 3. Total time, Best Time, Meantime, Maximum Speed, % Best and % Diff of the repeated sprint test among bouts and surfaces

Tables

Table 1. Physiological indicators and speed performance of SSP among bouts before and after the RS and between surfaces

Variable	Bout	Artificial Turf: Before the repeated sprint	Artificial Turf: After the repeated sprint	Natural Grass: Before the repeated sprint	Natural Grass: After the repeated sprint
V max (Km/h) of the S-AR	1	25.03 ± 1.71	24.44 ± 1.20	24.34 ± 1.50	24.16 ± 1.69
	2	24.31 ± 1.42	24.00 ± 1.47	24.07 ± 1.82	23.93 ± 1.35
	3	23.63 ± 1.47	24.15 ± 1.23	23.75 ± 1.82	24.01 ± 1.45
V mean (Km/h) of the S-AR	1	8.23 ± 0.40	8.10 ± 0.32	8.27 ± 0.36	8.24 ± 0.35
	2	8.09 ± 0.38	8.02 ± 0.32	8.19 ± 0.36	8.13 ± 0.36
	3	7.98 ± 0.32	8.06 ± 0.32	8.16 ± 0.43	8.13 ± 0.39
HR peak (b.p.m.)	1	184.07 ± 8.92	187.47 ± 8.50	179.73 ± 8.66	184.53 ± 8.43
	2	184.80 ± 9.17	186.07 ± 9.74	182.73 ± 9.23	185.73 ± 8.71
	3	183.08 ± 11.26	187.58 ± 11.83	184.00 ± 8.63	186.17 ± 8.52
HR peak (% HRmax)	1	93.13 ± 3.62	94.85 ± 3.46	90.96 ± 4.13	93.38 ± 4.01
	2	93.50 ± 3.96	94.15 ± 4.39	92.47 ± 4.38	93.99 ± 4.15
	3	92.52 ± 5.10	94.80 ± 5.49	93.00 ± 4.08	94.10 ± 3.99
HR mean (b.p.m.)	1	159.30 ± 12.59	174.28 ± 11.31*	155.87 ± 9.42	172.12 ± 9.12*
	2	167.48 ± 11.25	175.57 ± 10.78*	164.17 ± 9.30	175.50 ± 9.39*
	3	165.47 ± 12.35	174.36 ± 12.58	167.77 ± 8.94¥	176.17 ± 10.29
HR mean (% HRmax)	1	80.56 ± 5.48	88.15 ± 4.88*	78.86 ± 4.29	87.09 ± 4.17*
	2	84.71 ± 4.91	88.82 ± 4.77*	83.07 ± 4.34	88.80 ± 4.29*
	3	83.61 ± 5.59	88.11 ± 5.86*	84.79 ± 3.98¥	89.04 ± 4.81*
HR high-intensity (% of Total Time)	1	48.31 ± 26.87	75.81 ± 26.41*	36.68 ± 23.01	67.77 ± 27.01*
	2	62.76 ± 26.42	77.66 ± 31.95	52.08 ± 31.18	74.34 ± 27.61*
	3	57.36 ± 32.72	71.29 ± 35.61	60.98 ± 28.21	75.29 ± 28.58

* Significant differences (p<0.05) pre–post for both artificial turf and natural grass
# Significant differences (p<0.05) between surfaces for both pre and post
¥ Significant differences (p<0.05) among bouts for both pre and post
V: Speed; HR: Heart rate
High intensity = % of total time over 85% of HR max.

Table 2. Total time of each sprint among bouts and between surfaces

Variable	Bout	Artificial Turf			Natural Grass		
	1	2.82	±	0.21	2.89	±	0.26
Sprint 1 (s)	2	2.90	±	0.15	2.91	±	0.19
	3	2.93	±	0.18	2.92	±	0.24
	1	2.79	±	0.13	2.92	±	0.33
Sprint 2 (s)	2	2.98	±	0.23	2.94	±	0.25
	3	2.95	±	0.21	2.93	±	0.26
	1	2.83	±	0.15	2.86	±	0.26
Sprint 3 (s)	2	2.95	±	0.17	2.95	±	0.28
	3	3.01	±	0.24	2.87	±	0.25
	1	2.78	±	0.10	2.90	±	0.24
Sprint 4 (s)	2	2.94	±	0.19	2.89	±	0.24
	3	2.94	±	0.25	2.92	±	0.28
	1	2.77	±	0.13	2.85	±	0.24
Sprint 5 (s)	2	2.85	±	0.10	2.88	±	0.26
	3	2.99	±	0.31	3.03	±	0.37
	1	2.78	±	0.14	2.81	±	0.24
Sprint 6 (s)	2	2.88	±	0.12	2.86	±	0.25
	3	2.88	±	0.20	2.86	±	0.24

* Significant differences ($p<0.05$) among bouts; # Significant differences ($p<0.05$) among surfaces
¥ Significant differences ($p<0.05$) among sprints

Table 3. Agility test variables among bouts and between surfaces and pre–post

Variable	Bout	Artificial Turf: Before the repeated sprint	Artificial Turf: After the repeated sprint	Natural Grass: Before the repeated sprint	Natural Grass: After the repeated sprint
Time					
Agility test 1 (s)	1	9.20 ± 0.86	9.14 ± 0.71	9.60 ± 0.67	9.39 ± 0.70
	2	9.29 ± 0.67	9.30 ± 0.71	9.58 ± 0.90	9.60 ± 0.71
	3	9.45 ± 0.83	9.22 ± 0.73	9.54 ± 0.73	9.53 ± 0.52
Agility test 2 (s)	1	9.01 ± 0.61	9.27 ± 0.73	9.61 ± 0.55#	9.55 ± 0.62
	2	9.25 ± 0.72	9.37 ± 0.76	9.52 ± 0.86	9.58 ± 0.65
	3	9.40 ± 0.91	9.52 ± 0.89	9.68 ± 0.85	9.69 ± 0.78
Agility test 3 (s)	1	8.99 ± 0.75	9.35 ± 0.80	9.47 ± 0.62	9.43 ± 0.62
	2	9.22 ± 0.70	9.34 ± 0.86	9.50 ± 0.80	9.51 ± 0.58
	3	9.47 ± 1.07	9.41 ± 1.02	9.61 ± 0.87	9.58 ± 0.78
Agility test 4 (s)	1	9.03 ± 0.73	9.25 ± 0.66	9.51 ± 0.74	9.50 ± 0.73
	2	9.22 ± 0.68	9.41 ± 0.86	9.62 ± 0.78	9.65 ± 0.81
	3	9.41 ± 1.01	9.19 ± 0.71	9.78 ± 0.64	9.50 ± 0.73
S-AR 15 m Sprint Time (s)	1	2.76 ± 0.24	2.80 ± 0.14	2.92 ± 0.47	2.81 ± 0.21
	2	2.81 ± 0.12	2.95 ± 0.47	2.82 ± 0.28	2.80 ± 0.20
	3	2.84 ± 0.15	2.82 ± 0.12	2.85 ± 0.25	2.77 ± 0.17
S-AR Turn Time (s)	1	3.46 ± 0.40	3.56 ± 0.47	3.77 ± 0.21#	3.73 ± 0.20
	2	3.55 ± 0.45	3.59 ± 0.49	3.75 ± 0.23	3.76 ± 0.21
	3	3.58 ± 0.58	3.54 ± 0.54	3.76 ± 0.23	3.76 ± 0.16
S-AR Cut Time (s)	1	2.86 ± 0.25	2.89 ± 0.23	3.05 ± 0.49	3.50 ± 2.21
	2	3.01 ± 0.53	2.95 ± 0.28	3.04 ± 0.44	3.02 ± 0.30
	3	3.02 ± 0.29	2.97 ± 0.23	3.05 ± 0.33	3.03 ± 0.36
Speed					
Maximum Speed (Km/h)	1	24.36 ± 1.59	23.62 ± 1.18	23.75 ± 1.65	23.22 ± 2.49
	2	23.57 ± 1.25	22.98 ± 2.00	23.30 ± 2.06	23.08 ± 1.66
	3	22.97 ± 1.56	23.26 ± 1.40	23.10 ± 1.80	23.28 ± 1.62
Average Speed (Km/h)	1	18.80 ± 1.45#	18.40 ± 1.41	17.63 ± 1.45	17.96 ± 1.23
	2	18.40 ± 1.34	18.21 ± 1.47	17.75 ± 1.58	17.74 ± 1.21
	3	18.11 ± 1.80	18.26 ± 1.60	17.64 ± 1.35	17.40 ± 2.10
Fatigue					
Best Time (s)	1	8.79 ± 0.58	9.04 ± 0.72	9.31 ± 0.62#	9.22 ± 0.61
	2	9.04 ± 0.64	9.16 ± 0.70	9.34 ± 0.78	9.36 ± 0.56
	3	9.21 ± 0.84	9.04 ± 0.71	9.39 ± 0.65	9.34 ± 0.63
Total Time (s)	1	36.22 ± 2.79	37.01 ± 2.82	38.19 ± 2.44	37.87 ± 2.52
	2	36.97 ± 2.66	37.42 ± 3.10	38.23 ± 3.25	38.34 ± 2.61
	3	37.73 ± 3.75	37.34 ± 3.21	38.60 ± 2.96	38.30 ± 2.73
% Best	1	2.93 ± 1.98	2.41 ± 1.11	2.54 ± 1.52	2.71 ± 1.69

	2	2.23	±	1.30	2.08	±	1.07	2.36	±	1.03	2.33	±	2.09
	3	2.33	±	1.38	3.21	±	1.78	2.80	±	2.49	2.47	±	1.79
% Diff	1	5.88	±	4.39	4.73	±	2.14	5.34	±	3.62	5.50	±	3.06
	2	4.87	±	2.97	4.72	±	2.53	4.76	±	2.35	4.63	±	3.84
	3	4.90	±	2.61	6.70	±	3.56	5.60	±	4.00	4.75	±	3.05

* Significant differences ($p<0.05$) pre–post for both artificial turf and natural grass
\# Significant differences (p<0.05) between surfaces for both pre and post
¥ Significant differences (p<0.05) among bouts for both pre–post and surfaces
S-AR 15 m sprint time: time in first stretch of the agility test; S-AR turn time: time in second stretch of the agility test; S-AR cut time: time in last stretch of the agility test