Stone, Keeron J and Hughes, Michael G. and Stembridge, Michael R. and Meyers, Robert W. and Newcombe, Daniel J. and Oliver, Jon L. (2016) *The influence of playing surface on physiological and performance responses during and after soccer simulation.* European Journal of Sport Science, 16 (1). pp. 42-49. ISSN 1746-1391

Abstract

Purpose: The aim of this study was to investigate the effect of playing surface on physiological and performance responses during and in the 48 h after simulated soccer match-play. **Method:** Blood lactate, single-sprint, repeated-sprint and agility of eight amateur soccer players were assessed throughout a 90 min soccer-simulation protocol completed on natural turf and artificial turf. Counter-movement jump, multiple-rebound jump, sprint (10 m, 60 m), L-agility run, creatine kinase and perception of muscle soreness were measured before, immediately after, 24 h and 48 h after exercise. **Results:** Analyses revealed significant changes in blood lactate and single-sprint performance (both $P < 0.05$) during the soccer-simulation protocol but with no significant differences between surfaces. Conversely, repeated-sprint performance demonstrated an interaction effect, with reductions in performance evident on natural turf only ($P < 0.05$). Whilst L-agility run and 10 m sprint performance remained unchanged, 60 m sprint and multiple-rebound jump performance were impaired and perception of muscle soreness and creatine kinase were elevated immediately following the soccer-simulation protocol (*all* $P < 0.05$), but with no surface effects. Although performance, creatine kinase and perception of muscle soreness were negatively affected to some degree in the 48 h after the soccer-simulation protocol, there was no surface effect. **Conclusion:** For the artificial and natural surfaces used in the present study, physiological and performance responses to simulated soccer match-play appear to be similar. Whilst a potential for small differences in performance response exists during activity, surface type does not affect the pattern of recovery following simulated match-play.

Key Words: Artificial Turf, Fatigue, Recovery, Muscle Damage

Introduction

Soccer matches from amateur to professional levels are now frequently being played on third-generation artificial turf (AT) surfaces instead of natural grass turf (NT). Comparative research has shown that injury incidence (Williams, Hume, & Kara, 2011) and most match-play activity patterns, such as periods of high-intensity exercise and total distance covered (Andersson, Ekblom, & Krustrup, 2008), are similar between surface types. However, playing surface can influence the number and type of passes made (Andersson, Ekblom, & Krustrup, 2008), shooting accuracy and kinematics (Potthast & Bruggemann, 2010) and plantar loading during agility tasks (Ford et al., 2006). Soccer players also perceive matches to be more physically demanding on AT than those on NT (Andersson, Ekblom, & Krustrup, 2008). Despite this view, there is little comparative research examining the physiological responses to soccer activity, or the magnitude of fatigue experienced, on AT and NT.

It is known that players are likely to experience fatigue during a match (Mohr, Krustrup, & Bangsbo, 2005) or a simulated game of soccer (Morris, Nevill, Thompson, Collie, & Williams, 2003). Fatigue has been defined as "the failure to maintain the required or expected power output or force"(Edwards, 1983), which is typically observed in soccer as reductions in high intensity running and sprinting (Mohr, Krustrup, & Bangsbo, 2005). Initial sprint performance has been shown to influence decrements in multi-sprint activity performance (Gaitanos, Williams, Boobis, & Brooks, 1993). Given that sprint times (Fletcher et al., 2009; Hughes et al., 2013) and agility actions (Gains, Swedenhjelm, Mayhew, Bird, & Houser, 2010; Hughes et al., 2013) can be faster on AT than NT, this may have implications for the fatigue response during or following match-play. The occurrence and severity of fatigue during soccer activity on artificial turf surfaces may be a concern as the risk of injury during a match is greatest during periods of fatigue (Greig & Siegler, 2009; Small, McNaughton, Greig, & Lovell, 2010).Using a 90 minute soccer simulation protocol to accurately replicate the movement patterns and physiological demand of soccer, Hughes et al. (2013) reported that heart rate, blood lactate accumulation, as well as decrements in sprint and agility performances were not different between a NT and a third-generation AT. Players may also suffer long-lasting fatigue, as reflected by impaired neuromuscular function and biological markers, in the hours and days following a match (Andersson et al., 2008). Understanding the time-course of recovery of physiological and neuromuscular performances following soccer activity is essential, with incomplete recovery predisposing higher injury incidences (Barnett,

2006) and greater impairment of subsequent performance (Odetoyinbo, Wooster & Lane, *2009*). Nedelec et al. (2013) compared the recovery of physical performance and subjective ratings following soccer-specific exercise simulation on a NT and AT surface. Decrements in countermovement jump (CMJ) height and subjective ratings of fatigue were similar between surface types, however small differences in performance recovery were observed. Artificial turf elicited higher decrements in squat jump height but lower decrements in hamstring peak torque in the days following exercise (Nedelec et al., 2013).

Whilst the observations of Hughes et al. (2013) and Nedelec et al. (2013) suggest there may be little difference between surface types, further research is warranted to affirm their findings. Notably, Nedelec et al. (2013) observed differences in performance recovery between NT and AT in players who were familiar with artificial turf surfaces. Greater differences in within-match responses and post-match recovery between NT and AT may be observed in players who do not regularly play or train on artificial turf surfaces. The acute shift between playing surfaces may elicit greater disturbances. Indeed, natural and artificial surfaces can exhibit different stiffness characteristics (Naunheim, Parrott, & Standeven, 2004), which could influence movement biomechanics (Ford et al., 2006) as well as sprint and agility speeds (Fletcher et al., 2009; Gains, Swedenhjelm, Mayhew, Bird, & Houser, 2010; Hughes et al., 2013). These differences could influence the amount of eccentric stress and muscle damage experienced during soccer activity, with greater exercise-induced muscle damage (EIMD) associated with longer-lasting impairments in performance (Nosaka, Newton, & Sacco, 2002). Accordingly, the assessment of biochemical markers of muscle damage, such as creatine kinase (CK), may be useful in identifying potential differences in recovery response between playing surfaces. Further, given that playing surface can influence agility actions (Ford et al., 2006; Gains, Swedenhjelm, Mayhew, Bird, & Houser, 2010; Hughes et al., 2013), assessing agility performance during the recovery period following soccer activity may also be informative. Therefore, the aims of this study are to examine performance, physiological and perceptual responses during and in the 48 h following 90 min of simulated soccer activity completed on both NT and third-generation AT.

Methods

Participants.

Eight male Welsh Division 1 soccer players participated in the study. The mean (±SD) characteristics of the players were age 20.3 ±1.4 years, stature 177.1± 7.7 cm, and body mass 72.5±7.2 kg. The participants were all outfield players who trained twice per week and competed once a week for their club as well as engaging in their own personal fitness training.. The participants were not accustomed to regularly training or playing on a third-generation artificial surface. The institutional ethics committee approved the project and written informed consent was obtained from all participants.

Experimental design.

Participants were randomly assigned to two experimental groups and were required to perform a soccer-simulation protocol (SSP) on both NT and AT in a randomised, cross-over design. The AT was a 'FIFA 1 Star' rated third-generation artificial surface (Federation Internationale de Football Association FIFA, 2011) comprising of 60 mm polypropylene fibres stabilized with ground rubber granules and graded silica sand. The NT was a natural grass surface that was maintained by a professional groundsman and held Welsh League Division 1 matches. The SSP has previously been shown to elicit responses similar to match-play (Stone et al., 2011). The two SSP trials were performed at the same time of day and separated by 7 days. Participants wore the same footwear during both SSP trials (moulded studded soccer boots) and all recovery performance assessments (running shoes). The conditions were dry for both SSP trial days and the mean air temperature was 19.1 ± 2.5°C during testing.

Pre-post SSP and recovery performance measures.

Immediately prior to and immediately following each SSP trial, measures of sprint, jump and agility performance were taken on the respective NT or AT surface. Participants first performed a standardised warm-up consisting of jogging, dynamic stretching and three 15m sprints. Lasting approximately 10 minutes, the performance measures were completed in the following order; 'L-agility' run (L-AR), 60 m sprints, CMJ and multiple rebound jump test (MRJ). This test order was replicated between pre-post measures and between surfaces types. Agility was measured using the L-Agility Run (L-AR,Webb & Lander, 1983), where participants had to sprint 5m, turn 90°, sprint another 5m and turn 180° and return back to the start. Participants completed two trials (one in each direction), with the mean of the two trials representing their agility performance. The L-AR incorporates common turning angles in soccer (Bloomfield, Polman, & O'Donoghue, 2009) and demonstrates high test re-test reliability (*r* = 0.95)(Gabbett, Kelly, & Pezet, 2007). Participants completed two 60 m sprint trials with a 10-m split time being recorded. Timing for the L-AR and 60 m sprint was performed using commercially available timing gates (SmartSpeed, Fusion Sport, Brisbane, Australia) and performed on the same surface as the SSP. The CMJ and MRJ tests were assessed on a concrete surface using a contact mat (SmartJump, Fusion Sport, Brisbane, Australia). The MRJ test started with a CMJ immediately followed by 4 maximal rebound jumps (Lloyd, Oliver, Hughes, & Williams, 2009). The CMJ completed at the start of the MRJ test was used to represent maximal vertical jump performance. A reactive strength index (RSI) was calculated from the 4 rebound jumps by dividing jump height (cm) by contact time (m·s) which has demonstrated high test re-test reliability ($r > 0.95$) (Flanagan, Ebben, & Jensen, 2008). For the CMJ and MRJ, with hands fixed on hips participants lowered themselves from a standing position to a self-selected squat position and then immediately performed a vertical jump. For the MRJ part of the test, participants were instructed to maximise jump height and minimise ground contact time. To assess recovery from the SSP trials, the performance tests were also completed 48h h prior to the first SSP trial only (baseline data) and 24 h and 48 h after both SSP trials. To ensure that performance was not influenced by surface type, all performance recovery tests were completed on an indoor running track (National Indoor Athletics Centre, Cardiff, Wales).

Creatine Kinase and perception of muscle soreness (PMS) were measured before the warm-up and 15 min, 24 h and 48 h following the SSP. Creatine kinase concentrations were analysed from an earlobe capillary blood sample using a Refletron system (Boehringer Mannheim GmbH, Mannheim, Germany) which has demonstrated good measurement reliability (CV = 3.1%) and validity (Horder et al., 1991). Perception of muscle soreness was assessed with the participant's hands positioned on their hips whilst performing a squat exercise to an approximate knee angle of 90^{o}, before indicating the level of soreness of the knee extensors by placing an 'X' along a visual analogue scale of 10cm (Andersson et al., 2008). The verbal anchors on the scale were '1 = no pain' and '10 = very severe pain'. The distance in centimetres from the beginning of the scale to their mark was measured and this represented their muscle soreness.

Soccer-Simulation Protocol.

The SSP consists of six 16-minute sets with 3 minutes rest between sets and a 15-minute half time period after 3 sets (Stone et al., 2011) . Each set consisted of 8 cycles and one repeated-sprint (RS: 6 x 15 m sprints departing every 18s) block between cycles 4 and 5. Each cycle was structured as follows:

- 3 x 20 m at a walking pace of 1.43 $m \cdot s^{-1}$
- 1 x sprint-agility run at maximal intensity (20 s for sprint and recovery)
- 3 x 20 m at a running speed of 2.5 $m \cdot s^{-1}$
- 3 x 20 m at a running speed of 4.0 $m \cdot s^{-1}$

For analysis, the sprint agility run (S-AR) was split into two component parts; time taken to cover the initial 15 m straight sprint and time to cover the subsequent 27 m which involved a 180° turn and a 73° change of direction. The RS and S-AR were measured within the protocol using timing gates (Smartspeed, Fusion Sport, Brisbane, Australia). All instructions and running speeds during the SSP were provided by a pre-recorded audio track. Throughout the SSP participants were allowed to consume water *ad libitum* and up to 500 ml of a 6.4% CHO beverage. This drinking regime was replicated between the two trials. Blood lactate concentration (BLa) was assessed at the end of each set and analysed immediately using a Biosen C-Line lactate analyzer (EFK Diagnostics, Barleben, Germany). Participants completed 1 set of the SSP 48 h prior to the first SSP trial in order to become familiar with the protocol.

Statistical Analysis.

Two-way (surface x time) repeated-measures ANOVA's were used to identify the statistical significance of the differences between surfaces and time points for within-SSP, pre to post SSP and recovery variables. Bonferroni post-hoc tests were employed to determine the level of significance when a significant *F*-ratio was found. Homogeneity of variance was evaluated using Mauchly's test of sphericity and when violated the Greenhouse-Geisser adjustment was used. All data are presented as the mean ± SD. Statistical significance was set at $P < 0.05$ for all analyses. Partial eta squared (η_p^2) analyses were classified as weak (<0.1), modest (0.1-0..3), moderate (0.3-0.5) or strong (>0.5). All statistical analyses were performed using SPSS for Windows, version 17 (SPSS Inc., Chicago, IL, USA).

Results

Responses during and immediately after the soccer simulation protocol.

There were no differences between playing surfaces in the BLa response to the SSP (Main effects: AT *vs*. NT: η_p^2 = .008, Surface × Time: η_p^2 = .052, both P > .05, Table 1). Blood lactate was lower during set 4 (3.0 ±1.4 mmol·1^{1}) than sets 2 (4.1±1.6 mmol·1^{-1}) and 3 (4.0 ± 1.3 mmol·1^{-1}) (all P < .05, Main time effect: P = 0.01, η_p^2 = .448). Repeated-sprint time was the only 'within SSP' performance variable to show an interaction effect (Surface x Time: P = .028, η_p^2 = .292) with slower sprint times during set 5 than set 1 and slower sprint times in sets 3, 5 and 6 than set 4, on natural turf only (all P < .05, Figure 1). Single 15 m sprint times (NT *vs*. AT: η_p^2 = .062, Surface × Time: η_p^2 = .020) and agility run times (NT *vs*. AT: η_p^2 = .163, Surface × Time: η_p^2 = .182) were not different between surface types (all P > .05). Single 15 m sprint times in sets 4, 5 and 6 were significantly slower than set 1 (all P < .05, Main time effect: P < 0.0001, η_p^2 = .535, Table 1). Agility-run performance did not change during the SSP (P > .05, η_p^2 = .274).

None of the performance variables assessed before and immediately after the SSP showed an interaction effect (Surface x Time, all P > 0.05, Table 2). Ten-metre sprint, CMJ, MRJ and L-AR demonstrated weak effects (η_p^2 <.01) whilst 60m sprint performance demonstrated a moderate effect (η_p^2 = .355). A significant between-surface effect was found for L-AR only, with significantly faster times on the NT (NT *vs*. AT: 5.15 ± 0.15 s *vs*. 5.28 ±0.18 s, P = 0.014, η_p^2 = .599). Other 'pre-post' performance variables demonstrated non-significant weak (η_p^2 <.1: RSI), modest (η_p^2 <.03: CMJ and 10 m) and moderate between-surface effects (η_p^2 <.05: 60m). Both MRJ (Main time effect: P = .037, η_p^2 = .486) and 60 m sprint (Main time effect: P = .012, η_p^2 =.618) performances were impaired immediately after the SSP, while CMJ (η_p^2 = .349), 10 m sprint (η_p^2 =.018) and L-AR (η_p^2 = .027) times were not different (all P > 0.05).

***Recovery from the soccer simulation protocol*.**

There was no difference between playing surfaces in the recovery of performance variables (Table 2) , CK or PMS (Table 3) in the 48 h following the SSP (Main effects: AT *vs*. NT, Surface × Time, all $P > .05$). All recovery performances demonstrated weak between-surface and interaction effects (η_p^2 < 0.1 – 0.3). Creatine kinase was significantly higher than pre-exercise values immediately following the SSP ($P = .047$, Main time effect: $P = 0.01$, η_p^2 =.529), but was not different to pre-exercise values at 24 and 48 h post (both $P > 0.05$). Trial order had no effect on the CK response in the 48 h following the SSP ($P > 0.05$). Perception of muscle soreness was also higher than pre-exercise values immediately following the SSP ($P = .015$) and continued to be elevated at 24 h post ($P = 0.01$, Main time effect: $P < 0.0001$, η_p^2 =.625). Ten-metre sprint times were slower than baseline at 48 h post SSP ($P = .02$, Main time effect: $P = .002$, η_p^2 =.420) but not 24 h, whilst 60 m sprint performance was lower at both 24 h ($P = .019$) and 48 h post ($P = .002$, Main time effect: $P = .001$, η_p^2 =.653), with no difference within this period. Counter-movement jump (η_p^2 =.120), MRJ (η_p^2 =.100) and L-AR (η_p^2 =.152) performances remained unchanged in the 48 h after the SSP (all $P > 0.05$).

Discussion

The present study was designed to examine the effect of playing surface on physiological and performance responses to simulated soccer match-play and investigate the influence of playing surface on recovery. The main findings were that while a number of performance measures showed time effects during the SSP, only repeated-sprint performances were influenced by surface type. Further, playing surface had no effect upon the recovery of any of the performance measures, creatine kinase or perception of muscle soreness in the 48 h following the SSP.

Interestingly, while playing surface did not influence changes in single sprint, jump or agility performance either during or immediately after the SSP, repeated-sprint performances declined towards the end of activity on NT but not on AT. This finding is in contrast to that of Hughes et al. (2013) who observed similar performance decrements, including repeated-sprint performance, between surfaces. The disparity in findings may, in part, be due to the different standards of pitches used. The NT pitches used by Hughes et al. (2013) were verified as being of the highest quality according to peer reviewed criteria (Baker, Spring, & Wheater, 2007), whilst the AT pitches met the criteria of a 'FIFA 2 star' pitch, which is FIFA's highest rating for AT (Federation Internationale de Football Association FIFA, 2011). The good, but lower quality AT and NT pitches used in the present study may have differed in their surface characteristics to a greater extent than those used by Hughes et al. (2013) possibly eliciting different performance responses. Experimental evidence has shown that surface properties (e.g. compliance) can acutely alter the movement mechanics of locomotor muscles and the amount of work done (Ferris, Louie, & Farley, 1998). Though such differences may not be evident during sub-maximal running or single sprints, it may be evident during repeated sprints, where metabolic factors are the primary cause of fatigue (Glaister, 2005). The similar creatine kinase and perception of muscle soreness responses immediately following exercise indicate that any differences in the extent of fatigue experienced is not likely to be a result of greater exercise induced muscle damage. It is pertinent to point out that such a small difference, being observed in only one performance measure, is unlikely to significantly alter the overall response to match-play. The fact that the mechanical properties of the playing surfaces used were not characterized is a limitation of the study. However, the surfaces are representative of those used within semi-professional and amateur settings.

Blood lactate response during the SSP was similar to that observed during elite level soccer, with lower values during the second half (Krustrup, Zebis, Jensen, & Mohr, 2010), but did not differ between the AT and NT playing surfaces, which is in agreement with the findings of Hughes et al. (2013). Although not recorded in the present study, both Hughes et al. (2013) and Nedelec et al. (2013) reported comparable heart rate responses between NT and AT during simulated soccer activity. Thus, playing surface appears to have little influence on overall physiological response during soccer match-play. The decline in maximal sprint performance towards the end of and immediately following the SSP is also consistent with that reported during (Mohr, Krustrup, & Bangsbo, 2003) and after (Andersson et al., 2008; Krustrup, Zebis, Jensen, & Mohr, 2010) competitive match-play. Dehydration (Guerra, Chaves, Barros, & Tirapegui, 2004), hypoglycaemia (Ali, Williams, Nicholas, & Foskett, 2007) and muscle glycogen depletion (Krustrup et al., 2006) have been purported as primary causes of this performance decline. The threefold increase in blood CK and PMS immediately after the SSP also indicate the presence of significant intra-muscular structural disturbances, which may affect power-dependent activities through an impairment of the excitation-contraction coupling process (Byrne, Eston, & Edwards, 2001).

Although the findings of the present study and those of Hughes et al. (2013) suggest that there is little difference in physiological and performance responses during soccer activity the possibility remains that performance and recovery may still be influenced by surface type, owing to the known differences that exist in compliance properties (Sassi et al., 2011) and movement biomechanics (Ford et al., 2006). Understanding recovery patterns following soccer activity is essential as incomplete recovery may lead to injury (Barnett, 2006) or an impairment of subsequent performance (Odetoyinbo, Wooster, & Lane, 2009). This study has identified that playing surface does not affect the recovery of performance or markers of muscle damage in the 48 h following simulated match-play. In the main, this finding is consistent with that of Nedelec et al. (2013) who reported similar recovery responses in CMJ performance as well as perceptions of player fatigue and soreness following soccer activity on AT and NT. However,Nedelec et al. (2013) did report small differences between surface types, with AT eliciting higher decrements in squat jump height but lower decrements in hamstring peak torque in the days following exercise.

In the present study, performance in the L-agility run, multiple-rebound jump and countermovement jump were unchanged in the 48 h following the SSP. However, ten-metre sprint times were greater at 48 h but not 24 h and 60 m sprint did not return to baseline during the recovery period. The prolonged reduction in sprint performance is consistent with that reported in males following match-play (Magalhaes et al., 2010). The peak perception of muscle soreness and trend for a sustained elevation of creatine kinase(non-significant) at 24 h suggest that continued myofibrillar damage, which can disturb movement control and sense of force production (Brockett, Warren, Gregory, Morgan, & Proske, 1997), may explain the long-lasting impairment of sprint performance. There was no effect of trial for the creatine kinase response to the match simulation, demonstrating that the players were accustomed to the types of activity incorporated within the SSP and that the 7 day period between trials was sufficient for full recovery.

Conclusion

A significant difference in repeated-sprint performance during the SSP suggests that some surface-specific performance response may exist over time. However, the study demonstrated that the majority of variables elicited similar physiological and performance responses during simulated match-play on an artificial and natural turf. Furthermore, playing surface did not affect the pattern of recovery following simulated match-play. Cumulatively these findings suggest a limited influence of playing surface on performance and physiological responses during or following a 90 min soccer simulation. Knowledge that training or recovery programmes do not have to be altered to accommodate matches that are played on artificial surfaces, even if players are not accustomed to the playing surface, is useful for both coaches and players.

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Table 1. Sprint-agility run performance and blood lactate during the soccer simulation protocol (SSP) on artificial turf (AT) and natural turf (NT) (Mean ± SD).

	SSP Set Number					
	1	2	3	4	5	6
Blood lactate (mmol·l^{-1})				[a]		
AT	4.1 ± 2.7	4.0 ± 2.2	3.5 ± 1.9	3.0 ± 1.8	3.2 ± 1.2	3.4 ± 1.1
NT	4.3 ± 1.7	4.1 ± 1.6	4.0 ± 1.3	3.0 ± 1.4	3.4 ± 1.3	3.1 ± 1.1
Sprint-agility run: 15 m sprint (s)				[b]	[b]	[b]
AT	2.64 ± 0.14	2.72 ± 0.16	2.76 ± 0.18	2.73 ± 0.13	2.74 ± 0.16	2.76 ± 0.15
NT	2.68 ± 0.12	2.76 ± 0.16	2.78 ± 0.14	2.77 ± 0.12	2.77 ± 0.12	2.77 ± 0.15
Sprint-agility run: Agility Run (s)						
AT	5.77 ± 0.17	5.85 ± 0.20	5.89 ± 0.22	5.88 ± 0.16	5.83 ± 0.15	5.85 ± 0.16
NT	5.79 ± 0.19	5.71 ± 0.15	5.80 ± 0.18	5.84 ± 0.17	5.82 ± 0.17	5.87 ± 0.20

Main effect of time: [a] significantly different from sets 2 and 3 ($P < 0.05$), [b] significantly different from set 1 ($P < 0.05$).

Table 2. Performance results for natural turf (NT) and artificial turf (AT) at baseline, prior to, immediately, 24 h and 48 h after the soccer simulation protocol (Mean ± *SD*).

	Baseline*	Pre	Post	24 h post*	48 h post*
Counter-movement jump (cm)					
AT	30.49 ± 3.65	29.35 ± 2.79	27.42 ± 4.19	28.65 ± 4.09	31.06 ± 4.97
NT		30.33 ± 4.14	29.29 ± 3.65	29.58 ± 3.15	31.96 ± 3.48
Reactive strength index (mm·sec^{-1})					
AT	1.28 ± 0.21	1.33 ± 0.27	1.22 ± 0.25 ^{a}	1.40 ± 0.36	1.36 ± 0.31
NT		1.32 ± 0.31	1.22 ± 0.24	1.37 ± 0.32	1.49 ± 0.35
L – agility run (s)					
AT	5.18 ± 0.10	5.26 ± 0.14 §	5.30 ± 0.09	5.25 ± 0.18	5.23 ± 0.15
NT		5.12 ± 0.13	5.19 ± 0.23	5.22 ± 0.20	5.18 ± 0.15
10 m sprint (s)					
AT	1.69 ± 0.06	1.75 ± 0.11	1.75 ± 0.09	1.72 ± 0.11	1.72 ± 0.10 ^{b}
NT		1.72 ± 0.09	1.73 ± 0.11	1.74 ± 0.08	1.73 ± 0.06
60 m sprint (s)					
AT	7.52 ± 0.24	7.84 ± 0.40	7.91 ± 0.32 ^{a}	7.67 ± 0.26 ^{b}	7.66 ± 0.27 ^{b}
NT		7.61 ± 0.30	7.81 ± 0.37	7.73 ± 0.35	7.74 ± 0.21

*****Activity completed on an indoor running track. ***Main effect of time***: ^{a} Significantly different to pre SSP ($P < 0.05$), ^{b} Significantly different to baseline ($P < 0.05$). § ***Between-surface effect***: Significantly different to NT ($P < .05$).

Table 3. Markers of exercise induced muscle damage for natural turf (NT) and artificial turf (AT) immediately prior to and immediately, 24 h and 48 h after the soccer simulation protocol (Mean ± *SD*).

	Pre	Post	24 h post	48 h post
Creatine kinase (U-1-1)		[a]		
AT	369 ± 206	1046 ± 678	981 ± 571	588 ± 298
NT	395 ± 286	1124 ± 734	1505 ± 1342	950 ± 680
Perception of muscle soreness		[a]	[a]	
AT	1.2 ± 1.1	2.0 ± 1.5	2.9 ± 1.5	1.8 ± 0.7
NT	0.7 ± 0.7	3.3 ± 2.1	3.1 ± 2.2	2.0 ± 2.1

Main effect of time: [a] Significantly different to pre SSP ($P < 0.05$).

Figure Captions:

<u>Figure 1</u>: Mean repeated 15 m sprint times during the soccer simulation protocol (SSP) on natural turf (NT, *open circles*) and artificial turf (AT, *filled squares*). **HT**- half-time. ***Interaction effect:*** *Significantly slower than set 1 on NT (P < 0.05). **Significantly slower than set 4 on NT (P < 0.05).