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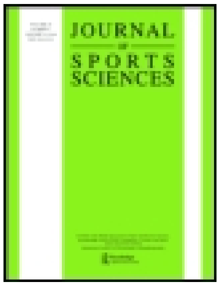

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Physical performance and subjective ratings after a soccer-specific exercise simulation: Comparison of natural grass versus artificial turf

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Abstract

This study aimed to compare the recovery kinetics of physical performance and subjective ratings in response to a soccer-specific exercise simulation on natural grass and artificial turf. Physical performance tests and subjective ratings were assessed on 13 professional soccer players before, immediately after, 24 h and 48 h after the test. Physical performance tests included squat jump, countermovement jump, 6-s sprint on a non-motorised treadmill and isokinetic eccentric hamstring assessment (2.09 rad $\cdot$ s^{-1}). Hamstring peak torque decrement was higher ($P < 0.05$) on natural grass than on artificial turf immediately (-4.0%, CI 95%: -10.0 to 2.0%, Effect Size [ES] = 0.29), 24 h (-3.1%, CI 95%: -9.3 to 3.1%, ES = 0.29) and 48 h (-3.8%, CI 95%: -8.5 to 0.9%, ES = 0.43) after the test. Squat jump performance decrement was significantly lower ($P < 0.05$) on natural grass than artificial turf 48 h after the test (+3.7%, CI 95%: 1.1 to 6.3%, ES = 0.40). Sprint performance showed no change from baseline performance for both trials throughout the protocol. No significant interaction between surface and time was found for countermovement jump and subjective ratings. These results suggest that a one-off exercise on artificial turf does not induce greater fatigue nor does it delay the recovery process when compared to natural grass among regular artificial turf players.

Keywords: *fatigue, recovery, football, field test, muscle soreness*

Introduction

The International Football Association Board decided to include artificial turf pitches in the Laws of the Game in 2004. These surfaces are currently used for competitive league games at professional levels in several countries (e.g. France, Russia, and Switzerland) and for training purposes in many professional clubs. Professional players reported subjectively a greater physical effort during matches played on artificial turf than natural grass despite similar activity profiles (i.e. total distance covered, high-intensity running, number of sprints) and technical standard (i.e. standing tackles, headers) (Andersson, Ekblom, & Krustrup, 2008a). Sassi et al. (2011) found a similar metabolic cost of running for both natural grass and artificial turf suggesting that such negative perceptions are not because of a higher cost of running, but due to other mechanical characteristics. In addition, Gains, Swedenhjelm, Mayhew, Bird, and Houser (2010) reported that change-in-direction speed during a one-off sprint is faster on artificial turf than on natural grass. This time differential between surfaces may be explained by more force being exerted during the change-in-direction motion resulting in more intense loading from accelerations and decelerations on artificial turf. Changes in direction, accelerations and decelerations are repetitively performed throughout a soccer match and induce muscle damage (Howatson & Milak, 2009; Magalhães et al., 2010; Thompson, Nicholas, & Williams, 1999). Young, Hepner, and Robbins (2012) found that players experiencing greater muscle damage 24 h post match covered significantly ($P < 0.05$) greater high-intensity running, accelerations and decelerations during the match.

The aim of the present study was to investigate the influence of playing surface on fatigue induced by changes in direction, accelerations and decelerations performed throughout a soccer match. The recovery kinetics of physical performance and subjective

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ratings in response to a standardised soccer-specific exercise simulation performed on natural grass and artificial turf were compared. A standardised soccer-specific exercise was used in order to control for the high variability of physical performance during a soccer match (Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Dupont et al., 2010). Based on previous findings (Gains et al., 2010), we hypothesised that post-exercise fatigue will be greater following the test on artificial turf resulting in delayed recovery process.

Methods

Participants

The participants were 13 professional soccer players (age: 17.7 ± 0.5 years; height: 180.2 ± 6.0 cm; body mass: 71.9 ± 6.9 kg; body fat: 9.4 ± 2.0%), but 12 were retained in the study, as one did not follow the recommendations. The players participated in one match and seven training sessions per week (volume: 11 to 14 h). They were used to training and playing on both surfaces (natural grass and artificial turf) for at least 2 years.

Experimental design

The study involved a randomised crossover experimental design. On two separate occasions (natural grass vs. artificial turf), players completed three sessions separated by 2 or 3 weeks. Before the experimentation, players completed a medical examination. All players were fully informed of the purpose, benefits and risks involved with participation before giving their written informed consent. This investigation was led in accordance with the local Ethics Committee in Biomedical Research and the recommendation of the Helsinki Declaration.

Experimental procedures

Players were accustomed to rating the global intensity of training sessions using the modified Borg scale from 0 to 10 points (Borg, 1982; Foster, 1998) and the feeling scale from -5 to 5 points (Rejeski, Best, Griffith, & Kenney, 1987). They were also familiar with rating their quality of sleep, fatigue, muscle soreness and stress using a scale from 1 to 7 points (Hooper, Mackinnon, Howard, Gordon, & Bachmann, 1995) and to performing the following tests of physical performance: squat jump, countermovement jump, sprints on non-motorised treadmill, and isokinetic eccentric hamstring assessment. Two preliminary sessions were performed in order to verify the inter-day reliability of the physical performance tests and to collect reference values. During the first session in each condition, the 7-point Hooper's scale (Hooper et al., 1995), the total quality recovery perceived scale from 6 to 20 points (Finnish: Kenttä & Hassmén, 1998) and location of muscle soreness (Thompson et al., 1999) were collected before completing a 90 min soccer-specific aerobic field test (SAFT90; Small, McNaughton, Greig, & Lovell, 2010). After completion of the 90 min soccer-specific aerobic field test and a 10 min rest interval, location of muscle soreness was recorded and physical performance tests performed in a testing room 200 m from the pitch. The second and third sessions corresponded to the subjective ratings, location of muscle soreness and physical performance tests performed 24 h and 48 h after the 90 min soccer-specific aerobic field test, respectively. Professional groundskeepers adjusted the soccer field watering to maintain the same experimental conditions. The 90 min soccer-specific aerobic field test on artificial turf was performed on third-generation artificial turf. The artificial turf pitch was not watered. The temperature ranged between [10 and 13°C]. Standardised verbal encouragement was provided during all the physical performance tests by experimenters. In order to limit dietary influences on test results, players were asked to follow standardised nutritional guidelines (quantity and content for food and drink) after each session and for breakfast, lunch and dinner. Each meal was eaten in the training centre. Participants were given written instructions to have their last meal at least 3 h before all testing sessions, and to avoid alcohol, tobacco and caffeine during the whole experimental period. During the period devoted to each condition, no training session was implemented and participants were requested not to use any different recovery treatments (cold bath, massage, compression garments), which may have affected the recovery pattern.

Players completed the 90 min soccer-specific aerobic field test protocol, which consists of two 45 min periods interceded by a 15 min passive rest period (half-time), performed as a shuttle run test over a 20 m distance (Small et al., 2010). The 90 min soccer-specific aerobic field test is designed to replicate the fatigue responses to soccer match-play and includes multiple backwards running, sidestepping, changes in direction and frequent acceleration and deceleration actions inherent to match-play. Thirty-six maximal shooting actions were performed during the 90 min soccer-specific aerobic field test protocol to increase the load to the quadriceps reflective of match-play (Small et al., 2010). Prior to the 90 min soccer-specific aerobic field test, players participated in a standardised warm-up performed on the surface on which they had to complete the test. The warm-up was the same as that used before a match and included 10 min light jogging (9–11 km · h^{-1}), dynamic activities (buttock kicks, high knee lifts, backwards running, sidestepping), sprints and familiarisation with the 90 min soccer-specific aerobic field test exercise protocol for a total duration of 15 min. Before the experimentation, players were asked to choose soccer boots that they would be required to wear in both conditions (natural grass and artificial turf). An experimenter checked that soccer boots worn by players were the same during each condition (natural grass and artificial turf). Players' nude body mass was recorded immediately before and after the 90 min soccer-specific aerobic field test with a digital scale (Seca 780, Hamburg, Germany). During half-time, players drank a sports drink containing 6% carbohydrate (Gatorade, PepsiCo, United States). The hydration plan was the same as that used during a match with players free to choose the fluid intake to the upper limit of 1 l. Players' fluid intake during the first condition was recorded and players consumed the same fluid intake during the second condition. The fluid loss was calculated by the following formula: Fluid loss = (body mass post-test - body mass pre-test) + fluid intake (Andersson et al., 2008b).

The order of physical performance tests was identical throughout each protocol and included the following: squat jumps, countermovement jumps, 6-s sprints and isokinetic eccentric hamstring assessment. Players performed three squat jumps and three countermovement jumps on a force platform (Kistler AG, Winterhur, Switzerland) with built-in charge amplifier. The force signal was sampled at 1000 Hz. A 1-min rest period was set between each jump. The best jump from three attempts was recorded. For the squat jump, participants were instructed to bend the knees at 90°, pausing for 3 s before jumping upwards on the verbal command 'go'. A goniometer (Lafayette Instrument Company, USA) was used to set the angle. For the countermovement jump, participants were instructed to jump explosively upwards immediately after descending to a self-selected depth. During both types of jump tests, the players placed their hands on their hips. The inter-day test-retest reliability for squat jump and countermovement jump was very high: the typical error (TE) was 1.4 and 1.5 cm, respectively, the intra-class correlation coefficient (ICC) was 0.90 and 0.92, respectively, while coefficient of variation (CV) was 3.1% and 2.9%, respectively. Players completed three 6-s sprints separated by 3 min of passive recovery on a non-motorised treadmill (Woodway Force 3.0, Waukesha, USA). Start position (standing start with hand on the handles) was standardised. The best value from three sprints was recorded for mean power output, mean speed and peak speed. Very high inter-day test-retest reliability was found for mean power output, mean speed and peak speed (TE: 90 W, 0.2 m · s^{-1} and 0.2 m · s^{-1}, respectively; ICC: 0.87, 0.89 and 0.88, respectively; CV: 3.1%, 2.6% and 2.2%, respectively). The non-motorised treadmill was calibrated before each test. Treadmill belt speed, distance and horizontal forces were collected at a sampling rate of 100 Hz via the XPV7 PCB interface (Fitness Technology, Adelaide, Australia) and analysed with the Force 3.0 Software (Innervations Software, Joondalup, Australia). Players performed three successive maximal voluntary isokinetic eccentric hamstring actions without rest on a dynamometer (Con-Trex, Duebendorf, Switzerland). During testing, players were seated on the dynamometer in an adjustable chair, with test positions recorded and repeated for each player in subsequent sessions. Actions were performed on the players' dominant leg (their 'kicking' leg) through a range of 90° (with 0° being full knee extension) at an isokinetic angular velocity of 2.09 rad · s^{-1} (120° s^{-1}). Hamstring peak torque was recorded. Peak torque showed very high inter-day test-retest reliability (TE: 7.6 N · m; ICC: 0.87; CV: 4.7%).

Heart rate was continuously monitored throughout the 90 min soccer-specific aerobic field test (Polar Team System, Kempele, Finland) with heart rate values averaged every 5 s.

At the beginning of each session, players were required to rate their quality of sleep, fatigue, muscle soreness and stress on the 7-point Hooper's scale (Hooper et al., 1995). They used highlighter to specify where they experienced muscle soreness (Thompson et al., 1999). Players were also asked to rate their recovery as an overall psycho-physiological rating for the previous 24 hours, including the previous night's sleep, using the total quality recovery perceived scale (Kenttä & Hassmén, 1998). After the 90 min soccer-specific aerobic field test, participants were required to rate the global intensity of the session using the modified Borg scale (Borg, 1982; Foster, 1998) and the feeling scale (Rejeski et al., 1987). Ratings of fatigue, muscle soreness and stress levels as well as location of muscle soreness were also collected immediately after the 90 min soccer-specific aerobic field test. Baseline values corresponded to values obtained the morning before the 90 min soccer-specific aerobic field test.

Statistical analysis

Simple descriptive statistics are reported as means ± standard deviations (mean ± *s*). The normality distribution of the data was checked with the

Shapiro-Wilk test. Comparison between conditions (natural grass vs. artificial turf) was analysed using 2-way analysis of variance (ANOVA) for repeated measures. The effects of the independent variables (surface and time) on the dependent variables – squat jump, countermovement jump, mean power output, mean speed, peak speed, hamstring peak torque and subjective ratings – were analysed using a 2-way ANOVA for repeated measures. Bonferroni post hoc was then applied when the significant F-value was found. Changes in the mean between reference and post-90 min soccer-specific aerobic field test testing values of the two conditions were expressed as a percentage of the reference values for objective tests and absolute values for subjective ratings. Comparisons between surfaces were assessed through the difference in change scores. Effect size data (ES) was calculated to determine the magnitude of the change score and was assessed using the following criteria: $< 0.2 =$ trivial, $0.2–0.6 =$ small, $0.6–1.2 =$ moderate, $1.2–2.0 =$ large, and $> 2.0 =$ very large (Hopkins, 2002). Concerning the diagram labelling of the body's musculature, differences in frequencies in muscle areas highlighted as sore between the two conditions were tested using the following criteria: $< 10\% =$ trivial, $10–30\% =$ small, $30–50\% =$ moderate, $50–70\% =$ large, $> 70\% =$ very large (Hopkins, 2002). Differences in heart rate, fluid loss, body mass and rating of the 90 min soccer-specific aerobic field test were tested for significance using the Student's paired t-test when parametric methods were used or the paired Wilcoxon test when non-parametric methods were used. Confidence intervals (CI 95%) were used to specify estimation of changes in performance tests, subjective ratings and differences in frequencies. Statistical significance was set at $P < 0.05$.

Results

90 min soccer-specific aerobic field test

No significant differences were observed between the mean heart rate during the 90 min soccer-specific aerobic field test on artificial turf (151 ± 15 bpm) and the mean heart rate during the test on natural grass (145 ± 14 bpm). Similarly, no significant difference was observed between the fluid loss during the 90 min soccer-specific aerobic field test on artificial turf (1321 ± 855 ml) and the fluid loss during the test on natural grass (1554 ± 480 ml). The body mass measured after the 90 min soccer-specific aerobic field test on both surfaces was significantly lower ($P < 0.05$) than those recorded before the test, with a loss of body mass of -0.7 ± 0.8 kg ($-0.9 \pm 1.0\%$) on artificial turf and a loss of body mass of -0.9 ± 0.5 kg ($-1.3 \pm 0.6\%$) on natural grass. The fluid intake in both conditions was 638 ± 158 ml. No significant differences were found for the rating of intensity after the 90 min soccer-specific aerobic field test performed on artificial turf and natural grass (4.3 ± 1.5 vs. 4.8 ± 2.2 respectively) or for the feeling scale (1.0 ± 2.4 vs. 1.4 ± 1.8 respectively).

Recovery kinetics for physical performance and subjective ratings after the 90 min soccer-specific aerobic field test

The effect of surface on physical performance and subjective ratings and comparisons between surfaces throughout the recovery period are presented in Tables I and II. A significant interaction was found for squat jump between surface and time ($P < 0.01$). Post hoc analysis revealed that squat jump performance decrement was significantly lower ($P < 0.05$) on natural grass than artificial turf 48 h after the test with a small difference (+3.7%, CI 95%: 1.1 to 6.3%, $ES = 0.40$) observed. A significant main effect for time was also found for the squat jump ($P < 0.001$). Post hoc analysis revealed that squat jump performance was significantly impaired immediately after the test ($P < 0.001$). No significant interaction was found for countermovement jump between surface and time with only trivial differences ($ES = 0.04–0.12$) between artificial turf and natural grass in changes in countermovement jump performance throughout the recovery period. However, a significant main effect for time was found for countermovement jump ($P < 0.01$). Post hoc analysis revealed that countermovement jump performance was significantly impaired immediately after the test ($P < 0.01$) and at 24 h ($P < 0.05$).

There was no interaction effect of surface and time on hamstring peak torque. However, there was a main effect of surface on hamstring peak torque ($P < 0.05$). Hamstring peak torque decrement was higher on natural grass than on artificial turf with small differences immediately (-4.0%, CI 95%: -10.0 to 2.0%, $ES = 0.29$), 24 h (-3.1%, CI 95%: -9.3 to 3.1%, $ES = 0.29$) and 48 h (-3.8%, CI 95%: -8.5 to 0.9%, $ES = 0.43$) after the 90 min soccer-specific aerobic field test. There was also a main effect of time on hamstring peak torque ($P < 0.05$). Post hoc analysis revealed that hamstring peak torque was significantly different from baseline immediately after the test and at 24 h ($P < 0.05$).

All three variables reflective of sprint performance (i.e. mean power output, mean speed and peak speed) showed no change from baseline performance for both trials throughout the protocol. There were only trivial differences ($ES = 0.01–0.17$) between artificial turf and natural grass on changes in mean power output, mean speed and peak speed.

Table I. The effect of playing surface on physical performance and subjective ratings throughout the recovery period (mean ± *s*) following a soccer-specific exercise simulation, with the change in the mean expressed as relative values (%) for objective tests and absolute values (av) for subjective ratings.

	Artificial Turf							Natural Grass						
	Baseline	0 h	Change (% or av)	24 h	Change (% or av)	48 h	Change (% or av)	Baseline	0 h	Change (% or av)	24 h	Change (% or av)	48 h	Change (% or av)
SJ (cm)	39.5 ± 3.9	37.3 ± 2.9**	−5.4 ± 3.9%	38.3 ± 3.2	−2.8 ± 5.1%	37.6 ± 3.6	−4.6 ± 4.8%	39.5 ± 3.9	36.1 ± 3.7**	−8.4 ± 4.5%	38.0 ± 3.2	−3.5 ± 4.8%	39.0 ± 3.6	−1.0 ± 5.7%
CMJ (cm)	42.3 ± 5.4	39.9 ± 4.2**	−5.2 ± 6.2%	40.6 ± 4.2*	−3.7 ± 5.2%	41.1 ± 4.0	−2.4 ± 4.4%	42.3 ± 5.4	40.1 ± 4.1**	−4.7 ± 6.3%	40.2 ± 3.3*	−4.4 ± 6.5%	41.3 ± 3.9	−1.7 ± 7.6%
H PT(Nm)	148 ± 17	138 ± 22*	−4.9 ± 11.1%	138 ± 14*	−4.9 ± 9.1%	139 ± 13	−3.9 ± 8.0%	148 ± 17	133 ± 18*	−8.9 ± 6.7%	133 ± 15*	−8.0 ± 7.0%	134 ± 13	−7.7 ± 7.8%
MPO (W)	2390 ± 241	2431 ± 269	1.8 ± 5.5%	2440 ± 308	2.0 ± 6.5%	2471 ± 260	3.7 ± 8.6%	2390 ± 241	2421 ± 319	1.2 ± 6.8%	2492 ± 298	4.3 ± 7.9%	2465 ± 289	3.3 ± 7.9%
MS ($m \cdot s^{-1}$)	4.75 ± 0.43	4.84 ± 0.43	1.8 ± 3.4%	4.83 ± 0.48	1.7 ± 4.2%	4.85 ± 0.43	2.3 ± 6.7%	4.75 ± 0.43	4.77 ± 0.49	0.2 ± 4.0%	4.89 ± 0.47	3.1 ± 6.0%	4.83 ± 0.47	1.8 ± 5.9%
PS ($m \cdot s^{-1}$)	5.63 ± 0.40	5.52 ± 0.43	−1.9 ± 3.7%	5.60 ± 0.39	−0.5 ± 3.4%	5.58 ± 0.37	−0.7 ± 4.5%	5.63 ± 0.40	5.53 ± 0.48	−1.8 ± 3.1%	5.59 ± 0.42	−0.6 ± 4.4%	5.60 ± 0.44	−0.4 ± 4.7%
Sleep (au)	2.8 ± 0.9	–	–	3.2 ± 0.9	0.3 ± 1.2av	2.6 ± 0.9	−0.3 ± 1.1av	2.6 ± 0.9	–	–	2.8 ± 1.1	0.2 ± 0.6av	3.0 ± 1.0	0.4 ± 1.4av
Fatigue(au)	3.5 ± 1.0	4.4 ± 1.0**	0.9 ± 0.9av	4.1 ± 0.7	0.6 ± 1.1av	3.5 ± 0.8	0.0 ± 1.3av	3.7 ± 1.2	4.8 ± 0.8**	1.2 ± 1.2av	4.2 ± 0.8	0.5 ± 1.0av	3.8 ± 1.1	0.1 ± 0.9av
Stress (au)	2.5 ± 1.1	2.6 ± 1.1	0.1 ± 0.9av	2.5 ± 1.1	0.0 ± 0.4av	2.3 ± 1.1	−0.2 ± 0.6av	2.2 ± 1.0	2.4 ± 1.1	0.3 ± 0.5av	2.3 ± 1.1	0.1 ± 0.5av	2.4 ± 1.3	0.3 ± 0.8av
Soreness (au)	3.6 ± 1.1	4.3 ± 1.5**	0.7 ± 1.1av	4.3 ± 1.1**	0.8 ± 1.2av	4.0 ± 0.9	0.4 ± 1.4av	3.3 ± 1.3	4.3 ± 0.9**	0.9 ± 0.8av	4.2 ± 1.4**	0.8 ± 1.0av	3.9 ± 1.1	0.6 ± 1.3av
TQR (au)	14.3 ± 2.0	–	–	13.3 ± 1.7	−1.0 ± 2.5av	15.1 ± 1.2	0.8 ± 2.2av	14.4 ± 2.0	–	–	13.8 ± 2.1	−0.7 ± 2.0av	13.8 ± 1.2	−0.7 ± 2.4av

* Significantly different from reference values ($P < 0.05$); ** Significantly different from reference values ($P < 0.01$).
Note: au: arbitrary units; CMJ: countermovement jump; H PT: hamstring peak torque; MPO: mean power output; MS: mean speed; PS: peak speed; SJ: squat jump; TQR: total quality recovery.

Table II. Comparisons between playing surfaces for physical performance and subjective ratings after a soccer-specific exercise simulation with the change expressed as relative values (%) for objective tests and absolute values (av) for subjective ratings (± 95% confidence intervals) and the magnitude of the change (effect size).

	Natural Grass-Artificial Turf Baseline			Natural Grass-Artificial Turf 0 h			Natural Grass-Artificial Turf 24 h			Natural Grass-Artificial Turf 48 h		
	Change (% or av)	Effect size	Descriptor	Change (% or av)	Effect size	Descriptor	Change (% or av)	Effect size	Descriptor	Change (% or av)	Effect size	Descriptor
SJ		–		−3.1 ± 2.7%	−0.34	Small	−0.7 ± 2.4%	−0.09	Trivial	3.7 ± 2.6% #	0.40	Small
CMJ		–		0.5 ± 3.8%	0.04	Trivial	−0.8 ± 3.2%	−0.12	Trivial	0.6 ± 3.5%	0.04	Trivial
H PT		–		−4.0 ± 6.0%	−0.29	Small	−3.1 ± 6.2%	−0.29	Small	−3.8 ± 4.7%	−0.43	Small
MPO		–		−0.6 ± 4.1%	−0.03	Trivial	2.3 ± 4.6%	0.17	Trivial	−0.4 ± 5.1%	−0.02	Trivial
MS		–		−1.6 ± 2.6%	−0.15	Trivial	1.4 ± 3.5%	0.13	Trivial	−0.5 ± 3.7%	−0.04	Trivial
PS		–		0.0 ± 3.1%	0.01	Trivial	−0.2 ± 2.6%	−0.02	Trivial	0.3 ± 2.6%	0.05	Trivial
Sleep	−0.3 ± 0.7av	−0.27	Small	–	–	–	−0.2 ± 0.9av	−0.40	Small	0.7 ± 1.3av	0.43	Small
Fatigue	0.2 ± 0.8av	0.15	Trivial	0.3 ± 0.9av	0.45	Small	−0.1 ± 1.0av	0.11	Trivial	0.1 ± 1.0av	0.27	Small
Stress	−0.3 ± 0.4av	−0.31	Small	0.2 ± 0.8av	−0.15	Trivial	0.1 ± 0.4av	−0.23	Small	0.4 ± 0.7av	0.07	Trivial
Soreness	−0.3 ± 1.3av	−0.21	Small	0.3 ± 0.8av	0.00	Trivial	0.1 ± 0.9av	−0.13	Trivial	0.2 ± 1.5av	−0.09	Trivial
TQR	0.2 ± 1.4av	0.08	Trivial	–	–	–	0.3 ± 1.9av	0.26	Small	−1.5 ± 2.0av	−1.12	Moderate

Significant difference between groups ($P < 0.05$).
Note: Magnitudes of effect sizes are assessed using the following criteria: < 0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, and > 2.0 = very large. CMJ: countermovement jump; H PT: hamstring peak torque; MPO: mean power output; MS: mean speed; PS: peak speed; SJ: squat jump; TQR: total quality recovery.

There was no interaction effect of surface and time on ratings of quality of sleep, fatigue, muscle soreness, stress and total quality recovery with only trivial to small differences (ES = 0.00–0.45) between artificial turf and natural grass on changes in sleep, fatigue, stress and muscle soreness ratings throughout the recovery period. However, for the variable fatigue, there was a main effect of time ($P < 0.001$) with an increase to 'average-high' (1 unit) for both trials observed immediately after the test ($P < 0.001$). For the variable muscle soreness, a main effect of time was also observed ($P < 0.01$) with significant increases observed immediately after the test and at 24 h compared with baseline values ($P < 0.01$).

Differences in frequencies in muscle areas highlighted as sore between the two conditions at different time points throughout the recovery period are shown in Table III. There were trivial or small differences for pubis, groin, tibialis and lower back. However, soreness in quadriceps immediately after the 90 min soccer-specific aerobic field test, in gluteus 24 h after the test and in hamstring 48 h after the test were all reported to be moderately lower (from 31 to 46%) on natural grass than artificial turf.

Discussion

The aim of the present study was to compare the recovery kinetics of physical performance and subjective ratings in response to a soccer-specific exercise test performed on natural grass and artificial turf. The 90 min soccer-specific aerobic field test is validated to replicate the movement demands of soccer match-play and includes multiple changes in direction, accelerations and decelerations associated with muscle damage (Howatson & Milak, 2009; Magalhães et al., 2010; Thompson et al., 1999). Based on previous findings, we hypothesised that the soccer test-induced muscle damage may be greater on artificial turf resulting in delayed recovery process. Warren, Lowe, and Armstrong (1999) stated that measurement of maximal voluntary contraction torque provides the best method for quantifying muscle damage as it is accurate and reliable. In the present study, eccentric hamstring torque was tested because the hamstring is particularly prone to injury (Woods et al., 2004) and fatigue in soccer (Greig, 2008; Small et al., 2010). Results show that our hypothesis was rejected since hamstring peak torque decrement was higher on natural grass than on artificial turf ($P < 0.05$) with small differences reported through the 48 h recovery period. Yet despite the higher peak torque decrement on natural grass, players reported moderately higher soreness in the hamstrings in the artificial turf condition 48 h after the 90 min soccer-specific aerobic field test confirming that soreness is poorly correlated with changes in muscle function (Warren et al., 1999). Here, 6-s sprint performance (i.e. mean power output, mean speed) was not affected throughout the recovery period. This result may be explained by the activity profile of the 90 min soccer-

Table III. Frequencies difference (±95% confidence intervals) in muscle areas highlighted as sore between the two conditions throughout the recovery period.

	Baseline		0 h		+24 h		+48 h	
	Freq. diff. (%)	Descriptor	Freq. diff. (%)	Descriptor	Freq. diff. (%)	Descriptor	Freq. diff. (%)	Descriptor
Anterior view								
Pubis	-8 ± 24	Trivial	-15 ± 27	Small	-8 ± 14	Trivial	-8 ± 14	Trivial
Left groin	23 ± 29	Small	-15 ± 35	Small	23 ± 35	Small	-8 ± 30	Trivial
Right groin	15 ± 27	Small	-15 ± 32	Small	23 ± 35	Small	-15 ± 32	Small
Left quadriceps	0 ± 20	Trivial	46 ± 31	Moderate	23 ± 33	Small	15 ± 27	Small
Right quadriceps	0 ± 20	Trivial	46 ± 31	Moderate	15 ± 35	Small	8 ± 30	Trivial
Left tibialis	0 ± 0	Trivial	0 ± 0	Trivial	0 ± 0	Trivial	0 ± 0	Trivial
Right tibialis	15 ± 20	Small	8 ± 14	Trivial	8 ± 14	Trivial	0 ± 0	Trivial
Posterior view								
Lower back	-15 ± 35	Small	-23 ± 35	Small	-15 ± 37	Small	-15 ± 37	Small
Left gluteus	15 ± 20	Small	23 ± 29	Small	38 ± 26	Moderate	-15 ± 27	Small
Right gluteus	8 ± 14	Trivial	23 ± 29	Small	31 ± 25	Moderate	-15 ± 32	Small
Left hamstring	-8 ± 36	Trivial	-15 ± 37	Small	15 ± 37	Small	38 ± 35	Moderate
Right hamstring	0 ± 37	Trivial	-23 ± 35	Small	23 ± 29	Small	46 ± 27	Moderate
Left calf	0 ± 20	Trivial	0 ± 32	Trivial	-15 ± 35	Small	23 ± 29	Small
Right calf	8 ± 24	Trivial	-8 ± 34	Trivial	-8 ± 36	Trivial	8 ± 30	Trivial

Note: Magnitudes of effect sizes are assessed using the following criteria: < 10% = trivial, 10–30% = small, 30–50% = moderate, 50–70% = large, > 70% = very large. For a given area, a positive value in a frequencies difference indicates that more players experienced soreness in the artificial turf condition than the natural grass condition, while a negative value in a frequencies difference indicates that more players experienced soreness in the natural grass condition than the artificial turf condition.

specific aerobic field test which does not include contact situations such as tackles or collisions between players observed during actual soccer match-play. In a comparison of the effect of a simulated team sport activity circuit either with or without 44 body contacts on sprint performance, Singh, Guelfi, Landers, Dawson, and Bishop (2011) found that performance was significantly slower 48 h following the protocol with body contact ($P < 0.05$). In contrast, performance was maintained 48 h after the protocol without body contact. Similarly, Pointon and Duffield (2012) found that an intermittent-sprint protocol with tackling resulted in a significantly slower mean sprint time compared to the same protocol without tackling ($P < 0.05$). This study proposed that the inclusion of tackling resulted in greater central fatigue compared to the control condition, as observed by a greater reduction in voluntary activation. The absence of any 6-s sprint performance impairment in the present study may therefore be attributed to insufficient levels of muscle damage resulting from the lack of contact actions, jumps and tackles. As a consequence, future studies investigating the recovery process after a soccer match simulation test should consider the inclusion of simulated contact, jumps and tackles, in the exercise protocol. Future studies may also compare the impact of a soccer match and the 90 min soccer-specific aerobic field test on muscle damage markers.

In the present study, no significant differences were observed between the mean heart rate during 90 min soccer-specific aerobic field test on artificial turf and natural grass which suggests a similar physiological load on both surfaces. The rating of the global intensity of the 90 min test performed on natural grass and artificial turf showed no significant difference as did the feeling during the test which was 'neutral-slightly good' on both surfaces. Andersson et al. (2008a) examined the movement patterns, ball skills, and the impressions of elite football players during competitive games on artificial turf and natural grass. On a 10-point scale, where 0 = 'better than' and 10 = 'worse than', players reported a negative overall impression (8.3 ± 0.2), poorer ball control (7.3 ± 0.3), and greater subjective physical effort (7.2 ± 0.2) on artificial turf than natural grass despite similar total distance covered, high-intensity running and number of sprints. The discrepancy between our results and those from Andersson et al. (2008a) could be due to the protocol used and/or the familiarisation with artificial turf. In the present study, players completed a standardised soccer test which did not include any changes in playing characteristics during matches (i.e. fewer sliding tackles and more short passes on artificial turf) reported by Andersson et al. (2008a). The absence of a negative impression of artificial turf in the present study may also be explained by the fact that we tested young players (17.7 years) who were accustomed to playing on artificial turf whereas Andersson et al. (2008a) tested predominantly regular natural grass players aged 28.8 years. Familiarisation is a key point in studying the recovery process. Lavender and Nosaka (2008) have shown that a light eccentric exercise, which does not induce changes in any of the indirect markers of muscle damage, confers protection against muscle damage after a more strenuous eccentric exercise performed two days later. In the present study, the absence of negative perceptions may likely be explained by the familiarisation with artificial turf, but also the timing of the test (almost the end of the season). The familiarisation with artificial turf may consequently be important when measuring players' impression of artificial turf versus natural grass.

Conclusion

Findings from the present study indicate that although within-condition differences can be observed in physical performance and subjective ratings after a soccer test designed to replicate the physiological and mechanical demands of soccer match-play, there is no evidence to indicate that exercise on artificial turf results in greater fatigue and delayed recovery process. Future studies are required to confirm that results are similar when exercise is performed on a surface which players are not accustomed to since non-regular artificial turf players anecdotally report that the acute transition from natural grass to artificial turf is particularly disturbing.

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