Effects of Different Training Interventions on the Recovery of Physical and Neuromuscular Performance After a Soccer Match

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Abstract

Trecroci, A, Porcelli, S, Perri, E, Pedrali, M, Rasica, L, Alberti, G, Longo, S, and Iaia, FM. Effects of different training interventions on the recovery of physical and neuromuscular performance after a soccer match. *J Strength Cond Res* XX(X): 000–000, 2019—In competitive soccer, players are frequently required to play in periods with congested fixtures in which they have limited time to recover between matches (3–4 days). Thus, finding the most appropriate intervention strategy to limit players' neuromuscular (muscle function of lower limbs) and physical (running performance) impairments in this short period becomes crucial. The aim of the study was to examine how muscle function of knee extensors and flexors and sprint performance recovered +72 hours after match in relation to different field-based training sessions. Using a crossover design, 9 subelite players (age 17.6 ± 0.5 years, height 1.77 ± 0.02 m, body mass 66.4 ± 5.8 kg) underwent a soccer-specific training (SST) session or an active recovery regime (AR) on the second day after a match. Immediately after (0 hour) and +72 hours after match, 30-m sprint and repeated sprint ability (RSA) were assessed. Maximum isometric voluntary force (MVF) of knee extensors and flexors was determined at 120° and 90° (with 180° being full extension), respectively. SST and AR promoted similar effects on the recovery kinetics of sprint, RSA, and MVF of knee extensors ($p > 0.05$). However, compared with SST, AR promoted a significantly better restoration of MVF of knee flexors ($p < 0.05$) after +72 hours from the match. Because muscle fatigue has been related with increased hamstring injury risk, a training based on AR can be a valid intervention to promote the recovery of muscle force production of knee flexors and reduce hamstring injury risk in the postmatch period.

Key Words: active recovery, soccer training, exercise-induced fatigue, injury

Introduction

Fatigue can be defined as an acute deterioration of performance that causes an increase in the perceived exertion and the inability to produce a desired force or power output (23). In soccer, match-related fatigue causes a decline in high-intensity speed, total distance covered, repeated sprint ability (RSA), and strength levels (15). Moreover, it has been recently pointed out that match-related fatigue can alter the physiological responses, physical performance, and perceptual measures for several hours after a match (8,25). In particular, earlier studies reported impairments in maximal voluntary force (MVF) and sprint ability until +72 hours after a match, accompanied with increased levels of muscle soreness (4,12). The authors suggested that the slow recovery time frame could likely be due to muscle damage or/and severe inflammatory responses (19), as suggested by altered levels of specific biochemical markers (e.g., creatine kinase, cortisol, testosterone, and C-reactive protein) collected in the days after a match (8,12,18,25).

Given the number of competitive matches per season, players often face congested schedules with 2 matches per week separated by few days (e.g., 3–4 days) of recovery/training, during which a complete restoration of normal homeostasis is hindered (20). Consequently, an exposure to a prolonged fatigue state derived by an insufficient recovery time frame may increase the injury rate during matches (10,11).

Several strategies have been examined to manage postmatch fatigue, including nutritional intake, cold-water immersion, sleeping, and massage (20). However, most of them lie outside of the field-based training context and do not consider that players should continue their training routine in accordance with the congested schedules. For instance, when 2 matches are planned within a few days (e.g., first match on Saturday or Sunday and second match on Tuesday or Wednesday), players usually train in-between (Monday or Tuesday, respectively). Hence, the content of training sessions before the second match may modulate muscle fatigue and physical performance.

To date, few studies focused on the effects of different training sessions on recovery between 2 matches separated by a few days (1–3). These studies examined the effects of 1-hour active recovery (overall 30 minutes of submaximal cycling at 60% HRpeak and 30 minutes of resistance training at < 50% one repetition maximum) in comparison with passive recovery in elite female soccer players. After 22 and 46 hours from the match, the authors did not find significant differences in the recovery kinetics for physical performance and neuromuscular variables between the 2 interventions (1–3). However, the proposed active recovery (cycling and general resistance training tasks) did not consider sport-specific (technical and tactical) needs of players preparing

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for the successive match. The lack of specificity could explain why this strategy did not affect recovery kinetics after a match. The current literature lacks scientific evidence regarding proper training intervention strategies to be adopted in the days after a match, and their impact on subsequent restoration of physical performance and neuromuscular variables. Moreover, while players often rest in the day immediately after a match (+24 hours), they usually perform a training session on the second day (+48 hours) to prepare for the forthcoming match (7). This training session might affect the recovery kinetics depending on whether players engage in active recovery or soccer-specific drills. However, research accounting for training contents of these postmatch sessions is still scarce. Additional and extended knowledge about this topic would help designing better training programs, especially when a few days separate 2 games (e.g., the weekend and midweek matches).

Therefore, the aim of this study was to assess the recovery kinetics of physical and neuromuscular performance after a soccer match in relation to different types of field-based training interventions. We hypothesized that the inclusion of an active recovery on the second day after a match would promote a better restoration of physical and neuromuscular performance compared with a soccer-specific recovery session, especially for hamstring muscles force production.

Methods

Experimental Approach to the Problem

This study was conducted in-season using a crossover design. In Figure 1, the experimental timeline is shown. The players familiarized with all experimental procedures and measurements in 2 different days separated by at least 48 hours. During the first day, anthropometric measures were collected with the subjects in underwear and without shoes. Height and body mass were recorded using a stadiometer to the nearest 1.0 cm (SECA 213, Germany), and a portable scale (SECA 813, Germany) to the nearest 0.1 kg, respectively. Subsequently, the subjects familiarized with the 5 × 30-m RSA test and underwent the aerobic fitness assessment over the Yo-Yo intermittent recovery test level 1 (Yo-Yo IRT level 1) to explore their training status. On the second day, knee extensors and flexors maximum voluntary contraction (MVC) were performed. Following these 2 sessions, the players were randomly assigned to 1 of the 2 group-specific interventions: sport-specific training session (SST) and active recovery regime (AR). MVC and RSA were tested at the beginning of the experimental period (PRE1). Forty-eight hours from PRE1 (on Saturday), the subjects played a 90-minute friendly game against same-level players (no substitutions were allowed). Before the start of the game, a 25-minute warm-up with standardized FIFA 11+–related running drills and dynamic stretching was performed (21). Within 1 hour from the end of the game, MVC and RSA were performed. Forty-eight hours after match (on Monday), the players underwent the first training intervention (SST or AR). The day after (on Tuesday, +72 hours after match), MVC and RSA were performed to monitor the physical and neuromuscular recovery levels. After a 4-week wash-out period, the same timeline and procedures were adopted following a crossover design (Figure 1). Baseline data for MVC and RSA tests were collected before the second intervention period (PRE2). The rationale for a wash-out period of 4 weeks was to minimize the impact of fatigue-induced carryover effects mainly due to the in-season schedule (i.e., number of training sessions and games per week of the players). No players reported any musculoskeletal issues, injury events, and diseases throughout the 4-week wash-out.

During each experimental testing session, MVC preceded RSA evaluation. Testing sessions, as well as matches and training interventions, were provided at the same time of the day (i.e., from 3.00 to 5.00 PM) in favorable weather conditions (no wind or rain). Before each physical and neuromuscular assessment, the subjects underwent a brief (e.g., 5 minutes) standardized warm-up including jogging (forward and backward running) (28) and dynamic stretching (27). Each player was instructed to refrain from any strenuous exercise, to avoid ergogenic and alcoholic beverages in the previous 48 hours. Testing sessions and training interventions were performed on third-generation artificial turf, while matches were played on a natural grass due to logistical constraints.

Subjects

Eleven young subelite soccer players were recruited for the study. All players were part of a U19 National league from a semi-professional soccer club. Exclusion criteria were (a) lower-limb injuries in the last year and any minor injury in the previous 2 months possibly compromising the players' capacity to perform at their maximal intensity during testing sessions and matches; (b) inadequate training volume in the previous 8 weeks (i.e., less than 4 training sessions per week and not playing at least a match at the weekend); (c) history of febrile illness; (d) and prescription of medications within the 6 months before the study. Two players did not meet the criteria and were excluded at this stage (Figure 1). As a result, 9 subjects (age range 17-18 years, height 1.77 ± 0.02 m, body mass 66.4 ± 5.8 kg, Yo-Yo IRT level 1 1,944 ± 388 m) completed the study. Their roles were defenders ($n = 3$), midfielders ($n = 3$) and attackers ($n = 3$). The players and their parents or legal guardians were informed about the benefits and potential experimental risks of the research before giving their written informed consent. If under the age of 18, both the player and the parent or legal guardian signed the written informed consent to participate to the study. The study was approved by the Ethical Committee of the University of Milan, and all the procedures were conducted in accordance with the Helsinki declaration.

Procedures

The SST intervention consisted of a training session lasting ~60 minutes administered as follows: (a) 10 minutes of warm-up with FIFA 11+–related running drills and 5 minutes of dynamic stretching; (b) ~20 minutes of small-sided games (4 × 3 minutes of 4 vs. 4 sized 18 × 24 minutes, interspersed by 3 minutes of recovery); (c) 15 minutes of tactical drills concerning attacking and defending maneuvers; and (d) 10 minutes of offensive/defensive set plays. This training regime was included to reflect the in-season training session used by several Italian soccer teams before a match, which is similar to that reported in literature (9). In the AR intervention, players performed a training session at a lower exercise intensity lasting ~30 minutes consisting of: (a) 15 minutes of circle drills and 5 minutes of dynamic stretching; and (b) ~10 minutes of straight-line jogging (1 × 8 runs of ~20 seconds from a penalty area to the opposite area interspersed by ~40 seconds of walking recovery).

Subjects' physical activity during the game and each training session were monitored using a portable nondifferential 10-Hz

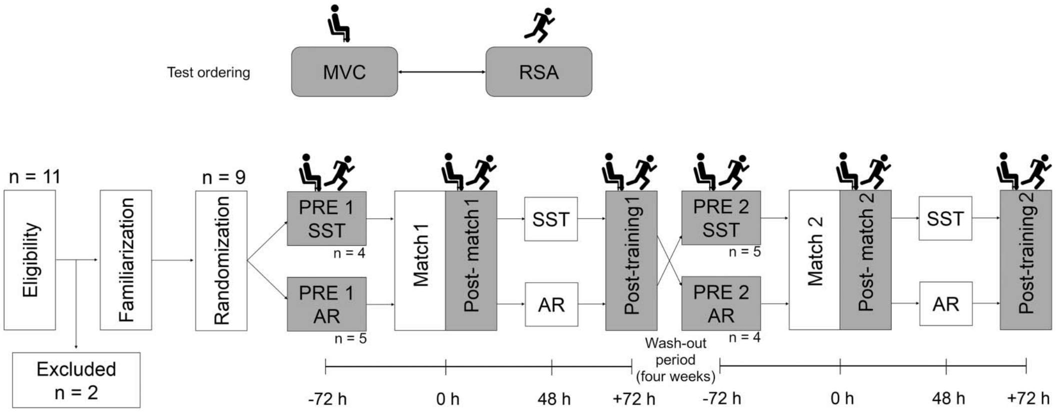

Figure 1. A schematic representation of the experimental schedule. The group-specific training interventions were completed 48 hours after the match-play while the testing sessions were performed before (−72 hours), immediately (0 hours), and 72 hours after the match. SST = sport-specific training session; AR = active recovery session; MVC = maximum voluntary contraction; RSA = repeated sprint ability.

global position system (GPS) trackers integrated with 400-Hz 3-D accelerometer, a 3-D gyroscope, a 3-D digital compass, and a 10-Hz 3-D magnetometer (Playertek GPS System; Kodaplay Ltd., Dundalk, Ireland). Subjects wore a tight vest with the GPS tracker placed right between their scapulae. All GPS trackers (i.e., the receivers) were turned on 15 minutes before each experimental session to favor an optimal acquisition of satellite signals. In addition, all players wore the same GPS device within the experimental sessions to avoid interunit error. Kinematic (i.e., total and sprint distances), metabolic (i.e., metabolic power level and zones), and mechanical loads (i.e., accelerations and decelerations) data were recorded and used to assess physical performance during the games and the training sessions (13). Heart rate (HR) response to exercise was monitored by a chest-band sensor (Polar Team system 2; Polar Electro, Kemple, Finland) throughout the game and testing sessions. The subjective rate of perceived exertion (RPE) was monitored by the Borg's category scale CR-10. Subjects rated their perceived effort within 30 minutes after the game and each experimental session.

Maximum Voluntary Force Assessment. The MVC test was performed on a custom-built ergometer previously used in the literature (22). Subjects were seated on a special chair, secured by a safety belt tightened around the shoulders and abdomen, with the arms grasping handlebars and the legs hanging vertically down. A strap was tightened around the subject's dominant ankle (i.e., the preferential kicking leg) immediately above tibial malleoli and was linked by a steel chain to a fixed frame. The chain length was regulated to obtain a knee angle of 120° and 90° (180° corresponding to full extension) for testing extension and flexion, respectively. These joint angles were selected because isometric peak force changes in relation to joint angle for each examined muscle group (30). The fixed frame was positioned behind the ankle to perform the isometric knee extensions and in front of the ankle to perform isometric knee flexion. A force sensor (TSD121C; BIOPAC Systems, Inc., Goleta, CA, USA) was connected in series to the chain, and force analog output was sampled at a frequency of 2 kHz using a data acquisition system (MP100; BIOPAC Systems, Inc.) connected to a personal computer by means of an universal serial bus port. Subjects began the experimental session by performing a warm-up consisting of 4–6 submaximal isometric contractions at a self-selected intensity (indicatively, between 50 and 70% of perceived maximal voluntary effort). Thereafter, subjects were asked to perform 3 MVC lasting 4–5 seconds each, interspersed by 1-minute recovery. The players were instructed to push as hard as possible, with verbal encouragement provided during contractions. Real-time force was displayed on a computer monitor in front of the subject to provide visual feedback during and between each MVC. A moving average value for each 1-second window was used to calculate the highest value achieved during any maximal contraction. The greatest value obtained among the 3 contractions was defined as the MVF for that session.

Physical Performance Assessment. The RSA test consisted of 5 repetitions of 30-m straight-line sprints interspersed by 25 seconds of passive recovery (13). The performance time was measured with timing gates (Witty System; Microgate, Bolzano, Italy) placed at 0.70 m at right angles relative to running direction. The subjects were instructed to run each 30-m sprint at their maximum ability. For the first sprint, the players started freely. For the remaining 4 sprints, a 5-second countdown was provided at the end of the passive recovery. For each sprint, the subjects started sprinting 0.30 m behind the starting line. The time of each sprint was recorded. The total sprint time was calculated by summing the time of all sprints and used as an index of RSA performance. Moreover, the time of the first sprint was used to assess the players' speed ability over 30 m (30-m sprint).

Statistical Analyses

According to the verified assumption of normality assessed by the Shapiro–Wilk's test, paired Student's *t*-tests were used to detect possible differences in MVF and RSA at baseline (i.e., PRE1 vs. PRE2), GPS metrics and RPE during the 2 matches (i.e., match 1 vs. match 2) and the 2 interventions (i.e., SST vs. AR). Test–retest reliability was performed using the intraclass correlation coefficient (ICC) for physical (30-m sprint and RSA total time) and neuromuscular (MVF) variables. A two-way analysis of variance (ANOVA) with repeated measures was used to detect possible interactions (time × intervention) throughout the 2 specific time points (i.e., 0 and +72 hours). In case of significant interaction, the Bonferroni's adjustment was used for comparisons. A significance level of 0.05 was chosen.

Table 1

Match activity profile of the 2 separate matches performed before the 2 interventions ($p > 0.05$).*†

Match activity	Total distance (m)	Sprint distance (m)	Metabolic power ($W \cdot kg^{-1}$)	RPE (a.u.)	Time in speed zones (s)			Top speed ($m \cdot s^{-1}$)	Distance in acceleration zones (m)		
					0–1 $m \cdot s^{-1}$	1–2 $m \cdot s^{-1}$	2–3 $m \cdot s^{-1}$		1–2 $m \cdot s^{-2}$	2–3 $m \cdot s^{-2}$	>3 $m \cdot s^{-2}$
Match 1	9,996 ± 1,070	777 ± 226	9.11 ± 1.03	6.7 ± 1.2	2,222 ± 634	2,884 ± 371	684 ± 358	8.12 ± 0.44	792.03 ± 142	188.71 ± 43	45.13 ± 17
Match 2	9,881 ± 1,300	785 ± 178	8.62 ± 1.26	6.7 ± 0.8	2,272 ± 630	2,731 ± 672	712 ± 386	8.01 ± 0.37	886.93 ± 206	219.35 ± 56	53.85 ± 12

*RPE = rating of perceived exertion.
†Data are presented as mean ± *SD*.

To focus on the practical relevance of the difference in the recovery kinetics (i.e., from 0 hours to +72 hours) of each intervention, the magnitude-based inference (MBI) approach was also used (5,14). For between-group changes, the chances that the true mean changes induced by each intervention were beneficial (i.e., greater than the smallest worthwhile change, SWC [0.2 multiplied by the between-subject *SD*]), unclear, or harmful were computed (5) for physical and neuromuscular performance. Likewise, quantitative chances of beneficial, unclear, or harmful changes were assessed qualitatively as follows: 25–75%, possibly; 75–95%, likely; 95–99%, very likely; and >99%, almost certainly. If the chance of having greater and poorer differences was both >5%, the true difference was assessed as unclear (5). Magnitude-based inference calculations and interpretations were used on a customized spreadsheet available at www.sportsci.org/index.html. The effect size (ES) of physical and neuromuscular changes was calculated to display within-group (match-related changes from −72 to 0 hours) and between-group (postmatch recovery from 0 to +72 hours between SST and AR) standardized differences. The ES was classified as trivial (ES < 0.2), small (0.2 < ES < 0.5), moderate (0.5 < ES < 0.8), and large (ES > 0.8). Data are presented as mean ± *SD*. Relative changes were expressed as means ±90% confidence intervals (CIs).

Results

In PRE1 and PRE2, 30-m sprint ($p = 0.556$), RSA ($p = 0.576$), and MVF of extensor ($p = 0.827$) and flexor ($p = 0.369$) muscles did not present significant differences.

Prevalues (at −72 hours) grouped by intervention were (a) 30-m sprint time: 4.26 ± 0.11 seconds (95% CI: 4.18–4.33) for SST, and 4.25 ± 0.07 seconds (95% CI: 4.20–4.29) for AR; (b) RSA total time: 21.94 ± 0.67 seconds (95% CI: 21.51–22.38) for SST, and 21.91 ± 0.58 seconds (95% CI: 21.54–22.30) for AR; (c) knee extensors MVF: 782.34 ± 90.72 N (95% CI: 723.07–841.61) for SST, and 777.85 ± 87.10 N (95% CI: 720.95–834.75) for AR; (d) knee flexors MVF: 351.23 ± 41.78 N (95% CI: 323.94–378.53) for SST, and 365.27 ± 30.60 N (95% CI: 345.28–385.26) for AR.

Test–retest showed a good-to-excellent reliability for 30-m sprint (ICC = 0.95 [0.82–0.99]), RSA total time (ICC = 0.97 [0.88–0.99]), and MVF of extensors (ICC = 0.95 [0.79–0.98]) and flexors (ICC = 0.95 [0.73–0.98]). Match activity profiles were similar between the 2 matches ($p > 0.05$) (Table 1).

Table 2 shows the activity profiles data for all players during SST and AR. Soccer-specific training elicited significantly higher physical demands ($p < 0.05$) for all parameters measured (RPE, total distance, metabolic power, time spent over 75% maximum HR, and distance covered at accelerating and decelerating up to 3 $m \cdot s^{-2}$) compared with AR.

Match-related changes (i.e., from −72 to 0 hours) are reported in Table 3. The 30-m sprint time of both SST and AR increased with large effects (ES = 1.33 and 2.39, respectively) immediately after the match. Likewise, RSA total time of both SST and AR increased with large effects (ES = 0.82 and 0.83, respectively). From −72 to 0 hours, MVF for knee extensors of both SST and AR decreased with large effects (ES = 0.81 and 1.32, respectively) immediately after the match. Likewise, MVF for knee flexors of both SST and AR decreased with large effects (ES = 1.02 and 1.99, respectively).

Table 2

Internal load assessed by the Borg's CR-10 scale after both group-specific interventions, and kinematic, metabolic, cardiovascular, and mechanical loads assessed by GPS during both group-specific interventions.*†

Intervention load	Variables	SST	AR
Internal	RPE	3.6 ± 1.2‡	1.1 ± 0.6
Kinematic	Total distance (km)	4.25 ± 0.51‡	1.88 ± 0.33
Metabolic	Metabolic power score ($W \cdot kg^{-1}$)	3.74 ± 0.67‡	1.90 ± 0.36
Cardiovascular	Time in HR zone 75–85% HRmax (s)	830 ± 182‡	102 ± 50
	Time in HR zone 86–96% HRmax (s)	273 ± 339	0 ± 0
Mechanical	Distance covered at acceleration of 1–2 $m \cdot s^{-2}$ (m)	348.4 ± 65.5‡	94.4 ± 28.4
	Distance covered at deceleration of 1–2 $m \cdot s^{-2}$ (m)	415.0 ± 88.3‡	126.5 ± 33.4
	Distance covered at acceleration of 2–3 $m \cdot s^{-2}$ (m)	105.8 ± 34.6	0 ± 0
	Distance covered at deceleration of 2–3 $m \cdot s^{-2}$ (m)	130.5 ± 40.2	0 ± 0
	Distance covered at acceleration >3 $m \cdot s^{-2}$ (m)	25.57 ± 13.34	0 ± 0
	Distance covered at deceleration <-3 $m \cdot s^{-2}$ (m)	32.78 ± 15.67	0 ± 0

*GPS = global positioning system, SST = soccer-specific training session, AR = active recovery session, RPE = rating of perceived exertion, HR = heart rate, HRmax = maximum heart rate.

†Data are presented as mean ± *SD*.

‡$p < 0.0001$ significantly different between from AR.

Postmatch Recovery in Physical Performance

Table 3 shows data regarding 30-m sprint and RSA performance in the 2 groups at different time points. No significant time × intervention interaction was found in 30-m sprint and RSA performance, while a significant main effect of time was detected ($p = 0.002$ and $p < 0.004$, respectively). Specifically, from 0 to +72 hours, both SST ($p = 0.005$) and AR ($p = 0.016$) improved significantly in the 30-m sprint time (~5.0%). Likewise, both SST ($p = 0.008$) and AR ($p = 0.027$) also improved significantly in the RSA total time (~3%).

Postmatch Recovery in Maximum Voluntary Force

Table 3 shows MVF data for knee flexors and extensors in the 2 groups at different time points. No significant time × intervention interaction was found in the knee extensors MVF ($p > 0.05$); the analysis revealed a significant main effect of time ($p = 0.002$) (Table 3). Knee extensors MVF increased significantly from 0 to +72 hours in both SST (~7.2%, $p = 0.045$) and AR (~11.1%, $p = 0.004$). A significant time × intervention interaction was found ($p < 0.05$) (Table 3), as well as a significant main effect of time ($p = 0.003$) was observed for knee flexors MVF. Muscle force increased significantly in AR (~25.7%, $p = 0.001$), whereas it did not recover in SST (~9.4%, $p = 0.083$).

Magnitude-Based Inference

The Figure 2 shows the overall between-group changes using MBI approach focusing on the changes between 0 hours and +72 hours. Analyses from MBI revealed that after AR knee flexors MVF was likely greater (ES = −0.60) at +72 hours compared with SST, while differences between interventions in the recovery kinetics of knee extensors MVF (ES = −0.23), 30-m sprint (ES = 0.26), and RSA (ES = −0.05) were unclear (Figure 2).

Discussion

This study evaluated for the first time the effects of a soccer-specific training session on the recovery kinetics of physical performance and neuromuscular variables in response to a match. The main finding of this study was that a regime of active recovery promoted a better restoration of muscle force of knee flexors within 72 hours after match compared with a more traditional training session composed by soccer-specific drills. In addition,

Table 3

Descriptive statistics (mean ± *SD*) of physical and neuromuscular variables of the 2 treatments with *F* values and *p* values for interaction (time × intervention) derived from the two-way ANOVA with repeated measures.

				Time × intervention	
Variables	**Intervention**	**Postmatch (0 h)**	**Postintervention (+72 h)**	$F_{(2,16)}$	*p*
Physical					
30-m sprint (s)	SST	4.47 ± 0.21 [4.33–4.60]	4.28 ± 0.13 [4.19–4.37]§§	0.287	0.607
	AR	4.51 ± 0.15 [4.41–4.61]	4.28 ± 0.22 [4.14–4.42]§		
RSA (s)	SST	22.58 ± 0.86 [22.01–23.14]	21.82 ± 0.89 [21.25–22.40]§§	0.007	0.906
	AR	22.54 ± 0.90 [21.95–23.12]	21.84 ± 0.90 [21.05–22.43]§		
MVF					
Extensors (N)	SST	702.99 ± 98.2 [638.84–767.15]	754.1 ± 93.1 [693.27–815.03]§	0.586	0.240
	AR	656.62 ± 95.4 [594.26–718.97]	729.6 ± 81.3 [676.47–782.79]§		
Flexors (N)	SST	298.24 ± 61.9 [257.76–338.72]	326.3 ± 54.0 [291.07–361.69]	6.329	0.036
	AR	280.75 ± 54.3 [245.26–316.23]	352.4 ± 55.3 [316.26–388.58]§‡		

ANOVA = analysis of variance; SST = sport-specific training session, AR = active recovery session, RSA = repeated sprint ability, MVF = maximum voluntary force.

Ninety-five percent (95%) confidence intervals are enclosed in square brackets.

‡$p < 0.05$ significant time × intervention interaction (between 0 and +72 hours).

§$p < 0.05$ significantly different from postmatch.

§§$p < 0.01$ significantly different from postmatch.

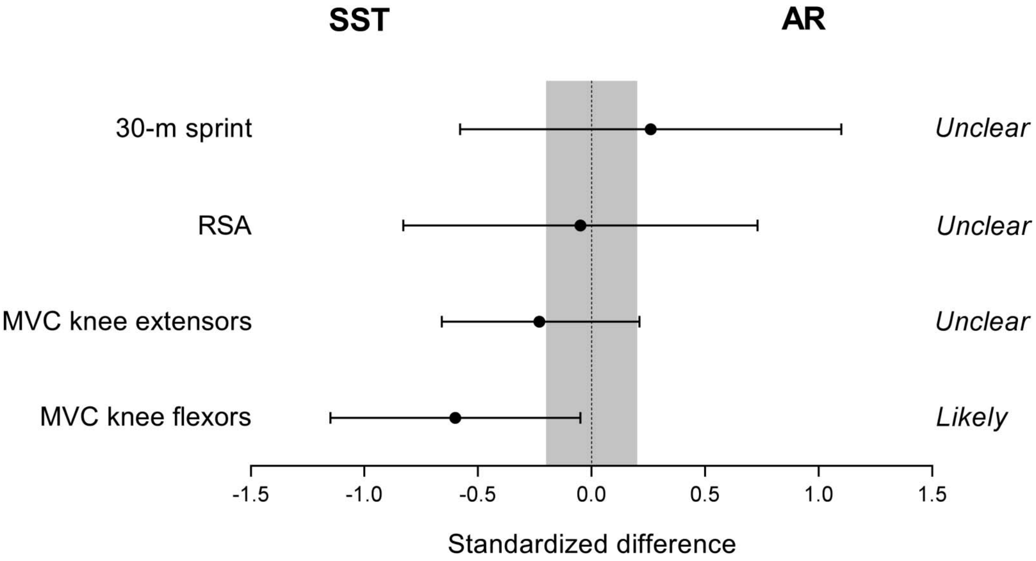

Figure 2. Between-intervention changes (SST vs. AR) on the restoration of physical (30-m sprint and RSA) and neuromuscular (MVC) performance from 0 to +72 hours after match. Data are presented as standardized difference (Cohen's d) ±90% CI. SST = soccer-specific training session; AR = active recovery session; RSA = repeated sprint ability; MVC = maximum voluntarily contraction; CI = confidence intervals.

the 2 interventions had similar effects on the recovery of sprint performance and MVF of knee extensors. These findings suggest that postmatch recovery strategies involving low-to-moderate activities (i.e., AR) may be effective in managing the restoration of neuromuscular function of knee flexor muscles (i.e., hamstrings).

In a congested fixture schedule, players may perform several matches within a few days along which they continue to train. The content of such training sessions may encompass active recovery (e.g., low-to-moderate demanding activities) or soccer-specific training (e.g., moderate-to-high demanding activities), which are aimed to alleviate postmatch fatigue and to preserve physical performance. Unfortunately, to date, there is no consensus on the best strategy to be adopted in the days after a match and its impact on subsequent restoration of physical performance and neuromuscular variables. In this study, we compared the effects of 2 training interventions (SST and AR) within the days after a match. The SST consisted of small-sided games, attacking and defending maneuvers, and set plays, which are commonly embedded in prematch training sessions to meet players' needs for an upcoming match (i.e., weekly or midweek match day). Recovery regime consisted of low-intensity physical activities (e.g., straight-line jogging) as demonstrated by the results reported in Table 2. Indeed, in the whole SST session, the sum of the distances covered accelerating (from 1 to 2, 2 to 3, and >3 m·s^{-2}) and decelerating (from -1 to -2, 2 to 3, and <-3 m·s^{-2}) were fivefold of those observed in AR. Interestingly, despite differences in intensities, SST and AR determined similar recovery kinetics in sprint performance, RSA, and muscle force production of knee extensors. Conversely, knee flexors MVF showed a different time course +72 hours from the match between interventions, with a mainly recovered force production only in AR. Our measurements were not aimed to investigate the cause of this difference, but it is known soccer-specific drills may increase exercise-induced impairment of knee flexors function due to the metabolic and mechanical workload imposed on each player (13). Consequently, it is possible to hypothesize that the amount of eccentric and concentric actions imposed by SST training (e.g., small-sided games) might have concurred in altering muscle function of knee flexors (9,25). Nevertheless, concentric and eccentric strength were not evaluated in this study; therefore, this hypothesis needs to be confirmed in future studies.

Previously, several studies investigated the recovery kinetics of muscle force production after a soccer match, with contrasting findings (9,15,23–25). Some authors demonstrated that lower-limb strength levels remained impaired up to 12–24 hours from a match (15,23,24), with a complete recovery reached from 36 to 48 hours. Other studies observed a more prolonged impairment of lower-limb strength until 60 (9) and 72 hours (25). This discrepancy of results can be related to several factors. For example, the exercise order throughout the session can have an impact. However, the most likely explanation may be linked to the activity performed in the postmatch days in terms of daily practice (e.g., passive and active recovery, as well as sport-specific training) (9). Among the above-mentioned studies, only Draganidis et al. (9) investigated the recovery of lower-limb neuromuscular function (knee extensors and flexors strength) with a special emphasis on the daily training performed during the postmatch period. The authors simulated 2 in-season training sessions approximately 24 and 48 hours after match lasting 50 and 70 minutes, respectively. The former session included low-to-moderate demanding activities comparable with the AR used in this study (e.g., technical drills and moderate-intensity endurance running), while the latter included more demanding soccer-specific drills, partially comparable with the present SST (e.g., technical training, agility drills, and set plays). Draganidis et al. (9) observed that players' neuromuscular function of knee extensors and flexors decreased significantly after 12 hours after match, and it remained lower than baseline values up to 60 hours after match. Moreover, the authors observed that the decrement magnitude of force was greater for the flexors than extensors muscles. The authors claimed that the activities performed during daily training after a match might have extended the time window of lower-limb strength decline. Furthermore, they also explained that a more intense training session might jeopardize the recovery of knee extensors and flexors strength (9). The results of this study seem to agree with the above-mentioned findings.

Interestingly, the time course of muscle force recovery for knee extensors was not affected by the 2 different training interventions. Indeed, knee extensors force production after the match was lower than before the match, and this force production impairment recovered about 10% from 0 to +72 hours after both training interventions. This study did not investigate the mechanistic bases of the different behavior of recovery kinetics of knee extensors and flexors MVF, but they may be related to the functional contribution and demands of each muscle group (quadriceps and hamstring muscles) (16) in response to sport-specific tasks. On one hand, quadriceps muscles are the main contributor to movements requiring knee extension (23), which is embodied in several explosive actions such as acceleration, kicking, and jumping (16). It has been shown that during sprinting, the knee flexors undergo the greatest muscle-tendon strain (larger in the biceps femoris muscle) at the late swing before foot–ground contact (26). Consequently, the hamstrings may undergo severe ultrastructural perturbations (25), which would lead to a reduced knee flexors force production and an increase in their injury risk. This hypothesis is supported by Marshall et al. (16) who suggested that the biceps femoris muscle may be primarily exposed to exercise-induced fatigue during soccer-related activity. Hence, it can be speculated that the content of SST may have played a role in slowing MVF restoration of knee flexors. On the other hand, when interpreting the present results, it should be considered that changes in knee flexors strength could also be affected by the playing position, as specific roles (e.g., external midfielder) prompt players to perform higher number of explosive actions, such as sprints. Furthermore, when comparing the effects of AR and passive rest on the recovery pattern of postmatch fatigue, no differences were found between methods (1–3). However, performing AR at +48 hours rather than passive rest could involve a higher practical applicability to the field for recovering physical fitness and performance, especially between close matches (3).

Regarding 30-m sprint and RSA, running times were impaired immediately after the match and recovered to baseline levels after 72 hours without differences between the 2 interventions. These results are in accordance with the literature reporting that postmatch recovery is faster in 30-m sprint (8,24) and RSA (25) than hamstring muscle function (25) regardless of daily practice on the second day after a single match. Silva et al. (24) observed a complete restoration in 30-m sprint time after 48 hours after match in professional players. The authors suggested that the postmatch recovery of sprint time in response to a match is affected to a smaller extent than biochemical disturbance and is confined to a time window of 24 hours (24). Accordingly, in this study, SST did not influence the fast recovery of sprint performance at +72 hours compared with AR, suggesting that players' sprint ability recovered earlier. In addition, given the findings of a recent meta-analytical review (25), it could be hypothesized that the present sprint performance recovered within the 48 hours after match. However, this suggestion should be taken cautiously due to the small sample size and the level (subelite) of our players. Moreover, Mohr et al. (18) observed that within a congested schedule (i.e., 3 soccer matches played in a week), players recovered their repeated sprint performance (5 × 30 m with 25 seconds of rest) 72 hours after the first match. However, after the second and the third match, the repeated sprint performance remained depressed on the third recovery day. Thus, the present findings suggesting that 72 hours might be an adequate time window to recover the RSA from a single match cannot be confirmed when 2 or 3 matches occur within few days. Although it would also be of interest to examine the extent of the recovery rate when playing multiple matches within a week, this was outside the scope of this study. Thereby, future research should be encouraged to investigate long-term effects of different training regimes on the restoration of both physical and neuromuscular performance during a congested weekly schedule.

In conclusion, this study shows that practicing low-intensity activities during postmatch days restores knee flexor muscle force production at a higher level compared with a soccer-specific training session. However, no differences were observed between active recovery and soccer-specific training sessions on the recovery pattern of sprint performance, RSA, and muscle force production of knee extensors.

Limitations

This study has 3 main limitations that should be acknowledged. First, the subjects were not professional or elite players, hereby generalizations should be made with caution. Indeed, players with higher competitive level may display different physical performance and recovery patterns (9,29), showing a different response to training (6).

Second, 2 friendly matches, rather than competitive matches, were used in the present protocol to induce soccer fatigue-related effects. Soccer team programs are characterized by congested scheduled with several competitive matches in few days. This has been observed to induce greater internal, kinematic, metabolic, and mechanical loads in player than that reported in this study (17,18,24). Thus, further studies will have to investigate the effects of several training sessions and competitive matches on physical and physiological parameters.

Third, the greatest limitation of this study was the small sample size, which could weaken the strength of the results. Nevertheless, the crossover design would partially compensate for this limitation by reducing data variability.

Practical Applications

Since hamstrings muscle strains are frequent injuries in soccer players, the results of this study may encourage the technical staff to opt for low-to-moderate training interventions (i.e., active recovery) to manage efficiently the restoration of neuromuscular function of knee flexors in the days after a match. However, bearing in mind the technical and tactical needs of players preparing for the successive match, it may not always be pertinent to perform AR on a certain phase of the competitive season. All together, these considerations are particularly relevant when congested calendars impose players to play 2 matches within few days.

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