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Post-match recovery of change of direction performance in soccer: Examining change of direction deficit and asymmetries

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Abstract

This study aimed to analyze the influence of a soccer match on change of direction performance immediately and after a 48-h recovery period, with special focus on change of direction deficit and change of direction asymmetries. Fifteen outfield male soccer players who belonged to the same regional-level team participated in this study (age: 27.20 ± 5.30 years; height: 176.20 ± 6.46 cm; body mass: 73.80 ± 10.36 kg; tier 2). A repeated-measures observational design was used, with two data collection periods during the competitive period of one season (i.e., midseason and end-season). Each data collection period included one official match and their corresponding 48-h recovery period. The 30-m linear straight sprint test and the 505 change of direction test were conducted at pre-, post- and 48-h post-match. Findings show increased change of direction completion time at post- ($p = 0.030$) and 48-h post-match ($p < 0.001$), greater change of direction deficit at 48-h post-match ($p < 0.001$) regardless of the method for classifying lower-limb dominance (i.e., dominant and non-dominant in the change of direction test, preferred and non-preferred kicking limb), and impaired change of direction performance with preferred kicking limb immediately after the match ($p = 0.024$). Thus, the acute and residual fatigue-induced by a soccer match resulted in different alterations at post- and 48-h post-match in both change of direction deficit and change of direction asymmetries. These results may be applicable by practitioners interested in understanding the influence of a soccer match on change of direction performance.

Keywords

Association football, fatigue, lower-limb dominance, sprinting, turning manoeuvres

Introduction

Agility is considered a rapid whole-body movement with change of velocity or direction in response to a stimulus.[1] This complex and multifaceted skill is determined by two group of components:[1,2] perceptual and decision-making factors (i.e., visual-scanning techniques, knowledge of situations, pattern recognition, anticipation) and change of direction (COD) speed (i.e., anthropometry, technique, straight sprint speed, leg muscle qualities - reactive strength, concentric strength, power, left-right imbalance -). Thus, COD speed provides the mechanical and physical basis underpinning agility.[1,2]

Most team-sports require recognition and appropriate reaction to a varied set of external stimuli (e.g., opponents' or teammates' actions and movements),[3] so planned directional changes are uncommon. However, COD manoeuvres in multiple directions and at different angles are related to decisive actions and successful performances in team-sports, such as soccer.[4,5] Although position-dependant, soccer players may perform up to 700 quick directional

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changes and swerves with different magnitudes at varying angles during match-play.[5] This ability to change direction efficiently is a key movement that can lead to players for faster positioning, fighting for the ball, dribbling or evading opponents and other actions that may ultimately influence match outcomes. For these reasons, soccer players should have the ability to effectively perform numerous multidirectional accelerations, decelerations, and cutting and turning manoeuvres at different intensities.[1,3,6]

Although an important topic, the acute and residual fatigue-induced alterations in COD performance have not been extensively analyzed in soccer players. Some studies explored these changes after simulated match-play protocols, but results are not conclusive.[7–9] Notwithstanding, between-halves variability of some external-load metrics, particularly accelerations and decelerations, may be related to subsequent COD performance decrements immediately after a soccer match,[10] so research in real-world exercise conditions might shed light upon interesting information on the player's COD performance impairments. In this context, some studies have also analyzed fatigue-induced adjustments on COD performance immediately after soccer matches and during the recovery period.[10,11] Immediately after friendly matches, both professional and semi-professional soccer players may evidence neuromuscular fatigue, as COD performance (i.e., 20 + 20-m shuttle sprint, T test) may be decreased.[10,11] 48-h of recovery may be longer enough to ensure a complete recovery of COD-derived metrics of performance,[11] but it is important to consider other match-related factors that could influence the recovery kinetics, such as congested schedules. For instance, youth soccer players presented greater impairments in the 505 COD test 72-h after the third match of a week in which three matches were played compared to 72-h after the match of a week with only one competitive match.[12] However, these results need to be interpreted with caution as it has also been reported that an official soccer match of elite players may not induce COD performance (i.e., adapted version of T test) decrements immediately after and during the 72-h recovery period, even with biochemical and neuromuscular alterations within 24–48-h of the recovery period.[13] Thus, future studies in the sport-specific scenarios are required to obtain robust conclusions on this topic.

Most of the aforementioned studies investigating the acute and residual fatigue-induced impairments in COD performance evaluated the soccer players' ability to change direction by reporting total or completion time in different COD tests.[8–13] From a performance perspective, the ability to complete the deceleration, reorientation and acceleration of the body's center of mass in the intended direction over the shortest time-period is critical. However, physical qualities such as acceleration and linear speed could mask deficiencies in COD ability so total or completion time may not exactly represent the ability of athletes to effectively change direction.[14–17] In this context, the COD deficit (CODD) was proposed as a more isolated measure of COD ability which is not influenced by an athlete's acceleration and linear speed qualities and provides complementary information on the efficiency to change direction.[16,18] Despite this interesting approach, no study has evaluated the acute and residual fatigue-induced changes in the CODD after a soccer match. From a performance perspective, being equally efficient at changing direction from both limbs and directions would also be advantageous for soccer players, so COD asymmetries and imbalances could indicate a deficiency in COD ability to a specific direction or side.[14] In this regard, it is difficult to derive explicit conclusions about the influence of exercise-induced fatigue on asymmetries and the relation to the injury risk,[19] but fatigue-induced changes in kinematics during COD tasks may have implications for injury incidence.[7] Although important to subsequently inform for future training, no study has comprehensively analyzed the plausible acute and residual fatigue-induced alterations in COD asymmetries after a soccer match. Therefore, this study aimed to analyze the influence of a soccer match on COD performance immediately and after a 48-h recovery period, with special focus on CODD and COD asymmetries.

Materials and methods

Participants

Twenty-one outfield male soccer players who belonged to the same regional-level team were initially recruited for participate in this study. As outlined in the Participant Classification Framework,[20] they should be classified as tier 2 players. Goalkeepers were excluded as their match-related loads are very different to those demanded to the outfield players. Participants were only included if they met all the following inclusion criteria in at least one data collection period: absence of any medical conditions or lower-limb injuries, train (~90 min) three times the week before the match and play at least 80 min during one match. Finally, data of fifteen outfield male soccer players (age: 27.20 ± 5.30 years; height: 176.20 ± 6.46 cm; body mass: 73.80 ± 10.36 kg) were included in the statistical analysis.

Design

A repeated-measures observational design was used in this study, with two data collection periods during the competitive period of one season (i.e., midseason and end-season). Each data collection period included one official match and their corresponding 48-h recovery period. Pre-match measurements were obtained at the end of the team typical prematch warm-up routine of the match-day (15:00 and

15:30 h), immediately post-, and at 48-h post-match (i.e., during the initial part of the first training session after each match). Matches were played against two different regional-level teams on a natural grass pitch (15:30 and 16:00 h) and lasted 90 min (with a half-time of 15 min). The team's coaching members freely decided their starting line-up and substitutions without any intervention from the research staff.

Procedures

All testing procedures lasted 10 min and were ordered as follows: 505 COD test and 30-m linear straight sprint test. All participants were familiar with the tests as instructions were provided during the recruitment session (i.e., two weeks before the first data collection period). Participants received again verbal instruction from researchers immediately prior to conducting attempts for each test during both data collection periods. With the aim of maximizing ecological validity regarding specific responses in sprinting mechanics,[21,22] both tests were performed in the soccer-specific competition environment (i.e., natural grass pitch) and with the usual clothing and specific footwear (i.e., soccer boots). Testing procedures were conducted within a temperature range of 13–23°C and a relative humidity range of 70%–84%.

Sprint performance was evaluated using the 30-m linear straight sprint test. Four pairs of single-beam photoelectric cells (Microgate Witty-system, Microgate®, Bolzano, Italy) were used and were placed 0.7-m above the ground. A standing start was used, 0.5-m away from the first photocell gate, and participants were free to choose their front leg in this stance. When ready, each participant ran as fast as possible until crossing the last photocell gate while the timer was activated automatically as the participant passed through each photocell gate. Participants completed two attempts interspersed with 1.5 min of passive recovery.

COD performance was assessed using the 505 COD test. The methodology for this test was as per originally established methods.[23] Participants were required to sprint to a turning line marked 15-m from the start line, placing either left or right foot on the line (depending on the trial, but always ensuring contact with the designated line), turn 180° and sprint back 5-m through the finish. The result of the test was the time taken for the participant to pass the timing point at 10-m from the starting point, turn 180° at the turning line, and then pass the timing point a second time. COD performance was monitored using a pair of single-beam photoelectric cells (Microgate Witty-system, Microgate®, Bolzano, Italy) placed 0.7-m above the ground at the beginning and arrival of the test. A standing start was used, 0.5-m away from the first photocell gate, and participants were free to start when ready and to choose their front leg in this stance. Because the 505 COD test involves pre-planned movements,[1,6] the order of the turn was established by researchers. A researcher was positioned at the turning line, and if the participant changed direction before hitting the turning line, or turned off the incorrect foot, then the trial was disregarded and reattempted after the recovery period. Another researcher employed an observational analysis of pacing strategy during the 10-m approach distance, requiring participants who did not appear to exert maximal effort to reattempt the test after a recovery period. Two trials interspersed with 1.5 min of passive recovery were recorded for both turns off the left and right side.

Prior to conducting any tests, participants conducted a standardized pre-match warm-up routine (22 min) consisting of low aerobic activity (2 min), technical drills (2 min), dynamic stretching (5 min), small-sided game (4 vs 4 + 2 jokers, no goals, 20 × 20-m, individual interaction space 40 m^2 per player, 3 sets of 2 min with one min of recovery), technical-tactical drills (2 min), and progressive sprinting with pre-planned COD (3 min). A similar warm-up routine was used during the training session at 48-h post-match.

Participants trained 20-h before matches as the team regularly did during the in-season period and were not involved in any type of training or physical activity during the 48-h recovery period. All of them were asked to attend testing in a fed and hydrated state, like their normal usual habits before matches, and to refrain from taking anti-inflammatory drugs, nutritional or multi-vitamin supplements, antioxidants or other prescription drugs and from using any recovery strategy during the two in-season microcycles of each data collection period. They were also advised to abstain from consuming caffeine and alcohol 24-h before pre-match testing and during the 48-h recovery period.

Test-derived metrics

Sprint performance was evaluated using sprint times (s), which were recorded at 10- (SPR10), 20- (SPR20) and 30-m (SPR30). Although using either the best or the average performance over a series of repeated sprints may have a similar ability to monitor changes in sprint performance,[24] the average value of both trials has been reported to be more sensitive than the best value to monitor changes in neuromuscular status during jumps.[25] Thus, the average result of both trials for each split time was included in the subsequent statistical analysis.

Several COD-derived metrics were obtained. Considering the above-mentioned reasons regarding best or average values, mean COD completion time (CODT; s) were calculated using the average result of both turns off the left and right side. Change of direction deficit (CODD) was calculated using the initially proposed time-based method.[18] Time-based CODD calculation (CODDt; s), which represents time difference between COD task and linear sprint of equivalent distance, was computed by the formula:[18,26]

$$\text{CODDt} = (\text{CODT}-10 - \text{m sprint time}).$$

Following recent suggestions,[27] both absolute and directional asymmetries in the COD performance were obtained. Absolute asymmetry (CODTaa; s) was calculated as follows[27]:

$$\text{CODTaa} = \sqrt{(right - left)^2}$$

Directional asymmetries in the COD performance were calculated using two different criteria. On one hand, to evaluate the directional asymmetries between dominant and non-dominant in the COD test, lower-limb dominance was classified for each participant using the task outcome (i.e., completion time). Dominant COD performance (CODd; s) was considered as the direction (limb) a participant displayed faster completion time from, whereas non-dominant COD performance (CODnd; s) was considered as the direction (limb) a participant displayed slower completion time from.[14,28] In this regard, directional asymmetry index in percentage between CODd and CODnd (CODd-nd; %) was computed by the formula[14,28]:

$$\text{CODd} - \text{nd} = [(\text{CODd}-\text{CODnd}) / \text{CODd}] \times 100$$

On the other hand, to evaluate the directional asymmetries between preferred and non-preferred kicking limb in the COD test, the self-preferred kicking limb was defined by participants in response to the question "which limb would you preferentially use to kick a ball with?".[27] COD performance with preferred kicking limb (CODp; s) was considered as the attempt when the preferred kicking limb performs the last support before changing direction and pushing off to the body's center of mass in the intended direction, whereas COD performance with non-preferred kicking limb (CODnp; s) was considered as the attempt when the non-preferred kicking limb performs the last support before changing direction and pushing off to the body's center of mass in the intended direction.[29] In this regard, directional asymmetry index in percentage between CODp and CODnp (CODp-np; %) was computed by the formula:

$$\text{CODp} - \text{np} = [(\text{CODp}-\text{CODnp}) / \text{CODp}] \times 100$$

Statistical analyses

All data is presented as mean values (M) and standard deviation (SD). The coefficient of variation (CV) was calculated to assess the reliability of measurements within each time point.[30] The Shapiro-Wilk test was used to identify normal distribution of the data and the Levene test was used to evaluate the homogeneity of variances. Due to the existence of normal and non-normal distribution of data, differences between time points were compared using one-way repeated measures analysis of variance (ANOVA) with a Holm post-hoc or using Friedman test. Differences within each time point were also compared using t-test for paired samples (metrics selected for this analysis were only normally distributed). Standardized differences were computed based upon Cohen's d effect size (ES) index and were interpreted as trivial (<0.2), small (0.2–0.5), moderate (0.5–0.8) or large (>0.8).[31] All statistical analyses were performed using JASP 0.16.3.0 software (University of Amsterdam, Amsterdam, Netherlands). The criterion for significance was set at $p < 0.05$, and where applicable, alpha levels were adjusted for multiple comparisons as indicated by the JASP software.

Results

Differences between time points of linear straight sprint performance, CODT and CODDt are reported in Table 1. Regarding linear straight sprint performance, a significant impairment was only obtained at post-match in SPR20 ($p = 0.028$). CODT was significantly increased at post- ($p = 0.030$) and remained elevated 48-h post-match ($p < 0.001$). A significant increase was also obtained in CODT when comparing post- and 48-h post-match ($p = 0.021$). CODDt showed small and non-significant changes post-match compared to baseline but significantly increased at 48-h post- relative to both pre- and post-match values ($p < 0.001$).

Table 2 display differences between time points of absolute and directional asymmetries in COD performance. No differences between time points were found on CODTaa, CODd-nd or CODp-np. Post- CODd and CODnd were similar to baseline but both were significantly increased at 48-h post- ($p < 0.001$) and only CODd was significantly increased at 48-h post- compared to post-match ($p = 0.007$). CODp was significantly increased at post- ($p = 0.024$) and remained elevated 48-h post-match ($p = 0.002$), but CODnp was significantly increased at 48-h post- compared to pre- ($p = 0.003$) and post-match ($p = 0.009$).

Differences between time points of directional asymmetries in time-based CODD are displayed in Table 3. Non-significant differences with respect to baseline were obtained at post-match. However, time-based CODD of both dominant and non-dominant COD performance was significantly increased at 48-h post- compared to pre- (CODDtd: $p < 0.001$; CODDtnd: $p < 0.001$) and post-match (CODDtd: $p < 0.001$; CODDtnd: $p = 0.006$). Similarly, time-based CODD with both preferred and non-preferred kicking limb was significantly increased at 48-h post- compared to pre- (CODDtp: $p < 0.001$; CODDtnp: $p < 0.001$) and post-match (CODDtp: $p = 0.033$; CODDtnp: $p < 0.001$).

Figure 1 display differences within each time point of directional asymmetries in COD performance. When lower-limb dominance was classified using the task outcome (i.e., completion time), significant differences were found at pre-, post- and 48-h post-match between CODd and CODnd (pre-: $p < 0.001$, d = 1.41, large; post-: $p < 0.001$, d = 1.42,

Table 1. Descriptive statistics and differences between time points of linear straight sprint performance, mean change of direction completion time and time-based change of direction deficit.

	Pre-	Post-	48-h post-	Pairwise comparisons Pre- Post-	Pre- 48-h post-	Post- 48-h post-
	M ± SD (CV, %)	M ± SD (CV, %)	M ± SD (CV, %)	p d, magnitude	p d, magnitude	p d, magnitude
SPR10 (s)	1.80 ± 0.09 (4.8)	1.83 ± 0.08 (4.2)	1.77 ± 0.08 (4.4)	0.374 0.34, small	0.374 −0.45, small	0.073 −0.78, moderate
SPR20 (s)	3.01 ± 0.22 (7.3)	3.17 ± 0.13 (3.9)	3.08 ± 0.11 (3.4)	0.028* 1.00, large	0.244 0.43, small	0.239 −0.58, moderate
SPR30 (s)	4.28 ± 0.13 (3.0)	4.40 ± 0.37 (8.4)	4.35 ± 0.15 (3.4)	0.544 0.47, small	0.876 0.27, small	0.876 −0.20, small
CODT (s)	2.33 ± 0.08 (3.5)	2.37 ± 0.08 (3.5)	2.42 ± 0.08 (3.4)	0.030* 0.53, moderate	<0.001* 1.16, large	0.021* 0.63, moderate
CODDt (s)	0.51 ± 0.09 (18.6)	0.54 ± 0.09 (15.8)	0.65 ± 0.09 (13.0)	0.273 0.34, small	<0.001* 1.65, large	<0.001* 1.31, large

CODDt: time-based change of direction deficit; CODT: mean change of direction completion time; CV: coefficient of variation; d: Cohen's d; M: Mean; SD: standard deviation; SPR10: time to cover a distance of 10-m; SPR20: time to cover a distance of 20-m; SPR30: time to cover a distance of 30-m.
* Statistically significant difference ($p < 0.05$).

Table 2. Descriptive statistics and differences between time points of absolute and directional asymmetries in change of direction performance.

	Pre-	Post-	48-h post-	Pairwise comparisons Pre- Post-	Pre- 48-h post-	Post- 48-h post-
	M ± SD (CV, %)	M ± SD (CV, %)	M ± SD (CV, %)	p d, magnitude	p d, magnitude	p d, magnitude
CODTaa (s)	0.08 ± 0.06 (70.8)	0.10 ± 0.07 (70.6)	0.08 ± 0.05 (63.7)	0.859 0.36, small	0.946 0.02, trivial	0.859 −0.34, small
CODd (s)	2.29 ± 0.07 (3.3)	2.32 ± 0.08 (3.5)	2.38 ± 0.08 (3.3)	0.105 0.42, small	<0.001* 1.21, large	0.007* 0.79, moderate
CODnd (s)	2.37 ± 0.09 (4.0)	2.42 ± 0.10 (4.1)	2.47 ± 0.09 (3.8)	0.052 0.57, moderate	<0.001* 1.00, large	0.078 0.44, small
CODd-nd (%)	−3.44 ± 2.43 (70.7)	−4.33 ± 3.09 (71.3)	−3.36 ± 2.16 (34.3)	0.802 −0.34, small	0.929 0.03, trivial	0.802 0.37, small
CODp (s)	2.32 ± 0.09 (3.7)	2.39 ± 0.11 (4.5)	2.42 ± 0.10 (4.3)	0.024* 0.71, moderate	0.002* 1.00, large	0.275 0.29, small
CODnp (s)	2.33 ± 0.10 (4.3)	2.35 ± 0.10 (4.0)	2.42 ± 0.09 (3.6)	0.515 0.17, trivial	0.003* 0.96, large	0.009* 0.79, moderate
CODp-np (%)	−0.58 ± 4.19 (727.9)	1.66 ± 4.80 (290.0)	−0.21 ± 3.95 (1883.4)	0.369 0.52, moderate	0.796 0.09, trivial	0.389 −0.43, small

CODd: dominant change of direction performance; CODd-nd: directional asymmetry index between dominant and non-dominant change of direction performance; CODnd: non-dominant change of direction performance; CODnp: change of direction performance with non-preferred kicking limb; CODp: change of direction performance with preferred kicking limb; CODp-np: directional asymmetry index between change of direction performance with preferred and non-preferred kicking limb; CODTaa: absolute asymmetry index in the change of direction performance; CV: coefficient of variation; d: Cohen's d; M: Mean; SD: standard deviation.
* Statistically significant difference ($p < 0.05$).

large; 48-h post-: $p < 0.001$, d = 1.57, large), and between CODDtd and CODDtnd (pre-: $p < 0.001$, d = 1.41, large; post-: $p < 0.001$, d = 1.42, large; 48-h post-: $p < 0.001$, d = 1.57, large). However, no significant differences emerged at any time point when comparing CODp and CODnp, or when comparing CODDtp and CODDtnp.

Table 3. Descriptive statistics and differences between time points of directional asymmetries in time-based change of direction deficit.

	Pre-	Post-	48-h post-	Pairwise comparisons Pre- Post-	Pre- 48-h post-	Post- 48-h post-
	M ± SD (CV, %)	M ± SD (CV, %)	M ± SD (CV, %)	p d, magnitude	p d, magnitude	p d, magnitude
CODDtd (s)	0.47 ± 0.08 (17.7)	0.49 ± 0.08 (16.4)	0.61 ± 0.08 (13.3)	0.434 0.24, small	<0.001* 1.78, large	<0.001* 1.54, large
CODDtnd (s)	0.55 ± 0.11 (20.4)	0.59 ± 0.10 (17.4)	0.69 ± 0.10 (13.8)	0.216 0.40, small	<0.001* 1.41, large	0.006* 1.02, large
CODDtp (s)	0.50 ± 0.09 (18.8)	0.56 ± 0.11 (18.9)	0.65 ± 0.10 (15.9)	0.125 0.57, moderate	<0.001* 1.48, large	0.033* 0.91, large
CODDtnp (s)	0.51 ± 0.12 (22.8)	0.52 ± 0.10 (19.4)	0.66 ± 0.09 (14.1)	0.911 0.03, trivial	<0.001* 1.36, large	<0.001* 1.33, large

CODDtd: time-based dominant change of direction deficit; CODDtnd: time-based non-dominant change of direction deficit; CODDtnp: time-based change of direction deficit with non-preferred kicking limb; CODDtp: time-based change of direction deficit with preferred kicking limb; CV: coefficient of variation; d: Cohen's d; M: Mean; SD: standard deviation.
* Statistically significant difference ($p < 0.05$).

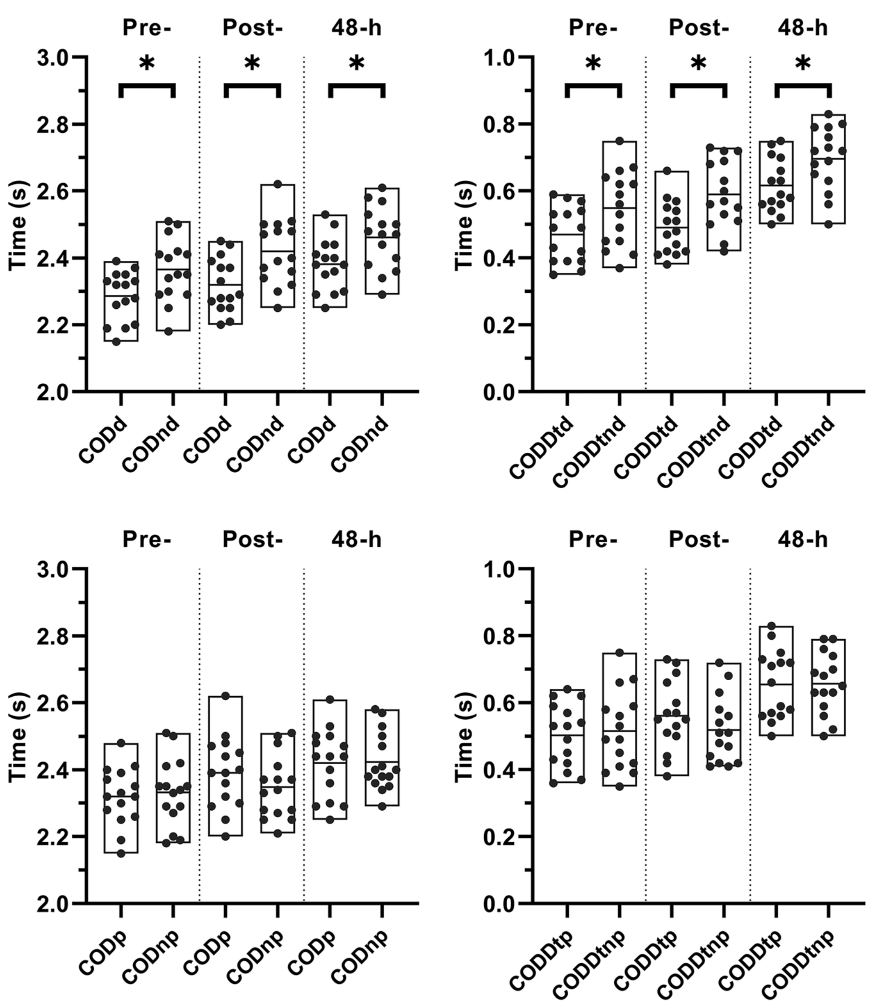

Figure 1. Differences within each time point of directional asymmetries in change of direction performance.
* Statistically significant difference ($p < 0.05$).

Discussion

This study aimed to analyze the influence of a soccer match on COD performance immediately and after a 48-h recovery period, with special focus on CODD and COD asymmetries. Findings show that acute and residual fatigue-induced by a soccer match resulted in different alterations at post- and 48-h post-match in both CODD and COD asymmetries. This was evidenced by increased completion time at post- and 48-h post-match, greater CODD at 48-h post-match regardless of the method for classifying lower-limb dominance (i.e., dominant and non-dominant in the COD test, preferred and non-preferred kicking limb), and impaired CODp immediately after a soccer match.

Neuromuscular fatigue involves several changes (e.g., maximal force, maximal shortening velocity, force-velocity relationship) due to different underlying mechanisms.[32] Concretely, soccer match-related fatigue is determined by a combination of central and peripheral factors,[11,33] but peak speed impairment after soccer matches may be mainly explained by a reduction in voluntary activation.[11] Thus, the capacity of the central nervous system to activate muscles may explain post-match reductions in the participants' sprint performance. However, the present findings partially disagree with a previous systematic review and meta-analysis which showed that sprint performance was moderately impaired following competitive soccer matches and was still impaired at 48-post-match.[34] In this regard, the current results indicate that sprint performance may be recovered earlier (e.g., 12-, 24- or 36-h). Whilst the use of soccer matches as a fatigue-inducing protocol may replicate real-world exercise conditions, these contrasting results may be related to several contextual factors that influence the magnitude of acute and residual fatigue and the time course recovery.[35,36]

Although in a lesser extent than linear straight sprint performance, COD performance has been analyzed to assess acute and residual fatigue in soccer players post-match.[34] In this regard, total or completion time in different COD tests may increase immediately after matches,[10,11] which agree with the current findings. However, previous results regarding time course recovery of COD performance after soccer matches are not conclusive.[11,13] It has been indicated that 48-h of recovery may be longer enough to ensure a complete recovery of COD performance,[11] but the current results show that COD-derived metrics of performance are still impaired at 48-h post-match. Some interactive factors may explain these contrasting results. As abovementioned, participants may experience different levels of fatigue in response to different match loads,[35,36] so the consequences of match-induced fatigue may be manifold. Moreover, multiple strength-related determinants of COD performance (i.e., linear sprinting ability, eccentric strength, concentric strength, power, and reactive strength)[1,2] may require different recovery periods for complete restoration (i.e., 48- or 72-h post-match).[34] Finally, different biomechanical alterations in COD performance following fatigue among soccer players[7,37] may decrease the ability to change direction efficiently.

Sprinting and acceleration capacities could mask a lower physical or technical proficiency to perform directional changes.[14–17] Specifically, linear sprint performance and eccentric strength are able to explain 58% and 67% of the variance in the 505 COD test, respectively.[38] In fact, given the characteristics of the 505 COD test, participants spend most of the time running linearly (69%) and a smaller time changing direction (31%).[16,18] Thus, CODD has recently been proposed as a complementary variable to evaluate COD performance.[16,18] With this respect, the current findings indicate that CODD was increased at 48-h post-match regardless of the method for classifying lower-limb dominance. One important reason for this augmented CODD may be the impaired muscle-stretch shortening cycle (SSC). A fatigued SSC involves performance decrements, induced by dramatic reductions in force and power production due to metabolic, mechanical and neural mechanisms.[39,40] Depending on the severity of exercise, the basic pattern of SSC fatigue response often shows the greatest evidence on the second day post-exercise and may need 4–8 days to fully recover.[39] These greatest responses take place when the symptoms of exercise-induced muscle damage and muscle soreness are also greatest after a soccer match.[34,41] Thus, the current findings suggest that a measurement of neuromuscular capacity involving the SSC, such as the CODD, may be sensitive to detect residual fatigue in soccer players following match-play. In contrast, the immediate post-exercise reduction in SSC can be explained primarily to be due to metabolic fatigue induced by exercise.[39] Due to the absence of differences of CODD at post-match, it may be hypothesized that the acute fatigue-induced impairment in SSC during a COD task was smaller than the residual fatigue-induced impairment (i.e., after a 48-h recovery period).

Analysis of COD asymmetries may provide insights into COD performance, as such imbalances could indicate a directional deficiency.[14] However, research assessing the effect of match-induced fatigue on COD asymmetries needs more systematization and consistency, as methods for classifying lower-limb dominance and equations for calculating asymmetries may influence the magnitude of the asymmetry.[19,27] In agreement, results of this study indicate that differences within each time point in COD performance were obtained when lower-limb dominance was classified using the task outcome (i.e., completion time) but not when was classified using the self-preferred kicking limb. However, only CODp increased at post- and remained elevated 48-h post- while CODd, CODnd and CODnp were significantly increased at 48-h post-match. This could suggest that using one foot over a great many different soccer situations may affect directional asymmetries in COD performance after a soccer match. On one hand, a strong bias toward the use of the right foot in right-footed players and toward the use of the left foot in left-footed players exist across free kicks, penalty kicks, corner kicks, dribbling, and passing, using the non-dominant foot only when facing intense pressure from opponents.[42] On the other hand, significant differences have been reported in the players with right dominance vs. left dominance in the lateral zones of the pitch, where they presented greater centripetal forces on the lateral side of their dominance.[43] Consequently, it may be hypothesized that neuromuscular fatigue on the dominant limb may affect directional asymmetries in COD performance immediately after a soccer match in a greater extent than during the recovery period. Although this hypothesis itself is very interesting, more research should be carried out to confirm it.

These findings should be interpreted with caution, because they could be specifically related to sample characteristics (e.g., sex, age, performance level, training status), the angle of the COD test (180°), methods for classifying lower-limb dominance and equations for calculating asymmetries. To obtain robust conclusions on this topic, further research is required utilizing different angled COD tests (e.g., 45°, 90°, 135°) and different methods and equations for classifying lower-limb dominance and calculating asymmetries in varied soccer teams. Furthermore, the absence of match load monitoring and other relevant markers (e.g., biomarkers, perceptual assessments, etc.) and the lack of direct measurement of pacing strategy during the 505 COD test should be acknowledged as limitations. This information could have offered a more comprehensive understanding of the magnitude of acute and residual fatigue and the time course recovery in the participants. Although it was not the aim of this study, the qualitative analysis of biomechanical and technical parameters of COD ability from either limb could provide interesting insights into the effects of match-induced fatigue.

From a practical perspective, it should be recommended to periodize and design training sessions inducing the lowest COD requirements during the 48-h post-match. Additionally, using the CODD appears to be a suitable method for analyzing residual fatigue-induced alterations in COD performance after a soccer match. Finally, the current results about the influence of match-induced fatigue on directional asymmetries provide better insight into the suggested causal relationship and its underlying mechanisms.

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Authors' contributions

Marqués-Jiménez, Diego: conceptualization, investigation, formal analysis, funding acquisition, writing – original draft, writing – review & editing; Izquierdo, José M.: conceptualization, investigation, writing – original draft, writing – review & editing; Castillo, Daniel: conceptualization, funding acquisition, writing – original draft, writing – review & editing; Losa-Reyna, José: investigation, writing – original draft, writing – review & editing; Domínguez-Díez, Marta: writing – original draft, writing – review & editing; Ramirez-Jimenez, Miguel: investigation, writing – original draft, writing – review & editing.

Consent to participate

Participants were informed about the objective, benefits and risks of present study and gave informed, written consent before the beginning of the study.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical considerations

This study was conducted in line with the ethical principles of the Declaration of Helsinki. Ethical approval was granted by the Ethics Committee of Área Salud Valladolid Este (PI 22-2908).

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