Changes in jump, sprint and coordinative performances following a senior soccer match.

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Abstract

This study aimed to verify the short-term after-effects of a soccer match on senior players' all-out and inter-limb coordination performances. Right before (pre-match) and after (post-match) a match, 10 senior (52.3±10.2years) male soccer players were administered jump (countermovement jump [CMJ]; repeated jump [RJ]), sprint (10m and 10m while dribbling the ball [$10m_{DB}$]), in-phase (IP) and anti-phase (AP) inter-limb coordination (synchronized hand and foot flexions and extensions at 80, 120, 180bpm). Heart rate (HR) responses, and subjective ratings of perceived exertion (RPE) and muscle pain (RMP) were used to evaluate the intensity of the friendly match. During the match HR>85% of individual HR_{max} occurred for 50% of playing time. Subjective ratings at the end of the match were 12.9±2.2pt and 2.7±2.2pt for RPE and RMP, respectively. Post-match CMJ, 10m, $10m_{DB}$, AP, IP 80bpm, and IP 120bpm performances did not show any difference with respect to pre-match values, whereas improvements ($P<0.05$) in RJ (pre-match: 17.4±3.9cm; post-match 19.3±4.8cm) and IP 180bpm (pre-match: 30.4±15.1s; post-match: 50.3±18.9s) emerged. These findings indicate that senior soccer players are able to cope with the high demands of match-play and suggest that an acute bout of intense exercise has an arousing effect that counteracts fatigue effects and facilitates the performance of old trained individuals on complex motor behaviors relying on central executive control. In considering that players consider soccer as highly motivating, with advancing years this sport could help players in preserving high mental and physical functions, as well as maintaining active engagement in life through social interactions.

Key-words: Coordination; Power; Fatigue; Executive Control

INTRODUCTION

Regular physical activity of moderate intensity contributes to the quality of life in later years, reducing the risk for several chronic degenerative diseases, slowing the decline of aerobic and anaerobic capacities, and maintaining reaction time, flexibility and coordination (9,34). Recently (11,12,18,37), maintenance of functional fitness and coordination have been reported in senior subjects engaging in team sports requiring intermittent physical exercise, high cognitive-attentional demands, and problem-solving skills under time pressure. In particular, being soccer a very popular sport, it has the potential to be a permanent health-promoting activity in older individuals regularly engaging in age-category championships, recreational tournaments, and friendly matches (18,19,37).

During a soccer match, players perform several dynamic movements (i.e., fast accelerations, abrupt decelerations, jumps, kicks, and changing directions) in response to a rapidly changing environment, and technical and tactical skills are required to finely control the movement of their feet, the ball, the teammates, and the opponents to have a successful performance. Thus, players are required high levels of coordination, agility, strength, speed, power, proper timing, and transfer of energy between body segments. In literature, sprints and vertical jump performances are used to assess the anaerobic profile of soccer players (1,35), and to address changes due to previous match-play (20,25), where inter-limb coordination performances (11,38), and running while dribbling the ball (37) have been used to evaluate a-specific and soccer-specific coordinative capabilities, respectively.

The frequent need to accelerate and decelerate during a soccer match is associated with a high energy cost and momentary fatigue in players (4,25), resulting in decreases of high intensity running and sprinting toward the end of elite (20,25) and senior (37) competitions. The effects of match-play on jump and sprint performances, and ratings of perceived exertion have been used as indirect measure of fatigue in young and elite soccer players (20,28). However, some issues arise when using such approach in older individuals. First, there are age-related changes in skeletal-muscle response to acute exercise that alter the time course of fatigue and recovery (15). Second, aging also affects other aspects of coordinated motor performance (6,34) more strongly relying on central control mechanisms whose effectiveness, in both younger and older individuals, may be facilitated by an antecedent bout of acute exercise (8). While the consistent evidence of facilitating effects of acute exercise has been attributed to a heightened level of arousal, the lack of evidence of fatigue effects after long lasting exercise bouts (up to two hours) has led to the hypothesis that typical laboratory-based exercise protocols designed to produce fatigue may be insufficient to simulate the physiological demands encountered in naturalistic sport environments (22).

Senior soccer matches might represent a potential platform for investigation (19). The examination of performance changes after a sport-specific exercise bout in an ecological sport setting is worthwhile, especially when focusing not only on all-out performances and their metabolic demands, but also on inter-segmental coordination tasks requiring central executive control (10,12,38). Thus, the purpose of this study was twofold: (i) to identify the intensity of the load posed by a soccer match on senior players, and (ii) to establish the acute after-effects of a soccer match on sprint, jump, and inter-limb coordination performances. It was hypothesized that while all-out performances recorded at the end of the match would be worsened by a fatigue effect with respect to those recorded before the match, metabolically less challenging, but coordinatively more complex performances relying on central executive control would profit from the exercise-induced arousing effect.

METHODS

Experimental Approach to the Problem

Using a multifaceted field-based approach, the effect of a soccer match on power, sprint and coordinative performances of senior players have been evaluated. The study included two experimental sessions planned during the last week of October (ambient temperature: 20°C; relative humidity: 56%). The first session was designed to familiarize players' with the testing procedure and to avoid any learning effect.

To maximize ecological validity, during the second session experimental data were collected (Figure 1) right before (pre-match) and immediately after (post-match) a friendly match (i.e., two self-refereed 35-minute halves with no competitive value), without interfering with their regular training schedule.

Insert Figure 1 about here

The load imposed by the match was ascertained by means of physiological (i.e., heart rate [HR]) and psychological (i.e., rating of perceived exertion [RPE]; rating of perceived muscle pain [RMP]) data. Jump, sprint, and inter-limb coordination tests were evaluated before and at the end of the match in a randomized order. To enhance the positive engagement of participants, players were informed about the aims of the study and verbally encouraged to perform the tests with full concentration and maximum effort. Recently (20,27,36), no effect on reduced performances at the end of team sport competitions has been reported as a result of a mild dehydration in players who were instructed to drink water *ad libitum*. Thus, the measurement of the individual fluid intake during the experimental setting was not included to avoid additional inconvenience for the participants.

Before starting the tests players underwent a 15-minute standardized warm-up period (40-60% of individuals' theoretical maximal HR [HR_{max}], calculated as 220-age) consisting of jogging, strolling locomotion, and stretching. During the experimental session, for each test, participants were allowed two trials, with a 1-minute recovery period in between. The individual best performance was used for further analysis and ratios between post-match and pre-match values were calculated.

To establish whether senior soccer players are actually able to cope with the physical demands of the match, in the present study the dependent variables were: the height (cm) of countermovement (CMJ) and repeated jump (RJ) performances; the time (s) of 10 m sprints with (10 m_{DB}) and without (10 m) dribbling the ball, and their ratio; and the time (s) of correct execution of in-phase and anti-phase synchronized hand and foot flexions and extensions at 80, 120 and 180 bpm. High test-retest Intra Class Correlation Coefficients (ICCs) were reported for jump (range: 0.97-0.99), 10 m sprints (range: 0.83-0.98), in-phase (range 0.95-0.96) and anti-phase (range: 0.72-0.98) hand and foot coordination performances (6,16,36).

Since it might be hypothesized that during the last part of the match the physical abilities of players would be compromised, differences between pre- and post-match all-out and coordinative performances might provide relevant information on the recreational players' capability to cope with the demands of the soccer match.

Subjects

Ten senior (52.3 ± 10.2 years) male soccer players volunteered to participate in the study. Both written and oral information regarding the possible risks and discomforts were given before the study. All subjects gave their written consent before participation. The test procedures were performed in accordance with the ethical standards in sport and exercise science research and the within-subjects study was approved by the local Institutional Review Board.

Participants answered the AAHPERD exercise/medical history questionnaire to ascertain their tobacco smoking and alcohol consumption, medication use, dietary and sleep habits and history of physical activity. Players declared that they maintained a soccer training regimen consisting of two 1.5-hour weekly sessions and a friendly match for the previous 10 years and their usual training sessions were organized without the supervision of a coach, aiming at entertaining themselves while maintaining their fitness levels. Since many of the ascertained factors seem to influence the relationship of interest between physical activity, motor coordination and cognitive functioning (33), individuals with any of the following conditions were excluded from the study: evidence, or a known history, of neuromuscular disorders, stroke, cognitive impairment, wrist and/or ankle arthritis, use of medications that would affect the test performances, or injury occurred to wrist and/or ankle during the past six months.

Procedures

Heart rate response and subjective ratings of exertion during the soccer match

During the two 35-minute halves of the senior soccer match, players' HR was continuously recorded (Polar Team System, Kempele, Finland) as average values of 5 s. According to the literature on team sports (12,37), intensities of effort were subsequently calculated and expressed as percentages of HR_{max} to estimate the amount and duration of aerobic (HR < 85% of HR_{max}) and anaerobic (HR > 85% of HR_{max}) work carried out. To provide more meaningful information on senior soccer players, HR responses were also grouped in five categories of intensity of effort: a) < 65% HR_{max}; b) 65-75% HR_{max}; c) 76-85% HR_{max}; d) 86-95% HR_{max}; and e) > 95% HR_{max}. Furthermore, the Borg's (5) RPE scale between 6 (no exertion at all) and 20 (maximal exertion) and RMP scale between 0 (nothing at all) and 11 (maximum pain) were administered 20 minutes after the end of the match to ensure that players' perceived effort was referred to the whole session rather than the most recent exercise intensity.

Performance evaluations

Jump performances were evaluated by means of an optical acquisition system (Optojump, Microgate, Udine, Italy), developed to measure with 10^{-3} s precision all flying and ground contact times. The Optojump photocells are placed at 6 mm from the ground and are triggered by the feet of the participant at the instant of take-off and are stopped at the instant of contact upon landing. Then, calculations of the height of the jump are made. For the CMJ, from the standing position soccer players were required to bend their knees to a freely chosen angle, followed by a maximal vertical thrust, while for the RJ they performed 7 consecutive jumps. The effect of the arm swings was minimized requiring the athletes to keep their hands on their hips during both tests. Because it was assumed that participants maintained the same position at take-off and landing, they were instructed to keep their body vertical throughout the jump, and to land with knees fully extended. Any jump that was perceived to deviate from the required instructions was repeated.

Sprint performances were measured by means of a dual infrared reflex photoelectric cells system (Polifemo, Microgate, Udine, Italy) positioned 10 m apart with the first timing gate at 0.5 m from the starting. For the 10 m_{DB}, participants were instructed to keep the ball as close as possible to their feet and to make at least four contacts with the ball. Any test that deviated from the required instructions was repeated. Then, to evaluate the technical difficulty of running while dribbling the ball, the ratio between the performance of the 10 m_{DB} and the 10m sprints (10 m_{DB}/10 m) was calculated.

Measurements of inter-limb coordination (6,11) included in-phase (associations of wrist extension with the homolateral ankle dorsal flexion and wrist flexion with the homolateral ankle plantar flexion) and anti-phase (associations of wrist flexion with the homolateral ankle dorsal flexion and wrist extension with the homolateral ankle plantar flexion) movements at three frequencies to 80, 120 e 180 bpm paced by a metronome (Taktell Piccolo 832, Wittner Cinetec GmbH & Co. KG, Ammersbek, Germany). Participants were seated shoeless on a table with their elbow and knee flexed at 90°. The position allows independent motion of the hand and lower limb in the sagittal plane. Subjects were instructed to make the cyclical homolateral hand and foot movements across the total duration of a trial (60 s) performing flexion and extension movements around the wrist and ankle joints with a 1:1 ratio. A "ready-go" command led to the start of a trial with the observer measuring the time (s) of correct execution (i.e., the time from the beginning of the movement up to when the individual failed to meet either the spatial and/or the temporal task requirements).

Statistical Analyses

Means and *SDs* were calculated for each of the analyzed variables. Statistical significance was set at $P \leq 0.05$. Before using parametric statistical test procedures, the assumptions of normality and sphericity were verified.

A repeated measures analysis of variance (ANOVA) was used to test for differences in duration of intensity of effort for HR (i.e., < 65%, 65-75%, 76-85%, 86-95%, and > 95% HR_{max}; < 85% and > 85% of HR_{max}) and between pre- and post-match psychological (i.e., RPE and RMP) and performances (i.e., CMJ, RJ, 10 m, 10 m_{DB}, 10 m_{LB}/10 m) data. Time of correct execution of inter-limb coordination test was submitted to a 2 (coordination mode: in-phase vs anti-phase) x 3 (execution frequency: 80 vs 120 vs 180 bpm) x 2 (experimental session: pre-match vs post-match) repeated measures ANOVA. If the overall F-test was significant, post hoc Fisher protected least significant difference comparisons with Bonferroni corrections were used. To provide meaningful analysis for significant comparisons from small groups, Cohen's effect sizes (*ES*) were also calculated, considering trivial $ES \leq 0.2$, small *ES* from 0.3 to 0.6, moderate $ES < 1.2$ and large $ES \geq$

1.2.

RESULTS

Heart rate response and subjective ratings of exertion during the soccer match

During the match, the frequency distribution of HR (Figure 2) showed differences for categories of effort ($P = 0.006$) and match halves ($P = 0.008$). Post hoc analysis showed that players significantly ($P < 0.05$; ES = 0.9) increased the intensity of efforts during the second half, with less occurrence of <65% and 65-75% of individual HR_{max} and more occurrences of 86-95% and >95% of individual HR_{max}. Comparison between aerobic (first half: 59.6 ± 32.1%; second half: 43.1 ± 30.2%) and anaerobic (first half: 40.4 ± 32.1%; second half: 56.9 ± 30.2%) work carried out approached significance ($P = 0.058$). RPE showed significantly ($P < 0.0001$; ES = 2.9) higher values (12.9 ± 2.2 points) at the end of the match with respect to pre-match ones (RPE: 7.5 ± 1.5 points), while no difference emerged for RMP (pre-match: 1.5 ± 2.1 points; post-match: 2.7 ± 2.0 points).

Insert Figure 2 about here

Performance evaluations

Table 1 shows pre- and post-match values for all-out performances. No difference between experimental sessions emerged for CMJ, 10m and $10m_{DB}$, whereas higher ($P < 0.05$; ES = 0.4) post-match values (19.3 ± 4.8 cm) were observed for RJ with respect to pre-match ones (17.4 ± 3.9 cm). Post- to pre-match ratios approached 1.0 (range: 1.01-1.11).

Insert Table 1 about here

For inter-limb coordination (Figure 3), main effects were found for coordination mode ($P = 0.007$; ES = 1.3) with better performances during the in-phase condition (52.1 ± 15.3 s, range: 10-60 s) with respect to anti-phase ones (24.5 ± 25.3 s, range: 0-60 s), execution frequency ($P < 0.0001$; ES range = 0.3-1.2), with a significant decrement between frequencies (80 bpm: 49.2 ± 21.4 s, range: 0-60 s; 120 bpm: 42.7 ± 24.5 s, range: 0-60 s; 180 bpm: 23.0 ± 21.7 s, range: 0-60 s), and the interaction coordination mode x execution frequency x experimental session (P = 0.04). In the in-phase coordination mode, soccer players showed a ceiling effect for the slowest frequency of execution (i.e., 80 bpm) and performance decrements at the highest execution frequency (i.e., 180 bpm), which showed significantly (P = 0.02; ES = 1.2) better post-match performances (50.3 ± 18.9 s) with respect to pre-match ones (30.4 ± 15.1 s). Conversely, no difference emerged for the anti-phase coordination mode. Post- to pre-match ratios for in-phase coordination mode were 1.0, 1.2 and 1.8 whereas for anti-phase were 2.7, 1.1, and 2.0 for 80 bpm, 120 bpm, and 180 bpm execution frequencies, respectively.

Insert Figure 3 about here

DISCUSSION

The purpose of the present study was to examine the load posed on senior players by a soccer match and to verify the acute after-effects of the match on performances differing in their metabolic and coordinative demands (sprint, jump, and inter-limb coordination). It was expected a deterioration of all-out performances due to fatigue (14), but an improvement of metabolically less challenging, coordinatively more complex skeletal-muscle responses due to an exercise-induced arousing effect that facilitates psychomotor speed and central executive control functions (8).

The main findings of the present study are: i) the soccer match posed a high cardiac load on senior players, who tended to increase the intensity of their efforts during the second half; ii) at the end of the soccer match players maintained their jump, sprint and anti-phase coordinative performance, whereas they increased in-phase inter-limb coordination performance under high (i.e., 180 bpm) temporal constraints and their performance of multiple consecutive jumps. These results suggest that the energizing effect of exercise on the central and peripheral nervous system (2) counteracts eventual effects of fatigue and, while the metabolic recovery occurs gradually, the heightened level of arousal during this period facilitates the cognitive executive control over inter-limb coordination (22).

In agreement with the literature (4,20,35,37), the match elicited HR above 85% of the individual HR_{max}, with peak values close to maximal. However, the high standard deviations of HR responses might indicate both large within-players and between-players variability, and the intermittent nature of playing activities, which provided plenty opportunities for active recovery from high-intensity actions (37). Although not significant, intensity of playing increased during the second half, opposite to what generally observed in soccer (13), probably due to a conservative match strategy of senior, who tend to spare energies for the last periods of the competition.

Coherently to what reported for recreational soccer (19), ratings of perceived exertion resulted "somewhat hard", mirroring the players' capability to successfully cope with the physical stress of the match and the combined effect of the challenging playing situations and the stimulating environment that may reduce the attention directed to internal sensations (17). Despite at the end of a match high muscle damage could be expected because of repeated sprints, accelerations and rapid decelerations, and near-maximal jumps (28), in the present study players perceived the muscle pain of the lower limbs as "weak". This could reflect age-related decreases of perceived pain (15) and the nature of the match-play of senior players who privilege walking and low-intensity running (37).

It is well established that a decline in performance parallels an increase in fatigue (14), strongly related to the fitness level of the individual. Thus, any performance decrease observed at the end of the soccer match should be the direct result of the previous exercise. In particular, jump and sprint performances have been considered good indicators of functional performance in soccer players (1,19,35,37), and post-match reductions have been interpreted as a consequence of the high physical demands of match-play (20,26). In this study, senior players showed CMJ and sprint performances comparable to those reported in the literature on older players (11,37), confirming that engagement in recreational soccer provides a sufficient stimulus to elicit neuromuscular adaptations to maintain the functional power of lower limbs (19) frequently required also during everyday activities (34).

In contrast to what expected, however, post-match CMJ, 10 m, and 10 m_{DB} showed no difference, whereas RJ performances improved. Although reduction in sprint performance has been often reported after team sport matches (12,20,26), the interpretation of CMJ performances after high intensity activities is controversial. A marked reduction in CMJ has been observed after a soccer-specific intermittent exercise in young players (28) and following futsal matches (36), while no change has been showed after a 90-minute soccer game modeling in amateur players (32). Conversely, age-related differences have been reported following a basketball match, with young players showing no change (10) and senior players exhibiting improvements (12). Because fatigue is dependent on the nature of the activity that causes it, two 35-min halves might not be sufficient enough to elicit reductions in all-out performances in senior soccer players who benefit from chronic exercise to minimize decrements observed with aging (34). Furthermore, compensatory mechanisms exist at various levels of the neuromuscular system acting to delay the effects of physical fatigue (3), and age-related differences in playing activities might favor recruitment strategies of senior players, thus improving their neuromuscular efficiency (10). This speculation could also help interpreting the increase of RJ performances observed at the end of the match, in line with those reported for young amateur players following a soccer-play simulation (31). In considering that RJ strongly depends on gastrocnemius activation (21), important also for stabilizing the upright standing posture, the present findings indicate that involvement in soccer might prevent age-related postural instability (34).

Coherently with the literature (6,11), inter-limb coordination performances varied as a function of coordination mode and frequency of execution, with better performances in the in-phase mode and at the slowest frequencies. As expected, the match benefited inter-limb coordination performances. This result may be explained referring to the arousing and activating effects of acute exercise. First, the arousing effect of an acute bout of exercise enhances the efficiency of central executive control mechanisms (8,22). Since older individuals, due to losses of automatized coordination and generalized slowing (34) more strongly rely on executive attention control to perform fast coordinated movements, any exercise-related increment in arousal and executive control function translates into better motor coordination. Second, the arousing effects of acute exercise seems also to be linked to an activation effect that influences later motor preparation stages (2). The fact that the high-intensity exercise of the soccer match selectively facilitated inter-limb coordination at highest execution frequency is in line with evidence showing that maximal and even supramaximal exercise intensities are beneficial to movement speed (24). The lack of facilitation of motor coordination in the anti-phase condition might be due to the general floor effect that renders older individuals, even though coordinatively well trained (7), unable to sustain complex anti-phase coordination over time.

In conclusion, beyond the evidence for the debilitating effect of acute fatigue on motor performances (14), evidence from exercise and cognition research indicates that a positive relationship exists between acute exercise and speeded motor performances relying on attention and cognitive control. This relationship is moderated by task (i.e., intensity, duration) and individual (i.e., physical fitness, coordinative and cognitive efficiency) constraints (29). In the present study, the soccer match represented an acute exercise bout of appropriate intensity and duration to find beneficial effects on performance of psychomotor, attention demanding tasks administered between 1 and 20 minutes after exercise cessation in the ecological sport context. In fact, when psychomotor tasks are performed following a delay of more than 1 minute, light intensity exercise no longer has positive effects, whereas high intensity exercise results in the biggest effects which decrease following a longer (> 20-minute) delay (8). As regards duration, the soccer match of 70-minute was above the 20-minute threshold required for physiological mechanisms to reach peak levels necessary to benefit psychomotor performance, but below the 2h threshold for fatigue effects to impair it (8). Finally, the high physical-aerobic training and extensive coping with high cognitive-attentional demands typical of strategic sports such as soccer playing has shown to counteract or offset the decline of attentional and coordinative performance (30). Therefore, the improvement of attention demanding coordinative performances observed in this study following the intense and prolonged exercise bout of the soccer match suggests that expertise enhances the potential to exploit the arousing and activating effect of physical effort to adjust motor coordination.

PRACTICAL APPLICATIONS

The results of this study indicate that despite a senior soccer match poses a high load on players, it does not hamper their overall post-match all-out performances and has a positive effect on their coordinative capabilities. Although fatigue during match play is a complex phenomenon with a number of contributing factors, the findings suggest an exercise-related arousing effect addressing the central nervous system ability to cope with the control of complex tasks in trained subjects. In considering that players reckon soccer as highly motivating, with advancing years this sport could help in preserving high mental and physical functions, as well as maintaining active engagement in life through social interactions. Although no amount of physical activity can stop the biological aging process, physical activity instructors are strongly advised to consider team sport practice, such as soccer, as a tool to minimize the effects of a sedentary lifestyle and increase active life expectancy by limiting the development and progression of chronic diseases. Indeed, since exercise prescription for older adults should include aerobic and muscle strengthening exercises (9), soccer could be included amongst the activities to be recommended, being characterized by high- and moderate intensity aerobic training, as well as periods of high anaerobic loading with multiple intense actions such as high-speed runs, sprints, turns, and jumps (19). Finally, the interactive nature of team sport environments serves to foster the development of social relations, important determinant of both cognitive and physical functioning toward a successful aging (23), thus providing a comprehensive impact on health-beneficial effects. Despite the small sample size and the lack of a control group could limit the generalizability of the present findings, it could encourage future studies on the effects of exercise type and intensity on coordinative capabilities of players of different ages and sports. In fact, the proposed field-based study design has the potential to be used to monitor all-out and coordinative changes as a result of training load.

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Figures and Table Legend

Table 1. Means and standard deviations of countermovement (CMJ) and repeated (RJ) jump, sprint (10m, $10m_{DB}$ and their ratio) performances before (pre-match) and after (post-match) the soccer match (* $P < 0.05$, significantly different compared with pre-match value).

Figure 1. Temporal sequence of the experimental session. CMJ = countermovement jump; RJ = repeated jump; 10m = 10 m sprint; $10m_{DB}$ = 10 m sprint while dribbling the ball; IP = in-phase inter-limb coordination; AP = anti-phase inter-limb coordination; RPE = rating of perceived exertion; RMP = rating of muscle pain; HR = heart rate.

Figure 2. Means and standard deviations of the frequency of occurrence of time spent at heart rate (HR) <65%, 65-75%, 76-85%, 86-95%, >95% of individuals' theoretical maximal HR (HR_{max}) during the soccer match (* $P = 0.002$, significantly different compared with 86-95% HR_{max}).

Figure 3. Means and standard deviations of the time of correct execution of homolateral hand and foot synchronized movements in relation to execution mode (i.e., in-phase and anti-phase) and velocity of execution (i.e., 80, 120, and 180 bpm) before (pre-match) and after (post-match) the soccer match (* $P = 0.02$, significantly different compared with pre-match).