The Effects of Interday Rest on Adaptation to 6 Weeks of Plyometric Training in Young Soccer Players

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Abstract

Ramírez-Campillo, R, Meylan, CMP, Álvarez-Lepín, C, Henriquez-Olguín, C, Martinez, C, Andrade, DC, Castro-Sepúlveda, M, Burgos, C, Baez, EI, and Izquierdo, M. The effects of interday rest on adaptation to 6 weeks of plyometric training in young soccer players. *J Strength Cond Res* 29(4): 972–979, 2015—The purpose of this study was to determine the effects of short-term plyometric training interposed with 24 or 48 hours of rest between training sessions on explosive and endurance adaptations in young soccer players. A total of 166 players, between 10 and 17 years of age, were randomly divided into 3 groups: a control group (CG; $n = 55$) and 2 plyometric training groups with 24 hours (PT24; $n = 54$) and 48 hours (PT48; $n = 57$) of rest between training sessions. Before and after intervention, players were measured in squat jump, countermovement jump, 20 (RSI20) cm drop jump reactive strength index, broad long jump, 20-m sprint time, 10 × 5-m agility time, 20-m multistage shuttle run test, and sit-and-reach test. The plyometric training program was applied during 6 weeks, 2 sessions per week, with a load from 140 to 260 jumps per session, replacing some soccer-specific drills. After intervention, the CG did not show significant performance changes. PT24 and PT48 groups showed a small-to-moderate significant improvement in all performance tests ($p < 0.001$), with no differences between treatments. Although it has been recommended that plyometric drills should not be conducted on consecutive days, the study shows that plyometric training applied twice weekly on consecutive or nonconsecutive days results in similar explosive and endurance adaptations in young male soccer players.

Key Words maturity, explosive strength, competitive sports, strength training

Introduction

Soccer is an intermittent sport that requires different physiological components. The capacity to produce varied powerful actions during a 90-minute game is associated with high aerobic capacity (33). However, the ability to produce explosive single-bout effort is as important as aerobic power for success in soccer (12), such as sprinting, jumping, or changing direction (33). Plyometric training (PT) is commonly used to increase these types of actions in young soccer players (7,27,28,34), with the advantage of being easy to integrate in soccer practice (space, time, equipment), and replicating the neuromuscular stimulus encountered in explosive soccer activities such as sprinting and jumping (13). Additionally, PT in young soccer players may increase endurance performance (38). Therefore, PT may be advocated as an appropriate approach for enhancing soccer-related performance abilities. However, the characteristics of between-session recovery of a PT that generates optimal gains are not clear (31), especially in young soccer players.

Plyometric training frequency (31) or the rest interval between training sessions (26) may affect its outcome. In young soccer players, PT frequencies of 1 (24,36), 2 (14,19,24,27,28,32,34,40), and 3 (7) sessions per week have been applied effectively. Curiously, most studies in which explosive strength training was applied to this group of

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athletes did not report the rest interval used between training sessions (7,14,19,24,34,40). It has been recommended that plyometric drills should not be conducted in consecutive days in youths (9,37) although no experimental evidence sustains these recommendations. In addition, several interventions in young soccer players used >72 hours (28,32) or >48 hours (27) of rest between PT sessions to allow for adequate recovery, suggesting that these time frames of rest would be necessary to induce adequate training stimulation in this population of young athletes. However, to the best of the authors' knowledge, no studies have evaluated the effect of the rest interval between PT sessions in explosive and endurance performance of young soccer players.

In adults, improved performance had been reported with PT frequencies of 4–5 sessions per week (15,31), suggesting that <24 hours of recovery between sessions may induce significant adaptations. In youths, the recovery capacity from high-intensity plyometric exercises has been reported to be higher than in adults, and <24 hours may be sufficient to recover from a previous explosive exercise stimulus (25). A higher level of flexibility (leading to less overextension of sarcomeres during eccentric exercise), slower muscle fiber-type composition, and a high level of habitual physical activity in youths may help explain their higher recovery ability after high-intensity PT (25). Therefore, because young athletes can recover from physical exertion faster than adults, especially from high-intensity exercise (11), one may hypothesize that 24 hours of rest between PT sessions could be viewed as an adequate recovery period to induce training adaptations in this population. Considering that from a practical and logistic point of view, some young soccer teams schedule training sessions on consecutive days, our research interest was to determine whether 2 PT sessions per week, with 24 or 48 hours of rest between these, would result in significant differences in explosive strength and endurance adaptations between the 2 recovery windows, as well as with no additional explosive training in young soccer players.

Methods

Experimental Approach to the Problem

We examined the ability of a twice weekly, in-season, short-term PT implemented with either 24 or 48 hours of rest between training sessions as a substitute for some soccer drills within regular soccer practice to improve physical performance compared with soccer practice only. Three groups were formed from young male soccer players; 1 group followed a twice weekly PT program with 24 hours of rest between training sessions (PT24), a second group followed the same twice weekly PT program but with 48 hours of rest between training sessions (PT48), and a third group followed their regular soccer practice (control group, CG). Before and after a 6-week period, all players executed a battery of 8 tests related to explosive and endurance performance. This was a randomized controlled trial. The assigned groups were determined by a chance process (a random number generator on a computer) and could not be predicted. This procedure was established according to the "CONSORT" statement, which can be found at http://www.consort-statement.org.

Subjects

Subjects were recruited from 2 different amateur soccer teams with similar competitive schedule (1 game per week) and similar soccer drills (2 sessions per week) resulting in similar soccer-specific weekly training load (session rating of perceived exertion) for all groups in the study design. Soccer players fulfilled the following inclusion criteria: (a) a background of more than 2 years systematic soccer training and competition experience; (b) continuous soccer training in the past 6 months, (c) no PT experience in the past 6 months, and (d) no background in regular strength training or competitive sports activity that involved any kind of jumping training exercise during the treatment. Initially, 189 subjects who fulfilled the inclusion criteria were chosen to participate in the study. To be included in the final analyses, participants were required to complete all the training sessions and attend all measurements sessions. As a result of these requirements, 23 subjects were removed from the study. Therefore, 166 male soccer players were included in the final analyses. The 166 subjects initially measured were divided into 3 groups: a CG ($N = 55$) and 2 PT groups with 24 hours (PT24; $N = 54$) or 48 hours (PT48; $N = 57$) of rest between training sessions. Mean values ± *SD* values for each group's characteristics are provided in Table 1.

Institutional review board approval for our study was obtained, and all subjects (and their parents or guardians) were carefully informed about the experiment procedures and about the possible risk and benefits associated with participation in the study, and an appropriate signed informed consent/assent document has been obtained pursuant to law before any of the tests were performed. We comply with the human and animal experimentation policy statements guidelines of the American College of Sport Medicine.

Testing Procedures

Subjects followed a familiarization period before testing to reduce any learning effects. Standardized tests during a period of 5 days were scheduled >48 hours after a competition or hard physical training and were completed in the same order, at the same time of the day, in the same indoor venue, with the same sport clothes, and by the same investigator before and immediately after the 6-week intervention period. In addition, all participants (and their parents or guardians) were instructed to have a good night's sleep (≥9 hours) before each testing day and to avoid drinking or eating at least 2–3 hours before measurements. All participants were motivated to give their maximum effort during performance measurements.

On day 1, players' characteristics (age, height, weight, self-assessed Tanner pubic hair and genital stage, soccer experience, and soccer-specific weekly training load) were assessed. On day 2, the squat jump (SJ) and countermovement jump (CMJ) tests were performed. The third day, the 20 (RSI20) cm drop jump reactive strength index and broad long jump (BLJ) test were assessed. The fourth day, 20-m sprint and running 10 × 5-m agility test were conducted. On the fifth day, the 20-m multistage shuttle run test (MST) and the sit-and-reach (SR) test were undertaken. At least 2 minutes of rest was allowed between each trial to reduce the effects of fatigue. While waiting, participants performed low-intensity activity to maintain physiological readiness for the next test. The best score of 3 trials was recorded for all performance tests, apart from the single MST.

Subject Characteristics. Height was measured using a wall-mounted stadiometer (Butterfly, Shanghai, China) recorded to the nearest 0.5 cm; body mass was measured to the nearest 0.1 kg using a digital scale (BC-554 Ironman Body Composition Monitor; Tanita, IL, USA); and body mass index was calculated ($kg \cdot m^{-2}$). Maturity was determined by self-assessment of Tanner stage.

Vertical Jump Tests. Testing included the execution of maximal SJ, CMJ, and RSI20. All jumps were performed on a mobile contact mat (Globus, Codogne, Italy) with arms akimbo. Take-off and landing was standardized to full knee and ankle extension on the same spot. The participants were instructed to maximize jump height and minimize ground contact time during the RSI20 after dropping down from a 20-cm drop box. The RSI20 was calculated as previously reported (41).

Broad Long Jump Test. The BLJ was used to assess maximal jump performance in the horizontal plain. The test was performed using a 5-m fiberglass metric tape laid on a wooden floor. Subjects were instructed to jump positioning (behind the starting line) their feet shoulders wide apart and to perform a fast downward movement (approximately 120° knee angle) followed by a maximal effort horizontal jump. Subjects were instructed to bend their knees after landing. Distance was measured from the starting line to the point where the heels of the subjects make contact with the ground after landing.

Twenty Meter Sprint Test. The sprint time was measured to the nearest 0.01 second using single beam infrared red photoelectric cells (Globus). The starting position was standardized to a still split standing position with the toe of the preferred foot forward and behind the starting line. Sprint start was given by a random sound that triggers timing. The photoelectric signal was positioned at 20 m and set approximately 0.7 m above the floor (i.e., hip level) to capture the trunk movement to avoid a false trigger from a limb.

Running 10 × 5-m Agility Test. The test was conducted as previously described (17). Markers were set at 5-m distance. The examinee was asked to run from one marker to another 10 times, with the fastest possible result and direction change. The examinee had to pass the marked space with both legs. The results were in seconds, determined with hand-held chronometer.

Twenty Meter Multistage Shuttle Run Test. The MST was conducted as previously described (1). Briefly, players ran back and forth between 2 lines, spaced 20 m apart, in time with the "beep" sounds from a compact disc. Each successful run of the 20-m distance was a completion of a shuttle. The beep sounded at a progressively increasing pace with every-minute of the test, and the athlete had to increase speed accordingly. The athlete was warned if he did not reach the end line in time once. The test was terminated when the examinee (a) could not follow the set pace of the beeps for 2 successive shuttles or (b) stopped voluntarily. The scores were expressed as the last minute that the athlete completed (20).

Sit-and-Reach Test. For the SR test, similar instruments and protocols were used as previously reported (23). Briefly, a scale calibrated in centimeters was placed on the top surface of a SR box. The test was performed by having athletes sitting on the floor. The athlete's feet were placed flat against the SR box, separated approximately by 40 cm. Players then slowly reached forward toward their toes, as far as possible, while keeping their knees, arms, and fingers fully extended, with palms down and placing their right hand over the left, with long fingers even, holding the position of maximal reach for 2 seconds. The precision of the measurement was 0.5 cm.

Treatment

The study was completed in autumn, during the mid-portion of their competition period. The CG did not perform the PT but performed their usual soccer training (technical-tactical exercises, small-sided games, simulated competitive games, and basic conditioning exercises). The PT groups performed plyometric drills as a substitute for some soccer drills within the usual 120-minute practice twice per week for 6 weeks. This time frame or number of sessions are higher (24,36), the same (24,34) or very similar (5,27) to those previously reported to induce significant explosive adaptations in young soccer players and youths (4). Plyometric volume was increased by 20% per week. Because players did not have any history of formal plyometrics, before beginning the training period they were instructed on how to properly execute all the exercises to be performed during this period. In addition, all training sessions were supervised, and particular attention was paid to demonstration and execution. Plyometric training sessions were separated with 24 hours for PT24 and with 48 hours for PT48. All plyometric sessions lasted approximately 30 minutes and were performed just after the warm-up. Aside from the formal training

Table 1. Descriptive data of the control group (CG), plyometric training 24-hour group (PT24), and plyometric training 48-hour group (PT48h).

	CG (n = 55)	PT24 (n = 54)	PT48 (n = 57)
Age (y)	14.0 ± 2.3	14.2 ± 2.2	14.1 ± 2.2
Height (cm)	160 ± 13.1	158 ± 12.4	159 ± 12.3
Body mass (kg)	52.1 ± 12.1	50.3 ± 12.1	51.8 ± 12.2
Body mass index ($kg \cdot m^{-2}$)	19.9 ± 2.0	19.8 ± 2.2	20.0 ± 2.1
Genital Tanner stage	3.9 ± 1.2	4.1 ± 1.1	3.9 ± 1.2
Pubic hair Tanner stage	3.8 ± 1.2	3.9 ± 1.1	3.9 ± 1.2
Soccer experience (y)	5.3 ± 2.0	5.0 ± 1.9	5.4 ± 2.4
Session rating of perceived exertion	432 ± 275	463 ± 229	451 ± 308

intervention, all participants attended their regular physical education classes. PT24 and PT48 completed the same amount of total jumps during intervention, used the same surface (grass soccer-field) and time of the day (afternoon) for training, with the same rest intervals between jumps and series. Half of the plyometric volume corresponds to cyclic and the other half to acyclic jumps. The combination of multilateral, multidirectional, cyclic, and acyclical plyometric drills was based on previous suggestions (6,27,31). The rest interval between series was of 120 seconds and between acyclic jumps was of approximately 15 seconds, as previously recommended (30). The same 13 exercises were completed by both the groups. All exercises were performed as a CMJ with arm swing (i.e., stretch shortening cycle involvement). In addition, both groups completed 2 sets of 10 repetitions of high-intensity bounce drop jumps from 20-cm high boxes. A detailed description of the 6-week training program is depicted in Table 2.

Statistical Analyses

All values were reported as mean ± *SD*. Relative changes (%) in performance and standardized effects (SE) are expressed with a 90% confidence limits. Normality and homoscedasticity assumptions for all data before and after intervention were checked, respectively, with Shapiro-Wilk and Levene tests. To determine the effect of intervention on performance adaptations, a 2-way variance analysis with repeated measurements (3 groups × 2 times) was applied. When a significant F value was achieved across time or between groups, Sheffe post hoc procedures were performed to locate the pairwise differences between the means. The α level was set at $p \leq 0.05$ for statistical significance. In addition to this null hypothesis testing, data were also assessed for clinical significance using an approach based on the magnitudes of change. Threshold values for assessing magnitudes of SE (changes as a fraction or multiple of baseline *SD*) were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively (16).

Results

Despite not pair-matching individuals based on an independent variable, there were no significant differences between groups' descriptive data (Table 1).

Table 2. Six-week plyometric training program.

	Set × repetitions					
Exercises*	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Cyclic horizontal left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic horizontal left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic horizontal right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic horizontal right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic vertical left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic vertical left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic vertical right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic vertical right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic bilateral vertical	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic bilateral vertical	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic bilateral horizontal	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic bilateral horizontal	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Bounce drop jumps 20-cm	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10

*Denotes that the order of exercises execution was randomized each training session.

TABLE 3. Training effects (with 90% confidence limits) for the performance variables for the control group (CG; n = 55), plyometric training 24-hour group (PT24; n = 54) and plyometric training 48-hour group (PT48h; n = 57).

	Baseline mean ± *SD*	Performance change (%)	Magnitude of training effect
Squat jump (cm)			
CG	31.9 ± 6.1	−1.1 (−2.1 to −0.1)	−0.05 (−0.1 to 0.0)
PT24	31.2 ± 6.1	4.4 (3.6 to 5.2)*	0.22 (0.18 to 0.26)†
PT48	32.8 ± 7.0	3.8 (3.3 to 4.4)*	0.17 (0.15 to 0.20)
Counter movement jump (cm)			
CG	33.1 ± 6.4	−0.4 (−1.4 to 0.6)	−0.02 (−0.07 to 0.03)
PT24	32.6 ± 6.1	7.4 (6.3 to 8.5)*	0.37 (0.31 to 0.42)†
PT48	34.3 ± 6.9	8.0 (6.7 to 9.3)*	0.39 (0.33 to 0.45)†
20-cm drop jump reactive strength index ($mm\cdot ms^{-1}$)			
CG	1.31 ± 0.42	1.2 (−0.5 to 3.0)	0.03 (−0.01 to 0.08)
PT24	1.32 ± 0.40	12.2 (10.2 to 14.2)*	0.34 (0.29 to 0.39)†
PT48	1.37 ± 0.39	12.0 (10.0 to 14.0)*	0.39 (0.33 to 0.45)†
Broad long jump test (cm)			
CG	184.3 ± 29.1	−0.1 (−0.9 to 0.7)	−0.01 (−0.06 to 0.05)
PT24	184.1 ± 29.8	5.6 (3.4 to 7.9)*	0.33 (0.20 to 0.45)†
PT48	188.2 ± 30.0	5.3 (4.4 to 6.2)*	0.33 (0.28 to 0.39)†
20-m sprint time test (s)			
CG	4.32 ± 0.49	1.2 (0.7 to 1.6)	0.10 (0.06 to 0.14)
PT24	4.37 ± 0.46	−5.6 (−6.4 to −4,7)*	−0.52 (−0.60 to −0.44)†
PT48	4.26 ± 0.41	−5.1 (−5.7 to −4.4)*‡	−0.51 (−0.57 to −0.44)†
Running 10 × 5-m agility time test (s)			
CG	17.2 ± 1.1	1.8 (1.1 to 2.5)*	0.28 (0.18 to 0.38)†
PT24	17.4 ± 1.0	−3.3 (−3.8 to −2.8)*§	−0.63 (−0.72 to −0.53)‖
PT48	17.3 ± 0.9	−2.7 (−3.2 to −2.3)*‡	−0.57 (−0.67 to −0.47)†
20-m multistage shuttle run test (min)			
CG	8.5 ± 1.8	2.4 (1.2 to 3.6)	0.10 (0.05 to 0.16)
PT24	8.5 ± 1.6	10.3 (8.9 to 11.8)*	0.49 (0.43 to 0.56)†
PT48	8.9 ± 1.7	10.0 (8.3 to 11.7)*	0.49 (0.41 to 0.56)†
Sit-and-reach flexibility test (cm)			
CG	41.0 ± 4.8	−0.8 (−2.1 to 0.5)	−0.07 (−0.17 to 0.04)
PT24	40.3 ± 4.9	5.7 (4.4 to 7.1)*	0.44 (0.34 to 0.53)†
PT48	41.2 ± 5.2	4.7 (3.7 to 5.7)*	0.35 (0.28 to 0.42)†

*Denotes significant difference pre to posttraining $p < 0.001$. Values in brackets represent 90% confidence limits.
†Small standardized effect.
‡Denotes significant difference with the CG posttraining $p \leq 0.05$.
§Denotes significant difference with the CG posttraining $p < 0.01$.
‖Moderate standardized effect.

Before training, no significant differences were observed between groups in SJ, CMJ, RSI20, BLJ, 20-m sprint time, 10 × 5-m agility time, MST, or SR test (Table 3).

No significant change in the CG was observed, except for an increase in 10 × 5-m agility test time (i.e., reduced performance), with a small clinically significant change (+0.28 SE).

The 2-way variance analysis with repeated measurements (3 groups × 2 times) showed that after training both plyometrically trained groups demonstrated a statistically significant increase in SJ, CMJ, RSI20, BLJ, 20-m sprint, 10 × 5-m agility test time, MST, and SR performance, with no differences between groups. Also, the magnitudes of change analyses showed that the PT24 and PT48 groups achieve a similar small to moderate clinically significant change in SJ (+0.17; +0.22 SE), CMJ (+0.37; +0.39 SE), RSI20 (+0.34; +0.39 SE), BLJ (+0.33 SE), 20-m sprint (−0.51; −0.52 SE), 10 × 5-m agility test (−0.57; −0.63 SE), MST (+0.49 SE), and SR (+0.35; +0.44 SE) performance, respectively.

DISCUSSION

This study suggests that 6 weeks of PT, with either 24 or 48 hours of rest between sessions, induced significant and small-to-moderate similar improvements in SJ, CMJ, RSI20, BLJ, 20-m sprint time, 10 × 5-m agility time, MST, and SR test performances in young male soccer players. Also, these results show that the combination of soccer drills and specific explosive strength training with no additional training time in-season is a meaningful stimulus to enhance explosive strength and endurance adaptations in young male soccer payers.

Although it has been recommended that plyometric drills should not be conducted on consecutive days in youths (7,37), and although some interventions in young soccer players used >72 hours (28,32) or >48 hours (27) of rest between PT sessions to allow for adequate recovery, suggesting that these time frames of rest would be necessary to induce adequate training stimulation in this population of young athletes, the study shows that PT applied twice weekly in consecutive or nonconsecutive days results in similar explosive and endurance adaptations in young male soccer players. It may be argued that the PT applied represented a low training load, therefore, a relatively short period of recovery (i.e., <24 hours) between training sessions to achieve performance adaptations was sufficient. However, during the first week of training players completed 140 jumps each session, including 1 legged jumps and BDJ, which can be considered high-intensity exercises (aside from the maximal voluntary intensity required to complete all jumps). In addition, each training week plyometric volume was increased by 20%, and during the sixth week of training athletes completed 260 jumps during each training session, a volume similar (7) or even higher (28,34) in comparison to the one used effectively in previous studies with young soccer players. Therefore, several possible mechanisms can be postulated to understand how this relatively short rest period between PT sessions allows significant explosive and endurance performance adaptations in the short term when PT was applied twice weekly in young male soccer players. Some of these are reduced susceptibility to muscle damage (compared with adults) and performance alterations, and higher ability to recover after PT (25); reduced proportion of fast twitch fibers (22); reduced relative power generation capacity related to maturation-dependent neuromotor factors (11); reduced body mass (38); greater muscle compliance (allowing rapid bone growth) (8); greater naturally anabolic-occurring processes (2); and adaptations achieved during training such as endurance capacity and, hence, an improved ability to recover from high-intensity exercise (35). Future studies must be conducted to elucidate the underlying mechanism that allows young soccer players to obtain significant performance adaptations with consecutive days of PT. Interestingly, it has been suggested that muscle function (i.e., jump ability, sprint performance) is probably the best indicator of muscle recovery after intense exercise, especially in athletes (8); hence, future studies in young soccer players may consider the evaluation of muscle function performance after PT sessions with different rest times between them to better understand the recuperation process in this population segment.

The PT24 and PT48 significantly increased jumping performance (SJ, CMJ, RSI20, and BDJ), with no difference between groups. Similar results have been reported in previous studies for SJ (7), CMJ (27), RSI (27), and horizontal jump performance (7) after PT intervention in young soccer players. The significant improvement in jump performance in SJ, CMJ, RSI20, and BDJ test confirms the effectiveness of the application of a PT stimulus in achieving explosive strength adaptations, which may improve players' performance. The improvement observed could have been induced by various neuromuscular adaptations, such as increased neural drive to the agonist muscles, improved intermuscular coordination, changes in the muscle-tendon mechanical-stiffness characteristics, changes in muscle size or architecture, and changes in single-fiber mechanics (26); but because no physiological measurements were made, only speculations are possible.

A significant and similar decrease in 20-m sprint time in the PT24 and PT48 suggested that PT may be a meaningful stimulus during the competitive period for the acceleration ability of young soccer players. These results agree with those previously reported (27). The horizontal nature of the PT stimulus in these studies may help to explain the increased acceleration sprint performance (31). In addition, the PT24 and PT48 significantly reduced their time to complete the running 10 × 5-m agility test, with no differences between groups. Previous studies in early and pubescent soccer players have reported reduced agility test times of −3.4% (6) and −3.1% (18), similar to the result of this study (−2.7 to −3.3%). It must be acknowledged that subjects from the PT24 and PT48 completed a training program with several plyometric exercises designed to induce short contact times; and a reduction in contact time with PT (29) may increase RSI, which may predict the ability to change directions while running (41). Contrary to the positive explosive adaptations observed in the PT24 and PT48, the CG exhibited a significant increase in their 10 × 5-m agility test time. These observations reinforce the value of an independent power-training program to enhance explosive actions of young soccer players.

To the authors' knowledge, a unique finding of this study was to report that a short-term PT program, implemented as a substitute for some soccer drills within regular in-season soccer practice, significantly enhances flexibility in young male players, and this improvement was similar in PT24 and PT48 groups. Similarly, previous results show that young people also increase flexibility after PT (10). Plyometric training has been advocated as a preventive injury strategy for young athletes (21), and as muscle flexibility is a risk factor for developing muscle injuries in male soccer players (39), these results may have important relevance. The increased flexibility may be explained by a possible reduction of the stiffness of the muscle-tendon complex and similar changes in the elastic behavior of adjacent joint subcomponents (26).

The PT24 and PT48 groups exhibited a significant increase in endurance performance (i.e., MST), with no differences between groups. Their relative increase in endurance performance was 4 times greater than that of the CG. The positive effects of PT on endurance performance in young soccer players have been previously reported (40). However, explosive training in young soccer players did not induce improvement in $\dot{V}O_2max$ (28) or lactate thresholds (14); therefore, the improvement in the MST may be related to neuromuscular power improvement useful for change of direction endurance test (3) or running economy adaptations (40). More studies must be conducted to clarify how PT influences endurance performance related to young soccer players.

In conclusion, PT24 and PT48 groups achieved similar small-to-moderate significant improvements in explosive and endurance performance after training. Therefore, when 2 PT sessions are performed per week, 24 or 48 hours of rest between these is adequate to induce significant explosive and endurance adaptations in young male soccer players.

Practical Applications

From a practical point of view, it must be considered that the PT applied induced explosive and endurance adaptations, which may have high transference into game-play performance. Thus, a twice weekly short-term high-intensity PT program, implemented as a substitute for some soccer drills within regular in-season soccer practice, can enhance explosive and endurance performance in young soccer players compared with soccer training alone, and these improvements can be achieved using 24 or 48 hours of rest between PT sessions. Considering that some young soccer teams schedule training sessions are on consecutive days, the current findings may be relevant to programming PT in this context.

Although concern has been expressed by some researchers with regard to the injury risk during PT, to the best of the author's knowledge, when adequate controlled PT intervention had been applied, no important injuries had been reported. In fact, PT had been advocated as a preventive injury strategy (21) and even as a rehabilitation tool. It is important to notice that in this investigation, no injuries were reported. More so, subjects reported little subjective muscle pain after the training sessions (data not shown). However, it is still unknown if consecutive days of PT may have a greater risk of injury occurrence over the course of a season in comparison to a periodized plan with greater between-days rest intervals, and precaution must be taken before implementing such regime with a long-term approach.

Also, it must be considered that although the results of the study demonstrated an increase in explosive and endurance ability after PT, it is recommended that this training method should be adequately incorporated in a comprehensive training program that develops the specific technical abilities that are critical to achieve adequate performance (especially at young ages), and with an adequate aerobic conditioning program to optimize training adaptations.

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