

Effects of short-term in-season plyometric training in adolescent female basketball players

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In this study, we tested the hypothesis that, during the regular in-seasonal basketball training, an additional 7-week plyometric training program improves lower extremity strength, balance, agility, and jump performance in adolescent female basketball players. Eighteen female basketball players less than 17 years of age were randomly assigned into an experimental group (plyometric training) and a control group. Both groups underwent the same basketball training program. Pre- and post-training test periods included quadriceps and hamstring strength, balance, jump performance, and agility measurements. Illinois agility test time ($p = 0.000$) and quadriceps strength ($p = 0.035$) increased uniformly in the two groups. Significant group by test period interaction was found for countermovement jump ($p = 0.007$), and countermovement height reduced significantly in the plyometric training group ($p = 0.012$), while it remained unchanged in controls. No significant change was found for T agility test, balance, hamstring strength or H:Q ratio. This study shows that the training program used in-season did not improve the measured variables, except for knee extensor strength. It is possible that regular basketball trainings and games combined with high-volume plyometric training did not show positive functional effects because of the fatigue caused by incomplete recovery between sessions.

Keywords: 7-week program, high intensity, adolescent females, team sport, female athletes

Introduction

In basketball games, women players perform short sprints with rapid change of direction 52% of the total sprints, which substantiate the prevalent role of agility. In addition, players perform jumps or other high-intensity movements between sprint bouts (10). Plyometric training (PT) is a well-known exercise modality among basketball players, and it has been used for several decades for developing athletic performance and preventing sport injuries. PT exercises such as jumping, skipping, and hopping in various directions (23) utilize the neuromuscular system's ability to activate the muscles during the eccentric phase of contraction and to enhance elastic energy storage and reuse in the concentric phase. PT programs are usually designed to improve athletes' various skills, such as maximal and explosive strength (1), power (9), agility, and balance (16, 18, 28, 32). The strength of knee flexors and extensors in basketball players determines athletic performance and is associated

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with injury risks (41). It has been suggested that PT prevents knee ligament injuries because of the improved hamstring to quadriceps (H/Q) ratio, a parameter often used for quantifying active knee joint stability (43).

Basketball players perform consecutive intense actions such as sprinting, shuffling, jumping, cutting, change of directions, and rapid accelerations and decelerations (4), components of agility that strongly depend on muscle strength, contraction velocity, and balance (19, 20, 21). Scientists and conditioning specialists often design PT programs for basketball players to target the aforementioned skills. However, despite that PT is recommended for adolescents, in scientific investigations, mostly male adult basketball players were examined. Authors mostly used 6-week-long (15, 18, 23, 26) or 8-week-long PTs (14, 27) for basketball players in previous studies. For example, 8 weeks of PT combined with dynamic stretching showed improved agility, vertical jump height, and sprint speed in professional players (37). In addition to these skills, a 6-week-long PT was also effective in dynamic balance and lower extremity strength development in semi-professional players (3). In Shallaby's experiment, PT improved vertical jump height, sprint speed, and agility in 16-year-old male players (39). Agility improvements in this age group after PT have been confirmed by Gottlieb et al. (14). The necessity to incorporate PT into the preparation of female adolescent athletes has been justified by previous studies showing the benefits of PT in various sports other than basketball (40).

Despite the large quantity of data, the problem with most PT studies recruiting basketball players is that periods with different length and/or different or unknown seasonal periods were examined. For example, Ramachandran and Pradhan (35) demonstrated favorable effects of PT performed for 2 weeks in contrast with Shallaby's (39) 12-week program, or studies were conducted in pre-season (3, 14, 26), in-season (27, 36), or in unspecified periods (2, 30, 35, 37, 38, 39, 45). Moreover, these authors failed to report basketball-specific training exercises (including loads and intensities) performed by players in addition to the investigated PT program, which limits results and interpretation. In a study by Santos and Janiera (36), adolescent male basketball players, besides the regular in-season basketball practices, participated in an additional 10-week PT program and the authors reported favorable changes in lower-body explosive strength in the experimental group. Hernandez et al. (17) found that in-season PT is effective for improving physical qualities in 10-year-old male basketball players besides that participants completed only technical-oriented familiarization sessions 2 weeks before the PT program and performed only two basketball-specific practices per week during the experimental period. In contrast to males, there is a lack of data on the effectiveness of in-season PT in adolescent female basketball players. Bouteraa et al. (7) examined the effect of 8 weeks that combines balance and PT on physical fitness of female adolescent basketball players. Although the training improved balance and agility, it is unclear which part of the training program induced these positive effects in the measured variables. Vescovi et al. (45) examined the effects of PT program only on peak vertical ground reaction force in collegiate women who competed in recreational basketball. Witzke and Snow (47) found that, in adolescent high-school girls, bone mineral content, muscle strength, muscle power, and static balance changed after 9 months of high-intensity PT.

There is a discrepancy in the results of the PT studies because of using different gender, age, duration, intensity, and seasonal periods in basketball, and little evidence exists on the effectiveness of PT in adolescent girls. Studies were performed in different seasonal periods and it is unknown whether in-season PT is beneficial to further improve basketball-specific conditional skills. In this study, we tested the hypothesis that during the regular in-season

basketball training, an additional 7-week PT program improves lower extremity strength, balance, agility, and jump performance in adolescent female basketball players. To test this hypothesis, a randomized controlled study was performed.

Material and Methods

Subjects

Eighteen female basketball players from an under-17 age group basketball team participated in the study. Subjects were randomly assigned into an experimental group that, besides the regular basketball practices, performed PT ($n = 9$; age = 15.8 ± 1.2 years, body height = 176.4 ± 8.6 cm, body weight = 63.5 ± 8.6 kg) and to a control ($n = 9$) group (age = 15.7 ± 1.3 , body height = 177.5 ± 7.4 cm, body weight = 66.1 ± 8.9 kg), which participated only in the basketball practices. Subjects had been playing basketball for at least 5 years. All subjects have previously undergone PT, including both unilateral and bilateral exercises. Subjects were familiarized with the testing exercises 5 days before the experiment. None of the subjects reported injuries during the experiment. The study confirmed to the ethical standards of the use of human subjects (Declaration of Helsinki), and written parental consent from the parents of each subject was obtained.

Measures

The study consisted of two measurement sessions. Pre- and post-training test sessions were performed 5 days before and after the training program, respectively, which included quadriceps and hamstring strength, balance, jump performance, and agility measurements. The PT program lasted 7 weeks. Subjects from both groups during the 7-week period continued their regular basketball practice program and participated in basketball games, which is detailed later. Both test sessions held on two consecutive days began with a standardized dynamic warm-up consisting of low-intensity jogging and 12 dynamic warm-up exercises for 10 min (8, 12, 48). On the first day of the pre-test session, balance, vertical jump performance, quadriceps, and hamstring strength were measured, whereas agility was tested on the second day.

Procedures

In order to clarify the results of the experiment later, we briefly describe the training periods shown in Fig. 1. The pre-season training lasted 8 weeks and consisted of 4–9 sessions/week with an average of 80-min practice/sessions. The pre-season included two periods

	Pre-season 1					Pre-season 2			In-season						
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. of sessions	9	9	9	9	9	4	5	4	5	5	5	5	5	5	5
No. of games	0	0	0	0	0	2	1	3	1	1	1	2	1	2	1

Fig. 1. Periodization of work load. 5 weeks (Week 1–Week 5) of pre-season-specific training with nine training session/week and number of games. Three weeks (Week 6–Week 8) pre-season specific training with 4-5-4 training sessions/week and 2-1-3 games. The experiment took place between the pre-test and the post-test sessions (Week 9–Week 15) with five basketball training sessions/week and one or two games

(pre-seasons 1 and 2), and these periods were different in the magnitude of load applied in conditional and technical skill drills. This preparation primarily served to provide physical basics for basketball performance required during the season. The specific goals were to improve agility, reaction speed, sprint speed, coordination, aerobic and anaerobic endurance, and muscle strength. Ladder drills, balance drills, medicine ball drills, and functional strength drills were included in the conditioning part. The basketball-specific part consisted of fundamental drills, such as dribbling, passing, shooting, offensive and defensive footwork, as well as individual and team tactics.

The PT experiment was carried out between the 1st and the 8th week of the in-season period (Fig. 1). During the experiment, subjects participated in 4–5 practices/week and seven games. In the basketball practices, the focus was mainly on developing technical and tactical skills (Table I). Practices also included conditioning drills in order to maintain the players' physical status developed during the pre-season period; however, the load-rest ratio was reduced.

Table I. In-season training for motor skills – U17 girls

	Day 1	Day 2	Day 3	Day 4	Day 5	Days 6 and 7
<i>Motor skills</i>						Game day or rest
Duration of training	90 min	100 min	85 min	100 min	85 min	
Agility	Agility ladder with ball (10 min)	Speed and agility drills with ball (15 min)		Agility ladder with ball (10 min)	Speed with ball (15 min)	
Coordination	Dynamic warm up with ball (10 min)		Running technique (15 min)		Dynamic warm up with ball (15 min)	
Endurance	Aerobic basketball (45 min)	Aerobic/ anaerobic basketball (45 min)	Anaerobic basketball (45 min)	Anaerobic basketball (40 min)	Anaerobic basketball (30 min)	
Upper body strength	Circle training (15 min)	Core training (10 min)	Core training (15 min)	Upper extremities with ball (15 min)	Core training (10 min)	
Lower body strength						
Flexibility	Stretching (10 min)	Stretching (10 min)	Stretching and cool down (15 min)	Stretching and cool down (15 min)	Stretching and cool down (15 min)	
PT		PT program (20 min)		PT program (20 min)		

PT: plyometric training; U17: under-17

Agility testing

Two types of tests were used in this study. First, subjects performed the T-sprint test (TST), which was designed to measure agility during forward sprints, change of directions, shuffles, and back pedaling (25, 29). Afterward, the Illinois agility test (IAT) was performed, which measures acceleration, deceleration, change of direction, and speed in different angles (5, 29). Both tests (applications, equipments, testing layouts, and procedures) have been described by Jones (25). Subjects performed two trials in both tests with 5- and 10-min recovery within and between tests, respectively. The best times of the trials were recorded for data processing.

Balance testing

A stabilometer (STRUKTURA Instruments Ltd., Tura, Hungary) was used to examine single-leg balance for 60 s. Players stood on the stabilometer with one foot without shoes and kept the contralateral knee bent; the hips were level to the ground; the eyes were open and fixed on a spot marked on a screen (42). Visual feedback was continuously provided on the screen by displaying the magnitude of postural sway. Three trials were performed with both legs, with 1-min recovery between trials. The instrument aggregated the results of the test and evaluated the performance between 0 and 100 points. The value of the best trial was recorded for each leg, which was then averaged and used for statistical analyses.

Jump performance testing

Double-leg countermovement jump (CMJ) test was used for investigating the reactive strength of the lower extremities (13). CMJ height was measured with a contact platform (Chronojump-Boscosystem, Barcelona, Spain), which is a reliable method in jump performance evaluation (33). Subjects performed four maximal effort vertical jumps, while keeping the hands on the hips to eliminate arm swing contribution. One minute recovery was allowed between trials. The best CMJ height was used for statistics.

Strength testing

The Multicont II isokinetic device (Mechatronic Ltd., Szeged, Hungary) with a sampling frequency of 1,000 Hz was used for measuring hamstring and quadriceps torques. Special details of the device and its calibration have been described previously (44). Subjects performed unilateral maximal voluntary contractions (MVC) concentrically with both the knee extensors and flexors. Among trials, 1-min recovery was given to the subjects. The range of motion was set between 10° and 80°, and the direction of limb movement depended on which muscle group was tested. Two constant angular velocities were used during contractions: 60°/ and 180°/s. Subjects performed three trials with both legs in all muscle group and velocity conditions, and the variables were named as MVC_{60flex}, MVC_{180flex}, MVC_{60ext}, and MVC_{180ext}. From the torque–time curve, we determined the peak torque. The best values obtained from the two legs were averaged and considered for statistics. Using the peak torques obtained at the specific contraction velocities, we also determined the hamstring to quadriceps (H:Q60 and H:Q180) torque ratios.

Plyometric training (PT)

All subjects were carefully preconditioned for performing PT and had previous experience in PT. Specific details of the PT program are presented in Table II. In our experiment, a 7-week program fit into the long-term preparation schedule. The first 3 weeks (W1–W3) were a preparatory phase, followed by additional 3 weeks (W4–W6) with increased volume, and

Table II. Plyometric training

	W1–W3		W4–W6		W7	
	Tue	Thu	Tue	Thu	Tue	Thu
Double-leg hurdle jump (50 cm)	4 × 4	–	6 × 4		3 × 4	–
Single-leg lateral cone jump (25 cm)	3 × 10	–	4 × 10		2 × 10	–
Single-leg forward hop	3 × 5	–	4 × 5		2 × 5	–
Double-leg depth jump (25 cm)	–	4 × 5	–	6 × 5	–	2 × 5
Double-leg lateral cone jump (35 cm)	–	4 × 5	–	6 × 5	–	2 × 5
Single-leg hurdle jump (25 cm)	–	3 × 10	–	4 × 10	–	2 × 10

W: week; Tue: Tuesday; Thu: Thursday

1 week (W7) with decreased volume, based on the methodology from Miller et al. (29). Training sessions were performed on Tuesdays and Thursdays to ensure time for regeneration. Accordingly, the total number of jumps increased from 61–70 to 84–100 per session, over 6 weeks. Subjects were instructed to maximize jumping height or distance and minimize ground contact time during the drills. A strength specialist gave verbal feedback to subjects during the drills in order to maintain acceptable technical execution. About 2- and 5-min recoveries were provided between sets and drills, respectively.

Table III. Partial η^2 values for the representation of effect sizes obtained from the ANOVA tests in the measured and calculated variables

Variable	Test period main effect	Group main effect	Interaction
IAT	0.691	0.121	0.079
TST	0.245	0.139	0.037
CMJ	0.267	0.176	0.466
B	0.120	0.089	0.024
MVC _{60ext}	0.379	0.007	0.206
MVC _{60flex}	0.312	0.120	0.003
MVC _{180ext}	0.781	0.081	0.043
MVC _{180flex}	0.728	0.025	0.039
H:Q ₆₀	0.206	0.009	0.206
H:Q ₁₈₀	0.379	0.017	0.081

IAT: Illinois agility test; TST: T-sprint test; CMJ: countermovement jump; CMJR: countermovement jump right leg; CMJL: countermovement jump left leg; B: balance right and left average; MVC_{60ext}: maximal voluntary isometric torque at 60°/s velocity extension; MVC_{60flex}: maximal voluntary isometric torque at 60°/s velocity flexion; MVC_{180ext}: maximal voluntary isometric torque at 180°/s velocity extension; MVC_{180flex}: maximal voluntary isometric torque at 180°/s velocity flexion; H:Q₆₀ ratio: hamstring and quadriceps ratio at 60°/s velocity; H:Q₁₈₀ ratio: hamstring and quadriceps ratio at 180°/s velocity

Table IV. Effects of the 7-week PT program on agility, vertical jump, balance, quadriceps and hamstring strength, and H:Q ratio

Variables	PT group		Control group		Test period main effect		Interaction <i>p</i>
	Before	After	Before	After	%	<i>p</i>	
IAT (s)	16.21 ± 0.81	16.95 ± 1.07	16.85 ± 0.71	17.34 ± 0.93	3.70%	0.000*	0.329
TST (s)	10.96 ± 0.48	11.13 ± 0.63	11.25 ± 0.51	11.6 ± 0.78	2.30%	0.072	0.509
CMJ (cm)	33.52 ± 3.89	31.96 ± 3.48*	28.72 ± 6.66	29.06 ± 6.81	-2.00%	0.058	0.007*
B (value)	74.82 ± 2.22	75.62 ± 4.31	73.28 ± 7.06	74.14 ± 5.58	0.50%	0.730	0.630
MVC _{60ext} (Nm)	165.64 ± 22.53	175.16 ± 21.61	157.44 ± 34.78	156.82 ± 32.28	2.80%	0.258	0.138
MVC _{60flex} (Nm)	94.54 ± 14.05	99.11 ± 17.96	88.87 ± 19.94	94.22 ± 17.05	5.40%	0.451	0.856
MVC _{180ext} (Nm)	120.25 ± 25.89	130.01 ± 19.06	108.92 ± 21.72	128.09 ± 24.49*	12.60%	0.035*	0.519
MVC _{180flex} (Nm)	94.82 ± 24.99	113.01 ± 26.80	92.01 ± 29.82	106.87 ± 12.73	17.60%	0.056	0.538
H:Q ₆₀ ratio (%)	60.42 ± 9.99	58.79 ± 7.72	56.05 ± 5.16	59.46 ± 4.64	1.50%	0.901	0.364
H:Q ₁₈₀ ratio (%)	78.52 ± 10.32	86.38 ± 10.51	83.57 ± 17.15	83.59 ± 13.74	4.90%	0.548	0.370

Mean values (±SD) for the individual group, and percentages of changes for the two groups combined (test period main effect) are presented. IAT: Illinois agility test; TST: T-sprint test; CMJ: countermovement jump; CMJR: countermovement jump right leg; CMJL: countermovement jump left leg; B: balance right and left average; MVC_{60ext}: maximal voluntary isometric torque at 60°/s velocity extension; MVC_{60flex}: maximal voluntary isometric torque at 60°/s velocity flexion; MVC_{180ext}: maximal voluntary isometric torque at 180°/s velocity extension; MVC_{180flex}: maximal voluntary isometric torque at 180°/s velocity flexion; H:Q₆₀ ratio: hamstring and quadriceps ratio at 60°/s velocity; H:Q₁₈₀ ratio: hamstring and quadriceps ratio at 180°/s velocity.

*Significant main effect or interaction for the ANOVA results and significant difference between "Before" and "After," revealed by the *post-hoc* test

Statistical analyses

Means and standard deviations were determined for the measured and calculated variables. No significant between-group baseline differences were observed for any examined variables. The Kolmogorov–Smirnov normality tests proved that all data were normally distributed. Training-induced changes in the dependent variables were tested using two-way (Group \times Test period) analysis of variance (ANOVA), where group and test periods served as between- and within-subject factors. If significant interactions were found, paired *t*-tests with the Bonferroni adjustment were used to compare the mean values.

Absolute agreement-type test–retest reliabilities of the performance measurements were assessed using intraclass correlation coefficients (ICCs). For this procedure, we used the intrasession baseline data sets in the variables. The ICCs were as follows: IAT = 0.88, TST = 0.82, CMJ = 0.96, balance = 0.84, MVC_{60ext} = 0.90, MVC_{60flex} = 0.86, MVC_{180ext} = 0.88, MVC_{180flex} = 0.84, H:Q60 = 0.88, H:Q180 = 0.82.

To calculate pre- to post-effect sizes, partial η^2 values were calculated in each variable (Table III). Statistical power values were computed *post-hoc*, and were as follows: IAT = 0.99, TST = 0.43, CMJ = 0.84, balance = 0.12, MVC_{60ext} = 0.62, MVC_{60flex} = 0.11, MVC_{180ext} = 0.60, MVC_{180flex} = 0.71, H:Q60 = 0.13, H:Q180 = 0.58. In every analysis, the statistical significance was set at $p < 0.05$.

Results

Means and standard deviations of the measured and calculated variables are presented in Table IV. There was a significant test period main effect in IAT ($p = 0.000$) and MVC_{180ext} ($p = 0.035$). The main effects of the test period in MVC_{180flex} and CMJ were close to the significance level ($p = 0.056$ and 0.058 , respectively). Significant group by period interaction was found for CMJ ($p = 0.007$), and the *post-hoc* analysis revealed that CMJ height reduced significantly in the PT group ($p = 0.012$). No significant change was observed for TST, balance, MVC60 extensor and flexor, and H:Q ratio in any of the tested conditions. Table IV shows the exact *p* values for the ANOVA tests and for the pairwise comparisons.

Discussion

An important feature of this study was that subjects performed high-intensity plyometric exercises built into their regular basketball-training program. We hypothesized that the program would produce improvements in jump performance, strength, H:Q ratio, agility, and balance. Our data provide evidence that the training program used in-season did not improve the measured variables, except for knee extensor strength.

Previous investigations suggested that PT is an effective strategy to improve agility in basketball players (35, 37). Most of the PT programs included only double-leg jumps unlike in a few studies (14, 36). This study includes unilateral and bilateral movements equally like depth jumps, hurdle jumps, and lateral cone jumps. This study showed that the 7-week in-season PT was not effective in agility development. In addition, IAT time increased uniformly (3.7%) in the two groups. Studies that examined the effects of PT on specific agility in basketball players were performed in different periods. Hernandez et al. (17) found improvement in agility after a high-intensity in-season PT program, although the program was designed for 10-year-old males and the additional basketball practices were performed only twice per week. Asadi and Arazi (3) found that high-volume (180 reps/session) 6-week PT performed in pre-season period

significantly reduced IAT (-7%) and TST time (-9%) in semi-professional male basketball players. Ramachandran and Pradhan (35) found significant improvements in the TST in professional basketball players after 2 weeks of PT with 75–150 reps/session. In that study, however, no information about the training period and content was given.

The level of inappropriate proprioceptive function may contribute to the development of lower limb ligament injuries (22). Effects of PT on balance have been tested in few studies, and in this study it was expected that the unilateral jumps performed in various directions would target the neuromuscular system's properties responsible for balancing. According to Myer et al. (31), an 8-week pre-season PT improved balance in adolescent female athletes. In that study, PT was conducted 3 times per week and lasted for approximately 90 min/session. Arazi and Asadi (2) found that an 8-week in-season PT (117–183 reps/session) did not improve balance in male basketball players. In this study, neither of the groups showed significant change in the balance values.

It has been previously demonstrated that PT could decrease landing force and increase vertical jump height (9.2%) in high-school female volleyball players (4). Several researchers tested whether PT could also improve jump performance in basketball players. Zribi et al. (49) reported 15% improvement in early pubertal male basketball players after 9 weeks of supplementary in-season PT program (60–100 reps/session) with two sessions per week. A 10-week-long in-season PT program was designed by Santos and Janiera (36) (90–152 reps/session), in which subjects were assigned to either a detraining group or a reduced training group for additional 6 weeks. The program promoted statistically significant increases in vertical jump height. In contrast, in this study, CMJ height is reduced by 5% in the experimental group. Because the only group by period interaction was found in CMJ height, we suggest that the present PT program induced a jump-specific overuse in the experimental group.

Few studies demonstrated the effect of PT on muscle strength. We found significant improvement only in MVC torque measured at $180^\circ/\text{s}$ velocity knee extension (12%), while hamstring torque improvements measured at the same angular velocity only approached the significance level. MVC torque at slow velocity ($60^\circ/\text{s}$) was unchanged, which can be explained with the fact that PT targets the fast muscle fibers, while slow fibers were untrained in this season. This is in agreement with others who found no change in isometric strength after PT (2, 15, 27, 35). Furthermore, in contrast with Tsang and DiPasquale (43), H:Q ratio did not improve in this study because knee flexor strength also tended to increase. We propose that PT should be supplemented with additional hamstring-strengthening exercises for the development of H:Q ratio.

Overall, the present in-season PT program did not improve the measured variables, except for knee extensor strength. Although the program had positive effect on MVC torque at $180^\circ/\text{s}$ velocity knee extension, it did not accumulate into favorable adaptations in functional skills, such as agility, CMJ jump height, and balance. Plyometric exercise kinematics and kinetics are similar to those in basketball-specific movements (46). High-intensity actions, such as sprints, rebounds, change of directions, and cuttings, are performed similarly to PT exercises, which involve reactive muscle contractions (stretch-shortening cycles) (11). Both the agility and the CMJ tests involve stretch-shortening cycles, and the reduced performance in these variables suggests that a combination of PT and basketball-specific in-season preparation impairs stretch-shortening cycle functionality in adolescent females.

Even though some studies imply that in-season PT has positive effects on various skills (2, 31), the basketball practices, and games supplemented with PT precluded functional improvements in the present protocol. The maximum number of ground contacts per session

is recommended between 80 (novice) and 140 (advanced) (34). The training load and exercise type were adopted from previous studies (14, 36) and were adjusted to our subjects. It is questionable that the high-intensity practices (both PT and basketball) led to incomplete recovery between-sessions, inducing muscle overuse. However, because knee extensor muscle contractility improved in this study, we suggest that the origin of performance decline in CMJ and agility is rather neural than muscular: both tests involve the stretch-shortening cycle, which requires unique activation strategies other than that used in MVC tasks. It has been previously reported that basketball players perform 40–65 jumping actions during a basketball game (24). In addition, actions like screening, blocking, or positioning for rebounds and court position involve additional lower-extremity muscle recruitments, specifically stretch-shortening cycle contractions. Although no age- and gender-specific recommendations were given, Bompa (6) theorized that 4–6 weeks for high-intensity PT is the most optional so that the central nervous system be stressed without fatigue; however, the concurrent sport-specific preparation was unconsidered. The lack of group by test period interactions in this study suggests that additional PT program applied in-season is neither recommended nor it is necessary even for maintaining agility and jump performance.

Finally, it is important to mention that although numerous researchers found that PT improves several functional skills in basketball players, the results have never been explained with respect to the actual preparation season in which PT was performed, or with the training variables (load, intensity, and duration) applied in the basketball practices (2, 7, 17, 30, 35, 37, 38, 39, 46). It is highly recommended that in future studies scientists provide detailed basketball-specific preparation and game programs, besides the experimental PT protocols for better understanding of the mechanisms of adaptation.

There are several limitations in this study. First, the low number of subjects does not allow us to generalize the results to the entire population of adolescent basketball players. The small power values indicate that larger sample size would have been needed to demonstrate significant effects on some of the measured variables. However, we aimed to standardize loads, volumes, and intensities in exercises other than the experimental PT; therefore, we were unable to recruit players from other teams because of their different training program. Second, uncontrolled psychological factors could have influenced not only the outcome of the performance tests but the effectiveness of the entire preparation in our players. Third, individual responsiveness to the different training stimuli may have prevented us from detecting statistically significant changes.

In conclusion, our results show that a 7-week-long PT program improved rapid contractility in quadriceps muscle, whereas agility and jump performance reduced, and balance remained unchanged in adolescent female basketball players. We suggest that in an in-season period, coaches and strength specialists avoid additional high-intensity PT exercises in adolescent female basketball players.

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