International Journal of Sports Physiology and Performance, 2016, 11, 102-107
http://dx.doi.org/10.1123/ijspp.2015-0058

Human Kinetics
ORIGINAL INVESTIGATION

The Effects of Frontal- and Sagittal-Plane Plyometrics on Change-of-Direction Speed and Power in Adolescent Female Basketball Players

Brian T. McCormick, James C. Hannon, Maria Newton, Barry Shultz, Nicole Detling, and Warren B. Young

Plyometrics is a popular training modality for basketball players to improve power and change-of-direction speed. Most plyometric training has used sagittal-plane exercises, but improvements in change-of-direction speed have been greater in multi-direction programs. ***Purpose:*** To determine the benefits of a 6-wk frontal-plane plyometric (FPP) training program compared with a 6-wk sagittal-plane plyometric (SPP) training program with regard to power and change-of-direction speed. ***Methods:*** Fourteen female varsity high school basketball players participated in the study. Multiple 2 × 2 repeated-measures ANOVAs were used to determine differences for the FPP and SPP groups from preintervention to postintervention on 4 tests of power and 2 tests of change-of-direction speed. ***Results:*** There was a group main effect for time in all 6 tests. There was a significant group × time interaction effect in 3 of the 6 tests. The SPP improved performance of the countermovement vertical jump more than the FPP, whereas the FPP improved performance of the lateral hop (left) and lateral-shuffle test (left) more than the SPP. The standing long jump, lateral hop (right), and lateral-shuffle test (right) did not show a significant interaction effect. ***Conclusions:*** These results suggest that basketball players should incorporate plyometric training in all planes to improve power and change-of-direction speed.

Keywords: agility, girls' basketball, vertical jump, lateral shuffle, horizontal jump

Agility is a motor ability important to success in team sports[1] and has been defined traditionally as speed in changing directions.[2] Basketball requires multidirectional movement skills and the ability to stop and start quickly. Despite its perception as a vertical game, basketball players have been shown to execute as many or more changes in direction and speed than maximal vertical jumps (VJs) during a game.[3] Men's basketball games have been found to require a change in movement every 2 seconds.[3,4] Despite the importance of these change-of-direction movements, training for basketball players has emphasized the VJ. National Basketball Association (NBA) strength and conditioning coaches have reported extensive use of VJ training and testing, whereas no direct mention was made of training specifically for change-of-direction speed (CODS), and only half of the sample tested for CODS.[5]

Plyometrics has been a popular training modality for athletes and has dominated basketball strength and conditioning programs.[5–7] Plyometrics is characterized by quick, powerful movements involving a prestretch of the muscle, followed by a shortening, concentric muscle contraction, thus using the stretch-shortening cycle.[8] Training interventions incorporating plyometrics have been shown to elicit improvements in CODS,[9,10] VJ height,[7] and long-jump distance.[9]

Plyometric training programs have emphasized sagittal-plane exercises such as box jumps, repeat hurdle hops, and depth jumps.[5–7,11] Few studies have examined the effects of plyometric training performed in different planes of movement. A multidirectional jump-training program was found to improve performance in 2 tests of CODS,[10] but the study did not investigate the effects of the plane of movement of the training. A 6-week program of frontal-plane plyometrics (FPP) and sagittal-plane plyometrics (SPP) found that only the SPP program improved VJ height in male high school basketball players.[7] A test of power in the frontal plane may have identified improved power by the FPP group,[7] which was not expressed in the VJ test due to the principle of specificity.[12]

The purpose of this study was to compare the effects of 6-week FPP and SPP training programs on CODS and power. The study attempted to answer 2 key questions: (1) Does plyometric training improve performance during a test of CODS? The hypothesis was that the FPP training program compared with the SPP training program would show improved performance in the lateral-shuffle test (LST). (2) Are the benefits of plyometric training specific to the plane in which it is trained? The hypothesis was that the SPP training program would improve performance in the countermovement VJ (CMVJ) and standing long jump (SLJ), and the FPP would improve performance in the lateral hop (LH).

Methods

Participants

The participants were female varsity high school basketball players (N = 14) from 2 high schools (10 from 1 school and 4 from the other) in the western United States. The participant characteristics are shown in Table 1.

Two high school basketball coaches volunteered to participate in the study with their varsity players. The study started with 29 players, but only 14 completed the 6 weeks of training and posttesting.

McCormick, Hannon, Newton, Shultz, and Detling are with the Dept of Exercise and Sport Science, University of Utah, Salt Lake City, UT. Young is with the Discipline of Human Movement and Sport Sciences, Federation University Australia, Ballarat, VIC, Australia. Address author correspondence to Brian McCormick at brian.mccormick@utah.edu.

Table 1 Physical Demographics for Frontal-Plane (FP) and Sagittal-Plane (SP) Groups, Mean ± SD

Group	n	Age, y	Body height, cm	Body mass, kg
FP	7	16.29 ± 0.76	169.82 ± 6.63	59.36 ± 10.53
SP	7	15.71 ± 0.76	173.99 ± 6.60	61.75 ± 4.59
Total	14	16.00 ± 0.78	171.91 ± 6.71	60.56 ± 7.90

Injuries (none due to the training intervention), illness, and other personal conflicts limited participation and led to the exclusion of the others from posttesting. None of the participants had sustained a significant ankle, knee, hip, or back injury in the 6 months before the intervention, and those injured during the duration of the study were excluded from the analysis. The study was approved by the University of Utah institutional review board and the school district, and written participant assent and parental permission were completed before data collection.

Design

The study used a quasi-experimental between-groups design. Participants were assigned randomly to 1 of the 2 groups (FPP or SPP). After random assignment, the groups were balanced based on their school, personal characteristics, and pretest CMVJ. Each participant was tested preintervention, completed a 6-week training intervention, and was tested postintervention. Six weeks of plyometric training have been shown to be sufficient to elicit performance improvements.[7,9,10] The training intervention occurred at the beginning of the teams' off-season basketball programs during their normally scheduled basketball classes. In addition to the plyometric training, the teams practiced twice per week during the study and played 1 game per week. The participants trained with the intervention twice per week, and any participant who missed more than 2 sessions during the 6 weeks was excluded from the analysis. The participants were asked to refrain from additional plyometric or CODS training during the duration of the study.

Methodology

Immediately before the intervention, the participants reported for their basketball class and presented their signed assent and parental permission forms. The participants filled out a questionnaire that asked for their age, body height, and body mass. After completing the questionnaire, the participants completed a 10-minute standardized warm-up consisting of the following exercises: jog, backpedal, quick skip, quick skip (thigh parallel to the ground), skip (knee above hip), high skip (reach as high as possible), monkey shuffle (lateral shuffle with arm swing), carioca, sumo squat × 10 (stationary), hip turn and walkover, high knees, butt kicks, walking lunge (elbow to instep), 3/4-speed sprint, backpedal, stork stretch, knee hug, 3/4-speed sprint, and backpedal. Next, all participants completed 6 tests in a single session in their high school gymnasium. A CMVJ and SLJ were used as the tests of power in the sagittal plane, and an LH was used as the test of power in the frontal plane. An LST was used as the measure of CODS. The researcher explained the tests to the participants, and they had an opportunity to practice each test twice. After the practice trials, the subjects completed 3 test trials of the CMVJ, SLJ, and LH. The LH was performed on each leg. The participants also completed 1 test trial of the LST in each direction. They were given 60 to 90 seconds to recover between trials.[13] Testing was completed in a randomized order for each participant.

The following week, the participants reported to their basketball class and were divided into the FPP and SPP groups. A certified strength and conditioning coach explained and demonstrated the training-intervention exercises to each group, and players were allowed to ask questions and practice each movement. After the explanation and demonstrations, the groups performed a standardized warm-up. After the warm-up, the groups split apart and performed their plyometric training. Each group trained together on one side of the gymnasium. Written instructions detailing the exercises were provided. The strength coach supervised both groups. Coaching was limited to technique instruction or cues to assist the participants to reduce the risk of injury. The subjects were encouraged to give maximum effort at the beginning, but nobody coached effort, praised or criticized participants, or otherwise coached the participants during the duration of the study.

Apart from the first day, training lasted 30 minutes each day. The participants were asked to follow specific instructions. The volume of jumps was within the recommended guidelines of 80 to 100 total contacts for beginners and 100 to 120 total contacts for intermediates.[14] Because the training experience of the subjects was unknown, training began within the range of beginners and progressed to the range of intermediates, similar to other studies.[7,15] Participants were instructed to rest for 60 seconds between sets and 15 seconds between exercises during weeks 1 to 3 and 60 to 90 seconds between sets and 30 seconds between exercises during weeks 4 to 6.[15] Training sessions did not occur on consecutive days.

After 6 weeks of training, the participants reported to the gymnasium to complete posttesting. They were allowed 1 practice trial and 3 test trials of the 4 tests and 1 test trial of the LST in each direction. The best performance was used for further analysis.

Testing Protocol

Participants completed the CMVJ, SLJ, LH, and LST testing at preintervention and postintervention. Testing was completed in a high school gymnasium with a wood floor. All participants performed a standardized dynamic warm-up before testing.

Countermovement Vertical Jump. A Vertec device (Jumpusa, Sunnyvale, CA) was used to measure the height of the CMVJs to the nearest 1.27 cm. To prepare the Vertec, the participants stood under it with their feet together and heels on the ground and reached with their dominant arm to measure their standing reach. The participants were instructed to use a countermovement jump with no extra steps. The participants were allowed to swing their arms and were instructed to jump as high as possible and reach for the vanes. To begin the test, the participants stood in an upright standing position. When ready, they flexed at the ankles, knees, and hips to make a preliminary downward movement to a self-selected depth, then extended their ankles, knees, and hips to jump vertically. At the top of their jump, the participants hit the vanes. Their vertical jump was measured as the difference between the highest vane hit on their jump and their standing reach. Participants completed 3 jumps, and the best jump was used for analysis.

Standing Long Jump. For the SLJ, the participants started in a standing position with their toes behind a line taped on the gym floor. They were allowed to swing their arms and were instructed to jump as far as possible. When ready, the participants flexed at the ankles, knees, and hips to make a preliminary downward movement to a self-selected depth, then extended their ankles, knees, and hips to jump forward. Their SLJ was measured with a measuring tape as the distance from the starting line to the heel closest to the takeoff line on landing. Participants completed 3 jumps, and the best jump was used for analysis.

Lateral Hop. The participants started the LH in a standing position with the medial border of their shoe on their stance leg behind a line taped on the gym floor. When ready, they raised 1 leg off of the ground and flexed at the ankles, knees, and hips on their stance leg to make a preliminary downward movement. They then extended their ankles, knees, and hips to hop medially in the frontal plane (to hop to the participant's left, she hopped off of and landed on her right foot). Participants landed on the same leg to reduce the effects of leg length on the distance measurements. The distance of the LH was measured with a measuring tape to the nearest millimeter from the medial border of the participant's shoe at takeoff to the lateral border of the shoe at landing. The participants completed 3 trials on their right foot and 3 trials on their left foot. The best performance for each foot was used for analysis.

Lateral Shuffle Test. The LST was chosen as the test of CODS because it appeared to be similar to the movements used by basketball players to play defense and because other tests of CODS had been shown to have a stronger relationship with straight-ahead speed than another test of CODS.[16] The LST was devised because there was no single Edgren side-step test.[17] Based on a previous study, an 8-foot distance and 6-second time frame were used.[17]

The test was marked with white athletic tape on the hardwood floor. A distance of 8 feet was marked with lines every 2 feet. A participant's score was the number of lines crossed during the duration of the test. A video camera (Flip Mino HD, Cisco Systems, Irvine, CA) was used to capture the trials, and the scores were counted and confirmed via video analysis. The time started on the participants' first visible movement. The participants started in an upright standing position straddling the center line. On the researcher's verbal signal, they shuffled from side to side continuously for 6 seconds. The subjects were instructed not to cross their feet during the duration of the test. The outside leg had to cross the outside line before changing directions. Each participant completed 1 test trial starting with her left foot (LH-L) as her push-off foot and one with her right foot (LH-R) as her push-off foot.

Training Intervention

The intervention was based on previous training protocols.[7,9,15] The first 3 weeks were considered a preparatory or foundational phase and focused on proper landing mechanics and deceleration.[7,11] The preparatory phase was important for the safety, health, and learning of the participants. The final 3 weeks emphasized short ground-contact times and moved from low- to high-intensity plyometrics.[11] The total volume of each session matched the volume used in a previous study of FPP and SPP, although the number of repetitions per set was reduced to 6 to focus more on power rather than endurance.[18] The FPP and SPP exercises were matched for bilateral and unilateral exercises to eliminate the effect of the execution of the exercise (Table 2).

The participants were instructed in the proper execution of the exercises during the first session of week 1. They trained twice per week with at least 1 day between sessions. They performed a standardized dynamic warm-up before the training intervention on each day. Training occurred shortly after the end of the basketball season during their off-season conditioning program.

Statistical Analyses

Data were analyzed with SPSS version 20. All data were screened and tested for the statistical assumptions. A 1-way ANOVA was used to test for significant differences between the FPP and SPP groups at preintervention due to the dropout rate. Multiple 2 × 2 repeated-measures ANOVAs were used to test for differences between CMVJ, SLJ, LH, and LST at the pretest and posttest for the FPP and SPP groups. Statistical significance was set at $P < .05$.

Results

The means, standard deviations, and percentage changes for the FPP and SPP groups at preintervention and postintervention for the CMVJ, SLJ, LH, and LST are shown in Table 3. There were no significant differences between the FPP and SPP groups for any of the personal characteristics or for the tests at preintervention.

There was a main effect for time for all 6 tests. Table 4 shows the F value, significance, and effect sizes for the main effect of time and the group × time interaction effect for the 6 tests. There

Table 2 Training Protocol for the Frontal- and Sagittal-Plane Groups During the Duration of the Study

Week	Sagittal plane	Frontal plane	Sets	Repetitions
1–3	Ankle jumps	Side-to-side ankle jumps	4	6
	Squat jumps and stick	Lateral jump and stick	4	6
	Single-leg hop and stick	Ice skater drill	4	6
	Broad jump and stick	Lateral hop and stick	4	6
4–6	Squat jump (rhythmical)	Side-to-side jumps	4	6
	Single-leg hop (continuous)	Lateral hop (continuous)	4	6
	Broad jump (continuous)	Lateral jump and bounce (continuous)	4	6
	Split squat jump	Ice skater drill (continuous)	4	6
	Tuck jumps	Zigzag tuck jumps	4	6

Note: Rest during weeks 1–3 were 15 s between exercises, 60 s between sets. Rest during weeks 4–6 were 30 s between exercises, 90 s between sets.

Table 3 Preintervention and Postintervention Means and SD for Frontal-Plane (FP) and Sagittal-Plane (SP) Groups, both n = 7

		Preintervention		Postintervention		
Test	Group	Mean	SD	Mean	SD	% change between pretest and posttest
Countermovement vertical jump (cm)	FP	48.26	5.39	50.07	5.33	3.8
	SP	47.72	7.07	52.61	9.36	10.3
Standing long jump (cm)	FP	176.89	18.47	187.05	14.19	6.0
	SP	177.89	30.07	191.95	29.06	7.9
Right lateral hop (cm)	FP	141.06	7.47	154.94	13.03	9.8
	SP	135.89	22.36	143.87	25.34	5.9
Left lateral hop (cm)	FP	137.16	12.97	153.49	6.02	11.9
	SP	140.06	25.81	142.60	32.33	1.8
Right lateral-shuffle test	FP	23.00	2.31	24.57	1.90	6.8
	SP	23.86	3.13	24.57	2.99	3.0
Left lateral-shuffle test	FP	22.71	2.22	24.71	2.36	8.8
	SP	24.00	3.06	24.14	2.55	0.6

Table 4 *F* Values for the Main Effect of Time and Interaction Effect of Time × Group for the 6 Tests

	Time			Time × Group		
Test	*F* ratio	*P*	Partial eta-squared	*F* ratio	*P*	Partial eta-squared
Countermovement vertical jump	32.086	<.0001*	.728	6.773	.023*	.361
Standing long jump	81.377	<.0001*	.871	2.112	.172	.150
Right lateral hop	41.677	<.0001*	.776	3.031	.107	.202
Left lateral hop	11.267	.006*	.484	6.017	.030*	.334
Right lateral-shuffle test	16.696	.002*	.582	2.348	.151	.164
Left lateral-shuffle test	8.437	.013*	.413	6.337	.027*	.346

*$P < .05$.

was a significant group × time interaction effect for 3 of the 6 tests. The SPP improved performance in the CMVJ more than the FPP, whereas the FPP improved performance in the LH-L and LST-L more than the SPP. Three tests did not show a statistically significant interaction effect.

Discussion

Based on the results from this study of female high school basketball players, it may be concluded that plyometric training is an effective modality to improve power and CODS performance. The FPP and SPP groups improved from preintervention to postintervention in the CMVJ, SLJ, LH, and LST. The trends of the results supported the hypotheses. The FPP training group compared with the SPP training group showed a significant improvement in the LST-L and a greater, though nonsignificant, improvement in the LST-R. The SPP group showed a significant improvement compared with the FPP group in the CMVJ and a greater, though nonsignificant, improvement in the SLJ, and the FPP group showed a significant improvement compared with the SPP group in the LH-L and a greater, though nonsignificant, improvement in the LH-R.

Plyometric training has been used to improve CODS, and the results support its use. The SPP group was found to have made improvements in CODS similar to those in previous studies of plyometric training, whereas the improvements of 8.81% (L) and 6.83% (R) in the LST made by the FPP group surpassed those found in previous studies.[9,10,19] Previous studies that demonstrated the greatest improvements in CODS used multidirectional jumps[10] or incorporated CODS training.[19] The similarity of the SPP group to other studies, and the larger improvements demonstrated by multidirectional training, suggested that the distinctiveness of the FPP training, and not the choice of the test, explained the greater improvement. The improvements of 6.8% and 8.8% fall near and within the proposed 7% to 13% range for practical improvements,[20] and the practical improvements supported the suggestion that FPP would increase lateral explosiveness.[7]

The specificity between training of the FPP group and the CODS test may explain the greater practical improvements by the FPP group and other multidirectional training interventions. Previous studies have suggested that the complexity of CODS tasks has limited the improvement of plyometric training in CODS tasks and caused smaller improvements than those found by the FPP group.[20]

The FPP group's improvement suggests that the specificity of the training, and not the complexity of the CODS tasks, affects the amount of improvement. It has been suggested that 6 weeks of plyometric training improved CODS performance due to motor recruitment or neural adaptations[7,10] and motor control rather than strength or power.[21] Whereas the measures of power improved, the FPP exercises compared with the SPP exercises may have facilitated greater motor control in these frontal-plane movements despite the absence of the LST in the training programs. To change directions, the athlete must create the correct angle of force opposite the direction of the desired movement. The FPP exercises may have facilitated learning of these movements and positions. The FPP exercises may have increased neuromuscular efficiency for the CODS because of the plane of movement and the angle of the lower limbs.

Whereas the trends and practical significance aligned with the hypotheses, the differences between the right and left legs were unexpected. One potential explanation is the body's asymmetry. Novice tennis players were found to have a significant difference in lateral speed between the 2 sides.[19] It has been suggested that leg asymmetry of 10% to 15% is typical and acceptable in noninjured populations.[22–24] Previous studies have found a significant difference in the unilateral vertical jump between dominant and nondominant legs[22] and a difference between dominant and nondominant legs, but not right and left legs, in a 5-hop test.[25] Whereas the dominant leg was not identified in this study, the differences between right and left legs could suggest an effect of leg dominance or normal asymmetry. The differences in improvement between the right and left legs during the 6-week intervention may have been the body's attempt to balance the asymmetry between the dominant and nondominant legs for the task.

The FPP and SPP training groups showed practical improvements, supporting the hypotheses in the CMVJ, LH, and LST, but the SLJ showed similar improvements in each group. A horizontal jump and a lateral jump have been shown to have a correlation similar (r = .605) to that of a horizontal jump and a vertical jump (r = .659) in females.[26] The results of this study align with this relationship between lateral, horizontal, and vertical jumps. The VJ test has been used as the primary measure of leg power,[27] and playing time in college basketball has been shown to have a strong relationship with VJ height.[28] However, a more recent study of male college basketball players found the SLJ to correlate with minutes (r = .67), rebounds (r = .63), and blocks (r = .55) per game, whereas there were no significant correlations between the CMVJ and any game performance variables.[29] Because the lateral shuffling movements used in this study have been shown to account for as much as 41% of the time in a basketball game,[3] a small improvement (0.58–2.98%) by the SPP group in the LST may question the efficacy of SPP training programs that measure success solely with a VJ test. The FPP group's practical improvement in the LST suggests the importance of FPP exercises in a basketball training program.

The primary limitation of this study was the low number of participants. In an effort to use female high school basketball players rather than the general population, the study was compromised by factors outside the control of the researchers, such as participants quitting their team midstudy, deciding to play another sport, injuring themselves in a spring league game, or lacking transportation. Based on the results, a subsequent study could identify dominant and nondominant legs as opposed to relying on right and left legs. Finally, because the LH was a unilateral test, it may have been better to test the CMVJ and SLJ unilaterally as opposed to bilaterally.

Practical Applications

The practical application of this study is that basketball coaches should use multidirection plyometric training rather than training in only 1 plane. Multidirection plyometric training programs have been shown to improve VJ[9] and CODS.[10] In addition, a combination of different plyometrics as compared with 1 type has been recommended to improve VJ height.[30] SPP clearly elicits greater improvements in the VJ, but FPP has a greater effect on CODS. The multidirectional nature of basketball[3] coupled with the principle of specificity[12] suggests that a training program focused on multidirection movements and not just VJ performance may enhance on-court performance. Furthermore, because the SLJ has been shown to have a relationship with performance variables from basketball games, and due to the FPP and SPP groups' showing improvements in the SLJ, the SLJ rather than the CMVJ may be the best test to use as a primary measure of lower-body power.

Conclusions

Plyometrics training is an effective modality to improve power and CODS performance, and basketball coaches should use multidirection plyometric training rather than training in only 1 plane.

References

1. Reilly T, Williams AM, Nevill A, Franks A. A multidisciplinary approach to talent identification in soccer. *J Sports Sci*. 2000;18:695–702. PubMed doi:10.1080/02640410050120078
2. Serpell BG, Young WB, Ford M. Are the perceptual and decision-making components of agility trainable?: a preliminary investigation. *J Strength Cond Res*. 2011;25:1240–1248. PubMed doi:10.1519/JSC.0b013e3181d682e6
3. Ben Abdelkrim N, El Fazaa S, El Ati J. Time–motion analysis and physiological data of elite under-19-year-old basketball players during competition. *Br J Sports Med*. 2007;41(2):69–75. PubMed doi:10.1136/bjsm.2006.032318
4. McInnes SE, Carlson JS, Jones CJ, McKenna MJ. The physiological load imposed on basketball players during competition. *J Sports Sci*. 1995;13:387–397. PubMed doi:10.1080/02640419508732254
5. Simenz CJ, Dugan CA, Ebben WP. Strength and conditioning practices of National Basketball Association strength and conditioning coaches. *J Strength Cond Res*. 2005;19:495–504. PubMed
6. Fulton KT. Off-season strength training for basketball. *Strength Cond J*. 1992;14:31–34. doi:10.1519/0744-0049(1992)014<0031:OSSTFB>2.3.CO;2
7. King JA, Cipriani DJ. Comparing pre-season frontal and sagittal plane plyometric programs on vertical jump height in high-school basketball players. *J Strength Cond Res*. 2010;24:2109–2114. PubMed doi:10.1519/JSC.0b013e3181e347d1
8. Wilk KE, Voight ML, Keirns MA, Gambetta V, Andrews JR, Dillman CJ. Stretch-shortening drills for the upper extremities: theory and clinical application. *J Orthop Sports Phys*. 1993;17:225–239. PubMed doi:10.2519/jospt.1993.17.5.225
9. Faigenbaum AD, McFarland JE, Keiper FB, et al. Effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years. *J Sports Sci Med*. 2007;6:519–525. PubMed

10. Miller MG, Herniman JJ, Ricard MD, Cheatham CC, Michael TJ. The effects of a 6-week plyometric training program on agility. *J Sports Sci Med*. 2006;5:459–465. PubMed
11. Flanagan EP, Comyns TM. The use of contact time and the reactive strength index to optimise fast stretch-shortening cycle training. *Strength Cond J*. 2008;30:32–38. doi:10.1519/SSC.0b013e318187e25b
12. Zatsiorsky VM. *Science and Practice of Strength Training*. Champaign, IL: Human Kinetics; 1995.
13. Farlinger CM, Kruisselbrink LD, Fowles JR. Relationships to skating performance in competitive hockey players. *J Strength Cond Res*. 2007;21:915–922. PubMed
14. Stone MH, Stone M, Sands WA. *Principles and Practice of Resistance Training*. Champaign, IL: Human Kinetics; 2007.
15. Santos EJ, Janeira MA. Effects of complex training on explosive strength in adolescent male basketball players. *J Strength Cond Res*. 2008;22:903–909. PubMed doi:10.1519/JSC.0b013e31816a59f2
16. Pauole K, Madole K, Garhammer J, Lacourse M, Rozenek R. Reliability and validity of the T-test as a measure of agility, leg power, and leg speed in college-aged men and women. *J Strength Cond Res*. 2000;14:443–450.
17. McCormick BT. The reliability and validity of lateral side-step tests. *Intl J Appl Sport Sci*. 2014;26:67–75.
18. Lohman W. Principles of beginners' training in jumping events. *Track Tech.* 1985;91:2891–2892.
19. Salonikidis K, Zafeiridis A. The effects of plyometric, tennis drills, and combined training on reaction, lateral and linear speed, power, and strength in novice tennis players. *J Strength Cond Res*. 2008;22:182–191. PubMed doi:10.1519/JSC.0b013e31815f57ad
20. Markovic G, Mikulic P. Neuro-musculoskeletal and performance adaptations to lower extremity plyometric training. *Sports Med*. 2010;40:859–895. PubMed doi:10.2165/11318370-000000000-00000
21. Young WB, James R, Montgomery I. Is muscle power related to running speed with changes of direction? *J Sports Med Phys Fitness*. 2002;42:282–288. PubMed
22. Hoffman JR, Ratamess NA, Klatt M, Faigenbaum AD, Kang J. Do bilateral power deficits influence direction-specific movement patterns? *Res Sports Med.* 2007;15:125–132. PubMed doi:10.1080/15438620701405313
23. McElveen MT, Riemann B, Davies G. Bilateral comparison of propulsion mechanics during single-leg vertical jumping. *J Strength Cond Res*. 2010;24:375–381. PubMed doi:10.1519/JSC.0b013e3181c06e0b
24. Paterno MV, Ford K, Myer G, Heyl R, Hewett T. Limb asymmetries in landing and jumping 2 years following anterior cruciate ligament reconstruction. *Clin J Sport Med*. 2007;17:258–262. PubMed doi:10.1097/JSM.0b013e31804c77ea
25. Newton RU, Gerber A, Nimphius S, et al. Determination of functional strength imbalance of the lower extremities. *J Strength Cond Res*. 2006;20:971–977. PubMed
26. Meylan C, McMaster T, Cronin J, Mohammad NI, Rogers C, de Klerk M. Single-leg lateral, horizontal, and vertical jump assessment: reliability, interrelationships, and ability to predict sprint and change-of-direction performance. *J Strength Cond Res*. 2009;23:1140–1147. PubMed doi:10.1519/JSC.0b013e318190f9c2
27. Patterson DD, Peterson DF. Vertical jump and leg power norms for young adults. *Meas Phys Educ Exerc Sci*. 2004;8:33–41. doi:10.1207/s15327841mpee0801_3
28. Hoffman JR, Tenenbaum G, Maresh CM, Kraemer WJ. Relationship between athletic performance tests and playing time in elite college basketball players. *J Strength Cond Res*. 1996;10:67–71.
29. McGill SM, Andersen JT, Horne AD. Predicting performance and injury resilience from movement quality and fitness scores in a basketball team over 2 years. *J Strength Cond Res*. 2012;26:1731–1739. PubMed doi:10.1519/JSC.0b013e3182576a76
30. de Villarreal ES, Kellis E, Kraemer WJ, Izquierdo M. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. *J Strength Cond Res*. 2009;23(2):495–506. PubMed doi:10.1519/JSC.0b013e318196b7c6