Comparison of Integrated and Isolated Training on Performance Measures and Neuromuscular Control

Lindsay J. DiStefano,[1] Michael J. DiStefano,[2] Barnett S. Frank,[3] Micheal A. Clark,[4] and Darin A. Padua[3]

[1]*Department of Kinesiology, University of Connecticut, Storrs, Connecticut;* [2]*Select Physical Therapy, Storrs, Connecticut;* [3]*Sports Medicine Research Laboratory, Department of Exercise and Sport Science, University of North Carolina, Chapel Hill, North Carolina; and* [4]*National Academy of Sports Medicine, Chandler, Arizona*

Abstract

DiStefano, LJ, DiStefano, MJ, Frank, BS, Clark, MA, and Padua, DA. Comparison of integrated and isolated training on performance measures and neuromuscular control. *J Strength Cond Res* 27(4): 1083–1090, 2013—Traditional weight training programs use an exercise prescription strategy that emphasizes improving muscle strength through resistance exercises. Other factors, such as stability, endurance, movement quality, power, flexibility, speed, and agility are also essential elements to improving overall functional performance. Therefore, exercises that incorporate these additional elements may be beneficial additions to traditional resistance training programs. The purpose of the study was to compare the effects of an isolated resistance training program (ISO) and an integrated training program (INT) on movement quality, vertical jump height, agility, muscle strength and endurance, and flexibility. The ISO program consisted of primarily upper and lower extremity progressive resistance exercises. The INT program involved progressive resistance exercises, and core stability, power, and agility exercises. Thirty subjects were cluster randomized to either the ISO ($n = 15$) or INT ($n = 15$) training program. Each training group performed their respective programs 2 times per week for 8 weeks. The subjects were assessed before (pretest) and after (posttest) the intervention period using the following assessments: a jump-landing task graded using the Landing Error Scoring System (LESS), vertical jump height, *T*-test time, push-up and sit-up performance, and the sit-and-reach test. The INT group performed better on the LESS test (pretest: 3.90 ± 1.02, posttest: 3.03 ± 1.02; $p = 0.02$), faster on the *T*-test (pretest: 10.35 ± 1.20 seconds, posttest: 9.58 ± 1.02 seconds; $p = 0.01$), and completed more sit-ups (pretest: 40.20 ± 15.01, posttest: 46.73 ± 14.03; $p = 0.045$) and push-ups (pretest: 40.67 ± 13.85, posttest: 48.93 ± 15.17; $p = 0.05$) at posttest compared with pretest, and compared with the ISO group at posttest. Both groups performed more push-ups ($p = 0.002$), jumped higher ($p < 0.001$), and reached further ($p = 0.008$) at posttest compared with that at pretest. Performance enhancement programs should use an integrated approach to exercise selection to optimize performance and movement technique benefits.

Key Words performance enhancement, flexibility, movement quality

Introduction

Resistance training is beneficial for improving many factors related to athletic performance, such as muscle strength (3,13), power (5,17), and speed (8,16). Historically, performance enhancement programs have primarily used isolated resistance training exercises for these reasons. Muscle force production is an important aspect of functional performance; however, muscle strength is only one aspect of overall functional performance. Other factors such as stability, endurance, movement quality, power, flexibility, speed, and agility are also essential elements to improving overall functional performance. Resistance training exercises usually target 1 primary muscle in a single plane using both concentric and eccentric muscle contractions. Most sport activities require multiplanar movements using multiple muscles together to dynamically stabilize, accelerate, and decelerate the body. Therefore, traditional isolated resistance training may not be optimal for eliciting gains in the overall functional performance.

Integrated, or functional, training programs have gained popularity in recent years as an alternative method to isolated resistance exercise programs. By definition, integrated training uses multiple modes of exercises, such as resistance, plyometric, balance, and agility exercises. Integrated training also incorporates multiplanar, functional movements of the entire body that mimic sport demands to improve functional strength and

Address correspondence to Dr. Lindsay J. DiStefano, lindsay.distefano@uconn.edu.

27(4)/1083–1090

Journal of Strength and Conditioning Research
© 2013 National Strength and Conditioning Association

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

TABLE 1. Subject demographics.*

Group	Sample size	Age (y)	Height (cm)	Mass (kg)
INT	13 Men, 2 women	19 ± 2	176 ± 9	77 ± 20
ISO	12 Men, 3 women	19 ± 1	178 ± 8	77 ± 21

*INT = integrated training program; ISO = isolated resistance training program.

neuromuscular efficiency. Integrated training programs have been shown to improve lower extremity muscle strength (11,12,24), power, and vertical jump height (18).

Although both isolated resistance and integrated training programs have been shown to be effective with improving strength, power, and sport performance measures, there have been few studies that have compared the 2 paradigms. Therefore, the purpose of this study was to compare the effects of an isolated resistance training program and an integrated program on lower extremity movement quality, vertical jump height, agility, muscle strength and endurance, and flexibility.

METHODS

Experimental Approach to the Problem

We used a randomized controlled trial design to compare the effects of the isolated and integrated training programs. The subjects were members of an introductory weight training course and were therefore, cluster randomized by class section to either the isolated (ISO; $n = 15$) or integrated (INT; $n = 15$) program after they completed the first of 2 test sessions (pretest). The ISO program involved progressive single-plane resistance training exercises for the upper and lower extremities. The INT program consisted of resistance training exercises, and stability, plyometric, and agility exercises that were multiplanar and progressive. Both programs were

Figure 1. The Landing Error Scoring System (LESS) jump-landing task.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

completed 2 times per week for 8 weeks in approximately 45 minutes for each session. The subjects were assessed for various performance measures and neuromuscular control before (pretest) and after (posttest) the intervention period.

Subjects

Thirty subjects (25 men, 5 women) volunteered to participate in the study and met the inclusion criteria (Table 1). The subjects were free from any injury or illness that prevented participation in physical activity at the time of testing. Before the pretest, all the subjects read and completed informed consent forms, which were approved by the university's institutional review board.

Testing Procedures

All the subjects completed 2 identical test sessions in a research laboratory 1 week before (pretest) and after (posttest) the 8-week intervention period. During the test sessions, the subjects performed 8 assessments to evaluate their neuromuscular control (jump-landing test) and functional performance on a variety of measures (sit-and-reach test, *t*-test, vertical jump, sit-ups, push-ups) in a randomized order. The tester for all assessments was blinded to group membership and not involved in any of the program implementation. All testing occurred on subjects' dominant limbs, which was the limb used to kick a ball for maximal distance.

Movement Control and Quality: Landing Error Scoring System. The subjects performed 3 trials of a standardized jump-landing test, which was videotaped by 2 standard digital video cameras (Sony DCR-HC30, Park Ridge, NJ, USA). One camera was placed directly in front of the subject, whereas the other camera was positioned to the side of the subject to capture both frontal and sagittal plane images. The jump-landing test required subjects to jump forward from a 30-cm high box a distance of half their body height, land with both feet in a target area, and jump for maximal vertical height immediately upon landing (Figure 1). The subjects were given verbal instructions, a visual demonstration of the task, and as many practice trials as needed until they reported they were comfortable with the task. The trials were repeated if the subjects jumped vertically from the box, if they did not land with both feet in the target area, or if they failed to jump for maximal effort upon landing.

Flexibility: Sit-and-Reach Test. The subjects sat on the floor with their feet shoulder width apart and flat (no shoes) against the measuring device (Sit-and-Reach Box; Novel Products, Inc., Rockton, IL, USA) with their knees maintained in full extension, and head and back against a wall. While keeping their head and back stationary, the subjects stretched their

TABLE 2. Isolated training program.

Week 1	Week 2	Week 3	Week 4
Exercises performed during both training sessions of weeks 1–4			
Power clean (2 × 5, 60%)	Power clean (3 × 5, 60%)	Power clean (3 × 5, 75%)	Power clean (3 × 5, 80%)
Leg press (2 × 10, 60%)	Leg press (3 × 10, 60%)	Leg press (3 × 6, 75%)	Leg press (3 × 6, 80%)
Hamstring curl (2 × 15, 60%)	Hamstring curl (3 × 15, 60%)	Hamstring curl (3 × 10, 75%)	Hamstring curl (3 × 10, 80%)
Bench press (2 × 10, 60%)	Bench press (3 × 10, 60%)	Bench press (3 × 6, 75%)	Bench press (3 × 6, 80%)
Lat pulldown (2 × 15, 60%)	Lat pulldown (2 × 15, 60%)	Lat pulldown (2 × 10, 75%)	Lat pulldown (2 × 10, 80%)
Triceps ext (2 × 15, 60%)	Triceps ext (2 × 15, 60%)	Triceps ext (2 × 10, 75%)	Triceps ext (2 × 10, 80%)
Upright row (2 × 15, 60%)	Upright row (2 × 15, 60%)	Upright row (2 × 10, 75%)	Upright row (2 × 10, 80%)
Ab crunch (2 × 20)	Ab crunch (2 × 20)	Ab crunch (2 × 20)	Ab crunch (2 × 20)
Week 5	**Week 6**	**Week 7**	**Week 8**
Exercises performed during the first training session of weeks 5–8			
Hang snatch (3 × 5, 80%)	Hang snatch (3 × 5, 80%)	Hang snatch (4 × 5, 80%)	Hang snatch (4 × 5, 80%)
Back squat (3 × 10, 75%)	Back squat (4 × 10, 75%)	Back squat (3 × 6, 80%)	Back squat (3 × 6, 80%)
Hamstring curl (3 × 12, 75%)	Hamstring curl (3 × 12, 75%)	Hamstring curl (3 × 8 80%)	Hamstring curl (3 × 8, 80%)
Lunge (3 × 12, 75%)	Lunge (3 × 12, 75%)	Lunge (3 × 8, 80%)	Lunge (3 × 8, 80%)
Calf raise (3 × 12, 75%)	Calf raise (3 × 12, 75%)	Calf raise (3 × 8, 80%)	Calf raise (3 × 8, 80%)
Exercises performed during the second training session of weeks 5–8			
Push jerk (3 × 5, 80%)	Push jerk (3 × 5, 80%)	Push jerk (4 × 5, 80%)	Push jerk (4 × 5, 85%)
Incline bench (3 × 10, 75%)	Incline bench (4 × 10, 75%)	Incline bench (3 × 6, 80%)	Incline bench (3 × 6, 80%)
Bentover row (3 × 12, 75%)	Bentover row (3 × 12, 75%)	Bentover row (3 × 18, 80%)	Bentover row (3 × 8, 80%)
Shoulder press (3 × 12, 75%)	Shoulder press (3 × 12, 75%)	Shoulder press (3 × 6, 85%)	Shoulder press (3 × 6, 85%)
Barbell curl (2 × 12, 75%)	Barbell curl (2 × 12, 75%)	Barbell curl (2 × 6, 80%)	Barbell curl (3 × 8, 80%)
Triceps push (2 × 12, 75%)	Triceps push (2 × 12, 75%)	Triceps push (2 × 8, 80%)	Triceps push (3 × 8, 80%)
Ab crunch (2 × 20)	Ab crunch (2 × 20)	Ab crunch (2 × 20)	Ab crunch (2 × 20)

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

TABLE 3. Integrated training program.

	Week 1	Week 2	Week 3	Week 4
Stability	Opposite arm and leg lift (2 × 15) Hip bridge (2 × 15) Side lying leg lift (2 × 15)	Opposite arm and leg lift (2 × 15) Hip bridge (2 × 15) Side lying leg lift (2 × 15)	Ball crunch with rotation (2 × 10) Ball back extension (2 × 10) Step-up to balance (2 × 10)	Ball crunch with rotation (2 × 10) Ball back extension (2 × 10) Single leg Romanian dead lift (2 × 10)
Reactive	Box jump up with stabilization (2 × 5)	Squat jump with stabilization (2 × 5)	Squat jump (2 × 10)	Side cone hops (2 × 10)
Agility	Speed ladder (×2)	Speed ladder (×2)	Speed ladder (×2)	Speed ladder (×2)
Resistance	Standing cable 2 arm chest press (2 × 20, 60%) Standing cable 2 arm row (2 × 20, 60%) Staggered stance dumbbell 2 arm press (2 × 20, 60%) Standing dumbbell 2 arm bicep curl (2 × 20, 60%) Supine lying dumbbell 2 arm tricep extension (2 × 10, 60%) Side step-up to balance (2 × 20, 60%)	Standing cable alternate arm chest press (2 × 15, 70%) Standing cable alternate arm row (2 × 15, 70%) Staggered stance dumbbell alternate arm press (2 × 15, 70%) Standing dumbbell alternate arm bicep curl (2 × 15, 70%) Supine lying dumbbell alternate arm triceps extension (2 × 15, 70%) Single leg squat (2 × 15, 70%)	Bench dumbbell 2 arm chest press (2 × 10, 75%) Ball push-up (2 × 10, 75%) Seated 2 arm lat pulldown (2 × 10, 75%) Ball dumbbell 2 arm row (2 × 10, 75%) Lunge (2 × 10, 75%) Single leg squat (2 × 10, 75%)	Bench dumbbell alternate arm chest press (3 × 10, 75) Ball push-up (3 × 10, 75%) Seated alternate arm lat pulldown (3 × 10, 75%) Single leg alternate arm dumbbell scaption (3 × 10, 75%) Step-up (3 × 10, 75%) Single leg squat touchdown (3 × 10, 75%)

	Week 5	Week 6	Week 7	Week 8
Stability	Ball crunch with rotation (2 × 10) Ball back extension (2 × 10) Step-up to balance (2 × 10)	Medicine ball lift and chop (2 × 10) Medicine ball rotation (2 × 10) Multiplanar hop to balance (2 × 10)	Medicine ball lift and chop (2 × 10) Medicine ball rotation (2 × 10) Multiplanar hop to balance (2 × 10)	Medicine ball lift and chop (2 × 10) Medicine ball rotation (2 × 10) Multiplanar hop to balance (2 × 10)
Reactive	Squat jump (2 × 10, 75%)	Squat jump (3 × 10, 85%)	Squat jump (3 × 10, 85%)	Squat jump (3 × 10, 85%)
Agility	Speed ladder (×2)	Speed ladder (×2)	Speed ladder (×2)	Speed ladder (×2)
Resistance	Bench dumbbell 1 arm chest press (3 × 10, 75%) Push-up with rotation (3 × 10, 75%) Seated 1 arm lat pulldown (3 × 10, 75%) Ball dumbbell 1 arm row (3 × 10, 75%) Seated dumbbell 1 arm press (3 × 10, 75%) Single leg/opposite 1 arm dumbbell scaption (3 × 10, 75%) Barbell squat (3 × 10, 75%) Single leg Romanian dead lift (3 × 10, 75%)	Incline dumbbell 2 arm chest press (3 × 10, 85%) Rotational medicine ball throw (3 × 10, 85%) Seated 2 arm row (3 × 10, 85%) Medicine ball soccer throw (3 × 10, 85%) Standing dumbbell 2 arm press (3 × 10, 85%) Medicine ball scoop toss (3 × 10, 85%) Barbell squat (3 × 10, 85%)	Incline dumbbell 2 arm chest press (3 × 5, 85%) Rotational medicine ball throw (3 × 10, 85%) Seated cable alternate arm row (3 × 5, 85%) Medicine ball soccer throw (3 × 10, 85%) Standing dumbbell alternate arm press (3 × 5, 85%) Medicine ball scoop toss (3 × 10, 85%) Barbell squat (3 × 5, 85%)	Incline dumbbell 1 arm chest press (3 × 5, 85%) Rotational medicine ball throw (3 × 10, 85%) Seated cable 1 arm row (3 × 5, 85%) Medicine ball soccer throw (3 × 10, 85%) Standing dumbbell 1 arm press (3 × 5, 85%) Medicine ball scoop toss (3 × 10, 85%) Barbell squat (3 × 5, 85%)

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

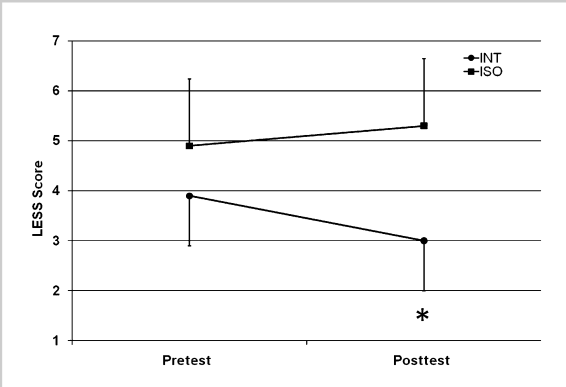

Figure 2. Landing Error Scoring System (LESS) scores between groups and across time points (*significantly lower than INT pretest and ISO posttest, $p < 0.05$). INT = integrated training program; ISO = isolated resistance training program.

arms out toward the box adjusting the sliding ruler so that the zero mark was at their fingertips. They were instructed to reach forward slowly, without bouncing, with their palms down as far as possible keeping the fingertips level with each other and the knees flat against the ground. They held this position for 2 seconds while the distance was recorded. The subjects performed 3 trials of the sit-and-reach test.

Agility: T-test. To complete the *t*-test, the subjects sprinted forward 9.14 m, shuffled 4.57 m to the left while facing forward, shuffled 9.14 m to the right, shuffled 4.57 m to the left, and then ran backward 9.14 m to the original starting line. The subjects completed 3 trials of the *t*-test. A wireless electronic timing device (Sparq XLR8 Digital Timing System, Wausau, WI, USA) measured the time each subject took to complete the *t*-test.

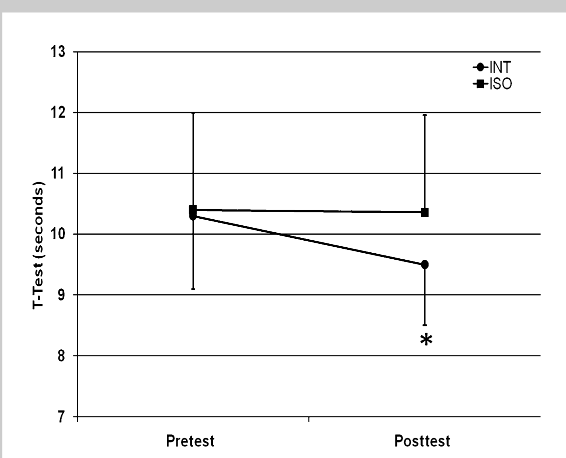

Figure 3. *T*-test results between groups and across time points (*significantly lower than INT pretest and ISO posttest, $p < 0.05$). INT = integrated training program; ISO = isolated resistance training program.

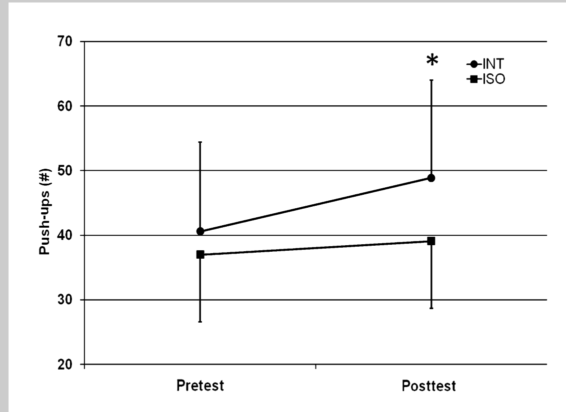

Figure 4. Push-up results between groups and across time points (*significantly higher than INT pretest and ISO posttest, $p < 0.05$). INT = integrated training program; ISO = isolated resistance training program.

Power: Vertical Jump Test. The subjects performed 3 trials of a double-leg, countermovement vertical jump test. They began the test standing with their feet shoulder width apart and were instructed to jump as high as possible to touch an overhead goal (Vertec Jump Training System, Sports Imports, Columbus, OH, USA). The subjects were given practice trials until they verbalized they were comfortable with the task and performed it correctly.

Strength and Endurance: Sit-Up Assessment. For the sit-up assessment, the subjects began by laying supine on the ground with their hands behind their neck, their knees bent 90°, and their feet flat on the floor. A partner anchored their feet to the floor while they performed as many sit-ups as possible in 1 minute. The subjects were required to touch their elbows to their knees and return their shoulders to the floor in order for a repetition to count.

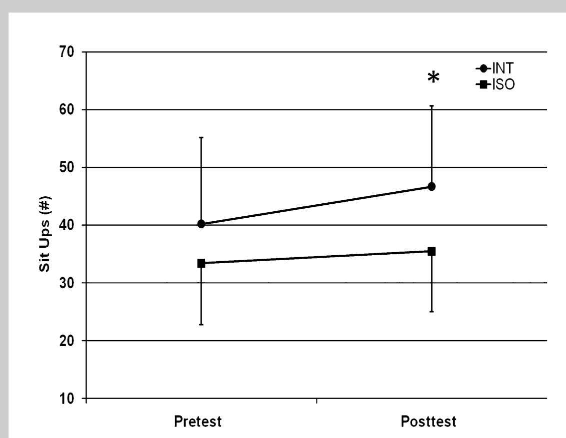

Figure 5. Sit-up results between groups and across time points (*significantly higher than INT pretest and ISO posttest, $p < 0.05$). INT = integrated training program; ISO = isolated resistance training program.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

TABLE 4. Vertical jump and sit-and-reach results.*

Variable	Group	Pretest (95% CI)	Posttest (95% CI)
Vertical jump (cm)†	INT	33.93 (27.22, 40.64)	41.37 (30.30, 42.69)
	ISO	32.33 (25.62, 39.03)	33.52 (27.33, 39.72)
Sit-and-reach test (cm)†	INT	39.37 (34.95, 43.78)	44.65 (40.91, 48.41)
	ISO	47.34 (42.77, 52.19)	48.66 (44.78, 52.55)

*CI = confidence interval; INT = integrated training program; ISO = isolated resistance training program.
†Posttest values greater than pretest values, regardless of group; $p < 0.05$.

Strength and Endurance: Push-Up Assessment. Men began the push-up assessment with their hands and feet on the ground, whereas women performed a modified version of the push-up with their hands and knees on the ground. The subjects were required to lower themselves down until their chest was 3 in. above the ground but without touching their body to the ground. The subjects performed as many push-ups as possible within 1 minute.

Implementation of Intervention Programs

One specific individual who was certified in strength and conditioning or athletic training supervised all training sessions for each group. The subjects and the supervisor were blinded from the other group to avoid any crossover or contamination between groups. Both intervention programs included standardized warm-up and cooldown activities during each training session. The ISO program involved participants first performing a series of standardized warm-up and cooldown exercises before and after the training program, respectively. Specifically, the participants rode a stationary bike for 10 minutes followed by static stretching of the calves, groin, hip flexor, low back, and chest muscle groups. The ISO program began with 5 upper- and lower-body resistance exercises for the first 4 weeks and progressed to 10 exercises for the last 4 weeks. The exercise resistance used in the ISO program also progressed over the 8 weeks. The static stretches were repeated as part of the cooldown after completing the ISO program.

The INT program also involved a standard warm-up and cooldown that was identical to the ISO program. The INT program involved exercises aimed at improving core stability, power, agility, and strength. These exercises were progressed to more demanding exercises over the 8-week training program. The intensity increased by adding more repetitions, resistance, and through exercise modifications. Details of both programs are presented in Tables 2 and 3.

Data Reduction

A single rater who was blinded to group assignment graded the jump-landing test videos using the landing error scoring system (LESS). The LESS is a valid and reliable clinical movement analysis tool used to evaluate specific lower extremity movements during a jump landing (22). The LESS uses a binary system to score obvious movement errors, such as medial knee displacement or limited knee flexion. A higher LESS score indicates a greater number of landing errors and consequently poor technique.

Statistical Analyses

An average value was calculated from the 3 trials of the jump-landing test, vertical jump test, sit-and-reach test, and *T*-test. Separate 2-way (group: ISO, INT; time: pretest, posttest) mixed-model analyses of variance were used to evaluate differences in each dependent variable ($\alpha < 0.05$). A Tukey post hoc test was used to evaluate any significant interaction.

RESULTS

All 30 subjects completed both test sessions and at least 80% of all training sessions (15 sessions). There were no differences between groups in age, height, weight, or any baseline measure. We observed a significant interaction for LESS scores ($p = 0.02$; Figure 2), the *T*-test ($p = 0.01$; Figure 3), sit-ups ($p = 0.045$; Figure 4), and push-ups ($p = 0.05$; Figure 5). Post hoc testing revealed that the INT group performed better on the LESS test (demonstrated lower LESS scores), faster on the *T*-test, and more sit-ups and push-ups at posttest compared with that at pretest, and compared with the ISO group at posttest. Both the INT and ISO groups performed more push-ups ($p = 0.002$), jumped higher ($p < 0.001$), and reached further ($p = 0.008$) at posttest compared with their respective pretest (Table 4).

DISCUSSION

The INT program was able to successfully improve all the aspects of functional performance that were assessed (movement quality, speed and agility, strength, endurance, flexibility, and power). However, the ISO program only improved power and flexibility. The specificity of training principle states that training must stress the systems engaged in performing a particular activity to achieve specific training adaptations (23). This principle provides one explanation for the greater effectiveness of the INT training program. The INT program involved a multicomponent and multiplanar approach while the ISO program only incorporated flexibility and strength and power exercises in a single plane. Therefore, the ISO program demonstrated improvements in the sit-and-reach exercise and the vertical jump, whereas the INT program improved all the performance measures in addition to movement quality. These results suggest that integrated training programs are superior to isolated programs to improve

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

functional performance measures and possibly reduce injury risk by modifying lower extremity movement quality.

Specific movements, such as landing with limited sagittal plane motion and excessive frontal or transverse plane motion throughout the lower extremity, have been shown to increase the risk for injury, such as patellofemoral pain syndrome and anterior cruciate ligament tears (1,2,6,15,25). Injury prevention efforts to change these detrimental movements and reduce injury rates have been successful by incorporating various plyometric, resistance, flexibility, balance, and agility exercises into a training program (7,9). The results of this study support this previous work as the INT program successfully modified lower extremity movement quality, as measured by the LESS. Not only may improved movement quality be beneficial for reducing injury risk but it may also be partially responsible for the observed improvements in functional performance measures by enhancing movement efficiency. The results of this study are novel, because there is limited previous research that has shown simultaneous improvements in movement quality and performance measures (18,20).

Previous studies have demonstrated that the LESS is sensitive to training effects from integrated programs in youth soccer populations (7,21). However, DiStefano et al. (7) showed that baseline movement quality affects the ability to see positive changes as athletes with poor quality achieved the greatest amount of improvement. In this study, the ISO group actually began the intervention period with worse movement quality than the INT group, but the INT group was the only group that improved movement quality. This finding was surprising but emphasizes the benefit of multiplanar and multimodal training to optimize the effects of a training program.

Training volume may also be a critical factor with modifying movement control. The program duration was 10–15 minutes in previous research that failed to improve movement control in individuals who began the program with relatively good movement technique (low LESS score) (7). However, the subjects in the INT program were able to significantly improve their movement technique despite starting the program with a good baseline level. The difference between this study and previous research with integrated programs may be the training volume. The INT program in this study was performed 3 times as long per day (45 minutes) resulting in a greater total volume of training. Therefore, this finding suggests that individuals with good movement quality can become even better with a greater integrated training load.

The current findings support previous work suggesting that integrated programs can improve agility, push-up, and sit-up performance (14,19,20). Although integrated programs have been shown to improve agility measures, this is the second study to demonstrate that isolated training programs using primarily resistance or balance exercises are ineffective (4). The INT program resulted in greater push-up performance compared with that in the ISO program. This finding is surprising because the specificity principle would suggest the ISO program could be as effective or more effective because of the incorporation of the bench press and other exercises that demand strength from similar muscles used during the push-up. We believe the finding that the INT program was more effective than the ISO program emphasizes the influential role of core endurance training that was included in the INT program.

Although the INT program demonstrated superior improvements compared with the ISO program in several measures, the programs elicited similar changes in flexibility and lower extremity power. Both programs involved flexibility and resistance training exercises, which have both been shown to be important for improving sit-and-reach performance (26). A recent systematic review with meta-analyses on resistance training in adolescents found that the volume of plyometric training exercises is a critical component for improving vertical jump performance (10). Although the INT program incorporated a plyometric exercise, this 1 exercise may not be sufficient to cause greater changes than resistance training alone. In addition, given the 8-week intervention period, the INT program did not progress to true reactive type training. Power training may be more effective and safer to introduce after individuals have completed an initial training period. These results do support that resistance training can improve vertical jump performance, but this improvement may be optimized by adding more plyometric training over time.

Practical Applications

Integrated training programs that incorporate agility, flexibility, balance, plyometric and resistance exercises in a multiplanar fashion appear to be more optimal than isolated resistance training alone with improving functional performance measures. In addition, integrated programs improve movement quality, which may make individuals more efficient with their movements and reduce lower extremity injury risk. Therefore, health and fitness professionals should consider making weight training programs integrated with balance, core, agility, and plyometric exercises when designing programs for individuals hoping to improve their sport performance and overall health.

Acknowledgments

The authors would like to acknowledge the National Academy of Sports Medicine for their financial support of this project. The results of this study do not constitute endorsement of the product by the authors or the National Strength and Conditioning Association.

References

1. Arms, S, Pope, M, Johnson, R, Fischer, R, Arvidsson, I, and Eriksson, E. The biomechanics of anterior cruciate ligament rehabilitation and reconstruction. *Am J Sports Med* 12: 8–18, 1984.
2. Boden, BP, Dean, GS, Feagin, JA, and Garrett, WE. Mechanisms of anterior cruciate ligament injury. *Orthopedics* 23: 573–578, 2000.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

3. Bruhn, S, Kullmann, N, and Gollhofer, A. Combinatory effects of high-intensity-strength training and sensorimotor training on muscle strength. *Int J Sports Med* 27: 401–406, 2006.

4. Cressey, EM, West, CA, Tiberio, DP, Kraemer, WJ, and Maresh, CM. The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. *J Strength Cond Res* 21: 561–567, 2007.

5. Cronin, J, McNair, PJ, and Marshall, RN. Developing explosive power: A comparison of technique and training. *J Sci Med Sport* 4: 59–70, 2001.

6. Devita, P and Skelly, WA. Effect of landing stiffness on joint kinetics and energetics in the lower extremity. *Med Sci Sport Exerc* 24: 108–115, 1992.

7. DiStefano, LJ, Padua, DA, DiStefano, MJ, and Marshall, SW. Influence of age, sex, technique, and exercise program on movement patterns after an anterior cruciate ligament injury prevention program in youth soccer players. *Am J Sports Med* 37: 495–505, 2009.

8. Dodd, DJ and Alvar, BA. Analysis of acute explosive training modalities to improve lower-body power in baseball players. *J Strength Cond Res* 21: 1177–1182, 2007.

9. Gilchrist, J, Mandelbaum, BR, Melancon, H, Ryan, GW, Silvers, HJ, Griffin, LY, Watanabe, DS, Dick, RW, and Dvorak, J. A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. *Am J Sports Med* 36: 1476–1483, 2008.

10. Harries, SK, Lubans, DR, and Callister, R. Resistance training to improve power and sports performance in adolescent athletes: A systematic review and meta-analysis. *J Sci Med Sport* 15: 532–540, 2012.

11. Hoffman, JR, Ratamess, NA, Cooper, JJ, Kang, J, Chilakos, A, and Faigenbaum, AD. Comparison of loaded and unloaded jump squat training on strength/power performance in college football players. *J Strength Cond Res* 19: 810–815, 2005.

12. Judge, LW, Moreau, C, and Burke, JR. Neural adaptations with sport-specific resistance training in highly skilled athletes. *J Sports Sci* 21: 419–427, 2003.

13. Kotzamanidis, C, Chatzopoulos, D, Michailidis, C, Papaiakovou, G, and Patikas, D. The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players. *J Strength Cond Res* 19: 369–375, 2005.

14. Kraemer, WJ, Vescovi, JD, Volek, JS, Nindl, BC, Newton, RU, Patton, JF, Dziados, JE, French, DN, and Hakkinen, K. Effects of concurrent resistance and aerobic training on load-bearing performance and the Army physical fitness test. *Mil Med* 169: 994–999, 2004.

15. Markolf, K, Burchfield, D, Shapiro, M, Shepard, M, Finerman, G, and Slauterbeck, J. Combined knee loading states that generate high anterior cruciate ligament forces. *J Orthop Res* 13: 930–935, 1995.

16. Marques, MC and Gonzalez-Badillo, JJ. In-season resistance training and detraining in professional team handball players. *J Strength Cond Res* 20: 563–571, 2006.

17. McCurdy, KW, Langford, GA, Doscher, MW, Wiley, LP, and Mallard, KG. The effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. *J Strength Cond Res* 19: 9–15, 2005.

18. Myer, GD, Ford, KR, Palumbo, JP, and Hewett, TE. Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. *J Strength Cond Res* 19: 51–60, 2005.

19. Myrick, S. Injury prevention and performance enhancement: A training program for basketball. *Conn Med* 71: 5–8, 2007.

20. Noyes, FR, Barber-Westin, SD, Smith, ST, and Campbell, T. A training program to improve neuromuscular and performance indices in female high school soccer players. *J strength Cond Res* In press.

21. Padua, D, DiStefano, L, Marshall, S, Beutler, A, de la Motte, S, and DiStefano, M. Retention of movement pattern changes following a lower extremity injury prevention program is affected by program duration. *Am J Sports Med* 40: 300–306, 2012.

22. Padua, DA, Marshall, SW, Boling, MC, Thigpen, CA, Garrett, WE Jr, and Beutler, AI. The Landing Error Scoring System (LESS) is a valid and reliable clinical assessment tool of jump-landing biomechanics: The JUMP-ACL study. *Am J Sports Med* 37: 1996–2002, 2009.

23. Reilly, T, Morris, T, and Whyte, G. The specificity of training prescription and physiological assessment: A review. *J Sports Sci* 27: 575–589, 2009.

24. Rhea, MR, Peterson, MD, Oliverson, JR, Ayllon, FN, and Potenziano, BJ. An examination of training on the VertiMax resisted jumping device for improvements in lower body power in highly trained college athletes. *J Strength Cond Res* 22: 735–740, 2008.

25. Shelburne, KB and Pandy, MG. Determinants of cruciate-ligament loading during rehabilitation exercise. *Clin Biomech* 13: 403–413, 1998.

26. Simao, R, Lemos, A, Salles, B, Leite, T, Oliveira, E, Rhea, M, and Reis, VM. The influence of strength, flexibility, and simultaneous training on flexibility and strength gains. *J Strength Cond Res* 25: 1333–1338, 2011.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.