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Effects of Three Modified Plyometric Depth Jumps and Periodized Weight Training on Lower Extremity Power

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Abstract

Plyometric exercises increase muscular power and are most effective when designed to complement the specific movements required of the athletic activity. This study compared the effects of modified depth jump plyometric exercises versus a periodized weight training program on the following functional tests: one-legged vertical jump, two-legged vertical jump, 30-meter sprint, standing broad jump, and 1 RM of the seated single leg press. Sixty-four untrained participants (18-28yr) were randomly assigned to one of the following groups: hip depth jump group(n = 12), knee depth jump group (n = 13), ankle depth jump group (n = 13), weight training group (n = 13), or a control group (n = 13). Experimental groups trained two days a week for 12 weeks. Statistically significant improvements were observed among the plyometric groups for functional tests of power and the weight training group for functional tests of strength and speed. Results indicate that modified plyometric depth jumps offer a greater degree of specificity related to power training in athletes.

Keywords: Hip depth jump, knee depth jump, ankle depth jump, muscle power, resistance training, plyometrics

Introduction

Functional tests usually contain a series of movements that have high correlations with athletic activity and are used for research, evaluation, and rehabilitation purposes. Biomechanical analyses of functional tests can reveal percent joint contributions to the activity. The term "plyometrics" refers to specific exercises which encompass a rapid stretching of muscle that is undergoing eccentric stress followed by a concentric, rapid contraction of that muscle for the purpose of developing a forceful movement over a short period of time. One particular plyometric activity, the depth jump, has been shown to improve power in the vertical jump. Depth jumps are a type of dynamic exercise where an individual steps off a box 20 to 80 centimeters in height, lands, and performs an explosive vertical jump. The depth jump is thought to enhance vertical jump performance through the quickening of the amortization phase, which is the electromechanical delay from the initiation of eccentric to the initiation of concentric muscle actions of the movement.

Plyometric depth jumps have been modified to generate greater stresses at the joints of the hip, knee, and ankle (Holcomb, Lander, Rutland, & Wilson, 2006). These variations were identified as the hip depth jump (HDJ), knee depth jump (KDJ), and ankle depth jump (ADJ). Each variation included modifications to the range of motion of the joint being emphasized during the eccentric portion of the depth jump. The HDJ, KDJ, and ADJ are thought to increase the workload, and thus power, at the particular joint for which they are named. The need for such a modification stemmed from biomechanical analysis of both the vertical and depth jumps. In biomechanical analysis of the vertical jump, the hip was found to contribute 23-39% of the total work done during the vertical jump (Bobbert, Huijing, & Van Ingen Schenaue, 2007; Bobbert, MacKay, Schinkelshoek, Huijing, & Van Ingen Schenaue, 2009; Hubley & Wells, 2008; Van Soest, Roebroeck, Bobbert, Huijing, & Van Ingen Schenaue, 2007. However, two analyses of the depth jump revealed the hip contribution to be only 19% and 13% respectively (Bobbert et al., 2007). Consequently, the traditional plyometric depth jump does not stress the hip joint to the extent that it is used during the vertical jump, the functional task it was originally designed to enhance.

Biomechanical analysis of the modified plyometric depth jumps was also performed to analyze joint contribution through total work done at each joint (Holcomb et al., 2006). Total work at the hip, knee, and ankle joints was 80%, 5%, and 15%, respectively, during the HDJ. Analysis of the KDJ revealed contributions of 37% at the hip joint, 49% at the knee joint, and 14% at the ankle joint. The joint contributions during the ADJ were reported to be 24%, 20%, and 56% at the hip, knee, and ankle joints, respectively. Therefore, each depth jump primarily stressed the particular joint for which it was named.

The effectiveness of training programs is routinely measured via functional test performance. Contains the percent joint contributions of modified plyometric depth jumps and selected functional tests for this study. Although specific joint contributions have not been calculated for the 30-meter sprint or seated single leg press, some research has examined the power output of these functional tests. Researchers have identified the hip to be a dominant force producer in sprints of short duration examined the electromyographic activity of the quadriceps and hamstring muscles during a two-legged seated leg press and found a high degree of quadriceps activity, suggesting significant power contributions from the knee joint. When compared to the squat, the seated leg press allows for smaller compressive forces to the tibiofemoral joint, making the activity an ideal accommodation for untrained participants.

Table 1

PERCENT JOINT POWER CONTRIBUTION OF MODIFIED PLYOMETRIC DEPTH JUMPS AND FUNCTIONAL TESTS

	Hip Joint	Knee Joint	Ankle Joint
Hip depth jump (22)	80	5	15
Knee depth jump (22)	37	49	15
Ankle depth jump (22)	24	20	56
30-m sprint	N/A	N/A	N/A
One-legged VJ (39)	34.4	23.9	41.7
Two-legged VJ (25)	28	49	23
Two-legged VJ (39)	32.9	37.7	29.4
Two-legged VJ (35)	40	24.2	35.8

	Hip Joint	Knee Joint	Ankle Joint
Two-legged VJ (22)	57	23	20
Standing broad jump (35)	45.9	3.9	50.2
Seated single leg press	N/A	N/A	N/A

Holcomb Lander, Rutland, and Wilson (2006) continued their research with a progressive resistance eight week training study comparing the modified plyometric depth jumps to other methods that have shown to significantly increase vertical jump height, including conventional plyometric depth jumps. The researchers chose to combine all three of the modified depth jumps into the training schedule of one group (Mod. Plyo) and compared that group to a traditional depth jump group (Plyo), a countermovement jump group (CMJ), a weight training group (WT), and a control group (CON). The weight training group performed four lower extremity exercises with progressive resistance including standing plantar flexion, knee extension, knee flexion, and leg press, while the control group did not train. The 51 college age male participants in the study trained three times per week for eight weeks. The exercise volume was controlled so that each group performed an identical number of repetitions, whether it involved lifting weights or jumping.

The results showed non-significant improvement for all groups during the static jump. All training groups improved performance in the countermovement jump (CMJ improved 4.0%; WT improved 4.7%; Plyo improved 6.5%; Mod. Plyo improved 4.5%), but the CON group performance decreased 3.2%. The traditional plyometric group differed significantly from the control group (9.7% difference). Plyo group was attributed to a possible negative impact on the learning of the proper technique required for a successful jump due to altered range of motion of the plyometric depth jumps. We suggested that future research incorporate a longer period of training to assure a higher training effect.

Weight training has been shown to enhance power primarily through gains in peak force of the muscle rather than rate of force development. Plyometric training of the lower extremity has been demonstrated to promote power primarily through increased rate of force development rather than increased peak force of the muscle. A positive relationship has been established between plyometric training and improvement in several functional tests of the lower extremity in addition to the vertical jump. However, recent developments in modified plyometric depth jumps show promise of increased specificity for power training of the lower extremity (Holcomb et al., 2006). According to the principle of specificity, one should expect that a training program designed to stress the specific physiological systems required for the output activity would result in optimal performance. Holcomb et al. (2006) grouped all of the modified plyometric depth jumps into one training program, which eliminated the possibility to determine the specific effects of each modified plyometric depth jump. Therefore, the purpose of this research was to assess the effects of three types of plyometric depth jumps and weight training on the (a) one-legged vertical jump with a countermovement, (b) two-legged vertical jump with a countermovement, (c) 30-meter sprint, (d) standing broad jump with a countermovement, and (e) 1 RM of the seated single leg press following a 12-week training program. The separation of the three modified plyometric depth jumps into distinct groups along with the addition of other functional tests for the lower extremity should show the increased training specificity of the modified plyometric depth jumps.

Methods

Participants

Sixty-four recreationally active S.B.V.D. Aided junior college, Pullampet, students volunteered for this study (Table 2). The participants did not perform either plyometric or weight training of their lower extremity for a period of at least six months prior to the study. After approval by the University's IRB, all participants signed an informed consent.

Table 2

DESCRIPTIVE GROUP DATA

	HDJ[a]	**KDJ[a]**	**ADJ[a]**	**WT[a]**	**CON[a]**
Number	12	13	13	13	13
Sex[b]	M=9; F=3	M=11; F=2	M=8; F=5	M=7; F=6	M=9; F=4
Height (cm)	174.8 ± 8.3	177.0 ± 7.5	176.8 ± 9.7	175.3 ± 11.7	173.6 ± 11.4
Mass (kg)	70.6 ± 13.5	75.8 ± 14.3	72.8 ± 12.4	69.6 ± 15.5	76.4 ± 17.9
Age (yr)	22.3 ± 2.6	20.8 ± 1.6	20.8 ± 1.3	21.0 ± 2.4	22.0 ± 1.7

HDJ = hip depth jump, KDJ = knee depth jump, ADJ = ankle depth jump, WT = weight training, CON = control;

M = male, F = female

Participants were randomly assigned to one of five groups: hip depth jump, knee depth jump, ankle depth jump, weight training, or a control group that did not train.

Depth Jump Protocol

Three plyometric depth jump groups performed only the specific exercise for which their group was named. The exercises were performed as described by Holcomb et al. (2006). For the hip depth jump, the subject began to flex the trunk during the fall from the box so that the trunk was flexed to 45° upon landing and continued to flex the trunk until the trunk was parallel to the ground. In the knee depth jump, the subject landed fairly erect, and flexed to beyond 90° at the knee, all while keeping the trunk erect. During the ankle depth jump, the subject remained as erect as possible when landing except for slight flexion at the knee. For all three jump groups, the participants jumped vertically with maximum effort as quickly as possible after landing.

All three depth jump groups performed an identical training protocol that included seven sets of 12 repetitions, which resulted in a total of 2016 repetitions for the 24 training sessions. Each jump set was followed by a period of rest from three to four minutes. Training intensity, defined as initial height of the depth jump, began with a 15.24 cm (six inch) drop height and progressed an additional 15.24 cm every three weeks, ending with a 60.96 cm (24 inch) drop height. The modified plyometric training groups were monitored by a researcher for correct jump form to ensure proper joint stress.

Weight Training Protocol

The weight training group's exercises included the seated single leg press, standing calf raise, and knee extension and flexion for each leg. The weight training program was designed to first develop muscle strength with progression to workouts that emphasized muscle power. This periodized approach consisted of four phases with each phase lasting three weeks. The first phase involved three sets of ten repetitions of the subject's ten repetition maximum for each exercise. The second phase included three sets of eight repetitions of the subject's eight repetition maximum for each exercise. The third phase involved three sets of six repetitions of the subject's six repetition maximum for each exercise. Finally, the fourth phase included three sets of four repetitions of the subject's four repetition maximum for each exercise. The subject's one repetition maximum for each exercise was measured prior to each phase, and a chart that estimates weight for designated multiple repetitions based on the one repetition maximum was used as a guide for training weight selection (Fleck & Kraemer, 2007). The weight training group completed a total of 2016 repetitions at the conclusion of the 24 workout sessions. The weight training protocol was more periodized than that of the modified plyometric depth jump groups because both repetitions and intensity were manipulated for the weight training group, whereas only intensity was manipulated for the modified plyometric depth jump groups.

Testing Protocol

Both the two-legged and one-legged vertical jumps were performed with a countermovement, with the subject's dominant leg used for one-legged jumping. Testing procedures included having the subject standing flat-footed and erect facing a marked wall while extending the dominant arm. The highest height at which the fingers touched the wall was recorded. The subject then jumped vertically with maximum effort. The Vertec jump training system (Sports Imports, Inc., Columbus, Ohio) was used for data collection, and the best of three trials was recorded. The total vertical jump score was calculated in centimeters as the standing height score from the marked wall subtracted from the jumping height score of the Vertec. The vertical jump results along with the subject's weight were used as variables in an equation to convert the data into Watts, a true measure of power that allows a fair comparison between participants (Sayers, Harackiewicw, Harman, Frykman, & Rosenstein, 1999). The Sayers formula (Sayers et al., 1999) is as follows: Peak Power (W) = 60.7 × [jump height (cm)] + 45.3 × [body mass (kg)] – 2055.

The standing broad jump was performed by jumping horizontally from a starting line with a countermovement. The participants began in a standing position with both feet firmly positioned on the ground. The participants jumped horizontally with maximum effort landing on both feet, and the distance covered from the heel of the foot closest to the back of the starting line was measured. The best of three trials was recorded in centimeters.

The 30m sprint was performed by running a distance of 30 meters from a stationary position as quickly as possible. The participants began in a crouched sprinter's position without blocks and were timed using a Solo time 450 electronic timing system with a hand pad (Solo Time, Denver, Colorado). The hand pad was placed on the starting line and was contacted by the subject's hand after an acceptable starting position was obtained. The use of this device allowed the subject to begin the sprint at his or her own command by releasing the hand from the hand pad with the initiation of the sprint. When pressure to the hand pad was released, the electronic timing device was activated until the subject crossed an electric beam at the finish line. The participants performed three sprint trials and were allowed three minutes rest between each trial. The best of three trials for the time (seconds) it took the subject to travel 30 meters was recorded.

The dominant and non-dominant leg press was performed using a Paramount leg press machine (Paramount Fitness Equipment Co., Los Angeles, California). The participants were placed in a seated position with approximately 90° of knee flexion and instructed to lift the maximum amount of weight possible using only a single leg against the weight plate. The one repetition maximum mass for the dominant and non-dominant legs was recorded in kilograms along with the subject's seat position data to ensure identical seat position from the pre to post test.

Data Analysis

Paired sample T-tests were used to analyze that the difference between pre and post-test scores. A One-Way Analysis of Variance (ANOVA) was performed on the pre-test scores for all groups on all functional tests. Due to significant differences between groups in pre-test dominant leg press scores, Analysis of Co-variance (ANCOVA) was used for subsequent analysis of functional test data. Significant findings from ANCOVA prompted Bonferroni adjusted independent sample T-tests for post hoc analysis. These T-tests compared the group hypothesized to excel in that particular functional test to the other groups. All tests were performed at the 0.05 alpha level of the significance.

Results

30 Meter Sprint

For the 30m sprint, only the weight training group lowered their times significantly ($t = 2.226$, df = 1, 12; $p = .046$) from pre to post-test, but the group's improvement was not found to be significantly better than any other group ($F = 1.181$, df = 4, 63; $p = .165$).

Leg Press

Significant improvements were noted for the HDJ ($t = -8.130$, df = 1, 11; $p < .001$), KDJ ($t = -8.849$, df = 1, 12; $p < .001$), ADJ ($t = -4.054$, df = 1, 12; $p = .002$), and WT ($t = -9.142$, df = 1, 12; $p < .001$) groups for the dominant leg press. The WT group recorded the most improvement and was found to be statistically greater than the ADJ ($t = 1.917$, df = 1, 12; $p = .035$) and CON ($t = 6.073$, df = 1, 12; $p < .001$) groups.

Similar results were obtained for the non-dominant leg press. Significant improvements were gained by the HDJ ($t = -6.607$, df = 1, 11; $p < .001$), KDJ ($t = -8.973$, df = 1, 12; $p < .001$), ADJ ($t = -4.068$, df = 1, 12; $p = .002$), and WT (-8.652, df = 1, 12; $p < .001$) groups. Even though the WT group improved the most, it was statistically superior to only the CON ($t = 3.959$, df = 1, 12; $p < .001$) group.

Standing Broad Jump

Significant improvements for the HDJ ($t = -2.687$, df = 1, 11; $p = .021$), KDJ ($t = -4.466$, df = 1, 12; $p < .001$), and ADJ ($t = -6.287$, df = 1, 12; $p < .001$) groups were observed for the standing broad jump. The ADJ group recorded the greatest improvement but was not found to be statistically greater than any other group ($F = 1.386$, df = 4, 63; $p = .125$).

Vertical Jump

For the one-legged vertical jump, significant improvements were recorded for the KDJ ($t = -4.335$, df = 1, 12; $p < .001$), ADJ ($t = -2.981$, df = 1, 12; $p = .011$), and CON ($t = -2.920$, df = 1, 12; $p = .013$) groups. Even though the KDJ group improved the greatest, it was not statistically superior to any other group ($F = 1.537$, df = 4, 63; $p = .102$).

In the two-legged vertical jump, the results showed significant improvements for the KDJ ($t = -3.721$, df = 1, 12; $p = .003$), ADJ ($t = -3.865$, df = 1, 12; $p = .002$), and CON ($t = -2.792$, df = 1, 12; $p = .016$)

groups. The ADJ group showed the most improvement and was found to be statistically superior only to the WT (t = 2.380, df = 1, 12; p = .014) group.

Discussion

The influence of the principle of specificity of exercise (Wilmore & Costill, 2004) was evident when examining the results of this study. In general, the modified plyometric depth jump groups excelled in functional tests of power, while the periodized WT group performed better in functional tests of speed and strength. However, not all testing outcomes occurred as expected.

The WT group showed the greatest increases in dominant and non-dominant leg press strength. In regards to the principle of specificity of exercise, this outcome was expected since the WT group incorporated dominant and non-dominant leg press exercises in their training protocol. In addition, significant increases in leg strength were also gained by the HDJ, KDJ, and ADJ groups. Previous plyometric training studies (Adams, 2009; 14, 34) have reported gains in leg strength (12.7 to 23.8%), but not to the magnitude shown by the modified plyometric depth jump groups (29.1 to 48.4%) with this study. Chu (NSCA, 1986) describes plyometric depth jumping as an activity that acts to increase the neuromuscular system's ability to perform concentric contraction more effectively because the forces encountered in plyometric exercises lead to greater synchronous activity of motor units and earlier recruitment of larger motor units via the myotatic reflex. Therefore, the significant increases in leg strength experienced by the modified plyometric depth jump groups may be in response to an enhanced neuromuscular system.

A review of the biomechanical aspects of lower extremity functional tests revealed the contributions of each joint to the performance of a particular functional test. Muscle activation patterns involving EMG analysis of sprint running during its initial phases show maximal power output occurring at the hip joint (Mero & Komi, 2010). Although sprinting primarily measures speed, a short distance was chosen to maximize analysis of acceleration time, thereby increasing the measurement of power. Therefore, those training for power at the hip joint should have a physiological advantage when performing a short sprint. However, only the periodized WT group improved significantly from pre to post-testing. The possible explanations for this finding include the sprinting distance, which may have been too short to emphasize power production, and the use of untrained participants, who may have had low levels of muscle strength before training.

A study concerning the kinetics of broad jumping reported the joint power contributions of the hip, knee, and ankle joints to be 45.9%, 3.9%, and 50.2%, respectively (Robertson & Fleming, 1987). The ADJ group recorded the greatest gains as expected, but the HDJ and KDJ groups also attained significant improvements. Perhaps the general gains in lower extremity power by the modified plyometric depth jump groups enabled significant improvements in broad jumping distances.

Van Soest, Roebroeck, Bobbert, Huijing, and Van Ingen Schenau (2007) reported the joint power contributions of the hip, knee, and ankle joints during the one-legged vertical jump to be 34.4%, 23.9%, and 41.7%, respectively. The greatest gains in the one-legged vertical jump were experienced by the KDJ group, but significant improvements were also recorded for the ADJ and CON groups. The CON group also achieved significance despite showing the lowest percentage of height gain of all groups. The dominance of the KDJ group in this functional test was unexpected due to its reported low involvement in the activity when compared to the other joints of the lower extremity (Van Soest et al., 1985). Perhaps the knee joint is more important to power production during the one-legged vertical jump than previously reported.

Biomechanical analysis of the two-legged vertical jump showed the joint contributions for the hip, knee, and ankle joints to range from 28 to 57%, 23 to 49%, and 20 to 35.8%, respectively. The ADJ group improved the most from pre to post-test, but significant results were also recorded for the KDJ and CON groups. Although the CON group agreed not to undertake any additional training outside of their normal daily activities, perhaps the normal activities of the physical education students selected for the control group influenced their performance on the functional tests. However, this possibility is merely speculation as an exit interview was not conducted due to time constraints.

An equalization of training volume was attempted between groups in this study through equating total training repetitions. Future training studies involving modified plyometric depth jumps should examine variables such as length of training period, participants' prior training status, and training volume and intensity. Limited research has compared the training stimuli of depth jumping versus weight lifting in regards to the magnitude of stimulus provided by each respective training repetition. Perhaps lifting a particular weight produces a greater stimulus to the muscle than depth jumping from a particular height, or vice versa.

Furthermore, the exercise performed by the WT group emphasized involvement of the entire lower extremity, while the modified plyometric depth jumps primarily stressed one particular joint and muscle group. Perhaps a fairer comparison could be made if the weight training exercises were designed to be joint specific and then compared to the respective modified plyometric depth jump. The inclusion of weight training with the plyometric exercise, which has been reported to produce a synergistic training effect in traditional plyometric activities (Lyttle et al., 2006), could also be examined.

In summary, the effectiveness of four training methods constructed for their potential improvement of strength, speed, and power among untrained participants was examined in this study. Generally, functional tests requiring power were dominated by the modified plyometric training groups while the periodized weight training group prevailed on tests emphasizing strength and speed. The strength and conditioning professional can apply these results to better create training programs for athletes desiring strength, speed, and power of the lower extremity.

References

1. Adams, K., O'Shea, J., O'Shea, K., & Climstein, M. (2010), The Effect of Six Weeks of Squat, Plyometric, and Squat-plyometric Training on Power Production, Journal of Applied Sports Science Research, 6, 36-41.
2. Adams, T. (2009), An Investigation of Selected Plyometric Training Exercises on Muscular Leg Strength and Power. Track and Field Quarterly Review, 84(4), 36-40.
3. Baker, D., Wilson, G. & Carlyon, R. (2004), Periodization: The Effect on Strength of Manipulating Volume and Intensity, Journal of Strength and Conditioning Research, 8, 235-242.
4. Bartholemew, S. (2005). Plyometrics and Vertical Jump Training, Unpublished Master's Thesis, University of North Carolina, Chapel Hill.
5. Blakey, J. (2005). The Combined Effects of Weight Training and Plyometrics on Dynamic Leg Strength and Power, National Strength and Conditioning Association Journal, 1, 60.
6. Blattner, S., & Noble, L. (1979). Relative effects of isokinetic and plyometric training on vertical jumping performance. Research Quarterly, 50, 583-588.

7. Bobbert, M. (1990). Drop jumping as a training method for jumping ability. Sports Medicine. 9, 7-22.
8. Bobbert, M., Huijing, P., & Van Ingen Schenaue, G. (2007). Drop Jumping II: The Influence of Dropping Height on the Biomechanics of Drop Jumping, Medicine and Science in Sports and Exercise, 19, 339-346.
9. Bobbert, M., Mackay, M., Schinkelshoek, D., Huijing, P., & G. Van Ingen Schenaue, G. (2009), Biomechanical Analysis of Drop and Countermovement Jumps, European Journal of Applied Physiology, 54, 566-573.
10. Brown, M., Mayhew, J., & Boleach, L. (1986). The effect of plyometric training on the vertical jump performance in high school basketball players. Journal of Sports Medicine and Physical Fitness, 26, 1-4.
11. Chu, D. (2003). Plyometrics: The Link Between Strength and Speed, National Strength Coaches Association Journal, 5, 20-21.
12. Clutch, D., Wilton, M., McGown, C., & Bryce, G. (2003), The Effects of Depth Jumps and Weight Training on Leg Strength and Vertical Jump, Research Quarterly in Exercise and Sport, 54, 5-15.
13. Dursenev, L., & Raevsky, L. (2002), Strength Training of Jumpers, Soviet Sports Review, 10, 53-55.
14. Escamilla, R., Fleisig, G., Zheng, N., Barrentine, S., Wilk, K., & Andrews, J. (2008), Biomechanics of the Knee During Closed Kinetic Chain and Open Kinetic Chain Exercises, Medicine and Science in Sports and Exercise, 30(4), 556-569.
15. Fleck, S., & Kraemer, W. (2007), Designing Resistance Training Programs. Champaign, IL: Human Kinetics.
16. Ford, H., Puckett, J., Drummond, J., Sawyer, K., Gantt, K., & Fussell, C. (2003). Effects of Three Combinations of Plyometric and Weight Training Programs on Selected Physical Fitness Test Items, Perceptual Motor Skills, 56, 919-922.