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A Comparative Study of 6 Weeks Single and Double Leg Resistance Training in Basketball Players

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Abstract: *The purpose of the study was to investigate the effects of 6 weeks single leg and double leg free weights resistance training on vertical jump and isometric strength (peak force of quadriceps & hamstring muscles) in male collegiate basketball players. Nineteen healthy male basketball players participated in the study. The subjects were divided into 2 groups and randomly assigned either to a single leg group (Group I; n = 9) or a double leg group (Group II; n = 10) and underwent a 6 weeks training protocol. Both groups were trained 2 days per week for 6 weeks with free weights i.e. the resistance training protocol, with same training volume and intensities for both the groups. Commencing from the 3rd week of training, Group I underwent training 2 days per week with single leg plyometric drills (alternate leg on alternate day of the week) without any stretching; while Group II underwent training 2 days per week with double leg plyometric drills (both legs simultaneously) along with dynamic stretching. The Kinematic Measurement System was used to measure vertical jump performance (flight time; height; absolute power and relative power) and HUR leg flexion/extension curl machine evaluated the isometric strength (peak force of the quadriceps and hamstring muscles) of the dominant and non-dominant legs, before and at the end of the training protocol. An intragroup comparison demonstrated significant increase ($p < 0.05$) for all the variables of vertical jump and peak force (for both dominant and non-dominant leg) in both the groups. When intergroup comparison was done a non significant increase ($p > 0.05$) was observed for all the variables of vertical jump and peak force for both dominant and non dominant hamstrings whereas significant increase in peak force was observed for dominant and non dominant quadriceps ($p < 0.002$). The results indicate that single leg and double leg resistance training do not differ in improving vertical jump performance but differ significantly in improving isometric strength.*

Keywords: *Plyometrics, Stretching, Power, Force, Free weights*

I. Introduction

Basketball like all other sports demands good fitness, flexibility, power, strength, agility, endurance and vertical jumping ability to achieve performance goals and prevent the chances of an injury. In basketball, athlete's performance is critically dependent on jumping ability during offensive and defensive skills (Langford et al., 2004). Vertical jump requires high levels of explosive muscular power which comes from the development of speed strength and pure strength abilities primarily involving the muscles of the lower body, namely, quadriceps, ankle plantar flexors and hip extensor muscles. Different styles of jumping require different strength properties and training for one type of jumping technique will not necessarily improve performance in another form of jumping (Young, 1995).

Numerous techniques have been developed over the past to help athletes improve their vertical jump height; amongst these, resistance training is one of the most effective approaches. Numerous studies have reported significant improvements in strength and power development as a consequence of resistance training (Adams et al., 1992; Wilson et al., 1993). Training with free weights is more beneficial to achieve superior strength gains compared to other techniques such as machine training (Boyer, 1990; Stone et al., 1979). Furthermore, single leg strength is extremely effective in improving vertical jump performance and aids in the reduction of injury (Langford et al., 2004). Most training programs focus on double-leg strength training to improve vertical jump performance and strength (Kraemer et al., 1998; McCurdy et al., 2005). A recent study conducted by McCurdy et al. (2005) who investigated the effect of unilateral and bilateral lower body resistance training on measures of strength and power concluded that both are equally effective for early phase improvements in untrained men and women. However, there is paucity of conclusive scientific evidence comparing the effects of single and double leg resistance training programs on performance variables such as vertical jump height and strength.

Ample body of scientific evidence is present suggesting that plyometrics increase both power output and explosiveness. It involves active muscle switching from a rapid eccentric muscle action to a rapid concentric muscle action or from a rapid deceleration to a rapid acceleration also known as the stretch-shortening cycle (Luebbers et al., 2003). Plyometric exercises are designed to enhance muscle performance, mainly through the use of jump training (Villarreal et al., 2009). This type of training can improve performance in explosive sports that rely on moving speed and power (Susan et al., 2002).

However, when combined, resistance training and plyometrics lead to greater improvement in vertical jump and strength parameters as compared to resistance training alone (Adams et al., 1992; Jason et al., 2008; Ebben, 2002; Faigenbaum et al., 2007). Thus, both resistance training and plyometric training are typically recommended for adults when gains in motor performance are desired (Adams et al., 1992).

Some authors also reported that neither ballistic nor dynamic stretching will result in an increase in vertical jump height (Jaggers, 2008). Others reported that sports requiring lower-extremity power should use dynamic stretching techniques as a warm-up to enhance flexibility (Yamaguchi et al., 2005). Some studies also reported that dynamic stretching combined with plyometrics are more beneficial as compared to plyometrics alone to improve vertical jump height (Shaji and Isha, 2009).

The purpose of this study was to compare the effects of 6 weeks single leg and double leg free weights resistance training combined with plyometrics and a dynamic stretching program on vertical jump and isometric strength (peak force (pf) of human quadriceps and hamstring muscles) in male collegiate basketball players. A six week resistance and plyometric training program was employed (Myer et al., 2005; Adams et al., 1992).

II. Material and Methods

A total of 19 healthy male basketball players (district level and minimum 5 years of experience) participated in the experimental study. The sample was divided into 2 groups (Table 1) and randomly assigned to either a single leg (Group I) or a double leg group (Group II).

The subjects were asked to refrain from any other exercises or any other training program throughout the study. The exclusion criteria included history of recent injury to upper or lower extremity, age above 23 years and any orthopaedic condition that would limit their ability to perform exercise. Limb dominance was determined by asking the participant to kick a ball.

Table 1: Basic characteristics of subjects participating in the study

Group	Age (years)	Body Height (cm)*	Body mass (kg)
I (n = 9)	21.67 ± 1.32	177.0 ± 4.33	77.89 ± 10.71
II (n = 10)	21.80 ± 1.61	175.55 ± 6.92	69.10 ± 8.17

The experimental protocol and potential risks of the study were explained to each subject both verbally and in writing before their informed consent were obtained. The study was approved by the institutional ethical committee (IEC). * The players selected were shorter in height as compared with the average sport specific normative values for height.

Data Analysis

The data were analyzed for statistical significance by using the statistical package for social sciences (SPSS 17.0) software. Descriptive data were calculated for all variables. The Paired sample t-test was used to compare the single leg and double leg vertical jump and isometric strength (of both dominant and non dominant legs) before and after the protocol within each group. The Unpaired/Independent t-test was used to find intergroup differences for all the variables of vertical jump and isometric strength. A statistical significance of $p < 0.05$ was set for all analyses. For strength measurement: Torque (Nm) was measured at 10 s isometric contraction for both dominant and non dominant quadriceps and hamstrings of both limbs in each group. It was normalized to force (N) by dividing the torque (Nm) by lever arm length (m).

Procedure

Before the evaluations, the subjects were instructed to perform a 5-minute jog as a warm-up exercise to prevent injury due to testing. Both single leg and double leg vertical jump power was measured with a counter movement vertical jump using contact timing mats interfaced with a computer (kinematic measurement system). Each subject had 3 trials and the highest jump was recorded. Subjects were instructed to keep their arms on their hips during the vertical jumps to eliminate upper body momentum (Soest et al., 1985).

Isometric strength was measured by using HUR 5340 Leg Extension/Curl computer controlled isotonic/isometric dynamometer (University of Technology in Helsinki, Finland) to determine peak force of quadriceps and hamstring muscles of both dominant and non dominant leg for both the groups and after 6 weeks of training a post-test was conducted using the same method.

Training protocol

Prior to training, the participants were given a 2-week instructional period to learn the proper technique of all the exercises. After getting familiar with these exercises both groups followed the resistance-training programs 2 days per week for 6 weeks. Group I trained with single leg exercises whereas Group II performed double leg exercises. Both single and double leg exercises were implemented to improve vertical jump and strength. Group I performed single leg squats each session with lunges or step-ups, which were alternated with each training session. Group II exercises consisted of double leg squats and front squats. Training volumes and intensities, based on sets, reps and percentage of each subject's predicted 1 RM, were equal for both groups. Both programs excluded upper body exercises to eliminate the possibility of altering the results from potential improvement in upper-body strength or power. The two study groups progressed from 3 sets of 15 repetitions at 50% of each subject's predicted 1RM to 6 sets of 5 repetitions at 87% through the 6 weeks of training.

After each set of an exercise, 2-3 min rest intervals were given for recovery. Strength and power performance is highly dependent on anaerobic energy metabolism, primarily via the phosphagens (ATP-PC). Studies showed that the majority of phosphagen repletion occurs within 3 min (Fleck, 1983). Therefore, in our study, we used 2-3 min rest intervals between sets. Also in our experiment, a frequency of 2 days per week was prescribed as previous studies had shown this frequency to be an effective maintenance frequency for those individuals already engaged in a resistance training program (Graves et al., 2004).

Additionally, commencing at 3rd week Group I underwent training 2 days per week with single leg plyometric drills (alternate leg on alternate day of the week) without any stretching; while Group II underwent training 2 days per week with double leg plyometric drills (both legs simultaneously) along with dynamic stretching before the resistance training session. Between resistance training and plyometrics 3-4 min rest was allowed for full recovery (Ebben, 2002). The subjects performed different types of plyometric drills initiated with low intensity and progressing to high intensity. Both groups completed pogo jumps and counter movement vertical leaps each session while progressing from 3 sets of 5 to 3 sets of 15 repetitions from week 3 to week 6. The pogo jump was executed with minimal hip and knee flexion upon landing before rebounding vertically for maximum height without the use of the arm swing, and the counter movement vertical leap was completed with a one-half to three-quarters squat (McCurdy et al., 2005).

III. Results

Vertical jump

Single leg group: intra group comparison using Paired sample t-test demonstrated significant improvements in all the variables of vertical jump namely, flight time (t = 9.5, $p < 0.001$*), height (t = 12.89, $p < 0.001$*), absolute power (t = 3.22, $p < 0.012$*), relative power (t = 4.23, $p < 0.003$*).

Double leg group: the findings in this group were similar which demonstrated significant improvement in all the variables of vertical jump namely flight time (t = 9.79, $p < 0.001$*), height (t = 10.14, $p < 0.001$*), absolute power (t = 3.69, $p < 0.012$*), relative power (t = 3.31, $p < 0.003$*) upon intra group comparison.

When intergroup comparison was done by using Unpaired/Independent t-test scores, a non significant increase was observed for all the variables of vertical jump (flight time, height, absolute power and relative power) between single leg and double leg group (Table 2).

Isometric Strength (peak force)

Single leg group: intra group comparison using Paired sample t-test demonstrated significant improvements in peak force of both dominant and non dominant extensors (quadriceps) as well as flexor (hamstrings) group of muscles. Dominant extensor (t = 4.61, $p < 0.002$*), non dominant extensor (t = 5.59, $p < 0.001$*), dominant flexor (t = 5.61, $p < 0.001$*) and non dominant flexor (t = 8.69, $p < 0.001$*) peak force.

Double leg group: the findings in this group were similar which demonstrated significant improvements in peak force of both dominant and non dominant extensors (quadriceps) as well as flexor (hamstrings) group of muscles upon intra group comparison. Dominant extensor (t = 8.54, $p < 0.002$*), non dominant extensor (t = 7.03, $p < 0.001$*), dominant flexor (t = 7.31, $p < 0.001$*) and non dominant flexor (t = 7.506, $p < 0.001$*) peak force.

When intergroup comparison was done using the Independent t-test, a significant increase in peak force was observed for both dominant as well as non dominant leg extensor group of muscles between double leg and single leg group. However, a non significant increase in peak force was observed for both dominant and non dominant leg flexor group of muscles between double leg and single leg (Table 3).

IV. Discussion

The results of the study highlighted that six weeks of single and double leg resistance training significantly improved vertical jump performance within both groups (both single leg as well as double leg groups). However, on inter group comparison these improvements were found to be insignificant.

Effect of single leg and double leg resistance training protocols in enhancing vertical jump:

Table 2: Comparison of Vertical Jump Height parameters (post training) in Single and Double Leg groups

Variable	**Single leg (n = 9)**		**Double leg (n = 10)**		**t**	***p***
	Mean ± SD	**SE**	**Mean ± SD**	**SE**		
Flight time (ms)	49.44± 15.61	5.204	51.90 ± 16.76	5.301	0.32	0.746^{NS}
Vertical jump	0.073± 0.017	0.006	0.076 ± 0.024	0.007	0.33	0.742^{NS}

height (m)						
Absolute power (W)	371.0± 345.17	115.06	307.90 ± 263.84	83.43	0.45	0.658 NS
Relative power (W x kg-1)	4.11 ± 2.91	0.972	4.064 ± 3.88	1.22	0.029	0.977 NS

Table 3: Comparison of Peak Force (post training) in Single and Double Leg groups

Variable Force (N)	**Single leg (n = 9)**		**Double leg (n = 10)**		**t**	***p***
	Mean ± SD	**SE**	**Mean ± SD**	**SE**		
Extensor dominant quadriceps	61.77± 40.19	13.39	137.75± 51.03	16.14	3.57	0.002*
Extensor non dominant quadriceps	48.59± 26.08	8.76	124.17± 55.83	17.65	3.706	0.002*
Flexor dominant hamstrings	39.64± 21.17	7.05	57.37± 24.81	7.84	1.66	0.114 NS
Flexor non dominant hamstrings	36.20± 12.49	4.16	46.95± 19.78	6.25	1.39	0.180 NS

Power represents the amount of work done by a muscle or a group of muscles per unit of time (Adams et al., 1992) and since vertical jump has long been used as a measure of power; therefore, in the present study vertical jump was used to access power. The results of our study demonstrate that upon inter-group comparison "insignificant" improvements were observed for all the variables of vertical jump (flight time, height, absolute power and relative power) between the single leg in comparison to the double leg group. The possible explanation for the same is likely due to the differences attributed to the subject selection. Scientific literature cites that it is easy to find the difference in unilateral and bilateral strength and power in untrained (McCurdy et al., 2005) as compared to the conditioned athlete. Since, the subjects who participated in our study were already trained and had at least one year of resistance training experience the improvements observed were insignificant. Also, the short duration of the training period itself could account for insignificant improvements observed in flight time, height, absolute power and relative power.

Upon intra-group comparison, non-significant percentage improvement was observed for all the variables of vertical jump in the single leg group in-comparison to the double leg group i.e. vertical jump height increased by 22% and 20%, absolute power increased by 23% and 19% and relative power increased by 18% and 16% respectively, which is in accordance with previously conducted studies (Langford et al., 2004; McCurdy et al., 2005). Since, during a vertical jump, high amount of eccentric forces are generated when one dips down, and the ability to absorb and stabilize these forces is an important step in developing great plyometric power (Kelly Baggett, 2005); this accounts for the improvement in vertical jump variables in both the groups.

However, a greater improvement for all variables of vertical jump was observed in the single leg group as compared to the double leg group. This may be attributed to the specific activities or exercises employed in the single leg resistance training protocol. Furthermore, it has been demonstrated that the force absorption training (the ability to absorb and stabilize high eccentric or negative forces) helps the athlete to improve the vertical jump height. Since single leg resistance training leads to better force absorption by the lower limb musculature in comparison to the double leg resistance training which leads to better force production, it can be deduced that single leg exercises account for significant improvements in the vertical jump as compared to double leg resistance exercises.

The bilateral deficit serves as another possible explanation. It has been described by Sale (1992) as the difference between the force output when the left and right sides act simultaneously and the sum of the forces produced by the left and right limbs acting alone. Training may either increase or reduce the deficit, as suggested by the fact that rowers, who train bilaterally, are stronger in the bilateral leg press than when summing their single leg presses, whereas cyclists, who normally alternate leg actions, display greater summed strength than bilateral strength (Sale, 1992). Hence, it is better to train basketball players with single leg exercises. The vertical jump height achieved in the single leg group was higher as compared to the double leg group what may be neuromuscular in nature (Coyle, 2001). These results were in congruence with the study conducted by McCurdy et al. (2005) who investigated the effect of unilateral and bilateral lower body resistance training on power production (evaluated through vertical jump) and concluded that both training programs are equally effective for early phase improvements in both untrained men and women. In future studies EMG can be incorporated to examine the neuromuscular activation in detail.

Effect of single leg & double leg resistance training protocols in enhancing isometric strength:

The results of the study also reported that six weeks of single and double leg resistance training significantly improved isometric strength within both groups and when intergroup comparison was done, it showed significant increases in dominant and non dominant extensors and insignificant in dominant and non dominant flexors.

Percentage improvement in strength as observed for double leg group of dominant extensor (quadriceps) increased by 34% and non dominant (quadriceps) by 31%, while single leg group dominant extensor (quadriceps) increased by 12% and non dominant (quadriceps) by 10% which highlights statistically the significant results and percentage improvement for double leg group of dominant flexor (hamstrings) increase by 24% and non dominant (hamstrings) by 21% while single leg group dominant flexor (hamstrings) by 16% and non dominant (hamstrings) by 15% which illustrates statistically in non significant results. By observing the percentage improvement in isometric strength between single and double leg, it may be inferred that double leg training significantly improved the isometric strength more as compared to single leg training. The possible reason could be that in the double leg group two leg squats produce greater demands on the quadriceps muscle as compared to the single leg squat, as greater demands lead to an increase of force output in overall muscle activity (McCurdy et al., 2010).

On the contrary, the study conducted by McCurdy et al. (2005) investigating the effects of unilateral and bilateral lower body resistance training on strength reported that both the training protocols were equally effective for early phase improvements in untrained men and women. Thus, the results do deviate from the previously published data. However, this discrepancy may be due to the difference in the methodologies of training and testing the muscle groups. In a previous study, both groups were trained and tested with free weights but in the present study free weights were used for training but not for testing. In the present study, the effect of isometric strength on maximum voluntary contraction of the dominant and non dominant quadriceps and hamstrings were measured in isometric mode rather than the isotonic or isokinetic modes, because studies have demonstrated that high correlations exists among the three testing modes (when tested at joint angles of peak isometric torque) (Kanapik et al., 1983).

Future research is required, to compare different strength calibrating procedures for measuring strength in order to determine if similar results will be obtained with this testing procedure in both, trained and untrained subjects.

Effect of dynamic stretching in enhancing combined effect of resistance training and plyometrics on performance variables:

It was hypothesized that six weeks of combined resistance training and plyometrics without dynamic stretching (group I) would lead to a similar improvement in vertical jump performance as compared to combined resistance training and plyometrics along with dynamic stretching (group II). It was observed that subjects in Group II were not able to achieve any significant improvements in all variables of the vertical jump as compared to the subjects in Group I. These findings were consistent with previous research which also suggested that combined plyometric and resistance training without dynamic stretching was observed to be the single most effective training regiment to improve vertical jump performance (Adams et al., 1992; Jason et al., 2008; Ebben, 2002; Faigenbaum et al., 2007). Our findings were also consistent with Jaggers (2008) and Little and Williams (2006) who reported that dynamic stretching does not improve vertical jump height. Furthermore, plyometric training itself is more effective in improving vertical jump performance, as it helps the athletes to use the elastic and neural benefits of the stretch shortening cycle which in turn leads to enhanced power production (Markovic, 2007; Shaji and Isha, 2009).

Rubini et al. (2007) suggested that stretching exercises generate an increase in muscle compliance that may limit more cross bridge coupling which is responsible for reduced muscular performance with resultant decreased power. Future research is required to compare the effects of combined resistance training and plyometrics with plyometrics and static or dynamic stretching in trained and untrained subjects and also muscle biopsy could be included to study and explain these effects in more detail.

Limitation of the study**:** Short study period, limited sample size, only two muscle groups evaluated, no EMG activity recorded for these muscle groups, only male participants included in the study.

V. Conclusion

We conclude that single leg and double leg resistance training enhanced vertical jump performance equally, but were not equal in improving isometric strength. The findings suggest that to design sports specific double leg resistance training programs, coaches and athletes should include single leg plyometric drills to increase the vertical jump performance and also single leg resistance training is an effective method to improve double-leg jump performance.

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References

[1] K Adams, JP O'Shea, KL O'Shea, Climstein M. The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *J Appl Sport Sci Res*, 1992; 6: 36-41

[2] Bobbert MF, Van Soest AJ. Effects of muscle strengthening on vertical jump height: A simulation study. *Med. Sci. Sports Exerc*, 1994; 26(8): 1012–1020

[3] Boyer BT. A Comparison of the Effects of Three Strength Training Programs on Women. *J Strength Cond Res*, 1990; 4(3): 88-94

[4] Coyle. Program design for improvement in vertical jump height in a collegiate volleyball player. *Cond. Competitive Athl*, 2001

[5] Ebben WP. Complex Training: A Brief Review. *J Sport Sci Med*, 2002; 1: 42-46

[6] Faigenbaum D, McFarland E, Keiper B, Tevlin W, Ratamess NA, Kang J, Hoffman JR. Effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years. *J Sport Sci Med*, 2007; 6: 519 525

[7] Fleck SJ. Bridging the gap: interval training physiological basis. NSCA J. 1983; 5: 57–62

[8] Graves JE, Pollock ML, Leggett SH, Braith RW, Carpenter DM, Bishop LE. Effect of reduced training frequency on muscular strength. *Int J Sports Med*, 1988; 9: 316–319

[9] Jaggers JR, Swank AM, Frost KL, Lee CD. The acute effects of dynamic and ballistic stretching on vertical jump height, force, and power. *J Strength Cond Res*, 2008; 22(6): 1844-1849

[10] Mihalik JP, Libby JJ, Battaglini CL, McMurray RG. Comparing Short-Term Complex and Compound Training Programs on Vertical Jump Height and Power Output. *J Strength Cond Res*, 2008; 22(1): 47-53

[11] Kanapik JJ, Wright JE, Battaglini CL, McMurray RG. Isokinetic, Isometric and Isotonic strength relationship. *Arch Phys Med Rehabil*, 1983; 64(2): 77-80

[12] Kelly Baggett. The vertical jump development bible. *Paperback publications;* 2005

[13] Kraemer WJ, Staron RS, Hagerman FC, Hikida RS, Fry AC, Gordon SE, Nindl BC, Gothshalk LA, Volek JS, Marx JO, Newton RU, Häkkinen K. The effects of short-term resistance training on endrocrine function in men and women. *Eur J Appl Physiol Occup Physiol*, 1998; 78(1): 69–76

[14] Kraemer WJ, Newton RU. Training for improved vertical jump. *Sports Science and Exercise*, 1994; 53(7): 6

[15] Kraemer WJ, Ratamess NA. Fundamentals of Resistance Training: Progression and Exercise Prescription. *Med Sci Sport Exe*r, 2004; 36 (4): 674–88

[16] Dalrymple KJ, Davis SE, Dwyer GB, Moir GL. Effect of Static and Dynamic Stretching on Vertical Jump Performance in Collegiate Women Volleyball Players. *J Strength Cond Res,* 2010; 24(1): 149-155

[17] Langford GA, McCurdy KW, Doscher M. The effects of single leg resistance training on measurement of jumping performance in NCAA Division 2 women volleyball players. *Int J Volleyball Res*, 2005; 8(1): 14-18

[18] Little T, Williams AG. Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. *J Strength Cond Res*, 2006; 20(1): 203–7

[19] Luebbers PE, Potteiger JA, Hulver MW, Thyfault JP, Carper MJ, Lockwood RH. Effects of plyometric training and recovery on vertical jump performance and anaerobic power. *J Strength Cond Res*, 2003; 17(4): 704–9

[20] Markovic G. Does plyometric training improve vertical jump height? A meta-analytical review; *Br J of Sports Med*, 2007; 41(6): 349-55. Discussion 355. Epub 2007 Mar 8

[21] McCurdy KW, Langford GA, Doscher MW, Wiley LP, Mallard KG. The effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. *J Strength Cond Res*, 2005; 19(1): 9–15

[22] McCurdy K, O'Kelley E, Kutz M, Langford G, Ernest J, Torres M. Comparison of Lower Extremity EMG between the 2-Leg Squat and Modified Single-Leg Squat in Female Athletes. *J Sport Rehabil*, 2010; 19(1): 57-70

[23] Myer GD, Ford KR, Palumbo JP, Hewett TE. Neuromuscular training improves performance and lower extremity biomecanics in female athletes. *J Strength Cond Res*, 2005; 19(1): 51-60

[24] Rubini EC, Costa LL, Gomes PS. The Effects of Stretching on Strength Performance. *Sports Med*, 2007; 37 (3): 213-24

[25] Sale DG, Komi PV. Neural adaptation to strength training. *Strength and Power in Sport*. Boston: Blackwell Scientific Pub, 249-265; 1992

[26] John S, Saluja I. Comparative Analysis of Plyometric Training Program and Dynamic Stretching on Vertical Jump and Agility in Male Collegiate Basketball Player. *Al Ameen J Med Sci*, 2009; 2(1): 36 -46

[27] van Soest AJ, Roebroeck ME, Bobbert MF, Huijing PA, van Ingen Schenau GJ. A comparison of one legged and two legged countermovement jumps. *Med Sci Sport Exer*, 1985; 17(6): 635-39

[28] Stone MH, Johnson RL, Carter DR. A short term comparison of two different methods of resistance training on leg strength and power. *J Athl Training*, 1979; 14: 158-160

[29] 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

[30] Wilson GJ, Newton RU, Murphy AJ, Humphries BJ. The optimal training load for the development of dynamic athletic performance. *Med Sci Sport Exer*, 1993; 25(11): 1279-86

[31] Yamaguchi T, Ishii K. The effects of static stretching for 30 seconds and dynamic stretching of muscle groups in the lower limbs on leg extension power. *J Strength Cond Res*, 2005; 19(3); 677-83

[32] Young W. Specificity of Jumping ability. *Sports Coach*. Winter 1995; 22-25