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Original Research Article

Effects of Six Weeks Plyometric Training in Comparison to Bent Leg Raise (BLR) plus Strength Training on Vertical Jump Height and Agility in Young Basketball Players

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ABSTRACT

Background and Objective: Basketball player needs good fitness, flexibility, power, agility, endurance, strength & vertical jump ability. The aim of this study was to compare and determine the effects of six weeks Plyometric training and Bent Leg Raise (BLR) stretching plus Strength training on vertical jump height (VJH) and agility by Illinois agility test (IAT) in young Basketball Players.
Method: 60 participants age between 17-25 years from different Colleges and school were assigned randomly into three groups using quasi randomization procedure. All groups included 20 participants. Group A, B and C performed Plyometric training, BLR stretching plus Strength training and as control group, respectively. Each participant was given training for six weeks with 3 days exercise protocol each week for each group. Outcome measures used were VJH and IAT. Measurements were taken first day prior to the training and at the end of the 3rd and 6th week of the training.
Results: ANOVA and repeated measure ANOVA were used. Results were considered to be significant at $p<0.05$. Significant difference in IAT at the end of 3rd and 6th week of the study between groups. Post Hoc analysis revealed plyometric group to be effective in improving agility. Within group, there was significant difference was found in VJH and IAT in group A and B with $p=0.000$.
Conclusion: Plyometrics and BLR plus strength training for a period of 6-weeks can improve VJH and agility in young basketball players.
Key-Words: Basketball, Plyometric training, Strength training, Vertical jump, Agility, Bent Leg Raise

INTRODUCTION

Basketball is one of the most popular team sport extensively played and viewed all over the world. It is one of the sports characterized by many of the basic and variable skills. [1] Basketball has developed to involve common techniques of shooting, passing, dribbling, including player's positioning as well as offensive and defensive structures. In basketball, the ability to generate maximal strength levels in the shortest period of time (muscular power) has been considered as essential to obtain high sport performance level. [2-4] Special physical preparation in basketball is the main pillar for the players to carry out the special requirements (physical, skillful and tactical). Physical adaptation of the player to perform the sport activities is one of the practical functions of the training which improve the training of the player to reach to higher levels in the sport activities. [5] Moreover, strength training is part of basketball preseason programs [6-7] with a

background of related benefits that improve sports performance, reduce injury rate, and provide higher motivation levels for the athletes. [8]

In basketball, the necessity of vertical jumps is due to the need for a successful performance of the various skills. [4,9-10] An important part that must be emphasized is the verticality of the jump so that the athlete can achieve maximum height and keep the balance of his/her body [11,12] A competent basketball player needs the ability to rapidly switch between forward, backward, lateral and vertical movement possibly through basic training or some enhanced training programs. Agility has been considered a physiological prerequisite in basketball, because players are frequently involved in a variety of sudden directional changes during the game. In view of the above, basketball player needs good fitness, flexibility, power, strength, agility, endurance and vertical jumping ability to achieve sporting targets. [13]

Strength and conditioning professionals have long relied on plyometrics as one of the primary tools for developing athletic power and speed. The eastern Europeans first used plyometrics in 1970's to develop greater strength and power in Olympic athletes. The term plyometrics was first coined by "Fred Wilt" in 1975. Plyometrics Training is also known as "Shock Training". It was developed by Yuriverkhoshansky in 1977. [14]

Plyometric exercises are those that describe any type of explosive movement being done for a series of repetitions at high speeds and high levels of intensity. Plyometric Training refers to performance of "Stretch-Shortening Cycle" (SSC) movements that involve a high-intensity eccentric contraction immediately after a rapid and powerful concentric contraction. [6] It is a form of exercise which links strength with speed of movement. Benefits from this type of training include improved measures of muscular strength and power, [15-22] joint function and stability, [17,21,23] reduced incidence of serious knee injuries [17,24] and running economy. [25] Plyometric exercises constitute a natural part of most sport movements because they involve jumping, hopping, and skipping (i.e., such as high jumping, throwing, or kicking). [26-28] Typical plyometric exercises include the countermovement jump (CMJ), the drop jump (DJ), and the squat jump (SJ).

Plyometrics involve stretching the muscles before quickly contracting them to generate power. Plyometrics for basketball can help to develop a solid strength base, increase vertical jump, improve speed on the court and hone ability to decelerate.

Plyometric training has been advocated for sports that require explosiveness and increased vertical jumping ability by the athletes. Plyometric drills usually involve stopping, starting, and changing directions in an explosive manner. These movements are components that can assist in developing agility. [29] Agility has been defined as the ability to maintain a controlled body position and rapidly change direction without a loss of balance, body control, or speed. [30] The components of agility have been defined as balance, coordination, power, and speed. [31] The majority of tests supported to assess agility are tests based on change of direction speed [e.g., the T-test, [32] the Illinois agility test, [33] the 505 test, [34] the L-run test, [35] and the zigzag test. [36] Although plyometric training has been shown to increase performance variables, little scientific information is available to determine if plyometric training actually enhances agility. [37] Strength training increases muscular strength and power and is an integral part of competitive athletics.

Flexibility is often overlooked as a factor in leaping ability of a player; jumping high is based on the elasticity of muscles and tendons. Without extreme flexibility, one can never jump as high as he can with proper training. Flexibility can be attained by proper stretching, it is a technique to elongate the muscle.

In this study, Bent Leg Raise (BLR) Mulligan stretching technique is used with

strength training program. BLR [38] is a Mulligan stretching technique which is a recent advancement in the management of hamstrings tightness.

Weight training has been able to improve vertical jumping performance in most cases by 2–8 cm (or by 5–15%), [39,26,40] with lighter more explosive lifts being more effective than the heavier and slower lifts. The comparison of plyometric exercises and weight-training protocols has produced controversial results. Plyometric protocols have been shown to be more effective, [41] equally effective, [39,26] or less effective, [41,42] than weight training in improving vertical jumping ability. Furthermore, two other studies showed that plyometric training was no more effective than isokinetic training [40] or flexibility training alone. [43] The combination of plyometric exercises and weight training increased [39,40] or maintained unaffected vertical jumping performance. [42] Adams et al. [39] suggested that this combination may provide a more powerful training stimulus to vertical jumping performance than either weight training or plyometric training alone. However, Clutch et al. [44] did not reach similar conclusions.

It seems that researchers have not come to an agreement about the relative effectiveness of plyometric training compared with strength training or the combination of both in the development of vertical jumping ability and agility.

Hence, the present study aimed to compare and determine the effects of six weeks Plyometric training and Bent Leg Raise (BLR) stretching plus Strength training on vertical jump height and agility by Illinois agility test in the young Basketball Players.

Significance of the Study:

Basketball players require good amount of jumping ability, strength and flexibility for the good performance. There are many studies that show the effect of plyometric and strength training in basketball players but less literature has been found whether plyometric training and BLR stretching plus strength training improve vertical jump and agility in young basketball players. The results of the study would be of significant to form a training protocol to improve playing skills in basketball players.

METHODS

This repeated measure experimental study conducted by collecting data from Surat Mahanagarpalika – Sports Sankul, Sports center– Veer Narmad South Gujarat University (VNSGU) Campus- Surat, Sir K.P. College of Commerce- Surat, Sir V. D. T. Girls high school, Vanita Vishram School- Surat. Sample size was calculated using G- Power version 3.1.9.2. At effect size 0.6, power 0.80 and α 0.05, the required sample size was 54. Assuming 10% as drop out chances the final sample size was adjusted to 60. 60 basketball players (30 males and 30 females) participated in this study based on the inclusion and exclusion criteria. All players voluntarily agreed and signed informed consent form to extend full cooperation and be available for data collection as and when required.

All the players were assessed for inclusion and exclusion criteria of the study. Inclusion criteria included males and females between the age group 17 – 25 years playing basketball at collage level, players participated at competitive level for minimum 2 years and physical activity practice volume was approximately 16 hours per week. Individual with any, musculoskeletal and neurological impairment, pathological condition of spine, hip, knee, and pelvis, any traumatic condition in past 6 months, cardiovascular disease, uncontrolled metabolic disorder such as Diabetes Mellitus, undergone any surgical procedure, poor balance, functional strength and flexibility, impaired ROM and Muscle power and players involved in any type of Plyometric training at the time of the study were excluded from the study.

The purpose of the study and requirement and schedule of the testing

procedure were explained to the players. Players participating in the study were required to fill a self – administrated questionnaire.

60 participants (30 males and 30 females) who met the inclusion criteria were assigned randomly into one of the three groups using quasi randomization procedure as explained below.

The first participant encountered by the researcher was assigned to Group-A, second to Group-B and third to Group-C. The same sequence of allotment was followed for consecutive participants throughout the study.

Group-A included 20 participants (10 male and 10 female) who performed Plyometric training. Group-B included 20 participants (10 male and 10 female) who performed the Bent Leg Raise (BLR) stretching plus strength training. Group-C included 20 participants (10 male and 10 female) as controls and they did their routine training activities. Participants were selected from respective school and various colleges of Surat as mentioned above.

The exercise training for each participant of Group-A, Group-B and Group-C were given for 6-weeks with 3 days exercise protocol each week. Group-A performed Plyometric training on Monday, Wednesday and Friday. Group-B performed BLR stretching plus strength training on Tuesday, Thursday and Saturday. The subjects were given exercises at the basketball ground of the Veer Narmad South Gujarat University (VNSGU), Surat Mahanagarpalika - Sports Sankul, Sir K.P. College of Commerce and Sir V. D. T. Girls high school, Vanita Vishram School. The study was approved by the Institutional Committee of Ethics of The Sarvajanik College of Physiotherapy.

Preliminary measurements were taken prior to the beginning of the study, in which subject's age, height and weight were measured. The procedure allowed the measurements of Vertical Jump Height and Agility score by using Illinois Agility Test which is mentioned below. The measurements were taken very first day prior to the training and at the end of the 3rd and 6th weeks of the training. Each test were explained and demonstrated. Before testing, players were given three practice trials to become familiar with the testing procedures.

VERTICAL JUMP HEIGHT:

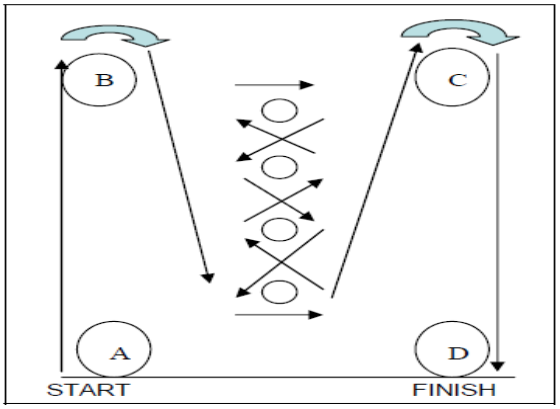
Vertical jump height is measured by the Stand and Reach test. [(45)] Materials used were measuring tape and chalk for marking wall. Participants were positioned so that they were standing with equal weight on bilateral lower extremities, which were approximately shoulder-width apart. The participant stands, side on with the dominant shoulder facing the wall, with a piece of chalk in the hand closest to wall, and was instructed to reach as high as possible and make a mark on wall; this is called the standing reach height and was recorded as a zero starting position. The participant was then asked to bend (flex) the knees approximately 120 degrees and swing the arms prior to the jump. The participant was not allowed a run up or a shuffle step prior to the jump. The participant was asked to jump and place a second chalk mark as high as possible on the wall, called as a jumping height. [(46)] This test is selected because it has high validity (0.80) and reliability (0.93) coefficients [(47)] and because it allows arm movement and a squat motion before the jump, such as those performed in sports like basketball. The participant's vertical jump score was measured as the distance between the two chalk marks; means the standing reach height and the jumping height. The difference between two chalk marks was measured in centimeters.

ILLINOIS AGILITY TEST:

The Illinois agility test is used to determine the ability to accelerate, decelerate, turn in different directions, and run at different angles. This test was selected based upon established criteria data for males and females and because of their reported validity and reproducibility of the

test. [48] Materials used were eight cones, stopwatch and measuring tape.

Direction of Illinois Agility test



Illinois Agility Test is shown in figure. Cones were placed on the flat nonslip Ground. Test was set up with four cones forming the agility area (10 meters long x 5 meters wide). Cone at point A, marking the start. Cone at B & C to mark the turning spots. Cone at point D to mark the finish. Four cones were placed in the center of the testing area 3.3 meters apart. Participant was positioned with both feet behind Cone A. Participant was instructed to signal the researcher by raising his right hand when he/she was ready. On the "go" command, participant sprinted forward 10m and then ran towards cone B and turned cone B, then they ran between the cones which were kept at the distance of 3.3m in a zigzag pattern as shown in figure, then the participant ran towards the cone C and turned cone C and finished the test by running the distance of 10m towards the cone D. Test was completed when the participant crossed the finish line and when no cones were knocked over. [30] Time shown in the stopwatch was recorded in seconds.

The 6-weeks training program consisted of a warm up period which included 5 minutes of jogging performed by both groups A and B, set of plyometric training performed by group A and BLR stretching plus strength training performed by group B. A cool down period of 5 minutes involving slow jogging was performed by both groups A and B. Group C performed only their routine training activities.

GROUP A: PLYOMETRIC TRAINING GROUP

This group performed different types of plyometric drills initiated with low intensity and winded up with high intensity. The participants were given 30 seconds of rest interval between sets of the Plyometric drills [49] and 2 minutes rest in between each plyometric drill. [50] Plyometric 6-weeks training protocol is as follows: [30]

Training Week	Plyometric Drill	Sets * Repetition
Week 1	Side to side Ankle hops Standing Jump and Reach Front cone hops	2*15 2*15 5*6
Week 2	Side to side Ankle hops Standing long jump Lateral jump over barrier Double leg hops	2*15 5*6 2*15 5*6
Week 3	Side to side Ankle hops Standing long jump Lateral jump over barrier Double leg hops Lateral cone hops	2*12 4*6 2*12 3*8 2*12
Week 4	Diagonal cone hops Standing long jump with lateral sprint Lateral cone hops Single leg bounding Lateral jump single leg	4*8 4*8 2*12 4*7 4*6
Week 5	Diagonal cone hops Standing long jump with lateral sprint Lateral cone hops Cone hops with 180 degree turn Single leg bounding Lateral jump single leg	2*7 4*7 4*7 4*7 4*7 2*7
Week 6	Diagonal cone hops Hexagon drill Cone hops with change of direction sprint Double leg hops Lateral jump single leg	2*12 2*12 4*6 3*8 4*6

Total training time during First week was approximately 30 minutes, during second week was approximately 45 minutes, during third week was approximately 60 minutes, during fourth week was approximately 75 minutes and during fifth and sixth week was approximately 90 minutes.

GROUP B: BENT LEG RAISE (BLR) PLUS STRENGTH TRAINING GROUP

This group performed different types of strength training and BLR stretching. Stretching was given by researcher. All participants first given BLR stretching and then performed strength training protocol.

BENT LEG RAISE (BLR) TECHNIQUE:

BLR technique consist of gentle isometrics stretching of hamstring in specific directions in progressively greater positions of hip flexion, the expecting results are increased flexibility of hamstring muscle with increased ROM of active knee extension. The procedure for performing BLR [(38)] is as follows:

Participant was in supine lying position on ground with the researcher lateral to the leg, which was being stretched. Hip and knee of the side to be stretched was bent at 90- 90 degree. Researcher placed participant's flexed knee over her shoulder, the popliteal fossa of the knee resting on her shoulder. A distraction (longitudinal traction force along the long axis of femur) was applied at the lower end of femur and the participant was asked to push the researcher's shoulder with his or her leg followed by voluntary relaxation.

At this point of relaxation, the researcher push the bent knee up as far as possible in the direction of the shoulder on the same side in a pain free range. This stretch was sustained for 5-10 seconds and then relaxed. If the pain or restriction eased, the hip was taken further in to flexion. It was ensured that there was no pain during the procedure, if it was painful the direction of the leg raise was altered medially or laterally. The process was repeated till the knee of the participant was beyond the shoulder of researcher. The contra lateral leg was kept relaxed and allowed to move as it goes. At the end of the range, the position was held for 10 seconds and limb brought back to the neutral position. The traction was maintained throughout the technique. 3 repetitions were given.

STRENGTH TRAINING:

Week wise strength training protocol was as follows: [(51)]

Strengthening Exercises	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Split Squats	8 Reps	10 Reps	8 Reps	10 Reps	8 Reps	10 Reps
Prisoner Squats	10 Reps	15 Reps	10 Reps	15 Reps	10 Reps	15 Reps
Basketball Pushups (1 Ball)	10 Reps	12 Reps	10 Reps	12 Reps	10 Reps	12 Reps
Basketball Pushups (Feet on Ball)	8 Reps	10 Reps	8 Reps	10 Reps	8 Reps	10 Reps
Forward Lunges	8 Reps	10 Reps	8 Reps	10 Reps	8 Reps	10 Reps
Lateral Lunges	8 Reps	10 Reps	8 Reps	10 Reps	8 Reps	10 Reps

The exercises were performed in 2 sets. The participants were given rest interval of 30 seconds between sets of strengthening exercises [(49)] and 2 minutes rest in between two strengthening exercises. [(50)] Total training time was approximately 90 minutes for both BLR stretching plus strength training.

GROUP C: CONTROL GROUP

This control group performed their routine training activities. Most of the participants commonly performed activities like running, stretching, step up and step down, curl ups and other activities as per their routine.

All test procedures were carried out by same researcher. The same testing procedure and materials were utilized for all participants. Readings were recorded in datasheet.

STATISTICAL ANALYSIS AND RESULT

STATISTICAL TESTS:

Descriptive statistics including mean, standard deviation were analyzed. Descriptive statistics of age, height and weight distribution among 60 participants was done. Mean±SD of age, height and weight were 19.25±1.704, 5.59±0.396 and 59.63±14.250 respectively. ANOVA was used for comparing means between all the three groups. Repeated measures ANOVA was used to compare the means of Vertical jump height and Illinois agility test measures at three time periods –baseline, end of 3rd week and end of 6th week within all the three groups. Results were considered to be significant at $p<0.05$ and confidence interval was set at 95 %. All statistical analysis was performed using SPSS version 20.

Table 3: Mean Comparison of VJH and IAT between three groups using ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
VJH BL	Between Groups	160.075	2	80.038	.936	.398
	Within Groups	4876.638	57	85.555		
	Total	5036.713	59			
VJH 3wk	Between Groups	208.825	2	104.413	1.288	.284
	Within Groups	4620.025	57	81.053		
	Total	4828.850	59			
VJH 6wk	Between Groups	490.408	2	245.204	2.897	.063
	Within Groups	4824.775	57	84.645		
	Total	5315.183	59			
IAT BL	Between Groups	13.027	2	6.514	1.910	.157
	Within Groups	194.381	57	3.410		
	Total	207.408	59			
IAT 3wk	Between Groups	30.110	2	15.055	4.508	.015
	Within Groups	190.367	57	3.340		
	Total	220.477	59			
IAT 6wk	Between Groups	63.172	2	31.586	9.249	.000
	Within Group	194.661	57	3.415		
	Total	257.833	59			

(VJH – Vertical Jump Height, BL – Baseline, IAT – Illinois Agility Test)

Table 3 represents mean comparisons of VJH and IAT between plyometric group, BLR stretching plus strength training group and control group. Significant differences were found between groups for IAT at end of 3rd week and at end of 6th week with p=.015 and p=.000 respectively.

Table 4: Post Hoc analysis of IAT at 3 weeks and 6 weeks between groups

Dependent Variables	I group	J Group	Mean Difference (I-J)	Std. Error	Sig.
IAT 3wk	Plyo	BLR+ST	-1.57*	.577	.023
		Control	-1.425*	.577	.043
	BLR+ST	Plyo	1.57*	.577	.023
		Control	.145	.577	.966
	Control	Plyo	1.425*	.577	.043
		BLR+ST	.145	.577	.966
IAT 6wk	Plyo	BLR+ST	-2.035*	.577	.003
		Control	-2.295*	.577	.001
	BLR+ST	Plyo	2.035*	.577	.003
		Control	-.26	.577	.658
	Control	Plyo	2.295*	.577	.001
		BLR+ST	.26	.577	.658

(IAT – Illinois Agility Test, Plyo – Plyometric, BLR+ST – Bent Leg Raise + Strength Training)

Table 4 shows post hoc analysis of IAT between groups at end of 3rd week. Plyo group showed significant difference than BLR plus strength training group (p=.023) and control

group (p=.043). At the end of 6th week, plyo group showed significant difference than BLR plus strength training group (p=.003) and control group (p=0.001). There was significant decrease in IAT in plyo group as compared to the other groups at the end of 3rd week and a further decrease observed in plyo group at the end of 6th week.

Table 5: Repeated Measures ANOVA of VJH at baseline, end of 3rd week and end of 6th week within groups

	VJH BL	VJH 3wks	VJH 6wks	F	p value
Plyo	33.75±9.35	36..35±9.01	40.675±9.64	235.29	0.00
BLR+ST	37.75±9.15	39.47±9.12	41.87±9.17	173.27	0.00
Control	35.82±9.23	35.02±8.87	35.30±8.76	2.03	0.16

Table 5 represents mean comparisons of VJH at baseline, end of 3rd week and end of 6th week. Significant differences were observed between the three time periods – baseline, end of 3rd week and end of 6th week in plyo and BLR plus strength training groups with p=0.000. However, no significant differences existed in control group when compared for the means at three time periods (p=0.16).

Table 6: Repeated Measures ANOVA of IAT at baseline, end of 3rd week and end of 6th week within groups

	IAT BL	IAT 3wks	IAT 6wks	F	p value
Plyo	20.51±2.23	19.87±2.19	18.99±2.12	62.78	0.00
BLR+ST	21.61±1.70	21.44±1.70	21.02±1.86	20.55	0.00
Control	21.31±1.53	21.30±1.51	21.28±1.49	.53	0.58

Table 6 represents mean comparisons of IAT at baseline, end of 3rd week and end of 6th week. Significant differences were observed between the three time periods – baseline, end of 3rd week and end of 6th week in plyo and BLR plus strength training groups with p=0.000. However, no significant differences existed in control group when compared for the means at three time periods (p=0.58).

Table 7: Pairwise Comparisons of VJH and IAT in plyo group

Measure	I (Time)	J (Time)	Mean Difference (I-J)	Std. Error	Sig.
VJH	BL	3wks	-2.60*	.187	.000
		6wks	-6.92*	.339	.000
	3wks	BL	2.60*	.187	.000
		6wks	-4.32*	.403	.000
	6wks	BL	6.92*	.339	.000
		3wks	4.32*	.403	.000
IAT	BL	3wks	.63*	.119	.000
		6wks	1.52*	.153	.000
	3wks	BL	-.63*	.119	.000
		6wks	.88*	.135	.000
	6wks	BL	-1.52*	.153	.000
		3wks	-.88*	.135	.000

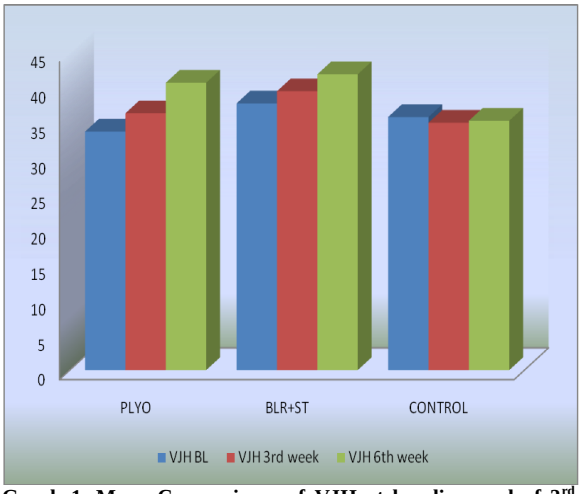
Table 7 represents pairwise comparisons of VJH and IAT at baseline, end of 3rd week and end of 6th week. Significant differences were observed between the three time periods – baseline, end of 3rd week and end of 6th week in plyo and BLR plus strength training groups with p=0.000. Mean values of VJH increased on 6th week post training as compared to baseline and 3rd week whereas a decrease in mean of IAT was observed on 6th week post training as compared to baseline and 3rd week.

Table 8: Pairwise Comparisons of VJH and IAT in BLR+ST group

Measure	I (Time)	J (Time)	Mean Difference (I-J)	Std. Error	Sig.
VJH	BL	3wks	-1.72*	.160	.000
		6wks	-4.12*	.232	.000
	3wks	BL	1.72*	.160	.000
		6wks	-2.40*	.263	.000
	6wks	BL	4.12*	.232	.000
		3wks	2.40*	.263	.000
IAT	BL	3wks	.17*	.040	.000
		6wks	.59*	.106	.000
	3wks	BL	-.17*	.040	.000
		6wks	.42*	.118	.000
	6wks	BL	-.59*	.106	.000
		3wks	-.42*	.118	.000

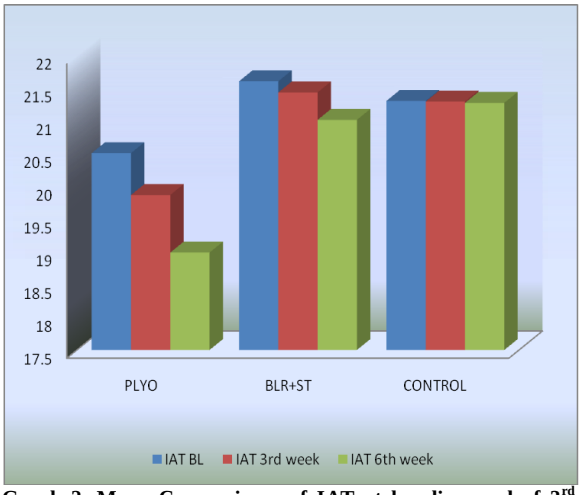
Table 8 represents pairwise comparisons of VJH and IAT at baseline, end of 3rd week and end of 6th week. Significant differences were observed between the three time periods – baseline, end of 3rd week and end of 6th week in plyo and BLR plus strength training groups with p=0.000. Mean values of VJH increased on 6th week post training as compared to baseline and 3rd week whereas a decrease in mean of IAT was

observed on 6th week post training as compared to baseline and 3rd week.



Graph 1. Mean Comparisons of VJH at baseline, end of 3rd week and end of 6th week between and within groups

Graph 1 represents that there is increase in Vertical Jump Height in both plyo and BLR plus strength training group at the end of 3rd and 6th week (between groups). But more increase is found in plyo group as compare to BLR plus strength training and control group from baseline to end of 6th week (Within group). There is no difference found in control group.



Graph 2. Mean Comparisons of IAT at baseline, end of 3rd week and end of 6th week between and within groups

Graph 2 represents that there is decrease in time in both plyo and BLR plus strength training group at the end of 3rd and 6th week (Between groups). But more decrease is found in plyo group as compare to BLR plus strength training and control group from baseline to end of 6th week (Within group). There is no difference found in control group.

DISCUSSION

The present study was conducted to determine the effects of plyometric training and BLR stretching plus strength training on vertical jump height and agility. It also aimed to compare the effects of plyometric training with bent leg raise stretching plus strength training on above mentioned outcome measures. Results of this study showed that there was significant difference in IAT at the end of 3rd week and 6th week of the study with p=0.015 and p=0.000 respectively (Table 3). Post Hoc analysis revealed plyometric group to be effective in improving agility as compared to the other two groups (Table 4). There was a difference of 1.57 seconds between plyometric and BLR plus strength training group and a difference of 1.425 seconds was observed between plyometric and control groups.

A study by Hamdy Kassem [52] concluded that plyometric exercise improves physical abilities and skillful performance. However, this study found a highly significant change in difference in percentage between the two groups (27.01%). The present study however, did not find improvements in vertical jump height as high as the above mentioned study. One reason can be attributed to the fact that our study applied plyometric exercises for a period of 6-weeks.

Studies by Faigenbaum et al., [53] showed that plyometric exercises combined with resisted training did not have any significant effect on vertical jump height. However, they found improvements in pro agility shuttle run time. These results were in contrast to our results which found plyometric group showing a significant improvement in vertical jump height as compared to other groups.

In Arabi (1994) research, the effect of weight training and plyometric exercises was assessed separately after the end of

training. Most of the studies conducted in the past Ford et al., [42] Adams et al., [39] Rahimi, [54] Duke and Ben Eliyahu, [55] and Fowler et al. [56] focused on studying the effect of combining plyometric exercises with resisted exercise or other forms of exercise. Whereas the present study focused on studying the comparative effects of plyometric exercise against a combination of weight training exercise and bent leg raise stretching.

Study by Fatouros et al., [57] focused on the effect of three training protocols – plyometric training, weight training, plyometrics plus weight training on vertical jump performance and leg strength. They found significant increase in vertical jump performance in combination exercise group than other two groups. Study by John Shaji and Saluja Isha [13] focused on comparative analysis of Plyometric training program and dynamic stretching on vertical jump and agility in male collegiate basketball player. The result demonstrates that the vertical jump height readings for the Sergeant jump test was improved by 4.8 cm (10.2%) in dynamic stretching group and 3.6 cm (7.9%) in plyometrics group while the group which received both i.e. dynamic stretching and plyometrics showed most significant improvement in vertical jump height by 7.6 cm (16.1%) which was statistically significant. The T-test agility score time was improved by 5.12% in dynamic stretching group, 6.20% in plyometric training group and by 10.67% in the Group which received dynamic stretching as well as plyometrics.

In our study repeated measure ANOVA was used. For the plyo group, mean comparison of VJH at baseline, end of 3rd week and end of 6th week was 33.75±9.35, 36.35±9.01 and 40.675±9.64 respectively with a difference of 6.925cm. For the BLR stretching plus strength training group, mean comparison of VJH at baseline, end of 3rd week and end of 6th week was 37.75±9.15, 39.47±9.12 and 41.87±9.17 respectively with a difference of 4.12cm. For control group, mean comparison of VJH at baseline, end of 3rd week and end of 6th week was 35.82±9.23, 35.02±8.87 and 35.30±8.76 respectively with a difference of 0.52cm. For the plyo group, mean comparison of IAT at baseline, end of 3rd week and end of 6th week was 20.51±2.23, 19.87±2.19 and 18.99±2.12 respectively with a difference of 1.52s. For the BLR stretching plus strength training group, mean comparison of IAT at baseline, end of 3rd week and end of 6thweek was 21.61±1.70, 21.44±1.70 and 21.02±1.86 respectively with a difference of 0.59s. For control group, mean comparison of IAT at baseline, end of 3rd week and end of 6thweek was 21.31±1.53, 21.30±1.51 and 21.28±1.49 respectively with a difference of 0.03s.

There was overall improvement in vertical jump height and agility score in plyometric and BLR plus strength training is consistent with the result of a study of comparative analysis of Plyometric training program and dynamic stretching on vertical jump and agility in male collegiate basketball player. The improvements achieved were the result of enhanced neuromuscular function. The occurrence of 'post activation potentiation' is believed to increase the rate of force development, thereby increasing speed and power production as described by Sale D et al., [58]

There is evidence to support the concept that an a six week, multi-component training program which included resistance training, plyometric training and speed training significantly enhanced strength, jumping ability and speed in female adolescent athletes as compared to a no exercising control group. [59]

Study by Miller G. et al., [30] focused on the effects of a 6-week Plyometric training program on agility. The results showed that the plyometric group improved their T-Test agility times by −0.62 ± 0.24 sec, while the control group times were virtually unchanged 0.01 ± 0.14 sec. The plyometric training group improved their Illinois agility test times by −0.50 ± 0.32 sec and the control group times changed by −0.01 ± 0.05 sec. In our study, subjects who underwent plyometric training were able to

improve their agility in measures of times significantly at end of 3rd and end of 6th week.

Effects of BLR plus strength training which was compared to plyometrics in our study has not been used in combination in any other studies. There were plenty studies on combinations of plyometrics and strength training but the authors could not find BLR plus strength training. The reason for choosing BLR plus strength training can be justified by the fact that it has similar dynamic stretching and strength improvement characteristics which can be compared to plyometrics and at the same time more safe as compared to plyometrics. However, our study results when compared between groups did not show significant improvements in vertical jump height and showed plyometrics to be a better exercise method to improve both vertical jump height and agility as compared to BLR plus strength training.

In contrast, within group comparisons of baseline, end of 3rd week and end of 6th week measurements of VJH and IAT using repeated measures ANOVA showed that there was significant improvement in VJH in both plyometrics and BLR plus strength training groups as compared to control group (Table 5). An increment of 6.92 cm was observed in plyometric group whereas an increment of 4.12 cm was observed in BLR plus strength training group. These changes can be considered clinically significant, however the mechanism behind the increase and its effect duration are unclear.

For IAT, there was a decrease of 1.52s in plyometric group and a decrease of 0.59s in BLR plus strength training group. In sports like basketball, agility is a major component to improve performance. The changes observed as a result of the interventions used in the study prove to increase the agility of the participants with plyometric group better than the other experimental group.

CONCLUSION

Plyometrics and BLR plus strength training for a period of six weeks can improve VJH and agility in basketball players. Improvements in VJH were observed at end of 3rd week after plyometric training and BLR plus strength training which improved even better at the end of 6th week suggesting a long term training effect. Improvements in agility were observed at end of 3rd week after plyometric training which improved even better at end of 6th week, but these changes were present only in the plyometric group. Regular training in the form of running, stretching, step up and step down, curl ups and other activities as per their routine in basketball players was not sufficient to improve VJH and agility.

Limitations

This study focused on set of plyometric exercises without preferences on outcome measures. Since variations in Plyometrics exercises exists, Plyometrics exercises specifically targeting outcome measures can be used for training. Flexibility was not included as an outcome measure, even though BLR stretching was used as a technique in one of the groups.

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