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# LOW INTENSITY PLYOMETRICS VERSUS PNF STRETCHING ON VERTICAL JUMP HEIGHT AND AGILITY IN COLLEGIATE BASKETBALL PLAYERS

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**ABSTRACT**

**Background:** Speed, jump, agility are important components in basketball. Lack of skills in a variety of directions and in an uncontrolled manner has been shown to predispose a person to several musculoskeletal injuries and significantly affect a person's level of performance.
**Objective:** To determine the effectiveness of PNF stretching and Low Intensity Plyometrics training for improving vertical jump height and agility.
**Method:** 60 participants of college basketball players were allocated into two groups (30 participants in each group). The outcome measure used was SVJT and IA test. Subjects of group A underwent with Low Intensity Plyometrics training, whereas the subjects of group B underwent with PNF stretching. For both experimental groups, the technique was performed three times a week for a total training period of four weeks.
**Results:** The results of this study indicated significantly ($p< 0.05$) improvements in vertical jump height and agility from post- test occurred for both LIP and PNF groups when compared to pre-test. There were also no significant differences ($p> 0.05$) between groups.
**Conclusion:** Both the treatment techniques found to be effective. However, Low Intensity Plyometrics showed better results when compared to PNF stretching in improving Vertical Jump Height and Agility in collegiate basketball players.



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## INTRODUCTION

Basketball is an extremely dynamic sport that requires movements in multiple planes of motion as well as rapid transitions from jogging to sprinting to jumping. The ability to quickly elude defenders, rapidly decelerate to take a jump shot or explosively jump up to grab a rebound are skills required to effectively play the sport (Scott Lucett, 2013). It is equally important for the athlete to be able to perform these skills in a variety of directions and in a controlled manner to ensure injuries do not ensue. Due to the myriad of physical demands that come with the sport makes speed and agility training a crucial component to incorporate into a basketball training program (Scott Lucett, 2013). Agility is often defined in terms of an individual sport, due to it being an integration of many components each used differently (specific to all of sorts of

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different sports). Sheppard and Young (2006) defined agility as a "rapid whole body movement with change of velocity or direction in response to a stimulus (Warren, 2015). Agility is the ability to change the direction of the body in an efficient and effective manner and to achieve this requires a combination of balance (the ability to maintain equilibrium when stationary or moving (i.e. not to fall over) through the coordinated actions of our sensory functions (eyes, ears and the proprioceptive organs in our joints)), static balance (the ability to retain the centre of mass above the base of support in a stationary position, dynamic balance (the ability to maintain balance with body movement), speed (the ability to move all or part of the body quickly), strength (the ability of a muscle or muscle group to overcome a resistance and lastly, co-ordination – the ability to control the movement of the body in co-operation with the body's sensory functions (e.g., in catching a ball [ball, hand, and eye coordination]).

Athlete body built, body size, and body composition had determinant effects on sport performance. The bigger the athlete, the better the performance in certain sports (football, basketball volleyball) and is not always same, smaller and lighter are considered to be better for performance (gymnastics, diving, figure skating) (Jack H. Wilmore, ?). Each aspect of athlete's physical and mental capabilities determines their performance. The decrease in performance is found due to poor warm-up techniques and time period, poor modification of shoes, increase duration of activity, faulty practice of stretching (Jack H. Wilmore, ?). Plyometrics training is defined as a system of high velocity resistance training characterized by a rapid eccentric contraction during which the muscle elongates, immediately followed by a rapid reversal of movement with a resisted shortening contraction of the same muscle (Carolyn Kisner, ?). Plyometrics activities for the upper and lower extremities are dribbling a ball on the floor or against a wall, clap pushups repetitive jumping on the floor in place, forward/ backward, side to side, diagonally to four corners, jump with rotation, zigzag jumping etc.

It is one such training strategy to improve the performance of the basketball players as the training approximates the basic needs of agility and power, allows the muscle to reach exponential increase in the maximum strength and speed of movement in the shortest duration.[5] Delayed onset of muscle soreness (DOMS) and soft tissue injury increasingly remains the potential risks of long duration and high- intensity Plyometrics training program that can have a detrimental effect on player performance. The dynamic stretching incorporated in to the Plyometrics training will help overcome the risks of DOMS and soft tissue injuries. Further low to moderate intensity Plyometrics training program is reported to have better gains in vertical jump height and agility than the high intensity Plyometrics training program (Selvam Ramachandran and Binita Pradhan, 2014). A warm up is vital in order to increase body temperature and blood flow to the muscles before exercising (Baechle and Earle, 2008). Suel conducted a study to evaluate the effect of skill- based maximal intensity training on power, agility and speed (PAS) in female team sport players. 31 subjects participated (basketball n= 10, handball n= 10, volleyball n= 11).Training program was conducted for 8 weeks and it was concluded that the training model can boost training efficiency, while the improvement of PAS can provide a competitive advantage for the female players (Suel, 2015).

Pojskic H, et.al, conducted a study to compare the effects of different warm-up interventions on jump, sprint and agility performance in collegiate soccer players. 21 subjects underwent four different randomized warm-up protocols (no conditioning contraction protocol (NCC), dynamic stretching (DS), prolonged intermittent low-intensity isometric exercises (ST) and ST with an additional external load equal to 30% of body weight). This study concluded that, a prolonged intermittent low- intensity isometric protocol using bodyweight only showed similar benefits with dynamic stretching in counter movements jump performance. When the same isometric condition with additional load equal to 30% of bodyweight was applied; effects in speed and agility were similar to dynamic stretching (Pojskic et al., 2015).

Alberto Carvalho, et.al, conducted a study to investigate the effects of a strength training program combined with specific plyometric exercises on body composition, vertical jump (VJ) height and strength development of lower limbs in elite male handball players. 12 male handball players participated for 12 week program with combined strength and specific plyometric exercises was carried out for 7 weeks. The conclusion was combining general strength- training with plyometric exercises can not only increase lower limb strength and improve VJ performance but also reduce body fat content (Alberto Carvalho, 2014). Abbas Fatahi- Bafghi, et.al, conducted a study to investigate enduring effect of stretching, dynamic stretching and no stretching methods on power and agility in collegian soccer players. 15 subjects participated and got result that collegian soccer players probably perform better agility and power after dynamic stretching as compare to static stretching and their muscular performances could be able to sustain in higher level as compare to static stretching (Abbas Fattahi- Bafghi and Mohammadtaghi Amiri- Khorasani, 2013). Mark Vaczi, et.al, conducted a study to investigate the effects of a short-term in-season plyometric training program on power, agility and knee extensor strength. Male soccer player were divided into two groups experimental and controlled group. Result of the study was that plyometric training consisting of high impact unilateral and bilateral exercises induced remarkable improvements in lower extremity power and maximal knee extensor strength and smaller improvements in soccer- specific agility. So the conclusion was that short-term plyometric training should be incorporated in the in-season preparation of lower level players to improve specific performance in soccer (Mark Vaczi et al., 2013).

Hubert Makaruk, et.al, conducted a study to examine the effects of unilateral and bilateral plyometric exercises on peak power and jumping performance during different stages of a 12 week training and detraining in women. 49 subjects were divided into three groups unilateral plyometric group (n- 16), bilateral plyometric group (n= 18) and control group (n=15).the result was unilateral plyometric exercises produce power and jumping performance during a shorter period when compared to bilateral plyometric training (Hubert Makaruk et al., 2011). Ali Aalizadeh, et.al, conducted a study to assess the effects of short term plyometric training program on sprint, strength and power and agility performance in non- athletic men. And they concluded that plyometric training have been effective on the physical preparation indices and can improve the non athletes performance (Ali Aalizadeh et al., 2015). Flexibility exercises are commonly used as a warm- up in sports and other physical activities. Stretching is traditionally used as part of a warm up to increase flexibility or pain- free

range of motion (ROM) about a joint in an attempt to promote better performances and/ or reduce the risk of injury[26]. In flexibility training, the static, dynamic or proprioceptive neuromuscular facilitation (PNF) techniques are used (Carvalho et al., 2009, Marek et al., 2005). Similarly, Mahmoud Raouf and Sahar Kamankesh noted the significant increase in the range of motion ($p < 0.05$). And assume reason behind their studies was the notion that PNF stretching has been shown to produce an increases in musculotendinous unit stiffness which is believed to be linked to an increased ability to store and release elastic energy (Mahmoud Raouf, 2014). Proprioceptive neuromuscular facilitation (PNF) is a stretching technique utilized to improve muscle elasticity and has been shown to have a positive effect on active and passive range of motions (Funk et al., 2003; Lucas and Koslow, 1984; Wallin et al., 1985). Two techniques are seen in the literature more frequently than others, the contract- relax method (CR) and the contract-relax-antagonist-contract method (CRAC) of PNF. The CR method included the target muscle ™ being lengthened and held in that position while the participant contracted the TM to its maximum isometrically for an allotted amount of time. This was followed by a shorter relaxation of the TM that usually included a passive stretch (Etnyre nd Abraham, 1986). The CRAC method followed the exact same procedure as the CR method, but was continued further. Instead of just passively stretching the TM, the participant contracted the antagonist muscle to the TM for another allotted period of time (Etnyre and Abraham, 1986).

Dr. Gopal Chandra Saha conducted a study to investigate the effect of PNF stretching on muscular strength and flexibility of non athletic college students. Hundred non- athletic subjects (50 male and 50 female). Conclusion was that significant difference was observed between pre-test and post-test on Sergent Vertical Jump test and Sit and Reach test for male as well as female non athletic college students (Gopal Chandra Saha, 2012). Kayla B. Hindle et al. conducted a study to review possible mechanisms, proposed theories and physiological changes that occur due to proprioceptive neuromuscular facilitation techniques. Four theoretical mechanisms were identified: autogenic inhibition, reciprocal inhibition, stress relaxation, and the gate control theory. This study suggests that a combination of these four mechanisms enhance range of motion. When proprioceptive neuromuscular facilitation stretching technique is performed consistently and post exercise, it increases athletic performance, along with range of motion (Kayla et al., 2012).

Costa E Silva et al conducted a study to investigate the acute effect of static stretching (SS) and proprioceptive neuromuscular facilitation (PNF) stretching on front crawl swimming performance. 13 young males were submitted to three randomly select experimental protocols as follows A) 50 m front crawl swimming maximal sprint test without any stretching training (CTRL). B) 50 m crawl swimming maximal sprint test preceded by SS (2 sets of 30 s) for pectoral and quadriceps muscles (SS) and C) 50 m crawl swimming maximal sprint test preceded by PNF (2 sets of 30 s using the scientific stretching for sports (3S) method) for pectoral and quadriceps muscles (FNP). The result demonstrated that SS and PNF caused statistically significant deleterious effects on swimming performance as evaluated by time taken to complete a 50 m front crawl swimming test (Costa et al., 2014). Paul S. Bradley et al. (2007) study was to compare the acute effects of different modes of stretching on vertical jump performance. They concluded that the vertical jump performance is diminished for 15 minutes if performed after static or PNF stretching, whereas ballistic stretching has little effect on jumping performance. Therefore, this type of stretching (PNF/ Static) may be particularly useful for athletes during breaks in competition (e.g., halftime in a soccer game) and for reserves or substitutes who are warming up (Michal Lehnert et al., 2013). Similarly, Carlos J. Nogueira et al., also noted the negative effects of the PNF stretching on the vertical jump performance[45]. Whereas, there are also few studies done who noted the positive effect of PNF stretching on performance. Like, NikBakht Hojatallah *et al.,* conducted a study to determine the effects of the proprioceptive neuromuscular facilitation (PNF) stretching on explosive power and agility. The finding of this study was a significant increase in vertical jump performance for experimental group during PNF stretching ($P=0.001$). And showed no significant difference ($p<0.05$) in agility (NikBakht Hojatallah et al., 2012).

## METHODS

An comparative study was conducted on total of 60 young collegiate basketball players (age 18 to 25years, gender male and female) who were included from Padmashree group of institutions based on the inclusion and exclusion criteria Subjects were randomly assigned into two groups:

Group A – Low Intensity Plyometrics training (n=30). Group B – PNF stretching (n= 30)

A proper warm up for 30 min, consisting of jogging in a place, forward and backward arms swing, side to side trunk rotation with arms extended outwards, forward and backward leg swings and side to side leg swings was performed before testing.

**Testing method**: Vertical jump height: The vertical jump height was assessed by SVJT. This was plotted on a sheet using a standard measuring tape and was fixed on a wall vertically. Subjects were instructed to stand flat foot next to a wall on their right side and right arm extended above the head by holding the chalk to mark the highest point reached on the sheet. During the jump bend the knees (squat) followed by a maximal effort of vertical jump and mark the highest point reached on a sheet. Three trials were given with a 45 seconds rest between each jump for recovery. The highest point was recorded for analysis. Agility: Agility was assessed using the Illinois agility test (IAT). The test was conducted on a ground. Time was recorded using a stopwatch. The IAT set up was done with four cones forming the agility area (10m long x 5m wide). A cone was placed at each corner. Another four cones were placed in the center of the testing area, 3.3 m from each other. During agility test, the subject started on the floor, face down, and begins with a command “start”. The subjects were instructed and motivated verbally to complete the circuit as fast as possible. Three trials were given with 60 seconds rest in between each trial. The shortest time taken to complete the circuit was recorded for analysis. After testing the vertical jump height and agility of two groups, particular training was given to each subject. Training was done three times per week for a period of four weeks. And total training timing was approximately 90 minute.

**Group A**: Group A were given Low Intensity Plyometric exercise training. Each exercise was done for 10 minute with 2-3 minute rest period in between each set. Exercises were:-

| S.no | Exercises | Set x repetitions |
|---|---|---|
| 1 | Zigzag drill | 2 sets x 5 repetitions each |
| 2 | $180^0$ jump in place | 2 sets x 10 repetitions each |
| 3 | Side- to- side jump | 2 sets x 10 repetitions each |
| 4 | Single leg jump in place | 1 set x 10 repetitions |
| 5 | Side-to-side alternate leg jump | 1 set x 10 repetitions |
| 6 | Alternate single leg jump on marked point (cross pattern) | 1 set x 10 repetitions |

**Group B**

Group B was given PNF stretching (hold relax). Each stretch was done alternatively on both legs for 30 seconds and was repeated three times with 1 minute rest period in between each stretch. Stretches were as follows: Quadriceps stretch: In standing position with back straight, bend the right knee and pull the ankle/ foot with the right hand towards buttock. Hold for 15 seconds and then rest for 10 seconds. Again, bend the right knee and pull the ankle/ foot more and hold for 15 seconds then relax. Hamstring stretch: In sitting position with leg extended and wide apart. Bend towards right knee and reach the feet with both hands. Hold it for 15 seconds and relax for 10 seconds. Again, bend more towards right knee and hold it for 15 seconds than relax. Calf stretch: In walking style (standing position) with back straight. Step forward on left leg, keeping both feet flat on the floor and right leg straight. Bend left knee and rest both hand on left thigh. Hold it for 15 seconds than 10 seconds rest. Again, bend the left knee more and hold it for other 15 seconds than relax.

## DATA ANALYSIS

- Data analysis was performed by using SPSS software (version 17) for windows.
- Alpha value was set as 0.05
- Descriptive measures such as range mean and standard deviation was used.
- Unpaired t-test was used to find out significant difference among demographic variable such as age.
- Chi – square test was performed to find out the gender differences among both groups.
- Paired t- test was used to find out significant difference within group for LIP and PNF stretching.
- Microsoft Excel and Word was used to generate graph and tables.

# RESULTS

The table shows the proportion of basket ball players according to gender. In group -A, the subjects administered with low intensity plyometric execises 20(66.7%) of them were males and 10(33.3%) of them were females. In group-B, the subjects administered with PNF stertching, 21(70.0%) were males and 9(30.0%) were females.

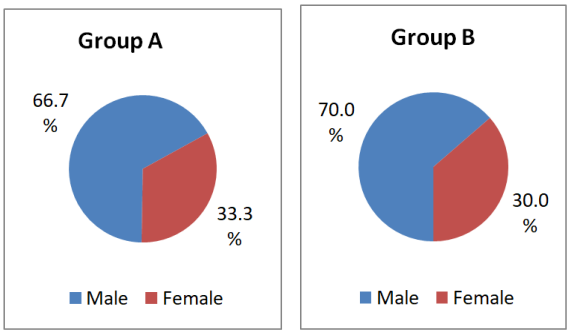
**Table 2. Distribution of basket ball players according to gender in both groups**

| Sno | Gender | Group | |
|---|---|---|---|
| | | Group-A | Group- B |
| 1 | Male | 20(66.7%) | 21(70.0%) |
| 2 | Female | 10(33.3%) | 9(30.0%) |
| | | Chi-Square value=0.077, df=1, p=0.781,NS | |

NS-Not significant. ie.,p>0.05.

There is no variation in between the groups according to gender and it was not significant ($\chi^2$=0.077, df=1) at 5% level ie., p>0.05.

It evidenced the baseline characteristic of gender is homogeneous in both the groups.



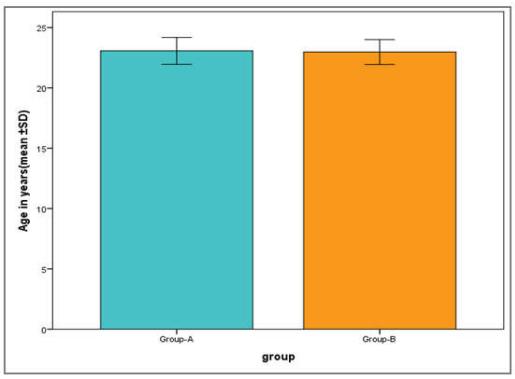

**Graph 1. Distribution of subjects according to gender in both groups**

**Table 3. Range, mean and SD of age among basket ball players in both the groups**

| Sno | Variable | Group-A | | Group-B | | Unpaired t-test |
|---|---|---|---|---|---|---|
| | | Range | Mean ± SD | Range | Mean ± SD | |
| 1 | Age in years | 21-25 | 23.07± 1.11 | 21-24 | 22.97± 1.03 | t=0.3342, p=0.745, NS |

NS-Not significant. ie.,p>0.05.

The table 2 presents the outcomes of age in years of the basket ball players in both the groups. In group-A the subjects were ranging within the age of 21-25 with mean 23.07 and SD of 1.11. In group-B the subjects were ranging within the age of 21-24 with mean 22.97 and SD of 1.03. The unpaired t-test was carried to compare the means, which was found to be not significant at 5% level (ie., p>0.05). It revealed that the baseline characteristic of age was similar in both the groups.



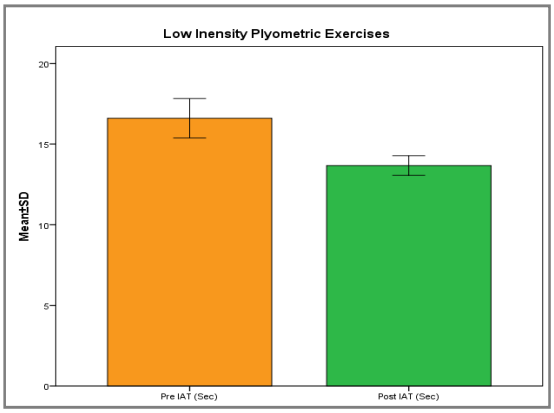

**Graph 2. Distribution of subjects according to age in both groups**

The above table-3 shows the outcomes of vertical jump in cinches(VJT) and agility in seconds(IAT) among the basket ball players treated by low intensity plyometric execises in group-A.

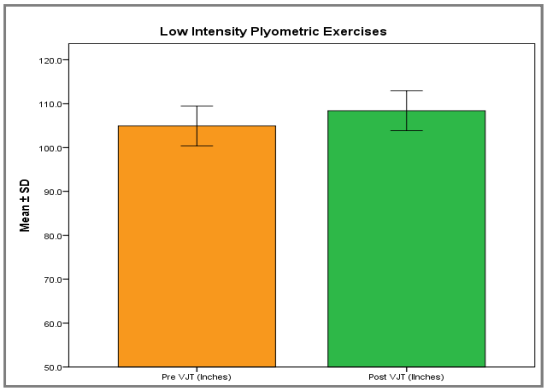
**Table 4. Range, mean and SD vertical jump (VJT) and Illinois agility test (IAT) of basketball players in group-A**

| Sno | Outcome measures | Low Intensity Plyometric Exercises | | | | Paired t- test | p-value |
|---|---|---|---|---|---|---|---|
| | | Pre test | | Post test | | | |
| | | Range | Mean ±SD | Range | Mean ±SD | | |
| 1 | VJT(Inches) | 97-113.5 | 104.92±4.54 | 100.3-117.2 | 108.38±4.51 | 27.48* | p=0.0001 |
| 2 | IAT(Sec) | 15-19 | 16.60±1.22 | 13-15 | 13.67±0.60 | 13.70* | p=0.0001 |

Note; * denotes –Significant (p<0.05).




**Graph 3. Pre and post difference within group A for SVJT score**




**Graph 4. Pre and post difference within group A for IAT score**

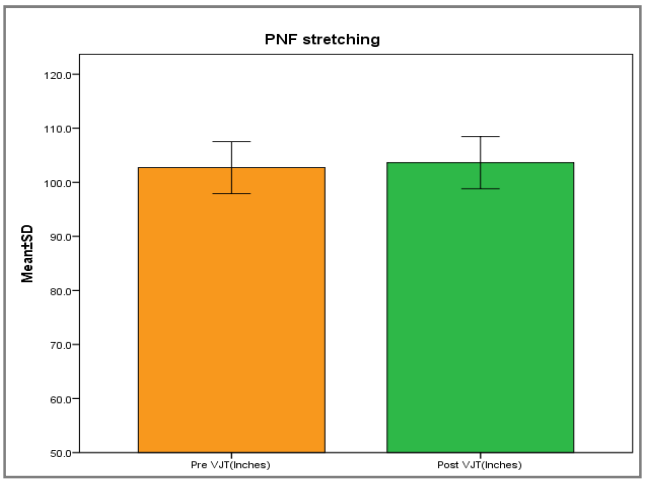
**Table 5. Range, mean and SD vertical jump (VJT) and Illinois agility test (IAT) of basket ball players in group-B**

| Sno | Outcome measures | PNF Stretching | | | | Paired t- test | p-value |
|---|---|---|---|---|---|---|---|
| | | Pre test | | Post test | | | |
| | | Range | Mean ±SD | Range | Mean ±SD | | |
| 1 | VJT(Inches) | 94.2 -112.5 | 102.60 ±4.81 | 95 -113.6 | 103.63 ±4.82 | 11.31* | p=0.001 |
| 2 | IAT(Sec) | 15-20 | 17.55 ±1.40 | 14-19 | 16.27±1.36 | 8.09* | p=0.001 |

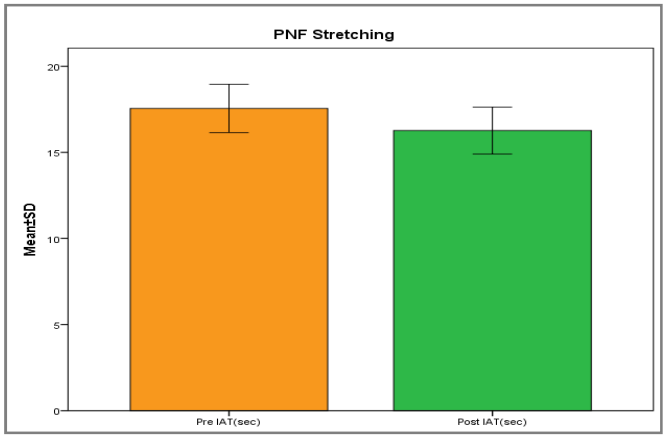
Note; * denotes –Significant (p<0.05).

In pre test, the VJT (inches) was ranging within 97-113.5 with mean 104.92 and SD 4.54. But in post test, the VJT (inches) was ranging within 100.3-117.2 with mean 108.38 and SD 4.51. The parametric test for comparison of dependent outcomes, the paired t-test was carried out and it was found to be significant at p=0.0001 (p<0.05). On other hand regarding the outcome measure of agility through IAT (Sec) was ranging within 15-19 with mean 16.60 and SD 1.22 in pre test. But, in post test it was ranged within 13-15 with mean 13.67 and SD 0.60. The parametric test for comparison of dependent outcomes, the paired t-test was carried out and it was found to be significant at p=0.0001 (p<0.05). It is evidenced that there is significant increase in VJT in inches and significant decrease in IAT (Sec) and hence the low intensity plyometric exercises was effective in improving the vertical jump and agility among the basket ball players.

The above table-3 shows the outcomes of vertical jump in cinches(VJT) and agility in seconds(IAT) among the basket ball players treated by PNF stretching in group-A. In pre test, the VJT (inches) was ranging within 94.2-112.5 with mean 102.60 and SD 4.81. But in post test, the VJT (inches) was ranging within 95-113.6 with mean 103.63 and SD 4.82. The parametric test for comparison of dependent outcomes, the paired t-test was carried out and it was found to be significant at p=0.001 (p<0.05). On other hand regarding the outcome measure of agility through IAT (Sec) was ranging within 15-20 with mean 17.55 and SD 1.40 in pre test. But, in post test it was ranged within 14-19 with mean 16.27 and SD 1.36. The parametric test for comparison of dependent outcomes, the paired t-test was carried out and it was found to be significant at p=0.001 (p<0.05). It is evidenced that there is significant increase in VJT in inches and significant decrease in IAT (Sec)




**Graph 5. Pre and post difference within group B for SVJT score**




**Graph 6. Pre and post difference within group B for IAT score**

**Table 6. Comparison of pre and post test vertical jump (VJT) and Illinois agility test (IAT) among the basket ball players in between the two groups**

| Sno | Outcome measures | Pre test | | Post test | |
|---|---|---|---|---|---|
| | | Group-A Mean ±SD | Group-B Mean ±SD | Group-A Mean ±SD | Group-B Mean ±SD |
| 1 | VJT(Inches) | 104.92±4.54 | 102.60±4.81 | 108.38±4.51 | 103.63±4.82 |
| 2 | IAT(Sec) | 16.60±1.22 | 17.55±1.40 | 13.67±0.60 | 16.27±1.36 |
| Between group comparison Unpaired t-test | | ➢ VJT: t=1.742, p=0.092, NS<br>➢ IAT: t=1.682, p=0.12, NS | | ➢ VJT: t=3.92, p=0.001, S<br>➢ IAT: t=2.68, p=0.003, S | |

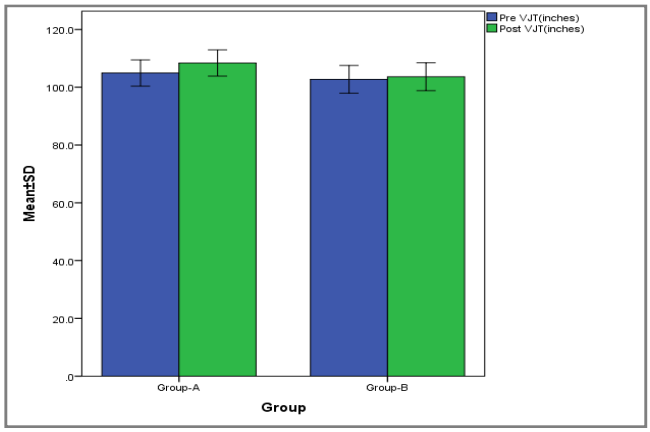
S-denotes significant (p<0.05); NS – not significant (p>0.05)

and hence the PNF Stretching was effective in improving the vertical jump and agility among the basket ball players. The above table-5 presents the outcomes of between group comparison of VJT (inches) and IAT (sec) among the basket ball players in between the two groups. The pre test scores of VJT(inches) 104.92±4.54 in group-A and 102.60±4.81 in group-B were more are less same and it not significant(p>0.05) . Similarly the IAT (sec) 16.60±1.22 in group-A and 17.55±1.40 in group B were not statistically significant (p>0.05). It evidenced that initially before the intervention the basket ball players in both the groups were similar in vertical jump and agility. But, while comparison of post test scores of VJT (inches) 108.38±4.51 in group-A is more than the VJT (inches) 103.63±4.82 in group-B and it was statistically significant. Similarly, while comparison of post test IAT (sec) 13.67±0.60 in group-A, is less than the IAT (sec) 16.27±1.36 in group-B and it was statistically significant.

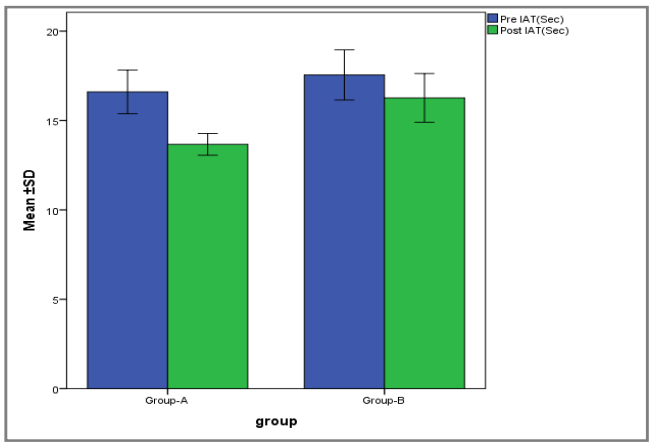
It evidenced that though both Low intensity plyometric exercises and PNF stretching individually effective in improving the vertical jump and agility of basket ball players, But, the low intensity plyometric exercises is significantly better than PNF stretching.

## INTERPRETATION OF RESULT

Subjects of group A were undergone to low intensity plyometric training, whereas the subjects of group B were undergone to PNF stretching. Paired t-test was used within the group and unpaired t-test was used in between group to determine and compare the effectiveness of low intensity plyometric and PNF stretching training. The results demonstrated significant improvement in vertical jump height and agility for subjects of group A when compared with those of group B (P= 0.001) at the end of four weeks.




**Graph 7. Between groups for SVJT score**




**Graph 8. Between groups for IAT score**

Although the study supports the experimental hypothesis that low intensity plyometric training is more effective than PNF stretching training for improvement of vertical jump height and agility but both the training are almost equal in their clinical effectiveness for improving vertical jump height and agility and that either of the training may be used in sports for improving vertical jump height and agility.

## DISCUSSION

The study was aimed to determine the effect of low intensity plyometric training and PNF stretching on vertical jump height and agility on collegiate basketball players. And also to compare the effect of low intensity plyometrics versus PNF stretching on vertical jump height and agility on collegiate basketball players. The baseline demographic variables were homogeneous in nature in both the groups. In group A there were 20 male subjects and 10 female subjects. Similarly, in group B there were 21 male subjects and 9 female subjects. The mean age in group A, was 23.7 with SD of 1.11 and in group B the mean age was 22.97 with SD of 1.03. In group A, the mean vertical jump height and agility has improved significantly. Possible explanation for the improved vertical jump height and agility for the subject in group A could be because of rapid eccentric action immediately followed by a concentric action of the muscle and connective tissue aiming at the development of maximum force in the shortest possible time (Bosco, 1985; Potach and Chu, 2008). This regime of muscle contractions called the stretch- shortening cycle (SSC) is a typical part of muscle activity in a number of specific basketball activities such as acceleration, changing the direction of running, vertical jump (shooting, blocking, rebounding), passing (Michal Lehnert et al., 2013). Plyometric training (PT) leads to an adaptation of CNS for a faster development of reaction strength during work and for improved utilization of elastic energy generated in elastic elements of the muscle tissue and tendons during the stretching phase of SSC (Bosco, 1985; Ishikawa and Komi, 2003; Potach and Chu, 2008). Cormie, Guigan, and Newton (2011) clarify the interactions between the contractile and elastic elements and point out that their different length- shortening behaviour is vital in SSC movements. Moreover, the power/ strength produced during the initial phase of the stretch- shortening cycle positively influences neuromuscular control and joint stabilization. From this point of view, decreased inhibition of muscle reflex, increased threshold of golgi receptors, and improved sensitivity of neuromuscular spindles are the most important adaptations (Bompa and Carrera, 2005; Boyle, 2004). In addition, plyometrics educate the muscles to pre stretch prior to jumping. Pre stretching led the muscles to store potential energy in them that aids to jump higher (Singh Harmandeep et al., 2005). Train the fast muscle fibers and the nerves activate them as well as reflex hence it is one of the primary tool which enhance both i.e strength and speed. Enhancement of explosive reaction takes place as a result of rapid eccentric contractions. This enhancement was due to some adaptive change in neuro-muscular functioning of body viz. improvement in nerve-based command to muscles of agonist group, improvement in intermuscular coordination, modification of muscle shape or size, changes in mechanism of single- fiber, increasement in the interaction of muscle fibers and tendinous tissue (Singh Harmandeep et al., 2005).

Eduardo Saez Saez De Villarreal conducted a study to examine the low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency and noted, enhancement in 20- m sprint time, jumping contact times and maximal strength by performing both a moderate and low number of jumps compared to high training volumes. By doing so, one could obtain similar explosive jumping enhancement with a smaller risk of muscular and articulation overload (Eduardo Saez Saez De Villarreal, 2008). Many researches suggest a large percentage of ACL injuries occur while landing from a jump, due to a combination of high peak- impact forces and poor lower extremity neuromuscular control. Hence, there was a study done by Bobbie S. Irmischer et al, on effects of a knee ligament injury prevention exercise program on impact forces in women and they noted that a low volume and intensity plyometric training program (KLIP) can improve landing mechanics in a manner conductive to injury prevention (Bobbie et al., 2014).

In group B, the PNF stretching has improved significantly. This is in accordance to PNF is a stretching technique utilized to improve muscle elasticity and has been shown to have a positive effect on active and passive ROMs (Funk et al., 2003; lucas and Koslow, 1984; Wallin et al., 1985)[24]. Stretching has long been viewed as beneficial to enhance performance and decrease risk of injury during exercise, as well as improve ROM and function following an injury (McCarthy et al., 1997). PNF stretching prior to exercise has been found to decrease performance when maximal muscle effort is required such as during sprinting, plyometrics, cutting, weight- lifting and other high intensity exercises (Bradley et al., 2007; Milkolajec et al., 2012). This may be due to the muscles being stretched too far outside of their capacity, causing inhibition

following the stretching (Kayla, 2012). Mahmoud Raouf et al concluded that short-timed PNF stretching protocols (as three ten- minute sets) at warm up level before any exercises or competitions, it is possible to be benefitted of stretching advantages and flexibility increase without muscle strength decrease. Since both factors of strength and flexibility are very important in basketball and both can be improved by applying short- timed PNF stretching, doing such stretching movements in the warm up level is recommended to basketball players (Mahmoud Raouf, 2014). There are some studies that have got decrease result of PNF in the performance. Such as, Carlos J. Nogueira et. al noted Significant ($p<0.05$) decreases in counter movement jump height in the experimental exercises, i.e, immediately after and 10 min after the PNF exertion compared with the initial value. No such decreases were noted in the control exercise, in which no PNF exertion was applied (Carlos et al., 2010). When compared to both the groups, group A, showed significant improvement in increasing vertical jump height and agility then group B. In group A the post mean SVJT score was 108.38 with SD of 4.51 and Illinois agility test score was 13.67 with SD of 0.60. In group B, the post mean SVJT score was 103.63 with SD of 4.82 and IAT score was 16.27 with SD of 1.36 which was statistically significant. Increased vertical jump height and agility in group A may be due to several factors.

The most prominent are the rapid eccentric action immediately followed by a concentric action of the muscle and connective tissue aiming at the development of maximum force in the shortest possible time (Bosco, 1985; Potach and Chu, 2008). Moreover, the power/ strength produced during the initial phase of the stretch- shortening cycle positively influences neuromuscular control and joint stabilization (Michal Lehnert et al., 2013). Hence, the study concludes that low intensity plyometric exercises are more effective in improving the vertical jump height and agility when compared to PNF stretching in collegiate basketball players.

**Conclusion**

Objective of the study was to compare the low intensity plyometric versus PNF Stretching on collegiate basketball players. Study concludes that low intensity plyometric exercise training was more effective than PNF stretching. Hence, the alternate hypothesis is accepted and null hypothesis is rejected. Both training showed improvement in vertical jump height and agility in collegiate basketball players. So, it can be used to train the players.

## REFERENCES


Abbas Fattahi- Bafghi and Mohammadtaghi Amiri- Khorasani. 2013. Sustaining effect of different stretching methods on power and agility after warm-up exercises in soccer players. *World Applied Sciences Journal*.,21 (4): 520 – 525.

Alberto Carvalho, Paulo Mourao, Eduardo Abade. Year missing. Effects of strength training combined with specific plyometric exercises on body composition, vertical jump height and lower limb strength development in elite male handball players: a case study. *Journal of Human Kinetics,* Volume 41/ 2014, 125-132.

Ali Aalizadeh, Sedighe Shirkhani, Ali Foroughi Borazjani, Saeed Changizi Ashtiyani, Naimeh Mobaseri, Adel Daneshi and Sedighe Rahimi. 2015. The effect of short-term plyometric training program on sprint, strength, power and agility performance in non- athletic men. *Biosciences Biotechnology Research Asia*.

Balaji Palaniappan, V. Pasupatham, Deivendran Kalirathinam. 2013. Effect of static stretching on vertical jump performance on apparently healthy subjects. *Journal of Nursing and Health Science,* Volume 2, Issue 2,pp 50-52.

Bobbie S. Irmischer, Chand Harris, Ronald P. Pfeiffer, Mark A. Debeliso, Kent J. Adams, and Kevin G. Shea. Effects of a knee ligament injury prevention exercise program on impact forces in women. Journal of Strength and Conditioning Research, 2004, 18(4), 703-707.

Bradley Jordan, J., Ajit D. Korgaokar, Richard S.Farley, and Jennifer L. Caputo. 2012. Acute effects of static and proprioceptive neuromuscular facilitation stretching on agility performance in elite youth soccer players. *International Journal Exercise Sciences*., 5 (2), 97-105.

Carlos J. Nogueira, Leonardo A. dos Santos Galdino, Rodrigo G. de Souza Vale, Danielli B. de Mello, Esteli H.M. Dantas. 2010. Biomedical Human Kinetics, 2,1-4.

Carolyn Kisner, Lynn Allen Colby, therapeutic exercise, 5th edition.

Chen Yongxin. 2013. Comparative analysis of the plyometric training and dynamic tensile on the influence of male basketball player's vertical jump and agility. Journal of convergence information technology (JCIT), volume8, number 10.

Chhaya Verma, Lakshmi Subramanium, Vijaya Krishnan. 2014. The effect of plyometric training on vertical jump height in high school basketball players. *International Journal of Medical Research and Health Sciences*., Vol 4 issue 1.

Costa G., Silva, E., Silveira, A., Novaes, J., Di F., Masi, M., Conceicao, E. Dantas. 2014. Acute effects of static and proprioceptive neuromuscular facilitation stretching on sprint performance in male swimmer. *Med Sport.,* 67: 119-28.

Dr. Gopal Chandra Saha. 2012. Proprioceptive neuromuscular facilitation stretching effect on muscular strength and flexibility of college students. Asian Journal of Physical Education and Computer Science in Sports, Volume.6 No.1 pp17-20.

Eduardo Saez Saez De Villarreal, Juan Jose Gonzalez- Badillo, and Mikel Izquierdo. Low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency. The journal of Strength and Conditioning Research. 2008, 22(3)/715-725.

Gustavo Z Schaun, Yuri S Ribeiro, Marcelo S Vaz, Fabricio B Del Vecchio. 2013. Correlation between agility, lower limb power and performance in a sport- specific test in female volleyball players. *International Journal of Sports Science*., 3(5): 141-146.

Hamid Reza Salimi, Amir Hosein Barati, Nahid Adibpour. 2015. Comparison 2 methods of resistance training (conventional and body pump) on the agility and vertical jump in male basketball players 16 – 18 years. *Turkish Journal of Sports and Exercise*, volume 17 – issue 2 – pages 8-13.

Hubert Makaruk, Jerzy Sadowski, Adam Czaplicki, Tomasz Sacewicz. 2011. Effects of unilateral and bilateral plyometric training on power and jumping ability in women. *Journal of Strength and Conditioning Research*.

Irineu loturco, Ciro Winckler, Ronaldo Kobal, Cesar C. Cal Abad, Katia Kitamura, Amaury W. Verissimo, Lucas A.

Pereira and Fabio Y. Nakamura. 2015. Performance changes and relationship between vertical jump measures and actual sprint performance in elite sprinters with visual impairement throughout a parapan American games training season. *Frontiers in Physiology*.

Jack H. Wilmore, David L. Costill. Physiology of sport and exercise, 3rd edition.

Jennifer L. Hunnicutt, Craig L. Elder, J. Jay Dawes, and Amanda J. Sinclair Elder. 2016. The effects of a plyometric training program on jump performance in collegiate figure skaters: A pilot study. *International Journal of Exercises Science,* 9(2): 175-186.

Karin Vassil, Boris Bazanovk. 2012. The effect of plyometric training program on young volleyball players in their usual training period. Journal of Human Sport and Exercise., Vol.7, No.1, pp- S34-S40.

Kayla B. Hindle, Tyler J. Whitcomb, Wyatt O. Briggs, Junggi Hong. 2012. Proprioceptive neuromuscular facilitation (PNF): its mechanisms and effects on range of motion and muscular function. Journal of human kinetics volume 31/, 105-113.

Kortney J. Dalrymple, Shala E. Davis, Gregory B. Dwyer, and Gavin L. Moir. 2010. Effect of static and dynamic stretching on vertical jump performance in collegiate women volleyball players. *The Journal of Strength and Conditioning Research*., 24 (1)/ 149- 155.

Kristopher Manuel Nava. 2015. The acute effects of different warm-up techniques on power output, agility and flexibility in athletes.

Mahmoud Raouf, Sahar Kamankesh. 2014. Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength of the basketball players. Reef Resources Assessment and Management Technical paper. RRAMT- Vol.40, 1.

Mandeep Kaur, Rajesh Paul, Sandeep Kumar, Reena Arora, Lalit Arora. 2014. A randomized controlled trial to compare the effectiveness of static stretching versus PNF stretching of hamstring muscles following superficial heat in athletes. *International journal of scientific and research publications,* volume 4, issue 7.

Marcela Gomes Ferreira, Welds Rodrigo Ribeiro Bertor, Alberito Rodrigo de Carvalho, Gladson Richardo Flor Bertolini**.** 2015. Effects of static, ballistic and proprioceptive neuromuscular facilitation stretching on vertical jump variables. Scientia Medica, Vol 25, No 4.

Mark Vaczi, Jozsef Tollar, Balazs Meszler, Ivett Juhasz, Istvan Karsai. 2013. Short term high intensity plyometric training program improves strength, power and agility in male soccer players. *Journal of Human Kinetics*. volume 36/, 17-26.

Metta Pinthong, Nattha bunlum, Weerawat limroongreungrat. 2015. Effect of hurdle heights on jumping mechanics in youth male soccer players. *Journal of sports science and technology*, volume 15, no.1.

Michal Lehnert, Karel Hulka, Tomas Maly, Jaroslav Fohler, Frantisek Zahalka. 2013. The effects of a 6 week plyometric training programme on explosive strength and agility in professional basketball players; Acta uni. *Palacki*. *Olomuc*., *Gymn*. vol 43, no.4.

Mohammadtaghi Amiri- Khorasani and Eleftherios Kellis. 2015. Acute effects of different agonist and antagonist stretching arrangements on static and dynamic range of motion. *Asian J Sports Med*., 6 (4).

NikBakht Hojatallah, Amirtash Alimohammd, Hossini Fatemeh, Masuodi Nezhad Monire. 2012. The effects of the proprioceptive neuromuscular facilitation (PNF) stretching on explosive power and agility. *Annals of Biological Research*. 3 (4): 1904-1908.

Nisha joshi, Arati Mahishale, Basavraj Motimath. 2015. Comparative study of 4 weeks of dynamic balance training program in collegiate football players: Randomized clinical trial. *J of Evidence Based Med. and Healthcare.*

Ognjen Andrejie. 2012. The effects of a plyometric and strength training program on the fitness performance in young basketball players. Physical Education and Sports., Vol.10, No 3, pp.221-229.

Parimalam, S., Dr. Pushparajan, A. 2014. Effect of basketball specific training and traditional method of training on agility, explosive power and passing ability of inter colligiate women basketball players, Vol 3 Issue 3.

Paul S. Bradley, Peter D. Olsen, and Matthew D. Portas. 2007. The effect of static, ballistic, and Proprioceptive Neuromuscular Facilitation Stretching on Vertical Jump Performance. *Journal of Strength and Conditioning Research,* 21(1), 223-226.

Paulo Gild a Costa Mendes de Salles, Fabricio Vieira do Amaral Vasconcellos, Gil Fernando da Costa Mendes de Salles, Renato Taveres Fonseca. 2012. Validity and reproducibility of the sergeant jump test in the assessment of explosive strength in soccer players. Journal of human kinetics, vol 33/ 115-121.

Pojskic H, Pagaduan JC, Babajic F, Uzicanin E, Muratovic M, Tomlanovic M. 2015. Acute effects of prolonged intermittent low- intensity isometric warm- up schemes on jump, sprint and agility performance in collegiate soccer players. 32; 129 – 134.

Saltan Asuman, Tutun Yumin, Eylem, Bakar Yesim. 2015. The effect of proprioceptive neuromuscular facilitation and static stretching techniques on jumping performance and flexibility in non-athletic individuals. *Merit Research Journal of Medicine and Medical Sciences*. June, Vol. 3(6), pp 221-227.

Scott Lucett. 2013. Speed and agility training for basketball. National academy of sports medicine.

Selvam Ramachandran and Binita Pradhan. 2014. Effects of short- term two weeks low intensity plyometrics combined with dynamic stretching training in improving vertical jump height and agility on trained basketball players. *Indian J physiol Pharmacol.,* 58(2); 133-136

Singh Harmandeep, Kumar Satinder, Rathi Amita and Sherawat Anupriya. 2015. Effects of six- week plyometrics on vertical jumping ability of volleyball players. *Research Journal of Physical Education Sciences*. April, Vol.3 (4), 1-4.

Spahi, A. Jarani, J. Bilali, A. 2015. An intervention study on velocity, agility and jump ability in youth basketball players in Albania. *Mediterranean Journal of Social Sciences.* Vol 6 no 4.

Suel. E. 2015. The effect of skill- based maximal intensity training on power, agility and speed (PAS) in female team sport players. *Anthropologist*, 21 (!,2): 120 – 128.

Utku Alemdaroglu. The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players. Journal of human kinetics volume 31/2012, 99 – 106. Year missing

Warren B. Young, Brian Dawson and Greg J. Henry. 2015. Agility and change- of- direction speed are independent

skills: implications for training for agility in invasion sports. International journal of sports science and coaching; volume 10. Number 1.

Younes Hachana, Helmi Chaabene, Mohamed A. Nabli, Ahmed Attia, Jamel Moualhi, Najiba Farhat, and Mohamed Elloumi. Test- retest reliability, criterion-relatedYounes Hachana, Helmi Chaabene, Mohamed A. Nabli, Ahmed Attia, Jamel Moualhi, Najiba Farhat, and Mohamed Elloumi. 2013. Test- retest reliability, criterion-related validity, and minimal detectable change of the Illinois agility test in male team sport athletes. *The journal of strength and conditioning research*.

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