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CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 8, Issue, 12, pp. 22777-22790, December, 2017

ISSN: 0976-3031

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

COMPARATIVE STUDY OF THE IMMEDIATE EFFECTS OF ECCENTRIC TRAINING, DYNAMIC STRETCHING AND STATIC STRETCHING ON HAMSTRING FLEXIBILITY AND VERTICAL JUMP PERFORMANCE IN BASKETBALL PLAYERS

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DOI: http://dx.doi.org/10.24327/ijrsr.2017.0812.1335

ARTICLE INFO

Article History:

Received 17th September, 2017
Received in revised form 21st October, 2017
Accepted 05th November, 2017
Published online 28th December, 2017

Key Words:

Eccentric training, dynamic stretching, static stretching, hamstring muscle, flexibility, vertical jump performance, basketball players.

ABSTRACT

Aim: To compare the immediate effects of eccentric training versus dynamic stretching versus static stretching of hamstring muscle on its flexibility and vertical jump performance in basketball players.
Objectives: To compare the immediate effects of eccentric training, dynamic stretching and static stretching of hamstring on its flexibility and vertical jump performance in basketball players
Conclusion:
The present study concluded that Hamstring flexibility was increased immediately after static stretching but vertical jump performance was reduced.
There was no significant change in hamstring flexibility immediately after dynamic stretching but vertical jump performance was improved.
There was increase in hamstring flexibility and improvement in vertical jump performance immediately after eccentric training through full ROM.

INTRODUCTION

Basketball is one of the most popular sports around the world and also the highest contributor to sport and recreation related injuries.(1) It is a very demanding and challenging game which requires sustenance of maximum performance throughout the game. The ability to generate lower body power is basic requirement of the basketball sport, which includes adequate strength of the muscles; endurance of the muscles in sustenance of activity; speed of movement; power of the muscles in delivering the movement (sprinting and jumping); and agility.(2) Basketball is an aerobic based anaerobic sport that requires high intensity activities such as jumping, turns, dribbles, sprints and some low intensity activities such as walking, jogging and stopping.(3)

James Naismith invented basketball in 1891 to provide an outlet for some energetic male students at the Young Men's Christian Association (YMCA) training school in Springfield Massachusetts.(4)

The game of basketball is played by two teams with five players in each team, on a rectangular court measuring 28 meters by 15meters. The objective of game is to shoot a ball through a hoop mounted on backboard at the height of 10 feetto score points.(5) In an attempt to do so; an athlete might perform a jump shot, set shot, layup or a free throw. As a result, the two legged jump shot has become more frequent, amounting to over 70% of all the shots during a game. This necessitates a greater performance level for athletes executing the jump shot to increase the height at which the ball is released. The factors that affect the height at which a shot is performed include the shooter body height, jump height and arrangement of the body parts.(6)

Basketball players need the ability to rapidly switch between forward, backward, lateral and vertical movements. Through specific training these movements are enhanced. Therefore, basketball players need good fitness, flexibility, power, strength, agility, endurance and vertical jumping ability to achieve sporting targets.(7)

Basketball was originally developed as a noncontact sport. During offense, players often avoid contact by using their athletic skills like running, cutting to free themselves for an uncontested shot. During defense, players use their athletic skills to defend against the opposing player and prevent them from getting free. Although the rules of game discourage most form of contact, the intensity at which this sport is played is

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increasing. As a result, increase in the number of injuries is reported to occur any time during athletic performance.[8]

Woods, Bishops, and Jones (2007) reviewed athletic injuries seen in sports medicine clinic and found that muscle injuries account for over 30% of the total injuries seen. They concluded that diminished contractibility and ability of the muscle to absorb energy, potentially made the muscle more susceptible to injury.[9]

A recent study by Powell and Barber-Foss (2000) reported an injury rate of 28.3% and 28.7% in both males and females basketball players respectively over a period of 3 years. Injuries to the lower extremity account for 51% of total injuries reported by Kingma & Jan ten Duis (1998) in recreational basketball players. Sprains appear to be most common injury in basketball players at all levels of competition, accounting for 36-56% of occurrence and muscle strains account for 15-18% of injury occurrence (Gomez *et al*. 1996, Kingma & Jan ten Duis, Messina *et al*. 1999, NCAA 1998, Powell & Barber-Foss 2000).[8]

Hamstring injury

Hamstring strain is one of the most common injuries in all forms of team and individual sports involving the lower body, for example basketball.[10]Hamstring injury tends to occur in specific sports that require turning sharply or cutting, sprinting and jumping. It is also seen in dancers and water-skiers who need maximal muscle lengthening.[11, 12]

Hamstring injury accounts for 29% of injuries in these sports.[11] Analysis of epidemiological studies assessing these sports, ranks hamstring strain as one of the most prevalent factors resulting in missed playing time by athletes.[10] Also the recurrence rate for hamstring injuries has been found to be 12-31%.[12]

Strain is overstretching, overexertion, overuse of soft tissue which occurs from slight trauma or unaccustomed repeated trauma of minor degree. This results in some degree of disruption of the musculotendinous unit.[13]

Muscle strain injuries are said to occur when muscles are actively lengthened greater than resting lengths. Mechanical strain is caused by the combination of rapid eccentric contraction with active muscle contraction in the musculotendinous unit leading to muscle injury.[11]

The biceps femoris, the semitendinosis and the semimembranous muscles are collectively known as the hamstrings. Each of these muscles originates on the ischial tuberosity. The biceps femoris crosses the posterior femur to insert into the head of the fibula and the lateral aspect of the lateral tibial condyle. The other two hamstrings insert on the medial aspect of proximal tibia .[14]

The hamstring muscle complex is a biarticular muscle group which flexes the knee and extends hip. This muscle complex can be vulnerable to injury during running, cutting, and sprinting; all of which involve a combination of hip flexion and knee extension. This causes maximal lengthening of the hamstring muscle group.

Several studies suggest that hamstring strains occur during the later part of the swing phase and early contact phase of running. Hamstrings have to contract eccentrically to decelerate knee extension in the late swing phase and change to contract concentrically to extend the hip. This rapid change from eccentric to concentric contraction leads the hamstrings to injury.[11, 12]

Since the biceps femoris has greater lengthening and electrical activity during the late swing phase of running, it may be more susceptible to injury than the medial hamstrings. Kouloris and Connell found that biceps femoris strains accounted for 80% of the 170 hamstring injuries that occurred in athletes.[15]

There are numerous risk factors for hamstring injury. Previous studies have cited some of the potential risk factors associated with hamstring strains such as muscle weakness, lack of flexibility, insufficient hamstring strength in comparison with the quadriceps, fatigue, inadequate warm-up and poor lumbar posture and core stability.[10, 16, 17, 18, 19]

Poor flexibility is one of the most common proposed risk factor for soft tissue injury.[17, 19, 20] It is believed that a tight musculotendinous structure may reduce the ability of the muscle to elongate rapidly without injury. A stiffer system may apply greater muscular opposition to the eccentric contraction, whereas a more compliant muscular system would transfer the eccentric loading to the tendon. This transfer of the load to the tendon would reduce myofibrillar strain, potentially reducing the risk of soft tissue injury. While this risk factor appears somewhat theoretically sound, previous research reveals inconclusive results. Some studies have found poor flexibility as a contributing factor while others have shown that it makes no difference.[17]

Flexibility

Flexibility is the ability to move a single joint or series of joints smoothly and easily through an unrestricted, pain-free range of motion.[21, 22] Flexibility is related to the extensibility of muscle-tendon units that cross a joint, based on their ability to relax or deform and yield to a stretch force.[21]

Flexibility is promoted as an important component of physical fitness. To increase flexibility various stretching techniques are included in training programs and pre-event warm-up activities of athletes.[23] Athletes competing in speed or power sports are often required to have both high leg muscle power and flexibility in order to perform explosive and wide movements and avoid injuries during training and competition.[24]

Prior to training and competition, athletes perform a warm-up routine, aiming to prepare their muscles to attain maximal power and coordination as well as to increase joint range of motion. A typical warm-up contains both stretching exercises and maximal or near maximal muscle actions, so that ample explosive movements can be performed in the training or competition that follows.[24]

Pre-event flexibility training program helps in decreasing the chances of an injury, warming the muscle, improving the flexibility of the muscle in preparation for the activity and alleviating muscle soreness.[24]

Athletes, coaches, trainers, physiotherapists, and physicians recommend stretching in an effort to both prevent injury and enhance performance. Although there have been reports referring to injury reduction due to stretching, Herbert and Gabriel in their review, concluded that stretching is unlikely to prevent injury.[23]

In the world of physical fitness, flexibility continues to be a misunderstood component of physical health.

Stretching is a maneuver designed to increase the extensibility of soft tissues. There are several stretching methods to increase flexibility [22]:-

- ***Static stretching-*** Slow, sustained muscle lengthening held by subject over a period of time,[21]
- ***Ballistic stretching-*** a rapid, forceful intermittent stretch that is high in speed and velocity,[13,32] it is characterized by use of quick, bouncing movements that create momentum to carry the body segment through range of motion to stretch shortened structures. Ballistic stretching is thought to cause greater trauma to stretched tissues and also greater residual muscle soreness than static stretching.[21]
- ***Dynamic stretching-***involves moving the limb from its neutral position to end range, where the muscles are at their greatest length and then moving the limb back to its original position and is repeated for a specified time period,[25]
- ***Proprioceptive Neuromuscular Facilitation (PNF) stretching -*** integrates active muscle contractions into stretching maneuvers to inhibit or facilitate muscle activation and to increase the likelihood that the muscle to be lengthened remains as relaxed as possible as it is stretched.[21, 26]
- ***Eccentric training-*** it involves dynamic loading of a muscle beyond its force-producing capacity, causing physical lengthening of the muscle as it attempts to control the load.[27]

Need For the Study

It is a common belief that stretching can improve flexibility and athletic performance. Hence, physical therapist, coaches and athletic trainers recommend stretching prior to strenuous activity and competition.

In recent years, many studies have been conducted using different type of stretching procedures. However, there is still disagreement among many authors concerning the effects of different stretching protocols on flexibility and performance.[19] Numerous studies have reported that static stretching before physical activity is detrimental to sports performance which has led some researchers to recommend against the practice of static stretching before such activities.[31,32] However, some researchers believe that static stretching improves flexibility without impairing performance.

Dynamic stretching is currently replacing static stretching in the modern athletic warm-up. Studies have stated that dynamic stretching improves muscle performance more than static stretching.[35]

Since, most of the muscle injuries take place during eccentric activity; eccentric training of muscle has gained attention in athletic training programs and rehabilitation. Recent studies have reported that eccentric training of muscle increases both flexibility and performance.[35]

Previous studies have evaluated the effects of static stretching, dynamic stretching and eccentric training on flexibility and performance individually or by comparing between two techniques. Therefore, this study is undertaken to find the most effective technique among the three in improving immediate flexibility and performance of the hamstring muscle.

Aim and objectives

Aim: To compare the immediate effects of eccentric training versus dynamic stretching versus static stretching of hamstring muscle on its flexibility and vertical jump performance in basketball players.

Objectives

1. To study the immediate effect of eccentric training of hamstring muscle on its flexibility and vertical jump performance in basketball players
2. To study the immediate effect of dynamic stretching of hamstring muscle on its flexibility and vertical jump performance in basketball players
3. To study the immediate effect of static stretching of hamstring muscle on its flexibility and vertical jump performance in basketball players
4. To compare the immediate effects of eccentric training, dynamic stretching and static stretching of hamstring on its flexibility and vertical jump performance in basketball players

Hypothesis

Alternate hypothesis

Eccentric training, dynamic stretching and static stretching of hamstring muscle will have a differential effect on immediate flexibility and vertical jump performance in basketball players.

Null hypothesis

Eccentric training, dynamic stretching and static stretching of hamstring muscle will have similar effect on immediate flexibility and vertical jump performance in basketball players.

Outcome measures Vertical Jump Performance

90/90 Test for Hamstring Flexibility

MATERIALS AND METHODOLOGY

Study Design: Interventional study

Type of Study: Randomized controlled trial

Sample Size: 90 (30 in each 3 groups) calculated using Open Epi version 2.3.1.

Pilot study was conducted on 15 individuals. Sample size was calculated with 95% confidence interval and 80% power using the formula:

$$n=\frac{\sigma^2(z_{(1-\alpha)}+z_{(1-\beta)})^2}{(\mu_0-\mu_1)^2}$$

Where,

Variance of the variable in population - σ^2
Standard normal deviate - Z
Difference between two means - ($\mu0$ - $\mu1$)
Type of sampling: Convenience sample allocated randomly

Place of study: Basketball clubs in Mumbai

Study duration: 18 months

Inclusion criteria

1. Basketball players both males and females between 18-25 yrs of age
2. Having more than 20 degrees of knee extension deficit with 90/90 test for hamstring flexibility.
3. Playing basketball for 3yrs and more

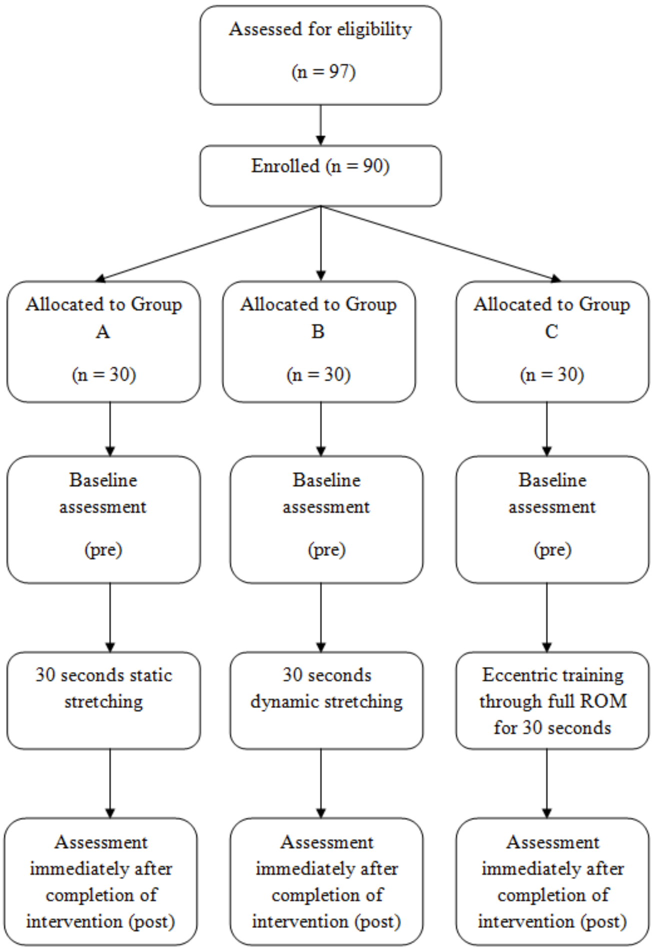
Exclusion criteria

1. History of any musculoskeletal conditions in the past 1 year
2. Any neurological and cardio respiratory diseases

Materials Used

Chalks, Measuring tape, 180 degree goniometer, Velcro straps, Black thera band, Marker, Push knee splint, Stopwatch, Weighing machine, Pen.

Flowchart explaining methodology



Study Procedure

- The study was approved by institutional ethics committee prior to commencement.
- It was conducted at basketball clubs.
- Permission was obtained from the basketball club authorities.
- All the players were screened according to the inclusion and exclusion criteria.
- 90 basketball players both males and females fulfilling the inclusion criteria and willing to participate were selected in the study.
- Players were randomly allocated in one of the three groups using computer generated random allocation list.
- Written consent was obtained from all the players after explaining the study procedure and benefits of the study in the language best understood by them.
- Individual information was documented in the case record form.
- Each group performed 5 minutes of jogging as warm-up.
- 90/90 test for hamstring flexibility and vertical jump test was conducted. Findings obtained were recorded in case record form.

Outcome Measures

90/90 test for hamstring flexibility procedure:(62, 63, 35)
Vertical jump test procedure:(64)

→ **M1**

Procedure

Following the assessment, the players were divided randomly into three groups of 30 each.
Group A received 30 seconds static stretching to bilateral hamstring muscles,
Group B received 30 seconds dynamic stretching to bilateral hamstring muscles,
Group C received 30 seconds of Eccentric training of bilateral hamstring muscles through full ROM.
Immediately after the intervention, subjects were assessed using the outcome measures.

Group A

The basketball players in Group A performed a single 30 second static stretch for bilateral hamstring muscles. To stretch the right hamstring muscles, each subject stood erect with the left foot on the floor pointing straight ahead with no rotation of the hip. The subjects stretched the right hamstring muscle by placing the heel of the right foot on an elevated surface with the knee fully extended, toes pointing to the ceiling, no rotation of the hip, and arms fixed to shoulder level. Each subject was instructed to flex forward from the hip, maintaining the spine in a neutral position, while reaching the arms forward until a gentle stretch was felt in the posterior thigh. Once subject achieved this position, the stretch was sustained for 30 seconds.(26) This stretching technique was used because it approximates the type of stretching procedure commonly used by athletes. Same technique was repeated to stretch the left hamstring muscles.

Group B

Group B basketball players performed 30 seconds dynamic stretching for bilateral hamstring muscles. To stretch the right hamstring muscles, subject lay supine. Right hip was flexed to 90 degrees and was maintained by subject holding the thigh with both the hands. Knee was initially allowed to relax in flexion. The left lower extremity that was not being stretched was resting with the knee fully extended and the hip in 0 degrees of flexion, extension, abduction, adduction and rotation. The subject then actively extended the right leg, held the leg at the end of maximum knee extension for 5 seconds, and then slowly lowered the leg. This was considered as one repetition and total 6 repetitions were performed. Performing dynamic stretching for six repetitions of 5 seconds each, allowed 30 seconds of actual stretching time, which could later be compared with the 30- second static stretches performed by the other group. Same stretching procedure was performed to stretch the left hamstring muscles.[46]

Group C

Basketball players in Group C performed 30 seconds eccentric training through full ROM for bilateral hamstring muscles. The subject lay supine with the left lower extremity fully extended. A 3 foot (0.91 m.) piece of black theraband was wrapped around the heel of right foot and the subject held the ends of the theraband in each hand. The subject was instructed to keep the right knee locked in full extension and the hip in zero degrees of abduction, adduction, internal and external rotation throughout the entire activity. The subject was then instructed to bring the right hip into full hip flexion by pulling on the theraband attached to the foot with both arms, making sure the knee remained locked in full extension at all times. Full hip flexion was defined as the position of hip flexion at which a gentle stretch was felt by the subject in the posterior thigh. As the subject pulled the hip into full flexion with the arms, he was instructed to simultaneously resist the hip flexion by eccentrically contracting the hamstring muscles during the entire range of hip flexion. The subject was instructed to provide sufficient pull with the arms to overcome the eccentric activity of the hamstring muscles, so that the entire range of hip flexion took approximately 5 seconds to complete. Once achieved, this flexed hip position was held for 5 seconds, and then the extremity was gently lowered to the ground (hip extension) by the subject's arms. This procedure was repeated 6 times, with no rest between repetitions, thereby providing a total of 30 seconds of stretching at the end range. [35] To maintain the right knee in full extension and to minimize the quadriceps activity, a push knee splint was used. Same technique was performed for the eccentric training of left hamstring muscles.

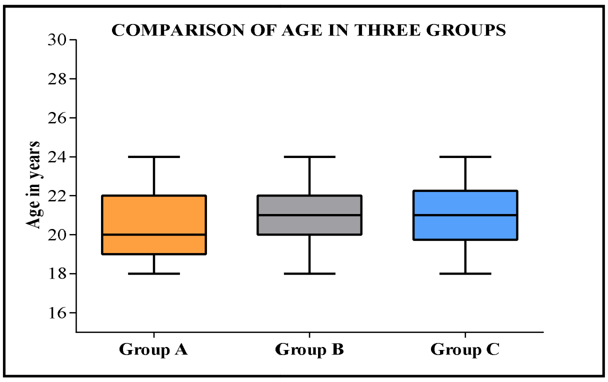
RESULTS

Statistical Analysis

- The data was entered using MS-EXCEL 2010 and analyzed using Graph Pad Prism6 version 6.05 software.
- Descriptive analysis of numerical data was expressed in mean and standard deviation for various parameters.
- Frequencies of categorical data were expressed in percentage.
- Normality was assessed using Kolmogorov-Smirnov test.
- Parametric tests were used whenever data passed the test of normality. Non-parametric tests were used whenever data did not pass the test of normality.
- ***Within-Group Analysis:*** Paired t test and Wilcoxon Signed Rank test were used for comparison of means within the groups.
- ***Between The Group Analysis:*** One-way ANOVA and Kruskal Wallis test were used for comparison of mean difference between the groups. Multiple comparisons between the groups were calculated using Tukey's post hoc test and Dunn's post hoc test.
- P-value less than 0.05 was considered statistically significant.
- The data of the present study was quantitative and continuous in nature hence graphical representation was done using box plots and bar diagrams.

Comparison of Age in Three Groups Table 1a

	N	Mean	SD	P value	Significance
Group A	30	20.43	1.775		
Group B	30	21.17	1.49	0.2651	Not significant
Group C	30	20.97	1.88		

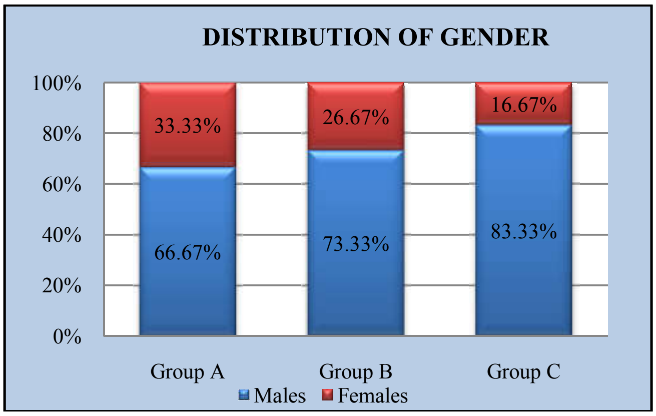


Graph 1

Inference: The above graph shows that age was similarly distributed between the three groups.

Distribution of Gender in Three Groups Table 1b

Gender	Group A		Group B		Group C	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Males	20	66.67	22	73.33	25	83.33
Females	10	33.33	8	26.67	5	16.67
Total	30	100	30	100	30	100

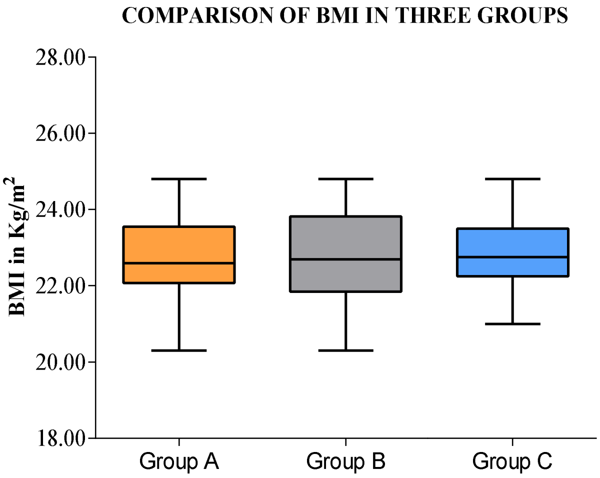


Graph 2

Inference: The above graph shows that gender was not similarly distributed between the three groups.

Comparison of Bmi In Three Groups Table 1c

	n	Mean	SD	P value	Significance
Group A	30	22.67	1.165	0.8249	Not significant
Group B	30	22.6	1.338		
Group C	30	22.81	0.8931		



Graph 3

Inference: The above graph shows that BMI was similarly distributed between the three groups.

Comparison of 90/90 Test for Hamstring Flexibility of Right Lower Limb in Three Groups

Table 2a Comparison within the groups

		n	Mean	SD	P value	Significance
Group A	Pre	30	31.73	5.42	<0.0001	Significant
	Post	30	28.93	5.439		
Group B	Pre	30	32.14	5.097	0.08	Not significant
	Post	30	32.03	5.179		
Group C	Pre	30	31.93	5.278	<0.0001	Significant
	Post	30	30.66	5.129		

On applying paired t test, it can be inferred that there is statistically significant improvement in hamstring flexibility in Groups A and C.

Table 2b Comparison between the groups

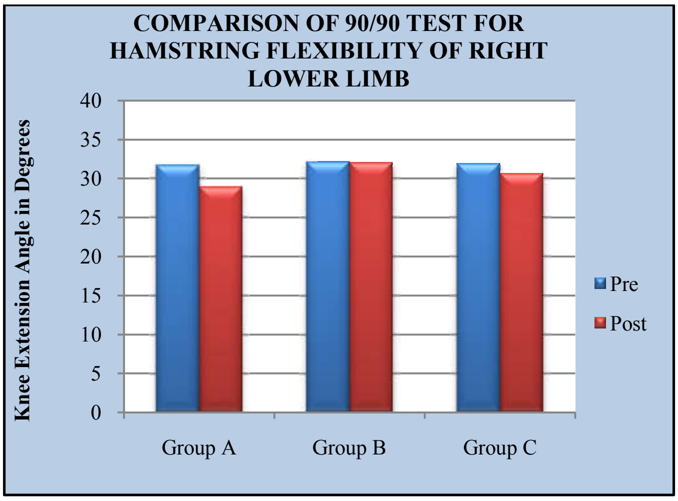
	N	Mean difference	SD	P value	Significance
Group A	30	2.8	0.7611	<0.0001	Significant
Group B	30	0.1	0.3051		
Group C	30	1.3	0.8769		

On applying Kruskal wallis test, it can be inferred that there is statistically significant difference between the groups.

Table 2c Multiple comparisons between the groups

	Mean rank difference	P value	Significance
Group A v/s Group B	53.00	< 0.0001	Significant
Group A v/s Group C	26.50	0.0001	Significant
Group B v/s Group C	-26.50	0.0001	Significant

On applying Dunn's post hoc test, it can be inferred that mean difference between Group A v/s Group B contributes most to the significance, followed by mean difference between Group A v/s Group C and Group B v/s Group C.



Graph 4

Inference: The above graph shows statistically significant increase in hamstring flexibility of right lower limb in the Groups A and C, whereas Group B did not show statistically significant difference. There is maximum difference in Group A as compared to Groups B and C.

Comparison of 90/90 Test for Hamstring Flexibility of Left Lower Limb in Three Groups

Table 3a Comparison within the groups

		N	Mean	SD	P value	Significance
Group A	Pre	30	31.7	5.22	<0.0001	Significant
	Post	30	28.9	5.346		
Group B	Pre	30	32.1	5.045	0.0831	Not significant
	Post	30	32	5.127		
Group C	Pre	30	31.93	5.284	<0.0001	Significant
	Post	30	30.55	5.193		

On applying paired t test, it can be inferred that there is statistically significant improvement in hamstring flexibility in Groups A and C.

Table 3b Comparison between the groups

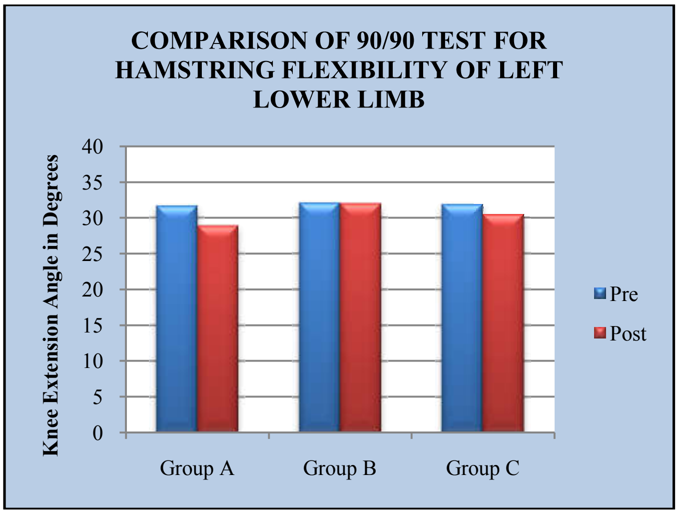
	n	Mean difference	SD	P value	Significance
Group A	30	2.8	0.9965	<0.0001	Significant
Group B	30	0.1	0.3051		
Group C	30	1.367	0.8503		

On applying Kruskal wallis test, it can be inferred that there is statistically significant difference between the groups.

Table 3c Multiple comparisons between the groups

	Mean rank difference	P value	Significance
Group A v/s Group B	51.92	< 0.0001	Significant
Group A v/s Group C	24.18	0.0006	Significant
Group B v/s Group C	-27.73	<0.0001	Significant

On applying Dunn's post hoc test, it can be inferred that mean difference between Groups A v/s B contributes most to the significance, followed by mean difference between Groups B v/s C.



Graph 5

Inference: The above graph shows statistically significant increase in hamstring flexibility of right lower limb in the Groups A and C, whereas Group B did not show statistically significant difference. There is maximum difference in Group A as compared to Groups B and C.

Comparison of Vertical Jump Performance in Three Groups

Table 4a Comparison within the groups

		n	Mean	SD	P value	Significance
Group A	Pre	30	30.38	2.456	<0.0001	Significant
	Post	30	29.43	2.408		
Group B	Pre	30	30.46	2.119	<0.0001	Significant
	Post	30	31.63	2.028		
Group C	Pre	30	30.4	3.261	<0.0001	Significant
	Post	30	31.72	3.042		

On applying Wilcoxon Signed Rank test, it can be inferred that there is statistically significant increase in vertical jump height in Groups B and C while Group A shows statistically significant decrease.

Table 4b Comparison between the groups

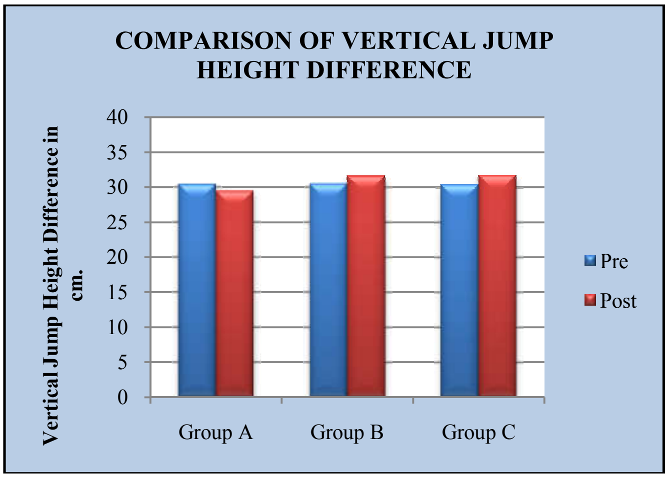
	n	Mean difference	SD	P value	Significance
Group A	30	0.9533	0.5277	<0.0001	Significant
Group B	30	-1.183	0.5802		
Group C	30	-1.323	0.9001		

On applying One-way ANOVA test, it can be inferred that there is statistically significant difference between the groups.

Table 4c Multiple comparisons between the groups

	Mean rank difference	P value	Significance
Group A v/s Group B	2.137	< 0.0001	Significant
Group A v/s Group C	2.277	< 0.0001	Significant
Group B v/s Group C	0.1400	0.7122	Not significant

On applying Tukey's test, it can be inferred that mean difference between Groups A v/s C contributes most to the significance, followed by mean difference between Groups A v/s B.



Graph 6

Inference: The above graph shows that vertical jump height is statistically significantly increased in Groups B and C while it is statistically significantly decreased in Group A. Group C shows maximum increase in vertical jump height than Group B.

DISCUSSION

The objectives of the current study were to compare the immediate effects of static stretching, dynamic stretching and eccentric training of hamstring on its flexibility and vertical jump performance in basketball players.

The study sample consisted of 90 basketball players both males and females who fulfilled the inclusion and exclusion criteria. They were randomly divided into three groups. Age and BMI were similarly distributed between the three groups. Descriptive statistics of the demographic data are presented in Table no.1a, 1b and 1c and Graph No.1, Graph No.2 and Graph No.3.

Each group received 5 minutes of warm up (jogging) before stretching of bilateral hamstrings muscle (for 30 seconds), wherein Group A received static stretching; Group B received Dynamic stretching; Group C received Eccentric training protocol through full range of motion.

Outcomes, 90/90 test for hamstring flexibility and vertical jump performance, were measured and recorded prior to intervention and immediately post intervention.

The results revealed in the study are

Results of 90/90 test for hamstring flexibility

- Group A demonstrated significant increase in hamstring flexibility immediately after static stretching of bilateral lower limb. (Table No.2b) (Table No.3b)
- Group B did not demonstrate significant increase in hamstring flexibility immediately after dynamic stretching of bilateral lower limb. (Table No.2b) (Table No.3b)
- Group C demonstrated significant increase in hamstring flexibility immediately after eccentric training of bilateral lower limb. (Table No.2b) (Table No.3b)
- The increase in hamstring flexibility was highest in Group A followed by Group C and then Group B which

was statistically significant. (Table No. 2c, 3c) (Graph No.4, 5).

Results of Vertical jump performance

- Group A demonstrated significant decrease in vertical jump height immediately after static stretching. (Table No. 4a).
- Group B demonstrated significant increase in vertical jump height immediately after dynamic stretching. (Table No. 4a).
- Group C demonstrated significant increase in vertical jump height immediately after eccentric training. (Table No. 4a).
- There was statistical significant difference between the three groups. Vertical jump performance was increased highest in Group C followed by Group B, while it was reduced in Group A. (Table No. 4b) (Graph No.6)

90/90 Test for Hamstring Flexibility

Comparison within the groups

Graph No. 4, 5 and table No. 2a, 3a shows that there was significant improvement in hamstring flexibility immediately after 30 seconds of static stretching. The rationale for static stretch improving flexibility could be attributed to changes in viscoelastic properties of the muscle. Keitaro Kubo *et al*, 2001; suggested that Static stretching decreases the viscosity of tendon but increases the elasticity, hence, in turn decreasing the stiffness of muscle.(65)

Another hypothesis for improvement in flexibility is that static stretching modifies the positional sensitivity of the Golgi tendon organs by affecting the series elastic component of the muscle.(42)

Golgi tendon organ is stimulated when small bundle of muscle fibers is "tensed" by contracting or stretching the muscle i.e. the tendon detects muscle tension.Increased tension in muscle stimulates its Golgi tendon organs, signals are transmitted to the spinal cord to cause reflex that is inhibitory in response. This prevents the development of too much tension in the muscle. When tension on the muscle and, therefore, on the tendon becomes extreme, the inhibitory effect from the tendon organ becomes so great that it leads to a sudden reaction in the spinal cord that causes instantaneous relaxation of the entire muscle. This effect is called the lengthening reaction.(66)

In accordance with our results, Phil Page (2012), in his article stated that static stretching is effective in increasing ROM and the greatest change in ROM with a static stretch occurs between 15 and 30 seconds of stretch.(39) Similarly Bandy WD, Irion JM (1994) have explained in their study that 30sec of static stretch is as effective as 60sec of static stretch in increasing the flexibility of the hamstring muscles. In addition, no increase in muscle elongation occurs after 2 to 4 repetitions of stretch.(26)

Many studies on static stretching state that an increase in ROM is due to an increase in stretch tolerance (ability to withstand more stretching force) and not extensibility (increased muscle length).(43) Duane Knudson (2006) in the biomechanics of stretching, stated that short-term increase in static flexibility is related to an increase in stretch tolerance; in other words, the increased ROM may be related to an analgesic effect that allows the person to tolerate higher levels of passive tension required to stretch the muscle farther than it was before. (44)

Table No. 2b and 3b and graph No.4, 5 shows that increase in hamstring flexibility after 30 seconds of dynamic stretching was statistically not significant. The duration of dynamic stretch used during study was 30 seconds which is in accordance with the study of Bandy *et al*. Similar findings were found by Bandy *et al* (1998) in his research. The mean difference between pretest and posttest hamstring flexibility after 6 weeks of intervention, in his study was 11.4° for the static group and 4.3° for the dynamic group.(46) In the present study there was no significant difference seen in pre and post intervention readings, the reason for which may be the short duration of study (immediate effect) in comparison to Bandy *et al* who conducted 6 weeks of dynamic stretching protocol.

Diego L. Gonsalves *et al*(2013) conducted a study to compare the acute and chronic effects of static and dynamic stretching program on the performance of young soccer athletes. They found that flexibility increased significantly in both the groups. Contrasting result may be because they used different protocol of dynamic stretching and they performed 4 different dynamic stretching exercises for stretching hamstring muscles. The test for measuring flexibility was also different from current study.(20)

Graph No. 4 and 5 and table No. 2c and 3c shows that hamstring flexibility was significantly increased immediately after 30 seconds of eccentric training through full ROM.

The possible mechanism for the increased flexibility with eccentric training through full ROM could be Sarcomerogenesis i.e. addition of sarcomeres in series, which has clearly been demonstrated after eccentric training in animal studies. After repeated bouts of eccentric training, a prolonged shift consistently occurs in the muscle length-tension curve, which suggests that muscles adapt to mildly damaging eccentric training by sacromerogenesis. This enhances generation of torque at more extended joint position.(36)

Sarcomerogenesis is thought to occur within 10 days of eccentric training,(36) whereas in the present study immediate positive effect of eccentric training on flexibility was demonstrated. The possible explanation for immediate increase in flexibility could be the effect of static hold which was incorporated in the eccentric training protocol. The addition of static hold may have lead to an increase in stretch tolerance of muscle, similar to static stretching.

Kieran O'Sullivan *et al* (2012) in the systematic review "The effects of eccentric training on lower limb flexibility" included 6 high quality studies and demonstrated consistent result that eccentric training is effective in increasing lower limb flexibility. They stated that eccentric training has been capable of increasing muscle fascicle length as shown in animal models, suggesting it may be an option for improving flexibility. This could be a possible rationale for improvement of hamstring flexibility after eccentric training. (36)

Another possible reason for increase in flexibility after eccentric training could be that the combination of stretching and contraction of the muscle may lead to the application of higher levels of tension on the musculotendinous unit which causes more viscoelastic stress. This in turn leads to diminished tension resistance which makes the muscle becomes more compliant.(10)

Faheem Ahmad *et al* (2009) in their study compared the effect of Static Stretching Versus Eccentric Training on Popliteal Angle in Normal Healthy Indian Collegiate Male. Their result showed that both groups showed significant improvement in flexibility, which is similar to present study results.(42)

Russel T. Nelson (2006) studied the immediate effect of eccentric training and static stretching on hamstring flexibility. His results also concluded that both eccentric and static stretching improved hamstring flexibility significantly.(24)

Similarly, W. D. Bandy *et al* (2004)indicatedsignificant increases in hamstring flexibility after eccentric training of hamstring muscles for 6 weeks.(35)

Comparison between the groups

Graph No. 4, 5 and Table No. 2b, 3b showed that there was significant difference in hamstring flexibility between the three groups.

The increase in hamstring flexibility was highest in Group A followed by Group C and then Group B which was statistically significant.

In coherence with current study, Amira H. Draz *et al* (2013) found that the gain in flexibility was statistically more significant after static stretching than after dynamic stretching.(37)

Similarly, M. Samson *et al* (2012) demonstrated that static stretching of major lower limb muscles increased sit and reach range of motion (ROM) by 2.8% more than dynamic stretching.(51)

The increase in hamstring flexibility was highest after static stretching than after eccentric training in the present study, which is in similar with the study conducted by Faheem Ahmad *et al* (2009). Their result revealed that both static stretching and eccentric training groups showed significant improvement in flexibility. When compared between the groups, the flexibility gains after static stretching was greater than eccentric training.(42)

Mohd. Waseem *et al* (2009) discussed the possible reason for less improvement in hamstring flexibility after eccentric training as compared to static stretching, in their study. They explained that during eccentric training, skeletal muscle has a large adaptation potential induced by eccentric contraction and morphological changes are related to addition of sarcomeres in series. Repeated contraction (eccentric) leads to disruption and membrane damage, which results in uncontrolled Ca^{2+} movements and the development of localized contracture.(41)

Vertical Jump Performance

Vertical jump consists of five distinct phases: (1) starting position, (2) countermovement, (3) jump or propulsion, (4) flight and (5) landing. (67)

Vertical jump is started with hip-to-shoulder stance. Athletes generate greatest force applied to the ground, power, and jump height from a hip-to-shoulder width stance.

Countermovement phase is characterized by rapid hip and knee flexion, ankle dorsi-flexion, and shoulder hyperextension.(67) This is the preparatory phase. Muscle activity is generally eccentric during this phase, with gravity providing the driving force. One proposed function of two-joint muscles of the lower limb during countermovement phase is to redistribute mechanical energy generated by concentric action of one joint muscles, for optimal performance of explosive leg extension movements.(68)

Jump or propulsion phase consists of explosive hip, trunk, and knee extension, plantar flexion, and shoulder flexion.(67)

During take-off phase, the net joint moments about hip, knee and ankle are positive, meaning that the net effect of all load-carrying structures (muscle, ligaments, and joint capsule) will be to extend the knee and plantar-flex the ankle. During this phase the joint powers are generally positive, indicating predominately concentric activity of one-joint muscles. (67)

P. Prokopow *et al* (2005) stated thatduring vertical jump, muscle control is most sensitive to precise tuning of muscles across the knee joint and ankle joint, where muscle control at the knee joint depends to a large extent on co-action of the monoarticular knee extensor with biarticular muscles. Among individual muscles the control of vastus medialis, soleus, hamstrings and other plantaflexors are found to be especially important for coordination in jumping. Muscle control is found to be very sensitive to intermuscular coordination.(59)

Comparison within the groups

Table No. 4b and graph No. 6 shows that vertical jump performance was significantly decreased after 30 seconds of static stretching of hamstring muscle.

Kallerud *et al* (2013) explained in the systematic review “Effects of stretching on performances involving stretch shortening cycle” the probable hypotheses behind the decrement in the performance following static stretching. It is assumed that high muscle tendon unit (MTU) stiffness increases the ability of series elastic component (SEC) to produce work. Series elastic component is a non linear elastic element in series with a contractile component, both bridged by another non elastic element. When muscle is stretched, tendons act as a spring to restore elastic energy in SEC. Static stretching reduces MTU stiffness and therefore, might also reduce the elastic potential produced during the stretched phase.(69)

Altered MTU compliance has been considered as one of the primary mechanisms underlying the stretch induced strength loss, possibly resulting in both neural and mechanical mechanisms purported to reduce performance. It has been hypothesized that static stretching reduces performance through alterations in the length tension relationships in the stretched muscle, which affects the force generating capacity.

Stretching may desensitize the muscle spindles; through alterations in mechanical properties of MTU, hence reducing the activity of group I and II afferents and reflex activity. Ensuing reductions to excitation of α motor neuron pool would lead to reduced muscle stimuli and reflexive contribution to force reduction.(69) This hypothesis is supported by Hough *et al* (2009), who reported lowered EMG activity and reduced jump performance following static stretching indicating reduced activation of motor neurons.[31]

The result of present study agrees with previous studies, which assessed the effect of static stretching on performance and found that it had negative effect.[49, 32, 70]

Study done by Winchester *et al* (2009) used 30 seconds of stretching and results demonstrated 0.6% impairment in jump height,[71] in addition Vetter (2007) used 60 seconds of stretching for each muscle group and result revealed 5.4% decrement in jump height. [72]

Diego L. Gonsalves *et al* (2013) observed in their study that static stretching of hamstring muscles performed for 30 seconds led to inhibition of electric activity of this muscle.[20]

Fowels *et al* (2000) indicated in his study, that reduced strength after passive stretch of human plantarflexor muscles i.e. initial decrease in peak torque after static stretching was due to changes in neuromuscular and mechanical properties of a muscle.[73]

Graph No. 6 shows that vertical jump performance was significantly improved in Group B after 30 seconds of dynamic stretching. This result is similar to previous studies, which demonstrated significant increase in performance after dynamic stretching.[1, 20, 33, 47]

Hough *et al* (2009) studied the "Effects of dynamic and static stretching on vertical jump performance and electromyographic activity (EMG)" and found that there was improvement in EMG activity and vertical jump performance after dynamic stretching.[D30]

The possible mechanism for the increase in vertical jump height following dynamic stretching may be attributed to decrease in muscle stiffness. Dynamic stretching causes increase in muscle and core temperature leading to increased compliance of both the contractile and non-contractile tissues within the muscle, thereby reducing muscle stiffness.[31]

Another hypothesis for improved lower limb performance after dynamic stretching could be post-activation potentiation (PAP) in the stretched muscle caused by voluntary contractions of the antagonist. Post-activation potentiation (PAP) is prevalently defined as the temporary increase in muscle contractile performance after a previous ''conditioning'' contractile activity. The mechanisms responsible for PAP include increased phosphorylation of myosin regulatory light chains and increased Ca^{2+} release from the sarcoplasmic reticulum, causing increase in muscular force. PAP may raise the rate constant of crossbridge attachments, which in turn may enable a greater number of crossbridges to form, resulting in an increase in force production.[22, 31] Yamaguchi and Ishii (2005) hypothesized that the increase in force output after dynamic stretching was caused by an intensification of neuromuscular function, and they hinted that the dynamic stretching had a PAP effect on performance.[54]

Amira H. Draz *et al* (2013) in their study, "The effect of body position and types of stretching on hamstring flexibility'' explained the probable hypothesis behind the increase in muscular performance after dynamic stretching. They stated that active dynamic stretching has effect on the nervous system, and elastic properties of the muscle during a stretch.

The nervous system regulation of tension and length is performed by Golgi tendon organ and muscle spindle, respectively. When a muscle is repeatedly stretched, muscle spindle records the change in length, thus activating the stretch reflex and causing a change of the muscle length through a muscle contraction. As a direct result of an increase in muscle spindle activity, a fast, dynamic stretch will increase a stretch reflex response causing the agonist muscle to contract with greater force. So, dynamic stretching is effective in increasing the muscle power and performance.[37]

Graph No. 6 and table No. 4c shows that vertical jump performance was significantly increased after eccentric training of hamstring muscle through full ROM.

The possible reason for improvement in vertical jump performance after eccentric training could be the increased ability of the stretched muscle to store elastic potential energy during eccentric contraction. This would later improve the strength of the concentric contraction. The combination of stretching and contraction causes more viscoelastic changes due to higher level of tension on musculotendinous unit. This in turn leads to diminished tension resistance and the muscle becomes more compliant. Thus, it would be able to store more potential elastic energy which results in improved performance.[52]

Batista LH *et al* (2008) concluded in their study that eccentric stretching program of knee flexors was effective for increasing the flexibility of the stretched muscles and the torque of the agonist (stretched) muscle groups and their antagonists. This could also be the possible reason for increased performance after eccentric training.[52]

Ross Clark *et al* (2005) studied the effects of eccentric hamstring strength training on dynamic jumping performance and isokinetic strength parameter and established that vertical jump height was significantly improved post intervention.[10] This result is in accordance with the present study results.

Comparison between the groups

Graph No. 6 and Table No. 4b shows that there was significant difference in vertical jump performance between the three groups.

The result of current study revealed that vertical jump performance was significantly reduced after static stretching and was significantly improved after dynamic stretching, which is similar to the results of Hough *et al* (2009) who assessed the effects of static and dynamic stretching on vertical jump performance. Their result indicated that vertical jump height was significantly less after static stretching and significantly greater in dynamic stretching. [31]

Amira H. Draz *et al* (2013) in their study, "The effect of body position and types of stretching on hamstring flexibility'' stated that the major advantage of active dynamic stretching compared to passive static stretching is its effect on the nervous system, and elastic properties of the muscle during a stretch. They explained that dynamic stretch will increase a stretch reflex response causing the agonist muscle to contract with greater force because of an increase in muscle spindle activity.[37]

The result of present study also indicates that vertical jump performance was increased most after eccentric training than after dynamic stretching but the difference was not statistically significant (Table No. 4c). Batista LH *et al* (2008) revealed in their study that eccentric stretching program of knee flexors was effective in increasing the torque of the agonist (stretched) muscle groups and their antagonists.[52] Unlike dynamic stretching, eccentric training has positive effect on antagonist muscle; hence, this could be the possible reason for increased vertical jump height after eccentric training than after dynamic stretching.

When analyzed statistically, there was statistical significant difference on hamstring flexibility and vertical jump performance between all three groups, thus rejecting the null hypothesis.

Limitations

- Study is limited to 18 to 25 years of age group
- Number of males and females between the groups was not equal

Suggestions

- Similar study can be done on basketball players in the age group of more than 25 years and in other sports like football, hockey etc.
- Chronic effects of different types stretching of hamstring muscle on its flexibility and vertical jump performance can be assessed.

CONCLUSION

The present study concluded that:

- Hamstring flexibility was increased immediately after static stretching but vertical jump performance was reduced.
- There was no significant change in hamstring flexibility immediately after dynamic stretching but vertical jump performance was improved.
- There was increase in hamstring flexibility and improvement in vertical jump performance immediately after eccentric training through full ROM.

Clinical Implications

Based on the conclusions drawn from the present study, basketball players and their coaches should be educated to involve eccentric training of hamstring muscles through full ROM in the warm-up, since it improves both the flexibility and vertical jump performance immediately.

Summary

The objective of the study was to evaluate the immediate effect of static stretching, dynamic stretching and eccentric training of hamstring on its flexibility and vertical jump performance in basketball players.

It was an interventional study, in which based on inclusion and exclusion criteria 90 basketball players were selected post screening. These players were randomly allocated into 3 groups; Group A consisted of 30 basketball players, 20 males and 10 females with mean age of 20.34 ± 1.775 years and mean BMI of 22.67 ± 1.165 Kg/m^2. Group B consisted of 30 basketball players, 22 males and 8 females with mean age of 21.17 ± 1.49 years and mean BMI of 22.6 ± 1.338 Kg/m^2. Group C consisted of 30 basketball players, 25 males and 5 females with mean age of 20.97 ± 1.88 years and mean BMI of 22.81 ± 0.893 Kg/m^2.

Each group performed 5 minutes jogging as warm-up. Group A received 30 seconds static stretching to bilateral hamstring muscles, Group B received 30 seconds dynamic stretching to bilateral hamstring muscles, Group C received 30 seconds of Eccentric training of bilateral hamstring muscles through full ROM.

Subjects were assessed using 90/90 test for hamstring flexibility and vertical jump performance before the intervention and immediately after the intervention.

Results of present study demonstrated that there was significant increase in hamstring flexibility in static stretching and eccentric training group ($p<0.05$), while there was no significant increase in dynamic stretching group ($p=0.08$). When compared between the groups, hamstring flexibility was increased most in static stretching group than in eccentric training group which was statistically significant ($p<0.05$). Vertical jump performance was significantly improved in dynamic stretching and eccentric training groups ($p<0.05$), while it was significantly reduced in static stretching group ($p<0.05$). When compared between the groups, vertical jump performance was most increased in eccentric training group than dynamic stretching group, the difference was not significant.

Thus from the present study it can be concluded that basketball players and coaches should incorporate eccentric training of hamstring muscles in warm-up protocol as it improves both flexibility and vertical jump performance immediately.

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How to cite this article:

Ruhi Pereira and Annamma Varghese.2017, Comparative Study of the Immediate Effects of Eccentric Training, Dynamic Stretching and Static Stretching On Hamstring Flexibility and Vertical Jump Performance in Basketball Players. *Int J Recent Sci Res.* 8(12), pp. 22777-22790. DOI: http://dx.doi.org/10.24327/ijrsr.2017.0812.1335

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