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Dr. Bhagyashree Salekar
MPT, Kempegowda Institute of Physiotherapy, Department of Musculoskeletal and Sports, Affiliated to Rajiv Gandhi University of Health Sciences, K. R. Road, V. V. Puram, Bengaluru, Karnataka, India

Dr. Sharath UR
Assistant Professor, Kempegowda Institute of Physiotherapy, Department of Musculoskeletal and Sports, Affiliated to Rajiv Gandhi University of Health Sciences, K. R. Road, V. V. Puram, Bengaluru, Karnataka, India

Dr. Pradeep Krishnareddy
Assistant Professor, Kempegowda Institute of Physiotherapy, Department of Musculoskeletal and Sports, Affiliated to Rajiv Gandhi University of Health Sciences, K. R. Road, V. V. Puram, Bengaluru, Karnataka, India

Dr. Sridhar S
Assistant Professor, Kempegowda Institute of Physiotherapy, Department of Musculoskeletal and Sports, Affiliated to Rajiv Gandhi University of Health Sciences, K. R. Road, V. V. Puram, Bengaluru, Karnataka, India

Dr. Radhakrishna AM
M.S. Ortho, Professor, Department of Orthopaedics, KIMS Hospital and Research Center, Affiliated to Rajiv Gandhi University of Health Sciences, K. R. Road, V. V. Puram, Bengaluru, Karnataka, India

Dr. Sumer Shah
MPT, Kempegowda Institute of Physiotherapy, Department of Musculoskeletal and Sports, Affiliated to Rajiv Gandhi University of Health Sciences, K. R. Road, V. V. Puram, Bengaluru, Karnataka, India

Corresponding Author:
Dr. Bhagyashree Salekar
MPT, Kempegowda Institute of Physiotherapy, Department of Musculoskeletal and Sports, Affiliated to Rajiv Gandhi University of Health Sciences, K. R. Road, V. V. Puram, Bengaluru, Karnataka, India

Compare the effect of static and dynamic stretching on hamstring muscle flexibility and on agility performance in tennis players

Dr. Bhagyashree Salekar, Dr. Sharath UR, Dr. Pradeep Krishnareddy, Dr. Sridhar S, Dr. Radhakrishna AM and Dr. Sumer Shah

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Abstract
Hamstring strains are one of the most common and recurrent injuries in the sporting world. Lack of hamstring flexibility was the single most important characteristic of hamstring injuries in athletes. Research indicated that flexibility measurements in tennis players were significantly lower in sit and reach compared with non-tennis athlete. Hamstring stretching may be considered as an intervention in both prevention and treatment of hamstring strains. Also hamstring muscles play a significant role in agility function in tennis players.
This interventional study was conducted to assess and compare the effect of static and dynamic stretching on hamstring muscle flexibility and on agility performance in tennis players. Sixty healthy tennis players were assessed for the inclusion and exclusion criteria and randomly divided into 2 groups. Group A received static stretching and Group B received dynamic stretching for 3 times a week for 6 weeks. Pre-intervention and post intervention evaluation was done by 4 outcome measures- Modified Sit and Reach Test, Active knee extension, Shuttle run test and Tennis specific agility test for both the groups. The result showed statistically significant improvement in hamstring muscle flexibility in both groups but dynamic stretching is more effective than static stretching. Dynamic stretching showed significant improvement in agility performance but static stretching did not show any positive or negative effect on agility performance.

Keywords: Hamstring muscles, flexibility, agility, static stretching, dynamic stretching, athletes, tennis players

1. Introduction
Hamstring strains are one of the most common, recurrent injuries experienced in the sporting world and often result in significant time out of sport and activity, accounting for 29% of all injuries in athletes and 12% to 31% of these athletes suffer re-injuries [1, 2].
Tennis involves repeated short bursts of activity with accelerations and sprinting which place high demands on the lower extremities [3]. Sprinting is the primary mechanism for hamstring strains; responsible for 57% of all hamstring injuries [4]. Woods *et al*. reported high eccentric forces (150 Jules) by the hamstring muscle group in the late swing phase in an attempt to decelerate the lower leg prior to ground contact [5]. Research has suggested that if hamstring muscles lack flexibility at this time during gait cycle they may be stretched beyond their ability to elongate; thus resulting in a tear [4]. Research indicated that flexibility measurements in tennis players were significantly lower in sit and reach compared with non-tennis athlete [6]. Many authors reported that hamstring injured subjects were less flexible than non-injured subjects [5]. Lack of hamstring flexibility was the single most important characteristic of hamstring injuries in athletes and in poor body mechanics in running [4]. Lack of flexibility has been related to both a decrease in athletic performance and an increase in muscular injuries [7]. In tennis players, strength and flexibility of hamstring as well as calf muscles have a significant effect on agility performance [8]. Hamstring stretching may be considered as an intervention in both prevention and treatment of hamstring strains [6]. Stretching techniques are the treatments used to improve muscular extensibility to improve ROM and it can help to prevent damage in daily life or sports, to reduce muscle pain and to improve muscle capability and athletic performance [4].

Static stretching is commonly used method of stretching in which soft tissues are elongated just past the point of tissue resistance and then held in lengthened position with a sustained stretch force over a period of time [9]. Fletcher and Jones (2004) described dynamic stretching as a controlled movement through the active ROM for each joint [10].

Recent studies reported that pre-exercise static stretching (SS) decreases maximal force production. However, the literature is not unanimous in reporting stretch-induced performance impairments. The increasing evidence of the negative effects of pre-event static stretching as well as the increasing prescription of the dynamic warm-up make it important to determine which type of warm-up protocol will be the most effective in preparing for sporting events that involve agility movements [10].

Hence, this comparative study is undertaken to evaluate and compare the effects of static and dynamic stretching on hamstring flexibility and agility performance to help the athletes make a more accurate prescription of the most effective method of pre-event stretching in the warm-up and to achieve maximum performance in agility sports.

In this study, hamstring muscle flexibility was assessed by Modified Sit and Reach Test (MSRT) and Active Knee Extension (AKE) and agility was assessed by Shuttle Run Test and Tennis Specific Agility Test for both groups before and after application of stretch.

Burkett utilized the Wells sit-and-reach method to determine hamstring flexibility [5] Hopkins and Hopkins and Hoeger proposed the Modified Sit And Reach Test to administratively negate the effects of shoulder girdle mobility and proportional differences between arms and legs. Werner W.K Hoeger *et al*. (1990) concluded that MSRT appears feasible and would eliminate the concern expressed by Wilmore and Costill and many practitioners concerning disproportionate limb length bias [11]. C. M. Norris and M. Matthews (2005) concluded that AKE when used in conjunction with goniometry, accurate surface marking, and manual monitoring of the test leg is a reliable measure of hamstring muscle length [12]. Anna Eriksson, Fredrik R Johansson and Maria Bäck (2015) concluded that shuttle run test is a reliable and valid test for use in competitive junior tennis players as a practical alternative to evaluate physical fitness [13]. Cooke, Quinn (2011) used tennis specific agility test to examine the testing methods and protocols for tennis specific speed and agility. [14]

2. Materials and methods

2.1 Study design: Comparative study

2.2 Study setting: Best Club, Sports Authority of India, Tenvic Sports, Karnataka State Lawn Tennis Association, Kittur Rani Chennamma Stadium, Sree Kanteerava Stadium in Bangalore, Karnataka.

2.3 Duration of study: 18 months

2.4 Sample size: 60

2.5 Sampling technique: A random sampling method

2.6 Method of data collection

The study was conducted on 60 healthy regular tennis players of age group of 18 to 25 years who consented to participate in the study. Subjects with hamstring or acute knee injuries and neurological deficits and musculoskeletal abnormalities of spine and lower limb and hyper flexibility were excluded.

The intervention was explained to subjects and an institutionally approved written consent was taken. Subjects were divided into 2 intervention groups by a random sampling method. Group A: static stretching (n=30) & Group B: dynamic stretching (n=30). Both groups received one intervention session a day for 3 days a week for 6 weeks. Materials used were a universal goniometer, modified sit and reach test box, stop watch, couch, cones, measuring tape, consent form, pen and data sheet. Pre intervention (day 1) and post intervention (end of 6th week) evaluation was taken with MSRT, AKE, Shuttle Run Test and Tennis Specific Agility Test for both the groups.

2.7 Intervention

Group A: Static stretching is done by standing erect with the contralateral foot planted on the floor and pointing straight ahead (no hip internal or external rotation). The hamstring muscles is stretched by placing the calcaneal aspect of the extremity to be stretched on an elevated surface (high enough to cause a gentle stretching sensation in the posterior thigh) with the knee fully extended and toes pointed to the ceiling (again, no hip internal or external rotation). The subject then flexed forward from the hip, maintaining the spine in a neutral position, while reaching the arms forward until a gentle stretching felt in the posterior thigh. After achieving this position, the stretch is sustained for 30 second. One repetition of static stretching was applied to both the extremities.

Group B: Dynamic stretching is performed by lying supine and holding their hip in 90 degree of flexion. The subject then actively extended the leg (5 seconds), held the leg at the end of knee extension for 5 seconds, and then slowly lowered the leg (5 seconds), which will be is considered one repetition. Six repetitions were given to each lower extremity.

This intervention for Group A and Group B was a six week program and each group received one intervention session a day for 3 days a week for 6 weeks.

2.8 Outcome measures

All subjects were evaluated on day 1 and at the end of 6th week using following outcome measures:

Assessment of hamstring flexibility:

1. Active knee extension (AKE)

Subject was in supine lying with the contralateral lower extremity in relaxed position and flexed their testing knee and hip to 90 degrees and then extended his leg as far as possible, keeping their foot relaxed, and held the position for 5 sec. Each subject performed a single repetition of the movement to familiarize themselves with the action. A second repetition was performed and at the end of the 5 sec holding period the angle of knee extension was measured using a standard goniometer. The lateral epicondyle was palpated and the goniometer was centered over it. The lateral malleolus of the tibia and the greater trochanter of the femur were then marked. The arms of the goniometer were aligned with the proximal and distal land marks. The goniometer measurement was taken at the end range of knee extension and recorded. [1]

2. Modified Sit and Reach test (MSRT)

Hopkins and Hoeger proposed the modified sit and reach test to administratively negate the effects of shoulder girdle mobility and proportional differences between arms and legs. In the modified sit and reach protocol, the subject was instructed to assume a sitting position with the head, back, and hips against the wall (90º angle at the hip joints and the feet against the sit and reach box. A sliding measurement scale or yardstick with a range of 0 to 90 cm was placed on

The box. The subject was instructed to place hand over hand and reach out level with the measurement scale. During the initial reach, the head and back remained in contact with the wall; only scapular abduction should was performed. The sliding measurement scale was then slid along the top of the box until the zero point of the scale was even with the tip of the fingers. This administrative technique established the finger to box distance (FBD). The FBD established a relative zero point for each individual based on proportional difference in limb lengths. After the relative zero point was established, the sliding measurement scale was held firmly in place and the subject was then instructed to complete the reach test that is to reach as far as possible without bending his knees. The score was the total distance reached. The MSRT appears to eliminate the concern of disproportionate limb-length bias expressed by many practitioners [11].

Assessment of agility performance

1. Shuttle run test

To administer shuttle run test 2 cones were placed on the tennis court 5 m apart. Subject was instructed to sprint from 1 cone to other, touch it with hands by bending down and sprint back to starting line twice for a total of 20 and time was recorded in seconds for the same [8].

2. Tennis specific agility test

Player was instructed to begin at centre mark on the base line of tennis court. Upon the command "go" of the assessor, player sprinted to doubles sideline to touch a cone placed at the centre of the line, and then he returned back to the starting position on centre mark. From the centre mark he then ran to the singles sideline and again touched the cone before returning to the starting position.

Next sprint was to the short diagonal at the intersection of singles sideline and service lines on the right hand side, again returning back to starting position. Player then sprinted forwards to touch the net and returned back to baseline keeping an eye on their opponent (backward sprint). Long diagonal to the left was the next direction here player sprinted from centre to intersection of net and left singles sideline and returned in side sprint to the centre point. It was then along the baseline to the left single sideline and back to the centre point. Finally last sprint was out to doubles sideline as fast as possible. Stopwatch was stopped as player crossed doubles sideline and time was recorded [8].

3. Results and Discussion

Data was analyzed using the statistical package SPSS19.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p<0.05$.

1. Descriptive statistics was performed to find out the mean and standard deviation of the respective groups.
2. Student-t test was used to compare the difference between pre-intervention and post intervention within each group.
3. Independent t test was used to compare the difference between SS (Group A) and DS (Group B).

Table 1: Age comparison of the study participants

	Mean	SD
Group A	22.17	2.7
Group B	23.28	2.1

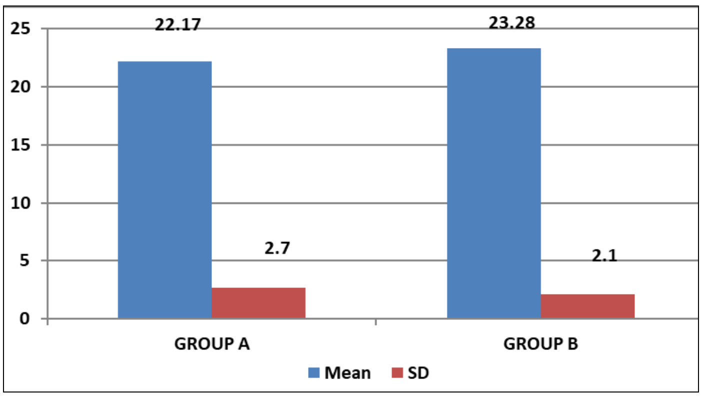

Fig 1: Age comparison of the study participants

Table 1 and fig. 1 show the mean value of age with standard deviation in each group. The higher mean age was observed in Group B (23.8) compared to Group A (22.17).

Table 2: Gender comparison of the study participants

	Male		female	
	Number	Percentage	Number	Percentage
GROUP A	25	83	5	17
GROUP B	27	90	3	10

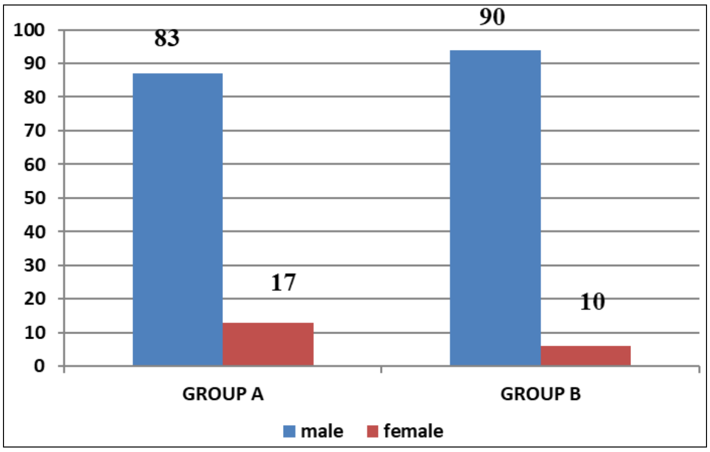

Fig 2: Gender comparison of the study participants

Table 2 and fig. 2 show gender distribution in each group. The number of males in group A and B were 25 (83%) and 27 (90%) respectively. The number of females in group A and B were 5 (17%) and 3 (10%) respectively.

Table 3: Comparison of MSRT between groups

		Group A		Group B		P value (Between group)
		Mean	SD	Mean	SD	
MSRT	PRE	30.94	3.81	30.94	3.45	0.91
	POST	32.89	3.72	33.05	3.28	0.55
	DIFF	1.95	0.57	2.11	0.55	0.0003*
P value (within group)		0.04*		0.018*		
% reduction		6.3%		6.8%		

<0.05 is statistically significant (unpaired t test)

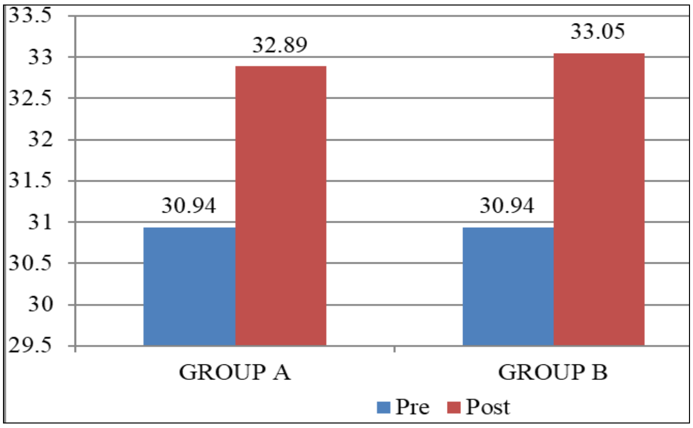

Fig 3: Comparison of MSRT between groups

The result showed that both static and dynamic stretching have significantly improved hamstring muscles flexibility ($p<0.05$). Significant difference present regarding MSRT between the group ($p<0.05$) showed that dynamic stretching is more effective in improving hamstring flexibility than static stretching (6.8% vs. 6.3%).

Table 4: Comparison of AKE (right leg) between groups

		Group A		Group B		P value (Between group)
		Mean	SD	Mean	SD	
AKE Right	Pre	57	7.31	55.26	7.63	0.37
	POST	62.83	6.96	62.24	7.12	0.74
	DIFF	5.83	1.76	7.2	1.64	0.0028*
P value (within group)		0.0025*		0.0005*		
% reduction		10.2%		13.1%		

<0.05 is statistically significant (unpaired t test)

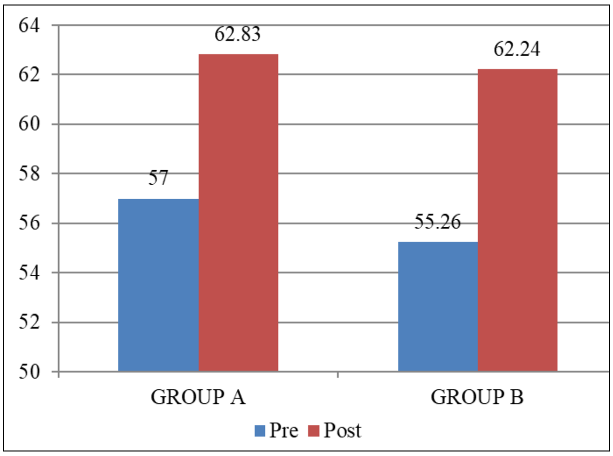

Fig 4: Comparison of AKE (right leg) between groups

Table 5: Comparison of AKE (left leg) between groups

		Group A		Group B		P value (Between group)
		Mean	SD	Mean	SD	
AKE Left	PRE	56.7	6.01	54.96	6.62	0.29
	POST	62.13	5.84	62.3	6.29	0.91
	DIFF	5.6	1.42	7	2.13	0.004*
P value (within group)		0.0001*		0.0001*		
% reduction		9.8%		12.73%		

<0.05 is statistically significant (unpaired t test)

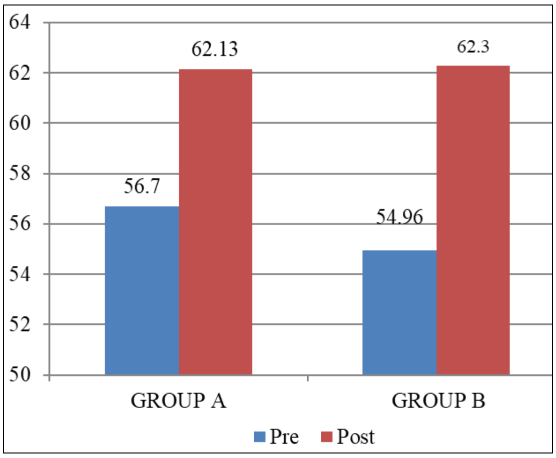

Fig 5: Comparison of AKE (left leg) between groups

Within group analysis showed that both static and dynamic stretching have significantly improved hamstring muscles flexibility ($p<0.05$). Significant difference present regarding AKE for both, right and left leg between the group ($p<0.05$) showed that DS is more effective in improving hamstring flexibility than SS (13.1% vs. 10.2% for right leg and 12.73% vs. 9.8% for left leg).

Table 6: Comparison of Shuttle Run Test between groups

		Group A(SS)		Group B(DS)		P value
		Mean	SD	Mean	SD	
Shuttle run test	PRE	6.24	0.69	6.30	0.61	0.72
	POST	5.91	0.72	5.46	0.45	0.0001*
	DIFF	0.33	0.09	0.84	0.39	0.0001*
P value (within group)		0.07		0.0001*		
% reduction		5.2%		13.3%		

<0.05 is statistically significant (unpaired t test)

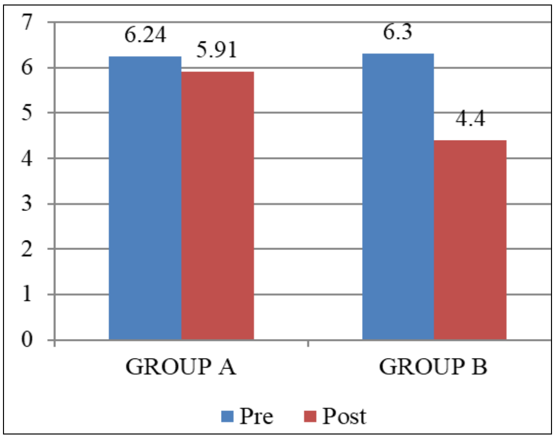

Fig 6: Comparison of Shuttle Run Test between groups

Results showed that Group B (DS) has significantly improved agility performance ($p<0.05$) but Group A (SS) did not show ant statistically significant improvement in agility performance. ($p>0.05$)

Table 7: Comparison of Tennis Specific Agility Test between groups

		Group A		Group B		P value (Between group)
		Mean	SD	Mean	SD	
Tennis Specific Agility Test	PRE	37.18	1.45	37.68	1.57	0.20
	POST	37.10	1.48	36.65	1.43	0.23
	DIFF	0.08	0.13	1.03	0.52	0.0001*
P value (within group)		0.83		0.012*		
% reduction		0.2%		2.7%		

<0.05 is statistically significant (unpaired t test)

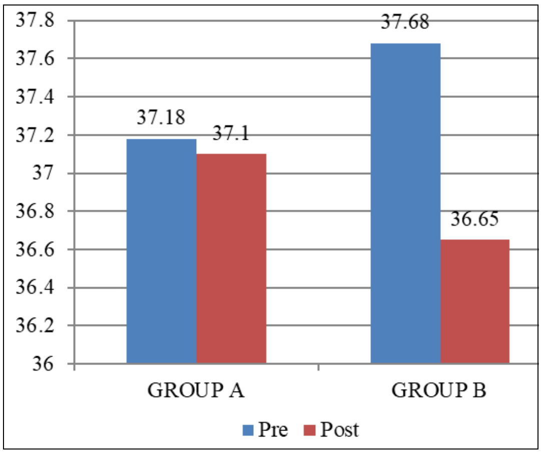

Fig 7: Comparison of Tennis Specific Agility Test between Groups

Results showed that Group B (DS) has significantly improved agility performance ($p<0.05$) but Group A (SS) did not show ant statistically significant improvement in agility performance. ($p>0.05$)

Discussion

The study findings indicate that both static and dynamic stretching significantly improved hamstring muscle flexibility in tennis players. Dynamic stretching causes contraction of the antagonist muscle which causes the lengthening muscle to relax due to the principal of reciprocal inhibition. Therefore it is a more natural way to elongate the muscle and does so in a relaxed state. Our findings are in agreement with those of

Bandy *et al*. who described the effect of dynamic stretching on hamstring flexibility of the high school males suggesting that there is a significant improvement in the hamstring flexibility. Similarly William *et al*. demonstrated the effect of dynamic stretching in slump sitting position on the hamstring flexibility and they found that the hamstring flexibility had improved markedly [1].

The static stretch takes advantage of the inverse myotatic reflex, which promotes muscle relaxation and hence further stretch and ROM. The slow, controlled movement allows the stretch to be performed safely, with reduced risk of injury as compared to the other forms of stretching [4]. One of the advantages of static stretching may be the facilitation of the Golgi tendon organ (GTO). Some other authors have stated that the slow build-up of the tension and the absence of pain involved with static stretching are believed to minimize stretch reflex response thus inducing muscular relaxation and allowing further stretching [15].

Davis, Ashby, McCale, McQuain, and Wine (2005) showed a significant increase in hamstring flexibility only after 4 weeks of SS [16]. Bandy *et al*. (1997) reported that a 30-second static stretch is just as effective at improving hamstring flexibility as 60-seconds in an average age population of 26 years.[17] Volkert *et al*. described the effect of static stretching and warm up exercises on hamstring length over a course of 24 hours and they found that there was a significant increase in the hamstring length [18].

The effects of SS on agility performance have received less attention in the literature. Some studies have reported deterioration or no effect of short to moderate duration SS on agility performance [15]. Avela *et al*. (1999) examined that prolonged and repeated stretching on the H reflex and found a depression in the H reflex after stretching [19]. A stretching-induced change in the length-tension relationship may also account for the negative effect on agility performance [20]. Our findings are in agreement with Knudson *et al*., 2001; Knudson *et al*., 2004; Unick *et al*., 2005; Alpkaya and Koceja, 2007; Samuel *et al*., 2008 who have concluded that acute static stretching neither helped nor inhibited performance [19].

The results of this study support the efficacy of dynamic stretching as compared to static stretching for improving performance as dynamic stretching significantly improved hamstring muscle flexibility and agility in tennis players. This finding is in accordance with those of Van Gelder and Bartz (2011) and McMillian *et al*. (2006). Little and Williams have stated that acute dynamic stretching improves the test performances of acceleration, speed and agility in professional soccer players [3].

The improvement on agility performance may be attributed to the post-activation potentiation phenomenon (PAP) due to increased muscle efficiency to produce force after a maximal or submaximal contraction (Chatzopoulos *et al*, 2007), and to the increase in muscle temperature which reduces muscles resistance (Fletcher and Monte-Colombo, 2010) contributing to a more dynamic muscle contraction and a faster relaxation (Shellock and Prentice, 1985) [21].

The pre-test contractions may have elicited a PAP response contributing to the significant differences between DS and SS protocol [3]. In addition, dynamic stretching may induce a positive effect on the stretch-shortening cycle with a greater action potential that may result in enhancing muscular performance [22].

Conclusion

This study can be concluded by stating that both the groups showed clinical as well as statistically significant improvement in hamstring muscle flexibility in tennis players. But subjects of Group B with DS showed better improvement in hamstring muscle flexibility than subjects of Group A with SS ($p<0.05$). DS showed clinical as well as statistically significant improvement in agility performance in tennis players ($p<0.05$) but SS did not show any clinical or statistically significant positive or negative effect on agility performance in tennis players. This suggests that focusing on dynamic stretching gives a better improvement in hamstring muscle flexibility and agility performance than static stretching in tennis players.

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