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Comparing the effect of static, ballistic and contract-relax stretching on hamstring muscles flexibility in young individuals

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Abstract
Muscular flexibility is an important aspect of normal human function. Sedentary individuals are susceptible to inflexible or reconditioned hamstrings. The tightness of hamstring muscles is one of the main factors hindering performance in daily and sporting activities. A variety of stretching techniques exist to enhance flexibility and range of motion. With the questions regarding the effective gains of different stretching methods, this interventional study was conducted to compare the effect of static, ballistic and contract-relax stretching on hamstring muscles flexibility in young individuals. 90 young, healthy individuals were assessed for the inclusion and exclusion criteria and randomly divided into 3 groups. Group A received static stretching, Group B received dynamic stretching and Group C received contract-relax stretching for hamstring muscles. Sit and reach test (SRT) and popliteal angle (PA) test were used as a standard outcome measures to measure pre and post intervention flexibility of hamstring immediately following the stretch. The result showed statistically significant improvement in SRT and PA concluding that all the three stretching techniques were effective in improving hamstring flexibility in young individuals. Specifically the contract relax stretching was more effective than static and ballistic stretching.

Keywords: Sit and reach test, popliteal angle test, static stretching, ballistic stretching, contract-relax stretching, hamstring tightness

1. Introduction
Hamstring muscles are reported to be the most commonly injured multi-joint muscle group in the body [1]. Sprain, most common muscle injury can occur due to hamstring tightness.Tight hamstrings can cause postural problems and back problems such as sacroiliac joint pain, lower back pain. It is the main contributing factor leading to the risk of pathological conditions of the knee and spine. Tight hamstrings can cause the hips and pelvis to rotate back which leads to flattening the lower back muscle and increased patellofemoral compressive force, which may eventually, lead to patellofemoral pain syndrome [2]. Hamstring tightness is often an indicator of muscle weakness elsewhere [3].
People who assume prolonged sitting position are prone to tight hip flexors, hamstrings and calves. Thus, sedentary individuals are susceptible to inflexible or reconditioned hamstrings, while athletes and very physically active individuals have healthy, well-conditioned hamstrings [3].
Maintaining normal muscle length requires regular stretching to prevent muscle stiffness and benefit from the decreased risk of musculoskeletal injuries and enhanced physical performance [1]. Stretching techniques are the treatments used to improve muscular extensibility to improve ROM, and can help prevent damage in daily life or sports, reduce muscle pain, and improve muscle capability, and athletic performance [4].
There are three main stretching techniques such as static stretching, proprioceptive neuromuscular facilitation (PNF) stretching and ballistic stretching. In static stretching 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 [5]. Ballistic stretching is a rapid, forceful intermittent stretch that is, a high speed and high-intensity stretch.

It is characterized by the use of quick, bouncing movements that create a momentum to carry the body segment through the range of motion to stretch shortened structures [5]. Proprioceptive neuromuscular facilitation a popular method of stretching that utilizes inhibition techniques; of these, contract-relax (CR), hold-relax (HR) and contract-relax antagonist-contract (CRAC) appear to be most commonly used [6].

In CR stretching the target muscle is lengthened and then held in that position while the participant contracted the target muscle isometrically to its maximum for an allotted amount of time. This was followed by a shorter relaxation of the TM that usually included a passive stretch [7].

Despite of having many stretching methods which help to increase flexibility, there are still questions regarding the most effective method. Literature should present studies comparing the effects of stretching protocols, assessing the advantages and disadvantages of stretching techniques, including static stretching, ballistic stretching and contract-relax stretching [8].

Hence, this interventional study aims to compare the immediate effect of static, ballistic and contract-relax stretching in improving hamstring flexibility in young individuals.

In this study, sit and reach test and popliteal angle were used as a standard testing for hamstring muscle flexibility. The sit-and-reach test is probably the most common measurement tool used for evaluating hamstring and lower back flexibility [9]. The popliteal angle test is a method that investigates hamstring muscle flexibility in isolation and it is easy to apply.

2. Materials and Methods

2.1 Study design: Comparative study

2.2 Study setting: Kempegowda Institute of physiotherapy, Bangalore and KIMS Men's hostel, Banashankari 2nd stage, Bangalore.

2.3 Study duration: 12 months

2.4 Sample size: 90 (30 subjects in each group)

2.5 Sampling method: A random sample method

2.6 Method of collection

The study was conducted on 90 healthy regular tennis players of age group of 18 to 25 years who consented to participate in the study. Subjects with lesions in hamstring muscles in the last three months, any hip, knee, or lower back pathology, recent abdominal injuries or surgeries, Spinal stabilization surgeries or lumbosacral region surgeries were excluded.

The intervention was explained to subjects and an institutionally approved written consent was taken. Subjects were divided into 3 intervention groups by a random sampling method. Group A: static stretching group (n=30), Group B: ballistic stretching group (n=30) & group C: contract relax stretching (n=30). Materials used were a universal goniometer, sit and reach test box, couch, consent form, pen and data sheet. Pre intervention and post intervention evaluation immediately following the stretch was taken with sit and reach test and popliteal angle to measure hamstring muscle flexibility. Both tests were performed three times and the average of the three measurements was used for data analysis [10].

2.7 Intervention

Group A: Static stretching

The patient was positioned in supine lying. The hip was flexed passively by the examiner up to the maximum flexion point with the knee joint maintaining full extension. Five cycles of 30 seconds each were performed with an interval of thirty seconds between cycles.

Fig 1: Static Stretching

Group B: Ballistic stretching

The patient was positioned in supine lying. Flexion-extension movements of the hip with knee fully extended were performed by the examiner, with the fastest speed as possible, respecting the limit of each volunteer. One cycle consisting of hip flexion and extension was performed in one second and followed by the rest interval of 1 second. Total 30 cycles were performed for 30 seconds with the rest interval of 1 second in between each cycle.

Fig 2: Ballistic Stretching

Fig 3: Ballistic Stretching

Group C: Contract-relax stretching

The patient was positioned in supine lying. The examiner flexed participant's hip joint passively to the maximum flexion point while maintaining the knee joint in full extension. Five cycles of thirty seconds each were performed, five seconds of isometric contraction and ten seconds of stretching with relaxed muscles. This process was performed twice so that the cycle of thirty seconds was completed with an interval of thirty seconds between the cycles.

Fig 4: Contract-Relax Stretching

2.8 Outcome measures

All subjects were evaluated before and immediately after applying stretch using following outcome measures:

1. Sit and reach test (SRT)

SRT, which assesses the flexibility of the posterior muscular chain, is performed with subjects instructed to sit with the hip joints at 90º angle, knees extended and feet against the sit and reach box. Subject was asked to place hand over hand and to perform a hip flexion and to reach as far as possible without bending his knees [10].

Fig 5: Sit and Reach Test Measurement

2. Popliteal angle test (PA)

The contralateral limb was stabilized in full extension and the dominant limb was stabilized at 90º of hip flexion with the knee relaxed. The goniometer was positioned with the fixed arm toward the greater trochanter of the femur and the movable arm toward the lateral malleolus. The volunteer was asked to extend his knee until the time he had the feeling of discomfort and goniometer measurement was taken [10].

Fig 6: Measurement of Popliteal Angle

3. Results and Discussion

Data was analyzed using the statistical package SPSS20.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p< 0.05$.

- Descriptive statistics was done by calculating Mean, Standard Deviation and Standard error.
- Normality test was done using Shapiro Wilkinson test. As the data set follows normal distribution parametric tests were planned for the analysis.
- Student- t test was used to compare the difference between pretreatment and post treatment.
- The difference between three groups was done using one way ANOVA test. Significance level was kept at 5%.

Table 1: Age Distribution between the Groups

	Group A		Group B		Group C	
Age group	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
18-20	13	43.33	14	46.67	11	36.67
21-23	11	36.67	11	36.67	14	46.67
24-25	6	20	5	16.66	5	16.66
Total	30	100	30	100	30	100

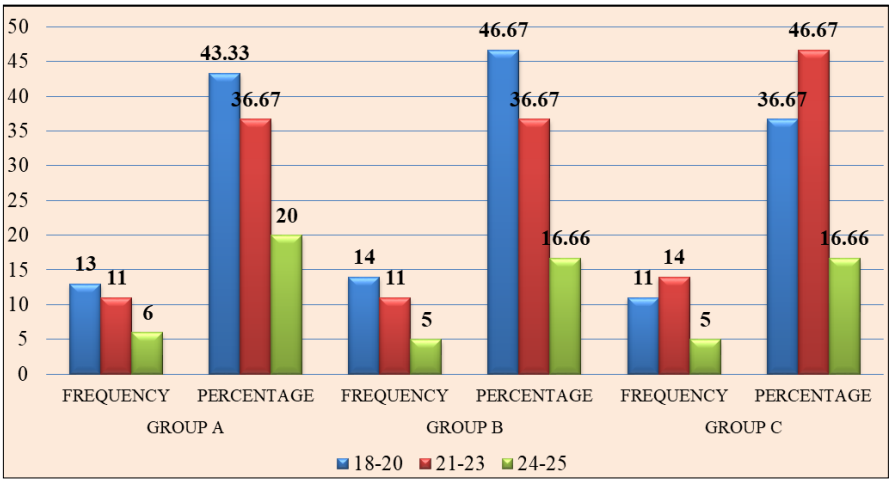

Fig 7: Age Group Distribution of Group A, B and C

Table 1 and Fig.7 show age group distribution that participated in this study. Those in the age group between 18-20 were 13(43.33%) in group A, 14(46.67%) in group B and 11(36.67%) in group C. Similarly those in the age group of

21-23 were 11 (36.67%), 11(36.67%) and 14 (46.67%) and in the age group 24-25 were 6 (20%), 5 (16.66%), 5 (16.66%) in group A, B and C respectively.

Table 2: Gender Distribution in Each Group

	Group A		Group B		Group C	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Male	18	60	20	66.67	19	63.33
Female	12	40	10	33.33	11	36.67
Total	30	100	30	100	30	100
Chi Square Value	0.095					
P Value	0.93					

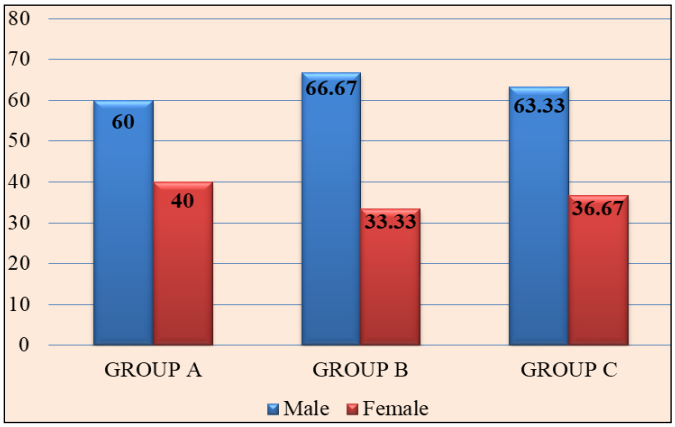

Fig 8: Percentage of Gender in Each Group

Table 2 and Fig. 8 show gender wise distribution in each group. P-value was 0.93 (>0.05), which was not statistically significant (0.93) with the chi-square value 0.095.

Table 3: Comparison within Group A for SRT

Sit and Reach Test	Pre Rx	Post Rx
Mean	15.5	18.1
SD	4.29	4.6
N	30	30
p value	<0.0001	

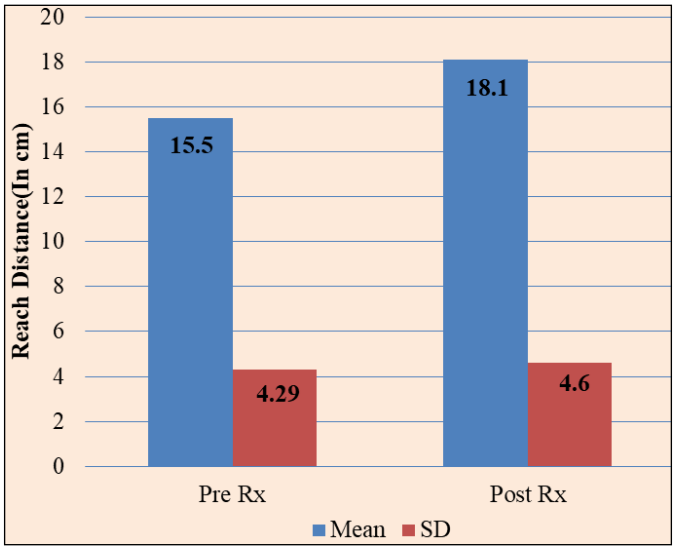

Fig 9: Score of Mean and SD of SRT of Group A

Table 3 and fig. 9 show the descriptive data (mean & SD) of SRT for Group A. The mean value was improved significantly (p< 0.0001) from the pre-treatment value showing that static stretching has significantly improved hamstring muscles flexibility.

Table 4: Comparison within Group B for SRT

Sit and Reach test	Pre Rx	Post Rx
Mean	15.37	17.83
SD	4.24	4.14
N	30	30
p value	<0.0001	

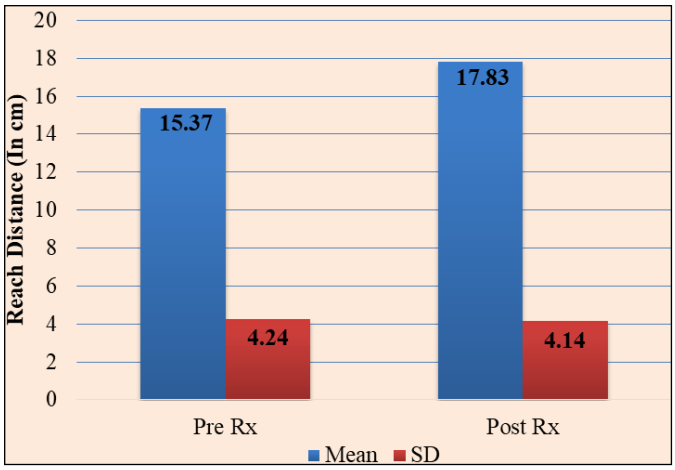

Fig 10: Score of Mean and SD of SRT of Group B

Table 4 and fig.10 show the descriptive data (mean & SD) of SRT for Group B. The mean value was improved significantly (p< 0.0001) from the pre-treatment value showing that ballistic stretching has significantly improved hamstring muscles flexibility.

Table 5: Comparison within Group C for SRT

Sit and Reach test	Pre Rx	Post Rx
Mean	16.27	20.3
SD	4.47	5.03
N	30	30
p value	<0.0001	

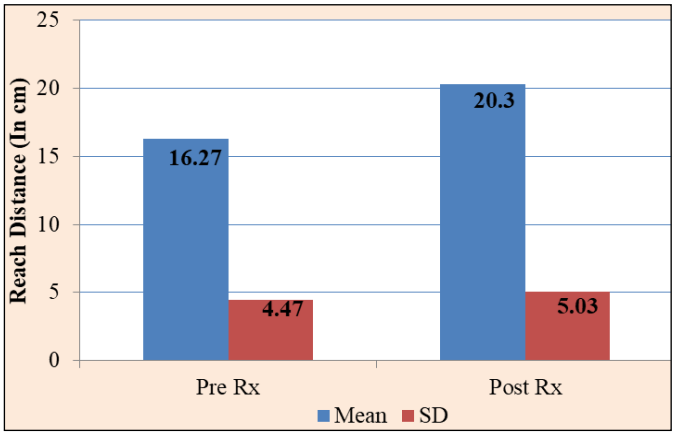

Fig 11: Score of Mean and SD of SRT of Group C

Table 5 and fig.11 show the descriptive data of SRT regarding for Group C. The mean value was improved significantly (p< 0.0001) from the pretreatment value showing that contract-relax stretching has significantly improved hamstring muscles flexibility.

Table 6: Comparison within Group A for PA

Popliteal angle	Pre Rx	Post Rx
Mean	119.23	131.23
SD	7.09	8.08
N	30	30
p value	<0.0001	

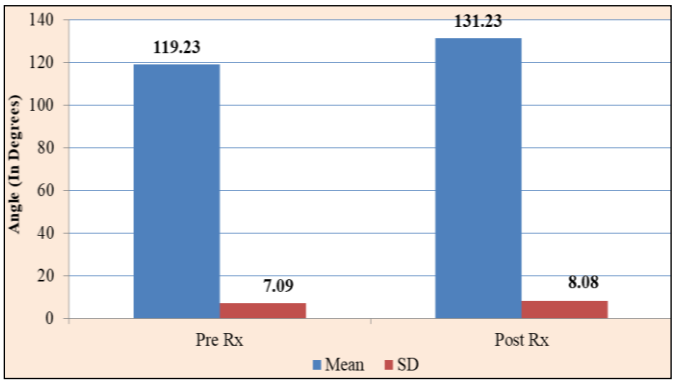

Fig 12: Score of Mean and SD of PA of Group A

Table 6 and fig. 12 show the descriptive data (mean & SD) of PA for Group A. The mean value was improved significantly (p< 0.0001) from the pre-treatment value showing that static stretching has significantly improved hamstring muscles flexibility.

Table 7: Comparison within Group B for PA

Popliteal angle	Pre Rx	Post Rx
Mean	118.13	128.97
SD	8.21	8.4
N	30	30
p value	<0.0001	

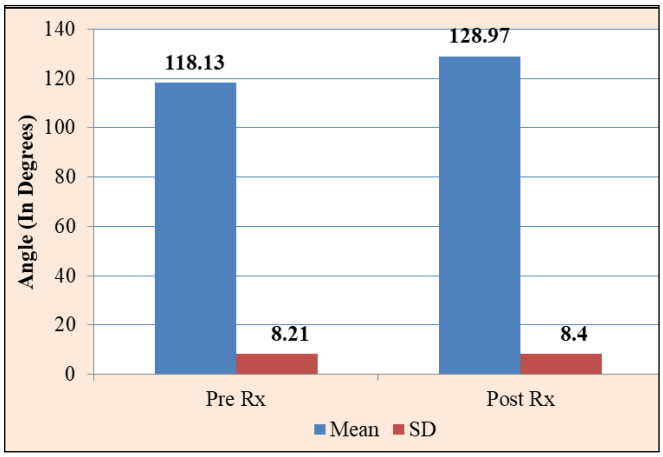

Fig 13: Score of Mean and SD of PA of Group B

Table 7 and fig. 13 show the descriptive data (mean & SD) of PA for Group B. The mean value was improved significantly (p<0.0001) from the pre-treatment value showing that ballistic stretching has significantly improved hamstring muscles flexibility.

Table 8: Comparison within Group C for PA

Popliteal Angle	Pre Rx	Post Rx
Mean	116.77	134.67
SD	6.75	6.73
N	30	30
p value	<0.0001	

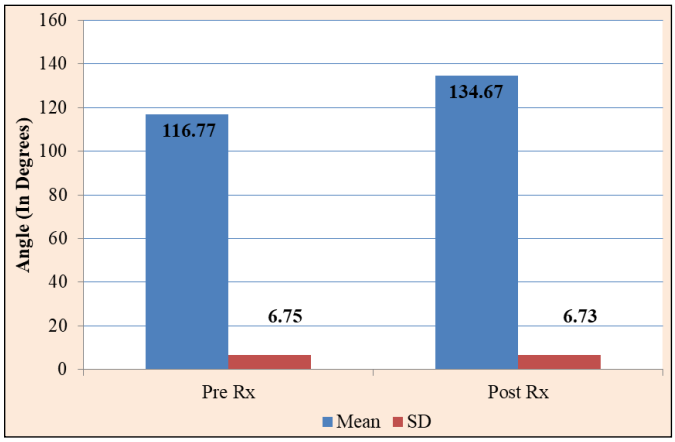

Fig 14: Score of Mean and SD of PA of Group C

Table 8 and fig.14 show the descriptive data of PA regarding for Group C. The mean value was improved significantly (p< 0.0001) from the pretreatment value showing that contract-relax stretching has significantly improved hamstring muscles flexibility.

Table 9: Comparison of SRT between Groups A, B & C

Treatments					
	Group A	Group B	Group C	Total	
N	30	30	30	90	
ΣX	543	461	609	1613	
MEAN	18.1	15.3667	20.3	17.9222	
ΣX^2	10443	7605	13097	31145	
SD	4.604	4.2384	5.032	5.0129	
ANOVA statistics	SS	df	MS	F	P value
Between treatments	366.4889	2	183.2444	8.52543	0.0004
Within treatments	1869.967	87	21.4939		
Total	2236.456	89			

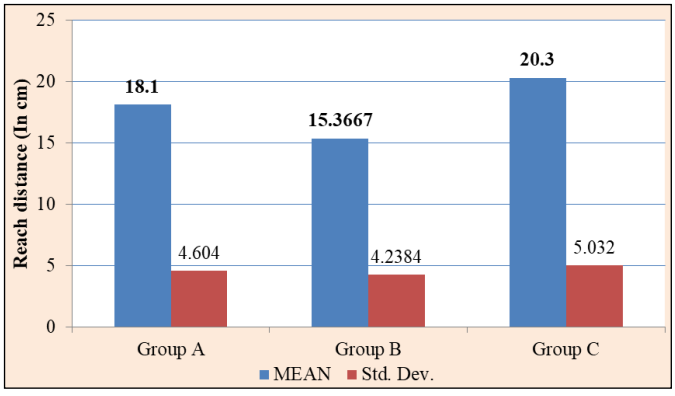

Fig 15: Comparison of SRT between Groups

Table 9 and fig. 15 show the descriptive data of SRT for all the three groups. The highest value was observed within the C group (134.67) and group B serves the least one (129.13). The ANOVA statistics reported a significant relationship (p=0.02759) between the treatment methods and the PA test

highlights the real significant potential of all the three methods.

Table 10: Comparison of PA between Group A, B & C

Treatments					
	Group A	Group B	Group C	Total	
N	30	30	30	90	
ΣX	3937	3874	4040	11851	
MEAN	131.2333	129.1333	134.6667	131.6778	
ΣX^2	518559	502498	545366	1566423	
Std. Dev.	8.0801	8.7798	6.7279	8.1487	
ANOVA test statistics	SS	df	MS	F	P value
Between treatments	468.1556	2	234.0778	3.74249	0.02759
Within treatments	5441.5	87	62.546		
TOTAL	5909.656	89			

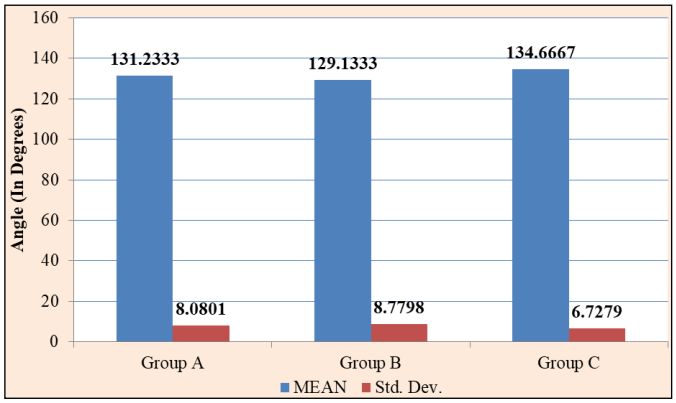

Fig 16: Comparison of PA between the Groups

Table 10 and Fig.16 show the descriptive data of PA for all the three groups. The highest value was observed within the C group (134.67) and group B serves the least one (129.13). The ANOVA statistics reported a significant relationship (p=0.02759) between the treatment methods and the PA test highlights the real significant potential of all the three methods.

Discussion

The findings of the current study indicate that all the three stretching techniques improve hamstring flexibility as statistically significant differences were found between pre and post intervention measurements of PA and SRT of dominant side in normal young individuals within the age group of 18-25 years.

Also the data suggests that contract-relax stretching technique was the most effective and ballistic stretching technique was the least effective in improving hamstring flexibility as the highest mean value for sit and reach test was observed within the group C (20.3±5.03) and the least one was observed in the group B (15.3±4.23). Similarly, for popliteal angle test, the highest mean value was observed within the group C (134.67±6.72) and the least one was observed in the group B (129.13±8.77).

The static stretch taking advantage of the inverse myotatic reflex 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 [11]. Golgi tendon organ (GTO) facilitation is one of the advantages of static stretching. 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.

Davis, Ashby, McCale, McQuain and Wine (2005) showed a significant increase in hamstring flexibility only after 4 weeks of SS [2]. 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 [4]. 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 [12]. Research often reports ballistic stretching to be less effective at improving flexibility than other types of stretching. One of the reasons for the lower effectiveness of ballistic stretching for improving static flexibility is inhibitory effect of the stretch reflex. Ballistic stretching is associated with increased potential of injury to the musculotendinous unit because of involvement of higher functions. The musculotendinous units of untrained and sedentary individuals may not be able to withstand this vigorous type of stretching without sustaining muscle damage. Our study findings are in accordance with Christopher A. Covert, Melanie P. Alexander, John J. Petronis, D. Scott Davis (2010) who concluded that both static and ballistic stretching groups produced greater increase in hamstring length than control group. But static stretching group demonstrated a statistically greater increase in hamstring muscle length than ballistic stretching group [13].

When compared to static stretching, contract-relax stretching provides greater tension on the tendon and aponeurosis because of isometric contraction. Therefore, it has more potential to increase tendon and aponeurosis compliance than static stretching.

In the same context, John O'Hora, Abigail Cartwright, Clive D. Wade, Alan D. Hough, and Gary L.K. Shum (2011) did a study comparing proprioceptive neuromuscular facilitation (PNF) and static stretching technique suggested that PNF was more effective in increasing hamstring flexibility than static stretching [14]. J. Brent Feland, J.W. Myrer, R.M. Merrill (2001) concluded that Contract Relax PNF stretch appears more beneficial than static stretch in senior male athletes of age less than 65 years [6].

Bekir Yuktasir, Fatih Kaya (2007) concluded that 30s PNF and passive static stretching program significantly increases ROM in the lower extremity. Hence 30s duration PNF and passive static stretching exercises may be useful for individuals who wish or need to increase their flexibility [15].

Dan Wallin, Björn Ekblom, Raymond Grahn, and Thomas Nordenborg (1985) concluded that contract relax stretching allows for a greater lengthening of muscle and an increased range of motion of corresponding joint than the classic Ballistic stretching method [16].

Conclusion

This study can be concluded by stating that all three static, ballistic and contract-relax stretching methods are beneficial in improving flexibility of hamstring muscles but contract relax stretching is more effective than the static stretching and ballistic stretching ($p<0.05$).

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