

# Comparison of static, ballistic and contract-relax stretching in hamstring muscle

*Comparação do alongamento estático, balístico e contrair-relaxar nos músculos isquiotrais*

*Comparación del alongamiento estático, balístico y contrae-relaja en los músculos isquiotrais*

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**ABSTRACT** | This study aimed to compare the effect of three stretching techniques (ballistic, static and contract-relax) on instant gain muscle flexibility on the hamstring muscle. We evaluated 23 subjects of both gender [means (SD) age 21.17 (1.4) years]. All volunteers performed static, ballistic and contract-relax stretching. Each technique was performed in a single session with an interval of seven days between sessions. To assess the immediate effects of the different techniques were performed two tests of flexibility, Sit and Reach Test and the Popliteal Angle Test. In comparison with the baseline there were significant increase in muscle flexibility in the Popliteal Angle Test after application ballistic (6.26%) and contract-relax technique (6.5%) respectively ( $p < 0.05$ ). When comparing the three techniques regarding the change score significant difference was found in the the Popliteal Angle Test for ballistic and contract-relax stretching, but Sit and Reach Test showed no significance difference. These data suggest that the ballistic and contract-relax were better than the technique of static stretching and both are equally effective. The ballistic contract-relax stretching techniques improved gain of muscle flexibility on the hamstring muscle.

**Keywords** | range of motion muscle stretching; exercises biomechanics.

**RESUMO** | Objetivou-se, por meio deste estudo, comparar o efeito de três técnicas de alongamento muscular (balístico, estático e contrai-relaxa) no ganho imediato de flexibilidade dos músculos isquiotrais. Foram avaliados 23 sujeitos, de ambos os gêneros [média (DP) idade 21,17 (1,4)]. Todos os voluntários realizaram o alongamento estático, o balístico e o contrai-relaxa. Cada técnica foi realizada em sessão única com intervalo de sete dias entre as sessões. Para avaliar os efeitos imediatos das diferentes técnicas, realizaram-se,

antes e após a série de alongamentos, os testes de flexibilidade Sentar e Alcançar e o Teste do Ângulo Poplíteo. Em comparação à linha de base, houve aumento significativo de flexibilidade para o teste do Ângulo Poplíteo após aplicação do alongamento balístico (6,26%) e contrai-relaxa (6,5%), respectivamente ( $p < 0,05$ ). Ao contrai-relaxar as três técnicas em relação ao escore de mudança, encontrou-se diferença considerável no teste do Ângulo Poplíteo para os alongamentos balístico e contrai-relaxar, porém, o Teste Sentar e Alcançar não apresentou relevância. De acordo com esses dados, as técnicas balísticas e contrai-relaxar foram melhores que a técnica de alongamento estático, e ambas as técnicas mostraram-se igualmente efetivas. As técnicas de alongamento balístico e contrai-relaxar melhoraram a flexibilidade dos músculos isquiotrais.

**Descritores** | amplitude de movimento articular; exercícios de alongamento muscular biomecânica.

**RESUMEN** | Se procuró, por medio de este estudio, comparar el efecto de tres técnicas de alongamiento muscular (balístico, estático y contrae-relaja) en el aumento inmediato de flexibilidad de los músculos isquiotrais. Se evaluaron 23 sujetos, de ambos géneros [media (DE) edad 21,17 (1,4)]. Todos voluntarios realizaron el alongamiento estático, el balístico y el contrae-relaja. Cada técnica fue realizada en sesión única con intervalo de siete días entre las sesiones. Para evaluar los efectos inmediatos de las diferentes técnicas, se realizaron, antes y después de la serie de alongamientos, los tests de flexibilidad Sentar y Alcanzar y el Test del Ângulo Poplíteo. En comparación a la línea de base, hubo aumento significativo de flexibilidad para el test del Ângulo Poplíteo, después de aplicación del alongamiento balístico (6,26%) y contrae-relaja (6,5%), respectivamente ( $p < 0,05$ ). Al comparar las tres técnicas en relación al

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escore de cambio, se encontró diferencia considerable en el test del Ángulo Poplíteo para los alargamientos balístico y contrae-relaja, sin embargo el Test Sentar y Alcanzar no presentó relevancia. De acuerdo con esos datos, las técnicas balísticas y contrae-relaja fueron mejores que la técnica de alargamiento estático y, ambas

técnicas, se mostraron igualmente efectivas. Las técnicas de alargamiento balístico y contrae-relaja mejoraron la flexibilidad de los músculos isquiocruales.

**Palabras clave** | amplitud de movimiento articular; ejercicios de alargamiento muscular biomecánica.

## INTRODUCTION

There are several consequences resulting from the shortening of hamstring muscles among them postural deviations<sup>1</sup>, change of the lumbopelvic rhythm, low back pain<sup>1,2</sup>, predisposition to lesions<sup>3</sup> and development of patellar tendinopathy<sup>2</sup>. Considering this reality the performance of stretching exercises both in the practice of sports as in rehabilitation centers is frequent<sup>3</sup>. The practice of stretching exercises promotes some benefits such as improved athletic performance and functional gains in addition to the maintenance of health and fitness<sup>4,5</sup>.

The main stretching techniques are: static stretching, ballistic stretching and contract-relax stretching<sup>6</sup>. Static stretching is described as a method in which the soft tissues are stretched to the point of resistance or tolerance of the tissue held in this position<sup>7</sup>. The ballistic stretching is characterized by the use of vigorous and rhythmic movements of a body segment throughout this range of motion in order to lengthen a muscle or muscle group<sup>8</sup> while the contract-relax technique uses a brief isometric contraction of the agonist muscle which inhibits the muscle to be stretched and then performs the static stretching during the muscle relaxation<sup>8,9</sup>.

There are studies that suggest that the contract-relax and ballistic stretching technique proves more effective in gain of hamstring flexibility than static stretching technique. In contrast, studies show that static stretching may be the only one able to maintain a significant gain in amplitude of hamstring muscles over a prolonged period<sup>4,6</sup>.

The importance of studies related to the shortening of the hamstring muscles is due to the possibility of the occurrence of lesions caused by biomechanical changes that can lead to some disorders such as patello femoral dysfunction, pubic pain, back pain, patellar tendonitis and postural disorder<sup>1</sup>. The hamstring injuries accounting for 29% of all injuries in athletes and 12% to 31% of these athletes suffer reinjuries. In addition considering that in clinical practice it is usual to apply stretching protocols, the 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<sup>10</sup>.

Thus the objectives of this study were: to analyze the effectiveness of static, ballistic and contract-relax stretching techniques and compare the immediate effects of these techniques on the flexibility of hamstring muscles.

## METHODOLOGY

### Subjects

Twenty-three university students from both genders, aged 18 to 25 years, were evaluated (Table 1). The volunteers were instructed not to practice stretching and/or muscle strengthening sessions of the lower limbs in the last three months prior to the study. Individuals who reported lesions in hamstring muscles in the last three months and those who made regular use of analgesic medication in the last two weeks were excluded from the sample. All volunteers signed a free and informed consent form.

### Procedures

The three stretching techniques were performed by all volunteers. Each stretching technique was performed in a single session with an interval of seven days between sessions in a randomization order. In assessing flexibility, the Sit and Reach Test (SRT) and the Popliteal Angle Test (PT) were used. Both tests, when using similar sample with the present study, showed in intraobserver analysis a ICC of 0.91 e 0.79 respectively, and in interobserver analysis a ICC of 0.71 and

Table 1. Subjects characteristic

Variables	Men (n=7) Mean±SD	Women (n=16) Mean±SD	Total (n=23) Mean±SD
Age (years)	20.85±1.57	21.31±1.35	21.17±1.40
Body mass (kg)	75.71±9.06	57.09±6.67	62.76±11.38
Height (m)	1.75±0.04	1.59±0.04	1.64±0.08
BMI (kg/m <sup>2</sup> )	24.76±3.91	22.33±2.32	23.07±3.03

SD: standard deviation; BMI: body mass index

0.72 respectively<sup>11</sup>. Tests and stretching techniques were performed by the same evaluator with previous experience. Each test was applied before and after the completion of each technique.

SRT which assesses the flexibility of the posterior muscular chain, was performed based on previous studies<sup>12,13</sup>. The subject was instructed to sit on the stretcher with knees extended and to perform a hip flexion with the elbow extended. The individual was asked to reach as far as possible without bending his knees.

To perform the PT styrofoam markers were placed in bony prominences of the greater trochanter, lateral epicondyle of the femur and lateral malleolus in the volunteer's dominant limb<sup>14</sup>. The contra lateral limb was stabilized in full extension and the dominant limb was stabilized at 90° 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. Both tests were performed three times and the average of the three measurements was used for data analysis.

The order of application of each stretching technique each day was randomly selected (Figura 1).

- *Static stretching*: the hip of the volunteer was flexed passively by the examiner up to the maximum flexion point with the knee joint maintaining full extension. Five cycles of 30 seconds were performed with an interval of thirty seconds between cycles.
- *Contract-relax stretching*: The hip of the volunteer was flexed passively by the examiner up to the maximum flexion point with the knee joint maintaining full extension. Five cycles of thirty seconds 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. An interval of thirty seconds between cycles was also performed.
- *Ballistic stretching*: flexion-extension movements of the hip with knee kept in full extension. The movements were performed by the examiner, with the fastest speed as possible, respecting the limit of each volunteer. Thirty cycles of thirty seconds were performed, with thirty seconds of interval between them.

## Statistical analysis

Data analysis used the SAS software for analytical statistical calculations. The normality of data distribution

was tested through the Shapiro-Wilk test. To compare data before and after stretching the 2-way repeated ANOVA (Analysis of variance) test was used followed by Tukey pos-hoc test. Furthermore, the data were reorganized according to the day. These data was reorganized to verify if the flexibility gain, regardless of the technique, was lasting. To compare data according to the day was used the 2-way repeated ANOVA followed by Tukey pos hoc test. The change scores between the three stretching techniques was performed by Friedman analysis of variance (ANOVA) test followed by Newman-Keus Student test, since the variances were not homogeneous. The significance level adopted for the data analysis was 5% ( $p < 0.05$ ).

## RESULTS

SRT had no significant increase in flexibility after the application of the static ( $p=0.59$ ;  $f=0.29$ ), ballistic ( $p=0.63$ ;  $f=0.22$ ) and contract-relax stretching ( $p=0.46$ ;  $f=0.5$ ) (Table 2).

Significant difference for the ballistic (6.26%) ( $p=0.01$ ;  $f=5.84$ ) and contract-relax stretching (6.5%) ( $p=0.009$ ;  $f=7.41$ ) was observed in the PT (Table 2).

There was no significant difference between initial values comparing the three techniques as well as between the final values both in the SRT ( $p=0.94$ ,  $f=0.58$ ;  $p=0.88$ ,  $f=0.12$  respectively) and in the PT ( $p=0.93$ ,  $f=0.67$ ;  $p=0.79$ ,  $f=0.22$  respectively) (Table 2). With regard to the difference in change score of each stretching technique, significance level was observed for the PT ( $p=0.01$ ) when comparing ballistic and static techniques ( $p < 0.05$ ) and static and contract-relax techniques ( $p < 0.05$ ); however no significant difference was found when contract-relax and ballistic techniques were compared ( $p=0.09$ ). There was no significant difference between final and initial values of each stretching technique applied to the SRT ( $p=0.66$ ) (Table 3).

Table 2. Popliteal angle test and Sit and reach test before and after the application of stretching techniques: static, ballistic and contract-relax

	Popliteal angle test (degree)		Sit and reach test (cm)	
	Before Mean±SD	After Mean±SD	Before Mean±SD	After Mean±SD
SS	135.87±11.83	141.49±11.4	21.73±10.83	23.41±10.51
BS	135.03±12.06	143.49±11.68 <sup>a</sup>	22.49±9.77	23.88±10.16
CRS	134.65±10.81	143.4±10.99 <sup>b</sup>	22.72±10.42	24.89±10.32

SS: Static Stretching; BS: Ballistic Stretching; CRS: Contract-Relax Stretching; SD: standard deviation.  
<sup>a</sup> significant difference before and after application of the technique of ballistic stretching.  
<sup>b</sup> significant difference before and after application of technical contract-relax stretching.

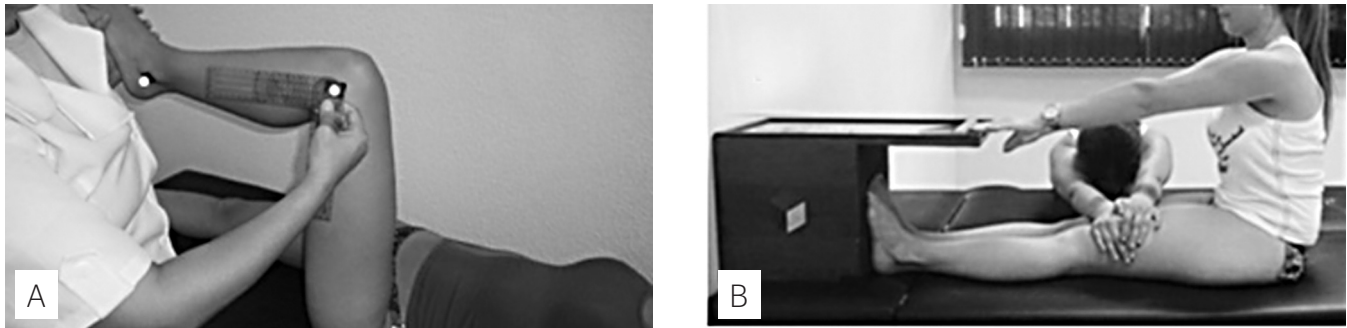


Figure 1. (A) Popliteo Angle Test; (B) Sit and Reach Test

Table 3. Change score of the Sit and Reach Test and of the Popliteal Angle Test for the three stretching techniques applied

	Static Stretching	Ballistic Stretching	Contract-relax Stretching	p-value
Sit and Reach Test (cm)	1.13 (0.03-5.63)	1.17 (0-5.33)	2.1 (0-6.03)	0.66
Popliteal Angle Test (degrees)	5.33 (0-16)	8.67 (1.67-3.33)	9 (1-17.66)	0.01 <0.05* <0.05**

\* p<0.05 in relation to static stretching and ballistic stretching; \*\* p<0.05 in relation to static stretching and contract-relax stretching; Values presented in median (minimum-maximum)

Table 4. The initial values of the Sit and Reach Test and of the Popliteal Angle Test in three days regardless of the stretching technique applied

	Sit and Reach Test (cm) Mean±SD	Popliteal Angle Test (degrees) Mean±SD
1 <sup>o</sup> Day	21.8±11.0	134.7±11.4
2 <sup>o</sup> Day	22.1±9.8	135.9±10.9
3 <sup>o</sup> Day	22.8±10.1	134.9±12.3
P value	0.94	0.93
F value	0.61	0.71

SD: standard deviation

The initial values of the SRT and PT in each day (D1, D2, D3), regardless of stretching technique, are shown in Table 4. There was no statistically significant difference for these values.

## DISCUSSION

This study aimed to compare the immediate flexibility gain of the hamstring muscles after applying the static, ballistic and contract-relax stretching techniques. The results of PT suggest that the ballistic and contract-relax stretching were able to increase the immediate flexibility of the hamstring muscles. These data corroborate the findings of other studies on the implementation of stretching protocols to increase the flexibility of the hamstring muscles<sup>15,16</sup>.

There are several techniques to assess changes in muscle flexibility based on the joint and movements to be evaluated. Thus functional tests used to assess the flexibility of hamstring muscles may include knee extension

movements and flexion of the trunk on the hip joint<sup>12</sup>. PT measures the flexibility of hamstring muscles<sup>17</sup> and shows good reliability when performed in healthy subjects<sup>18</sup>. SRT also shows good reliability to assess the flexibility of hamstring muscles<sup>19,20</sup>, but also measures the flexibility of the lower body segment<sup>19</sup>. PT may have been more sensitive to changes in flexibility of hamstring muscles after application of three stretching techniques.

The immediate flexibility gain can be explained by the viscoelastic properties of the muscle. This property is a response of the muscle-tendon unit to stretching with fixed length, which generates a decrease in stress over time. This reduced length of the muscle-tendon unit is known as stress relaxation and allows a deformed of the muscle-tendon unit more easily in the next repetition, thus providing greater flexibility<sup>16</sup>. Another explanation found is based on the increased tolerance of the muscle-tendon unit to elongation, although this mechanism is still unknown<sup>21</sup>.

Further, contract-relax stretching can also be explained by neurophysiological factors based on the findings of reciprocal inhibition and subsequent induction. Reciprocal inhibition describes the phenomenon that while a muscle group is activated, its antagonist is inhibited, thereby facilitating the elongation of this muscle-tendon unit<sup>22</sup>. Concerning to gains of flexibility that was observed after application of ballistic stretching, the literature reports that movements produced to perform the ballistic stretching can lead to a warming up of the body musculature. The increase of muscle temperature during strain can produce a decrease in viscosity of tissues and rectify the undulations of collagen<sup>23</sup>.

The results of change score of PT suggest that ballistic stretching and contract-relax are both equally effective and better than static stretching. Even though no significant difference between ballistic and contract-relax stretching techniques in the immediate flexibility gain of these muscles was found.

There are studies showing effects similar to those of this study in relation to the flexibility of the hamstring muscles and found lack of significant improvement in flexibility after the implementation of the ballistic and contract-relax techniques when compared to static stretching<sup>24,25</sup>. However others studies have found no significant difference between the static and contract-relax stretching or between static and ballistic techniques in the flexibility gain of hamstring muscles<sup>15,26</sup>.

The difference between results observed in this study to those reported in literature are due to the performance of stretching protocols that used the onset of pain sensation as reference, whereas in the present study, maximum tolerance to stretching without pain was used<sup>21</sup>. Moreover these differences may also have occurred due to the various protocols used in the studies, variations in positions to perform the muscle stretching techniques, the choice of the lower limb to be used and also the evaluation methodology. This suggest new researches that include a larger number of subjects, different genders and ages are important.

Moreover there was no significant difference in the initial values of the SRT and PT for each collection day regardless of the stretching technique applied. This demonstrates that the performance of any of the three stretching techniques applied in five series of 30 seconds and only once a week is not enough to gain lasting flexibility.

In this study no interference of the accumulation of stretching exercises in initial assessments that took place in the second and third days was observed since no significant statistical difference was observed in the initial values of each day for both tests regardless of the stretching technique applied.

In terms of limitations of the study the number of subjects is small and so the extrapolation of data for different populations and muscle groups should be made with caution. Further randomized controlled trials should be performed in order to establish specific benefits of static ballistic and contract-relax stretching.

## CONCLUSION

The results of this preliminary study suggests that ballistic and contract-relax techniques may improve the immediate flexibility gain of the hamstring muscles. The ballistic stretching and contract-relax stretching are both equally effective and better than static stretching which had no any effect on flexibility gain.

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