

Comparison of effects of static, proprioceptive neuromuscular facilitation and Mulligan stretching on hip flexion range of motion: a randomized controlled trial

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ABSTRACT: The aim of this study was to compare the effects of static stretching, proprioceptive neuromuscular facilitation (PNF) stretching and Mulligan technique on hip flexion range of motion (ROM) in subjects with bilateral hamstring tightness. A total of 40 students (mean age: 21.5 ± 1.3 years, mean body height: 172.8 ± 8.2 cm, mean body mass index: 21.9 ± 3.0 kg \cdot m⁻²) with bilateral hamstring tightness were enrolled in this randomized trial, of whom 26 completed the study. Subjects were divided into 4 groups performing (I) typical static stretching, (II) PNF stretching, (III) Mulligan traction straight leg raise (TSLR) technique, (IV) no intervention. Hip flexion ROM was measured using a digital goniometer with the passive straight leg raise test before and after 4 weeks by two physiotherapists blinded to the groups. 52 extremities of 26 subjects were analyzed. Hip flexion ROM increased in all three intervention groups ($p < 0.05$) but not in the no-intervention group after 4 weeks. A statistically significant change in initial–final assessment differences of hip flexion ROM was found between groups ($p < 0.001$) in favour of PNF stretching and Mulligan TSLR technique in comparison to typical static stretching ($p = 0.016$ and $p = 0.02$, respectively). No significant difference was found between Mulligan TSLR technique and PNF stretching ($p = 0.920$). The initial–final assessment difference of hip flexion ROM was similar in typical static stretching and no intervention ($p = 0.491$). A 4-week stretching intervention is beneficial for increasing hip flexion ROM in bilateral hamstring tightness. However, PNF stretching and Mulligan TSLR technique are superior to typical static stretching. These two interventions can be alternatively used for stretching in hamstring tightness.

CITATION: Yıldırım MS, Ozyurek S, Tosun OÇ, Uzer S, Gelecek N. Comparison of effects of static, proprioceptive neuromuscular facilitation and Mulligan stretching on hip flexion range of motion: a randomized controlled trial. *Biol Sport*. 2016;33(1):89–94.

Received: 2015-07-09; Reviewed: 2015-08-12; Re-submitted: 2015-08-13; Accepted: 2015-08-21; Published: 2016-02-08.

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Key words:

Biomechanical phenomena
Muscle stretching exercises/
methods
Proprioception/physiology
Proprioceptive neuromuscular
facilitation
Range of motion
Static stretch
Warm-up

INTRODUCTION

Flexibility is defined as the ability of a muscle to lengthen, allowing one joint or more to move through a range of motion (ROM), and is an essential component of normal biomechanical functioning [1,2]. If the resting length of a muscle is altered, the capacity of a muscle to develop maximum tension is also affected [3].

Stretching is the key element of both rehabilitation programmes and sport-related activities in order to restore optimum muscle length [4]. Hamstrings are the most investigated muscle group in stretching studies because of their ease to be evaluated as they are biarticular muscles and are stretched without obstruction by the joint capsule and ligaments [5]. Hamstring tightness is also associated with low back and lower extremity musculoskeletal disorders leading to biomechanical changes of the pelvis and low back [6].

Although static stretching is one of the most preferred interventions aimed at increasing ROM, there are still some doubts related to its beneficial effects on athletic performance as it leads to stretching-induced force deficits [7]. Proprioceptive neuromuscular facilitation (PNF) is also very popular among clinicians and researchers as

it is considered to be more effective than static stretching in increasing ROM due to neurophysiological mechanisms mediated by the Golgi tendon organ and muscle spindle [8]. Mulligan traction straight leg raise (TSLR) technique has been suggested as an alternative procedure to increase the range of straight leg raise (SLR) when there is a limitation due to hamstring tightness or low-back dysfunction [9]. Although there are many articles in the literature comparing mainly the effectiveness of different stretching interventions on hip flexion ROM, there is no study comparing also the effects of the Mulligan TSLR technique. Therefore, the aim of our study was to compare the effects of three different types of stretching – static stretching, PNF stretching and Mulligan TSLR technique – on hip flexion ROM in young adults with bilateral hamstring tightness.

MATERIALS AND METHODS

The study was planned as a randomized, prospective, single-blind design including 4-week interventions. Sixty-seven healthy young adults (44 males, 23 females) volunteered to participate in the study.

Hip flexion ROM was assessed with the passive SLR test [10]. The subject's hamstring muscles were considered tight if there was SLR of ≤ 70 degrees [11]. Subjects were in a supine position, lying on a standard size pillow supporting their lumbar lordosis. The same pillow was used in all measurements. One of the physiotherapists passively flexed the hip joint while the knee was fully extended to the end point where firm resistance was detected in the hamstring muscle group [12]. The other physiotherapist measured the hip flexion angle with a digital goniometer (Lafayette Guymon Goniometer, Model 01129). This procedure was repeated three times for each extremity, and the average of all three consecutive measures was recorded.

Subjects with more than 70 degrees of hip flexion, a history of hamstring injury and current musculoskeletal pain were excluded. Subjects were informed about the aim and method of the study, which was approved by the local ethics committee of Dokuz Eylül University according to the 1975 Declaration of Helsinki and gave written informed consent.

Measurement of hip flexion ROM was performed at the beginning of the study (initial assessment) and subsequently at the fourth week (final assessment) by two different physiotherapists blinded to the intervention groups.

After the initial assessment, subjects with SLR of ≤ 70 degrees were randomly assigned to one of the four following interventions: (I) typical static stretching, (II) PNF stretching, (III) Mulligan TSLR technique, (IV) no intervention. All the interventional groups were supervised by three different physiotherapists. All the stretching interventions were performed once a day, between 12.00 and 13.00 a.m., three days a week for four weeks.

Study Interventions

Static stretching

Subjects performed typical static stretching bilaterally under supervision of a physiotherapist. The procedure most commonly used in clinical practice was chosen for the current study. The subject stood erect with one foot on the floor pointing straight ahead with no internal or external rotation of the hip and stretched the contralateral hamstring muscle by placing the other foot on an elevated surface at or slightly below hip level. Then the subject was instructed to keep the back straight, while hinging forward at the hips, until slight to moderate discomfort was felt in the back of the thigh being stretched. Ten repetitions of each stretch being held for 30 seconds with 10-second intervals were performed (Fig. 1) [12].

PNF stretching

Subjects performed the hold-relax technique bilaterally as a self-stretch under the supervision of a physiotherapist. The technique consisted of an active SLR with dorsiflexed ankle and toes. The subject raised his legs by turning the heel towards the opposite shoulder while clasping the hands around the back of the thigh. Then the subject performed a hold contraction for 10 seconds and relaxed



FIG. 1. Static stretching.



FIG. 2. Proprioceptive neuromuscular facilitation stretching.



FIG. 3. Mulligan traction straight leg raise technique.

Stretching techniques for hip flexion range of motion

for 10 seconds, allowing the knee to bend. Finally, the leg was straightened and the technique was finished (Fig. 2) [13].

Mulligan TSLR

A trained physiotherapist applied traction to the leg while lifting the limb through a pain-free range of SLR while the subject was lying supine. The maximum traction force was implemented in line with the long axis of the leg while the knee was fully extended. Simultaneously, the therapist passively moved the limb through the range of SLR until the onset of discomfort and then returned to the resting position. It was ensured that there was no pain during the procedure. If the subject reported pain, the direction of the leg raise was altered (slightly rotated, abducted or adducted). Three repetitions of pain-free TSLR were applied to each subject (Fig. 3) [14].

No intervention

A group of subjects did not receive any interventions.

Statistical Analysis

Statistical analyses were performed using the SPSS software version 15.0 (SPSS Inc., Chicago, IL, USA). Descriptive data are presented as means with standard deviation. The paired t-test was used to compare the hip flexion ROM measurements at two time points (initial assessment and final assessment) in each group. The Δ value represents the amount of change between two measurements. One-way ANOVA was used to compare demographics and changes in hip flexion ROM (Δ value) among the groups (static stretching, PNF stretching, Mulligan TSLR technique and no intervention). An overall p-value of less than 0.05 was considered to show a statistically significant result. When overall significance was observed, pairwise post-hoc tests were performed using Tukey's test. To evaluate the magnitude of change in hip flexion ROM, we estimated effect sizes according to the method of Kazis et al. [15]. An effect size of 0.8 or more is considered high. The significance level was set at 0.05.

RESULTS

Three students in the static stretching group, three students in the PNF stretching group and two students in the Mulligan TSLR technique group failed to attend the 4-week programme. Moreover, two students in the static stretching group, one student in the PNF stretching group and three students in the no-intervention group missed the final assessment. Fig. 4 indicates the flowchart of subjects who participated in the study. In total 52 lower extremities of 26 subjects (17 male, 9 female, mean age: 21.5 ± 1.4 years, mean body mass index: $21.9 \pm 3.02 \text{ kg} \cdot \text{m}^{-2}$) were analyzed. The groups were homogeneous in terms of age, body mass index and initial hip flexion ROM (Table 1). A significant increase in hip flexion ROM was found in all intervention groups after a 4-week period ($p < 0.05$), but not in the no-intervention group (Table 2, Fig. 5).

Analyses of variance demonstrated a statistically significant ($p < 0.001$) difference in changes of hip flexion ROM among intervention groups. Post-hoc analysis showed that the increase in hip flexion ROM was significantly higher in both the Mulligan TSLR technique and PNF stretching groups than the typical static stretching group ($p = 0.02$ and $p = 0.016$, respectively). No significant difference was found between Mulligan TSLR technique and PNF stretching groups ($p = 0.920$). The initial-final assessment difference of hip flexion ROM was similar in typical static stretching and no-intervention groups ($p = 0.491$) (Table 2).

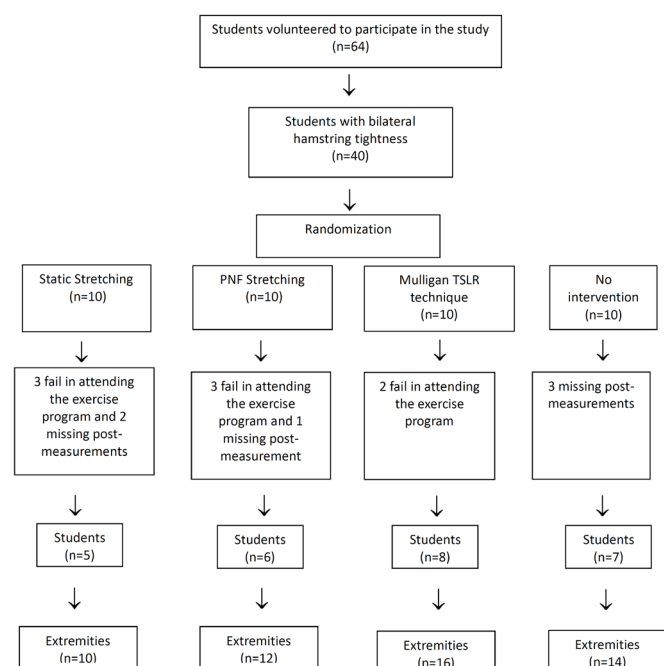


FIG. 4. Flowchart of the study.

TABLE 1. Demographic features and initial hip flexion range of motion of the groups.

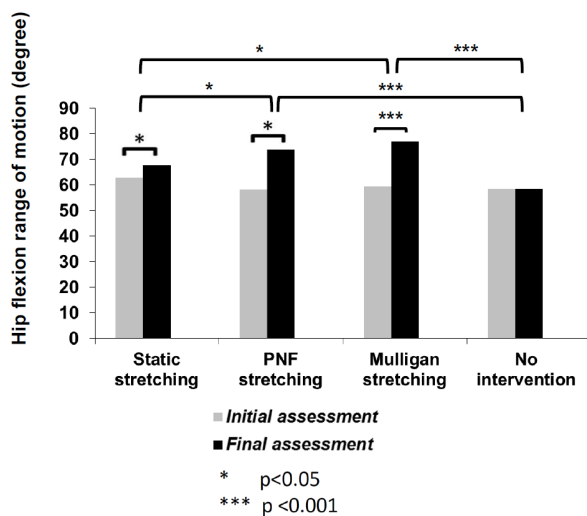
	Static stretching	PNF stretching	Mulligan TSLR technique	No intervention	p
Age (years)	21.4 ± 0.8	21.8 ± 1.3	21.6 ± 1.68	21.4 ± 1.8	0.958
Body Mass Index (kg · m ⁻²)	23.2 ± 4.9	21.7 ± 2.2	20.8 ± 2.7	21.9 ± 2.3	0.585
Initial Hip Flexion ROM (degree)	62.9 ± 5.0	58.1 ± 7.3	59.3 ± 8.0	58.4 ± 8.8	0.456

Note: PNF - proprioceptive neuromuscular facilitation; TSLR - traction straight leg raise; ROM - range of motion.

TABLE 2. Comparisons of hip flexion range of motion between four groups.

Hip flexion ROM (degree)	Static stretching	PNF stretching	Mulligan TSLR technique	No intervention	p
Initial	62.9 ± 5.0	58.1 ± 7.3	59.3 ± 8.0	58.4 ± 8.8	
4 weeks	67.6 ± 6.2‡	73.8 ± 8.7‡	77.0 ± 5.4‡	58.3 ± 8.8	
Δ	4.7 ± 4.1†§	15.6 ± 11.9	17.6 ± 10.0	-0.1 ± 0.7¥£	<0.001*
Effect size	0.94	2.15	2.21	0.01	

Note: ROM - range of motion; Δ - the amount of change between initial-final assessments; ‡ - significant difference between initial-final assessments; * - significant difference between four groups ($p < 0.001$, one-way ANOVA); § - significant difference between Mulligan TSLR technique and static stretching group ($p < 0.05$); † - significant difference between PNF and static stretching group ($p < 0.05$); ¥ - significant difference between Mulligan TSLR technique and no-intervention group ($p < 0.001$); £ - significant difference between PNF stretching and no-intervention group ($p < 0.001$).

**FIG. 5.** Hip flexion range of motion before and after 4 weeks.

DISCUSSION

The purpose of the present study was to compare the effects of three different types of stretching techniques on hip flexion ROM in subjects with bilateral hamstring tightness. All stretching interventions increased the passive SLR degree after a 4-week intervention. However, Mulligan TSLR technique and PNF stretching were superior to typical static stretching.

Recent literature shows conflicting results related to the effects of different stretching methods. Some studies have shown the efficiency of active stretching exercises, especially PNF stretching, in increasing muscle flexibility and joint ROM [4,16,17]. However, some evidence exists indicating the equal efficacy of static and active stretching techniques as well as the superiority of static stretching exercises [3,18-20].

These alterations in responses to stretching were attributed to some mechanical and neural factors. Hence, changes in hip joint ROM after static stretching can be explained by the changes in musculotendinous stiffness or pain tolerance as well as neural adaptations. The two well-explained mechanisms of prolonged static stretching are the change in tension-length relationship due to viscoelastic properties of a muscle tissue and the decrease in Hoff-

mann (H) reflex amplitude [21,22]. Different presynaptic and postsynaptic changes are responsible for the decrease in H reflex response. Presynaptic mechanisms include an autogenic decrease in Ia afferents induced by presynaptic inhibition and an altered capacity for synaptic transmission during repetitive activation. Postsynaptic changes are autogenic inhibition induced by the Golgi tendon organ afferents, recurrent inhibition via the Renshaw loop and postsynaptic inhibition as a result of afferents from joint and cutaneous receptors [21]. However, Konrad and Tilp argued that increased ROM following stretching was due to an altered perception of stretch, and pain or stretch tolerance by the adaptations of nociceptive nerve endings rather than altered muscular or tendon structures [23].

PNF stretching is already being used as an alternative active stretching technique by both clinicians and researchers. Macefield et al. reported the activation of Golgi tendon organ tension receptors within the hamstring muscle-tendon unit during hold-relax technique and an inhibition of hamstring muscle with autogenic inhibition [24]. Besides the traditional underlying mechanisms, recent literature suggests that decreases in the response amplitude of the H reflex and muscle stretch reflexes following contraction of a stretched muscle may be a result of presynaptic inhibition of the muscle spindle sensory signal [16].

A great deal of studies have investigated the efficacy of PNF stretching on muscle length and ROM and also compared its effects with other stretching techniques. The hold-relax technique was mostly used as PNF stretching in previous studies. Youdas et al. compared two modified PNF stretching techniques and detected significant improvements in hamstring muscle length and knee ROM after a one session hold-relax (10-second and 20-second) with antagonist contraction technique [8]. Spernoga et al. found a significant increase in hamstring flexibility after a sequence of 5 modified hold-relax stretches [25]. Additionally, Bonnar et al. confirmed the efficacy of hold-relax technique in increasing hip flexion ROM for three different contraction times: 3, 6 and 10 seconds [26]. Similarly, we performed the 10-second hold-relax technique for 3 sets including 10 repetitions in each as PNF stretching. The results of our study showed a significant increase in hip ROM after 4-week PNF stretching, which was also superior to typical static stretching.

Although Mulligan technique's efficacy for flexibility has already been shown, its effect on muscle length has not been compared to other stretching methods yet [9,14,27]. Hall et al. found a significant increase in range of SLR after TSLR technique in both patients with low back pain and in healthy subjects [14,27]. The authors suggested that the increase in SLR ROM was mainly due to the increase in pain-free stretch tolerance of the posterior hip joint structures. In this context, TSLR technique might enhance the stretch tolerance of hamstring muscles [14]. The inhibition of the muscle itself could also lead to improvement in the ROM. This inhibition probably occurs as Golgi tendon organ activation during stretching movements, decrease in afferent activity of type II muscle spindles or the decrease in motor neuron excitability via I-b fibres [28,29]. Similar to Hall et al.'s findings, our results showed a significant increase in hip flexion ROM after a 4-week Mulligan TSLR technique [9]. Moreover, Mulligan TSLR technique was significantly more effective than typical static stretching, but no significant difference was found between Mulligan TSLR technique and PNF stretching. Interestingly, we found no statistically significant difference between typical static stretching and the no-intervention group, although typical static stretching led to significant improvement in hip flexion ROM within the group.

To our knowledge, this is the first study comparing the effects of Mulligan TSLR technique and the other most common stretching interventions on hip flexion ROM in subjects with bilateral hamstring tightness. The most important limitation in this current study was the lack of follow-up assessments after a period of cessation. However, it is necessary to determine the sustainability of the stretching effect after withdrawal of the interventions.

CONCLUSIONS

After all 4-week stretching interventions (typical static stretching, Mulligan TSLR technique and PNF stretching) significant improvements were found in hip flexion ROM. Moreover, our results revealed the superiority of Mulligan TSLR technique and PNF stretching to typical static stretching. These two interventions can be used alternatively in order to obtain more effective improvements in hip flexion ROM in subjects with bilateral hamstring tightness.

Conflict of interests: the authors declared no conflict of interests regarding the publication of this manuscript.

REFERENCES

1. Zachezewski JE. Improving flexibility. In: Scully RM, Barnes MR, eds. *Physical Therapy*. Philadelphia, PA: JB Lippincott; 1989:698-9.
2. Hopper D, Deacon S, Das S, Jain A, Riddell D, Hall T, et al. Dynamic soft tissue mobilisation increases hamstring flexibility in healthy male subjects. *Br J Sports Med*. 2005;39:594-8.
3. Winters MV, Blake CG, Trost JS, Marcello-Brinker TB, Lowe LM, Garber MB, et al. Passive versus active stretching of hip flexor muscles in subjects with limited hip extension: A randomized clinical trial. *Phys Ther*. 2004;84:800-7.
4. Fasen JM, O'Connor AM, Schwartz SL, Watson JO, Plasteras CT, Garvan CW, et al. A randomized controlled trial of hamstring stretching: Comparison of four techniques. *J Strength Cond Res*. 2009;23:660-7.
5. Ylinen JJ, Kautiainen HJ, Hakkinen AH. Comparison of active, manual and instrumental straight leg raise in measuring hamstring extensibility. *J Strength Cond Res*. 2010;24:972-7.
6. Meroni R, Cerri CG, Lanzarini C, Barindelli G, Morte GD, Gessaga V, et al. Comparison of active stretching technique and static stretching technique on hamstring flexibility. *Clin J Sport Med*. 2010;20:8-14.
7. Marek SM, Cramer JT, Fincher AL, Massey LL, Dangelmaier SM, Purkayastha S, et al. Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. *J Athl Training*. 2005;40:94-103.
8. Youdas JW, Haeflinger KM, Kreun MK, Holloway AM, Kramer CM, Hollman JH. The efficacy of two modified proprioceptive neuromuscular facilitation stretching techniques in subjects with reduced hamstring muscle length. *Physiother Theory Pract*. 2010;26:240-50.
9. Hall T, Anuar K, Darlow B, Gurumoorthy P, Ryder M, Smith T. The effect of Mulligan Traction Straight Leg Raise in participants with short hamstrings. *Ann Acad Med Singapore*. 2003;32:56-7.
10. Bandy WD, Irion JM, Briggler M. The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. *J Orthop Sports Phys Ther*. 1998;27:295-300.
11. Li Y, McClure PW, Pratt N. The effect of hamstring muscle stretching on standing posture and on lumbar and hip motions during forward bending. *Phys Ther*. 1996;76:836-49.
12. Rancour J, Holmes CF, Cipriani DJ. The effects of intermittent stretching following a 4-week static stretching protocol: A randomized trial. *J Strength Cond Res*. 2009;23:2217-22.
13. Schuback B, Hooper J, Salisbury L. A comparison of a self-stretch incorporating proprioceptive neuromuscular facilitation components and a therapist-applied PNF-technique on hamstring flexibility. *Physiother*. 2004;90:151-7.
14. Hall T, Beyerlein C, Hansson U, Lim HT, Odermark M, Sainsbury D. Mulligan traction straight leg raise: A pilot study to investigate effects on range of motion in patients with low back pain. *J Manual Manipulative Ther*. 2006;14:95-100.
15. Kazis LE, Anderson JJ, Meenan RF. Effect sizes for interpreting changes in health status. *Med Care*. 1989;27(3 Suppl):S178-89.
16. Chalmers G. Re-examination of the possible role of Golgi tendon organ and muscle spindle reflexes in proprioceptive neuromuscular facilitation muscle stretching. *Sports Biomech*. 2004;3:159-83.
17. Sharman MJ, Cresswell AG, Stephan R. Proprioceptive neuromuscular facilitation stretching mechanisms and clinical implications. *Sports Med*. 2006;36:929-39.
18. O'Sullivan K, Murray E, Sainsbury D. The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. *BMC Musculoskelet Disord*. 2009;10:37-45.
19. Davis DS, Ashby PE, McCale KL, McQuain JA, Wine JM. The effectiveness of 3 stretching techniques on hamstring flexibility using consistent parameters. *J Strength Cond Res*. 2005;19:27-32.
20. Willy RW, Kyle BA, Moore SA, Chleboun GS. Effect of cessation and resumption of static hamstring muscle stretching on joint range of motion. *J Orthop Sports Phys Ther*. 2001;31:138-144.

21. Guissard N, Duchateau J, Hainaut K. Mechanisms of decreased motoneurone excitation during passive muscle stretching. *Exp Brain Res.* 2001;137:163-9.
22. Condon SM, Hutton RS. Soleus muscle electromyographic activity and ankle dorsiflexion range of motion during four stretching procedures. *Phys Ther.* 1987;67: 24-30.
23. Konrad A, Tilp M. Increased range of motion after static stretching is not due to changes in muscle and tendon structures. *Clin Biomech (Bristol, Avon).* 2014 Jun;29(6):636-42.
24. Macefield G, Hagbarth KE, Gorman R, Gandevia SC, Burke D. Decline in spindle support to alpha motoneurons during sustained voluntary contractions. *J Physiol.* 1991;440:497-512.
25. Spornoga SG, Uhl TL, Arnold BL, Gansneder BM. Duration of maintained hamstring flexibility after a one-time, modified hold-relax stretching protocol. *J Athl Training.* 2001;36:44-8.
26. Bonnar BP, Deivert RG, Gould TE. The relationship between isometric contraction durations during hold-relax stretching and improvement of hamstring flexibility. *J Sports Med Phys Fitness.* 2004;44:258-61.
27. Hall TM, Cacho A, McNee C, Riches J, Walsh J. Effects of Mulligan traction straight leg raise on range of movement. *J Manual Manipulative Ther.* 2001;9:128-33.
28. Guissard N, Duchateau J, Hainaut K. Mechanisms of decreased motoneurone excitation during passive muscle stretching. *Exper Brain Res.* 2001;137:163-69.
29. Cameron-Tucker H. The neurophysiology of tone: The role of the muscle spindle and the stretch reflex. *Aust J Physiother.* 1983;29:155-64.