Low Load Prolonged Stretch of Hip Flexors Using a Designed Stretch Tool

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Abstract: Background: Tightness of hip flexors and hip joint capsule contributes to excessive force that reaches the lumbo-pelvic joints. Permanent lengthening is most favored by low force and long duration stretch. The effect of low load prolonged stretch of hip flexors on range of motion of hip extension was examined using a designed stretch tool. The study was done on 12 patients complaining of chronic low back pain with accentuated lumbar lordosis more than 50˚. Myrin goniometer was used to apply measurements for hip extension. Stretch tool with a changeable angle was designed to stretch hip flexors. The duration of stretch was 17 minutes; five minutes repeated 3 times with 2 minutes rest in between. There was significant increase in hip extension equal to 6.66˚ after 7 weeks of right hip flexors stretch. The calculated loads were 1.14 and 2.27 Kg at 5 and 10 degrees elevation of stretch tool respectively. Low load prolonged stretch, using the designed stretch tool, had significant improvement on hip extension following 21 sessions of static stretch 3times/week. Low load stretch using 1.3% and 2.7% of body weight at 5˚ and 10˚ elevation of stretch tool respectively is safe for stretching hip flexor in patients with low back pain associated with increased lumbar lordosis.

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1. Introduction

Muscle extensibility is defined as the ability of a muscle to extend to a predetermined end point. In human research this end point is most often subjective sensation. An increase in muscle extensibility after intermittent stretch has been explained by many theories; most of these theories advocated a mechanical increase in the length of the stretched muscle. More recently a sensory theory has been proposed suggesting that increase in muscle extensibility is due to a modification of sensory input [1].

Static stretch was more effective than self stretch and proprioceptive neuromuscular facilitation [2, 3]. In static stretching, the passive torque was decreased during the loading and the unloading, with the main changes at the end of the ROM While in cycling stretching the passive torque decreased by a nearly constant value during the loading, but remained relatively unchanged during unloading [4] .The effects of cyclic and static stretching on passive torque angle curves are different. A constant change in range of motion across torque levels after static stretching is indicative of changes in muscle and tendon length primarily, while variable changes across torque levels after cyclic stretching are more indicative of a thixotropic response. Thixotropy refers primarily to damping or viscous responses of tissues [5].

Permanent lengthening is most favored by low force and long duration stretch [6]. Repeated prolonged loading is the more appropriate method for increasing the length of connective tissue [7]. One minute was selected as the demarcation between short duration and long duration stretch [8]. A single bout of 4x20 seconds static stretches of the hamstring muscles resulted in an immediate small increase in knee joint ROM and decrease in passive stiffness. There was no clear evidence that the increase in ROM lasted longer than five minutes [9]. Six weeks program once a day static stretching for up to 2 minutes is not sufficient to increase active ankle dorsiflexion in healthy subjects [10]. Calf muscles stretch provided a small but statistically significant increase in ankle dorsiflexion, particularly after 5-30 minutes of stretching [11]. Five minutes of static stretches significantly decreased muscle tendon unit stiffness and muscle stiffness immediately and after 10 minutes static stretch [12].

Low intensity stretch was defined as a stretch based on each subject's perception of an onset of discomfort [2]. A low load equal to 0.5% of body weight was subjectively found to be very comfortable; where most subjects didn't even feel a sensation of stretch during the procedure, no report of any residual problems with function or sensation, the study was applied on healthy shoulder[13]. Stretching to subject's foot using a rope and pulley with approximately 1/3 of the body weight for 10 minutes was uncomfortable for some subjects [8].

Tightness of hip flexors and hip joint capsule contributes to excessive force that reaches the lumbo-pelvic joints .Unless the hip range of motion (ROM) is restored, an abnormal force reaches the lumbar pelvic tissues and contributes to a continued damage and prolonged symptoms [14]. Limited hip extension ROM results in compensations at segment above and below the hip during gait [15].The global resultant of psoas activation is included to increase lordosis [16.] A stretching force of 15% of the subject's body weight was applied using weights suspended through a strap around the subject's mid thigh. The stretching force was maintained for two minutes .The cycle was repeated three times, resulting in a total stretching time of 6 minutes period for each thigh interspersed by two minutes periods of no stretch. The subjects underwent this stretching routine two times/week for total stretching sessions over a three weeks period in a healthy athlete. This study suggested that intervention program involved a longer duration of stretch to achieve an improvement in gait economy [15]. Winter *et al.* [17] supported the use of either an active or passive stretching program to increase ROM presumably by increasing the flexibility of tight hip flexor in relatively young patients with low back pain and lower extremity complaints. Passive stretches from prone and lung position were done for 10 repetitions each, in a single daily session, each stretch was held for 30 seconds with an 8 seconds rest between repetitions. Stretching was done as a home program and no measures were implemented to monitor adherence in either group. The level of adherence in both groups was inadequate to demonstrate the differences between the groups.

No study was found to investigate the effect of low load prolonged stretch of hip flexors using a tool and/ or different angles. The purpose of this study was to examine the effect of low load prolonged stretch of hip flexors on ROM of hip extension using a designed stretch tool with changeable angles

2. Subject and method

The subjects of the current study included 12 adult patients (8 females and 4 males), Their ages averaged (39.3± 4.5) years, weight (81.66±12.8 kg) and height (161.75±6.9 cm). Nineteen patients with chronic low back pain selected consequently from the outpatient clinic with age ranging 30- 45 years. They were clinically examined by orthopedist then referred to department of radiology. They were complaining of back pain in spite of previous methods of treatment including bed rest, pain killer, physiotherapy modalities and acupuncture. They complained of low back pain which was continuous for more than one year. The study included only the twelve patients who had lumbar lordosis greater than 50 degrees measured on X ray. Subjects were excluded if they had nerve root pain, neurologic sign and symptoms, previous spinal surgery or structural deformities such as scoliosis or spondylolisthesis. The study has been done in the Orthopaedic clinc, departments of Radiology and Physical Therapy of Elharm Hospital, Giza Egypt. Informed consent was obtained and the right of subjects was protected [18]**.** The work has been approved by the faculty review board of cairo university. The experimental design has been previously described [18] but the effect of stretch tool on hip range of motion and calculation of load were not published before.

Designed stretch tool

Stretch tool was designed to stretch hip flexor. The main idea of the tool was to design a tool with a changeable angle started from 5˚ to 30˚ with 5˚ increment (Fig.1). The stretch tool was designed to stretch hip flexors. The method of stretching provides low force, long duration stretch. Posterior tilt through idiokinetic imagery exercises [18] preceded stretching to increase tissue temperature and allows elongation to occur with less structural damage.

The starting position of stretch was prone with cushion under the abdomen and the pelvis was stabilized to the bench with a belt, one leg was extended with the foot outside the short side of the bench, the other leg was flexed over the long side of the bench [18] this position showed approximately 23.4 more posterior tilted pelvis compared to prone position with both leg extended on the bench[19]. The stretch was done for the hip flexor of extended limb (Fig.2). The starting position was maintained for 5 minutes then the flexed leg was raised to the bench for one minute. From the starting position, the limb was supported on the designed stretch tool for 5 minutes, elevated 5 degrees then lowered for one minute rest in the prone position. The second elevation performed 10 degrees for the last 5 minutes followed by one minute rest in prone position. The stretch was repeated for the other leg. The time was calculated using stop watch. The stretching exercise was modified after 3 weeks. Patient elevated the extended leg 10 degrees – three times for five minutes each, with one minute rest in between. A mathematical model was used to calculate the value of the low load of hip flexor stretch (Fig. 3)

Mathematical model for calculation of low load used by the stretch tool

The calculation of load used to stretch hip flexor using the stretch tool is based on the calculation of segmental body weight. The mass of the leg has been expressed as a percentage of the total body mass. The mass of the total leg/total body weight was found to be equal to 0.161[20] so, a mathematical model was used to calculate the quantity of load used.

Measurements

Myrin goniometer was used to apply the measurements for hip extension to test flexibility of hip flexors. Myrine Goniometer often used to determine flexibility. Reliablity of measurement with Myrine goniometer was excellent[21].The measurements were assessed by the same therapist, using the same goniometry, at the same time of the day for each patient and using the same patient position either in pre or post treatment assessment. Flexibility of iliopsoas was measured from prone position using hip extension test, the examiner stabilized the posterior ilium then grasped and raised the extended knee. Hip extension test appears to have good reliability [22].

Data Analysis

1- Normality test, as normal data is an underlying assumption in parametric testing.
Shapiro-Wilk test is more appropriate for sample series (<50), for this reason we will use the Shapiro-Wilk test as a numerical mean of assessing normality. If the significant value under the Shapiro –Wilk test is greater than 0.05; we can conduct that individual is normally distributed.
2- One way analysis of variance
--Null hypothesis (H0) is that the low load stretch has no effect and range of motion will remain the same among repeated 3 measurements of range of motion.
--The alternative hypothesis (H1) is that the low load stretch will have an effect and range of motion will differ among the three repeated measurements.
3- Post hoc test, if the ANOVA found a significant effect. Post hoc test was used to determine which specific pair/pairs are differently expressed. All data were analyzed using SPSS 12.

3. Results

The mathematical Calculation of the twelve patients is shown in Table 1. The mean of leg weight was approximately 13.067 ±2.05kg. The mean of low load at 5 degrees was approximately 1.14 ± 0.18kg. While the low load at 10 degrees was approximately 2.7 ± 0.36kg. As the mean of body weight equal to 81.66Kg so the low load used in the current study represent 1.3% and 2.7% of body weight at 5 and 10 degrees elevation of the designed tool.

Normality tests using Shapiro -Wilk tests are shown in Table 2 The significant value of the dependant variables is greater than 0.05 then the data is normal. Table 3 shows the results of one way analysis of variance of repeated measurements of range of motion of hip extension. For the right hip the mean of hip extension was increased by 4.166˚ and 6.66˚ after 3 and 7 weeks of stretch respectively, the increase of ROM was significant, P value <0.05 (*P* =0.001)

The results of post hoc test for hip extension (Table 4) show that the significant improvement was between the first and second measurements and between the first and third measurements either for right or left side but the improvement between the second and third measurements was insignificant where *P* value >0.05. The comparison between the three measurements of hip extension also shown in (Fig. 4) for Rt and Lt side.

Table 1: Calculation of load at 5 and 10 degrees of stretch tool

Body weight (kg)	Leg weight (W) =0.16 * Body weight (kg)	Load (T) at 5˚ (kg)	Load(T) at 10˚ (kg)
60	9.6	0.836695	1.667023
96	15.36	1.338712	2.667236
74	11.84	1.031924	2.055994
90	14.4	1.255043	2.500534
72	11.52	1.004034	2.000427
99	15.84	1.380547	2.750587
80	12.8	1.115594	2.222697
89	14.24	1.241098	2.47275
80	12.8	1.115594	2.222697
89	14.24	1.241098	2.47275
61	9.76	0.85064	1.694806
90	14.4	1.255043	2.500534
Mean=81.667	13.06667	1.138835	2.269003
±STDEV	±2.050514	±0.178714	±0.356068

Table 2 : Test of normality

	Shapiro- wilk test		
	Statistic	**df**	**sign**
Hip extension Rt	**.888**	**12**	**.111**
Hip extension Lt	**.879**	**12**	**.085**

Table 3: One way ANOV for repeated measurement of range of motion

	Pre-treatment	3weeks after	7weeks after	F	Sig
Hip extension right	10.3±4.1	14.5±3.6	17±3.7	9.443	0.001
Hip extension left	10.8±4	15.3±3.4	17.7±4.6	8.702	0.001

Table 4: Post hoc tests (Multiple comparisons)

Dependant variable	(1) time	(J) time	Mean difference I-J	Sig.
Hip extension Rt	Pre -treatment	after 3weeks after 7weeks	-4.16667 -6.66667	.011 .000
	After 3weeks	Pre –treatment After 7weeks	4.1667 -2.50000	.011 .116
	After 7weeks	Pre -treatment after 3weeks	6.66667 2.50000	.000 .116
Hip extension lt	Pre -treatment	after 3weeks after 7weeks	-4.50000 -6.83333	.011 .000
	After 3weeks	Pre –treatment After 7weeks	4.50000 -2.33333	.011 .170
	After 7weeks	Pre -treatment after 3weeks	6.83333 2.33333	.000 .170

Fig 1: Designed stretch tool for low load stretch of hip flexors (**Elhamalawy, 2011**).

Fig 2: Stretch of hip flexor of extended limb using a designed stretch tool (**Elhamalawy, 2011**).

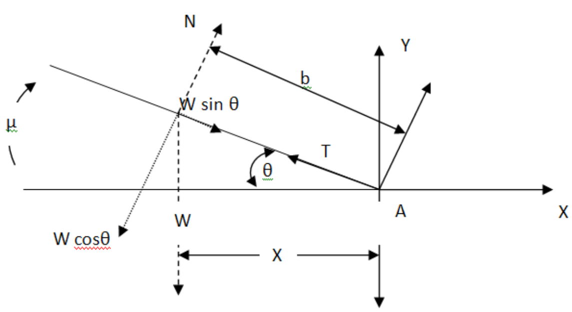


Fig 3: Schematic illustration of a free body diagram for the tool. W: concentrated weight of the leg, N: normal force acted as a reaction from the tool upper surface against the leg weight, T: tension acted on the muscle

Mathematical model:

$$\sum F_y = 0$$

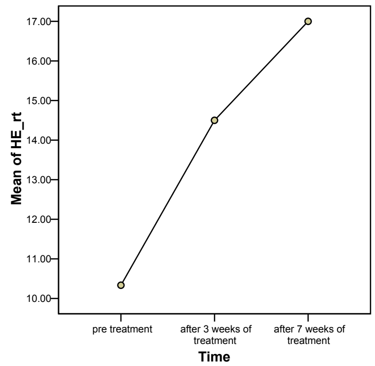
$$N - W\cos\theta = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$N = W\cos\theta$$

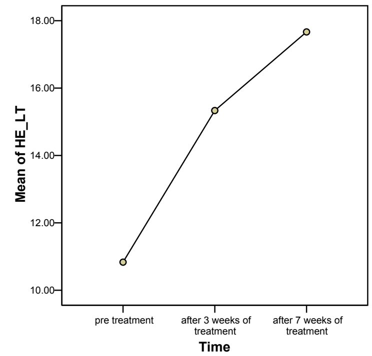
$$\sum F_x = 0$$

$$W\sin\theta - T = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$W\sin\theta = T$$



(Right)



(Left)

Fig 4: Means Plots of right and left hip extension

4. Discussion

One of the most clinical challenges is to stretch the hip joint capsule and anterior thigh musculature without creating an extension force to the lumbar spine. The method used for stretching has several advantages. The starting position for stretch kept the pelvis rotated posterior; this implies a decreased risk of hyperextension [19].

The starting position of stretch also helped the stretch to begin when the muscle in a relaxed state to minimize the amount of tension developed by the contractile component. The pelvis was stabilized by a designed belt to reduce the magnitude of electrical activity in the sacrospinalis, following the study of Fisher and Houtz [24]. The stretch was increased slowly, thus eliminating the likelihood of activating stretch reflex and ultimately the contractile component. The amount of tension for a given amount of stretch is more than doubled by a quicker stretch as compared to a slow stretch [25].

In the current study low load stretch was applied 3 times /week. Stretching 3 times /week were sufficient to improve flexibility compared to stretching at a higher frequency. It yielded better gains in flexibility than those performed once /week and similar to those performed five times a week when the goal is the improvement in flexibility and range of motion [26]. The study revealed a significant increase in hip extension equal to 6.66˚ for right side after applying 21 sessions of stretch. This finding is verification to the suggestion of Bohannon [27]. He suggested that weeks or months may be necessary before a sufficient increase can take place in muscle length, as he loaded the hamstring 8 minutes, only for 3 sessions and found no significant improvement. Repeated prolonged loading is more appropriate method for increasing the length of connective tissue.

The actual time of weighted stretch was 15 minutes (five minutes repeated 3 times) followed the protocol of Lentell [13] however he applied only three setting of low load stretch on normal shoulder and recommend using low load stretch for pathological conditions. Five minutes of static stretch significantly decreased muscle tendon unit stiffness and muscle stiffness immediately and after 10 minutes static stretch [12].

Stretching in the current study was applied at different degrees of elevation as stretching results in a reduction in load on the muscle-tendon unit for any given length [28, 29]. Stretching program with the knee bent at various angles (0, 10, 90˚) was applied for athlete after training and found to decrease hamstring injury rates [30]. Toft and Espersen [31], suggested that as the joint reaches end range, more parallel tissue elements become loaded, therefore the stretch in the current study progressed in the latter 4weeks and repeated 3 times 5 minutes each at 10 degrees elevation of stretch tool . The majority of length gains occurred in the first few stretch, no additional gains were made between the fourth and tenth stretch [32], hence in the current study the stretch repeated 3 times.

The pilot study by Peres, Draper [8] to determine how much weight to apply revealed that applying the same weight to subjects was uncomfortable for some subjects and ineffective for larger subjects. Lentell *et al.* [13] and Peres, Draper [8] applied percentage of body weight. As Lentell *et al.* [13] applied 0.5% body weight to the subject's shoulder to increase external rotation ROM. While Peres *et al.*[[8] chose to apply approximately one third of the subject's body weight to the calf but he strayed from this formula when this weight was too difficult for the subject. In the current study with the mathematical model the mean of calculated load was approximately 1.1kg at 5 degrees and 2.2kg at 10 degrees angles which represent and 1.3% and2.7% of body weight consequently.

In the current study, LLPS was subjectively found to be very comfortable with all subjects at 5 and 10 degrees elevation. There were no reports of any residual problems with function or sensation similar to the feeling reported by most subjects in the study done by Lentell *et al.* [13]. He used a calculated weight of 0.5% of each subject body weight to normal subject's shoulder to increase external. So there was a need to calculate the load applied using the stretch tool. Using 1.3% and 2.7% of body weight is safe for stretching hip flexor in all patients in the current study with low back pain associated with increased lumbar lordosis.

The current study resulted in gaining 6.6° hip extension, however in another study, the increase in hip extension following a stretch force of 15 % of subject body weight 2 minutes repeated 3 times were 12.1 degrees for right hip extension [15], the great difference may be justified; that the study by Godges *et al.* [15] was under went on healthy athlete, in addition the load used was high compared with the current study. A low force static stretching method requires more time to produce the same amount of elongation as a high force method [8].

In the current study warming up preceded low load stretch of hip flexor through posterior tilt exercises implemented through idiokinetic imagery exercises [18].

It is believed that the light activity performed during warm up with increase muscle temperature, decrease muscle stiffness and increase range of motion[33].

The greatest gain in hip extensor strength has been shown to be attained when the hip is exercised in the end range of extension. Such a position cannot be achieved in the presence of tight hip flexors. Following stretch initial attention in the first 3 weeks was focused on gluteal setting exercises which elicited a large degree of activity. It is the best method for isolating the gluteus maximus from the hamstring muscles. In the latter 4 weeks of stretch as hip flexor has been improved. Hip extension was performed, while the hip is abducted and externally rotated. This exercise exhibited the strongest contraction of the gluteus maximus [24]. In the current study following the low load stretch of hip flexor by active extension exercise may help to produce long term changes in the viscoelastic properties of hip flexor muscle; as flexibility can be maintained or increased through active contraction of the antagonist [34, 35]

Conclusion

Low load prolonged stretch using the designed stretch tool had significant improvement in hip extension equal to 6.66 degrees following 21 sessions of static stretch 3times/week. Low load stretch using 1.3% and 2.7% of body weight is safe for stretching hip flexors in patients with low back pain associated with increased lumbar lordosis.

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