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The Effect of Therapeutic Ultrasound and Duration of Stretching of the Hamstring Muscle Group on the Passive Knee Extension

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Only a few studies were conducted to investigate the effect of ultrasound in conjunction with stretch duration on the hamstring muscle flexibility. This study aimed to determine passive knee extension in subjects with tight hamstrings and to evaluate the effectiveness of stretch duration and therapeutic ultrasound on the flexibility of this muscle. Fifty boy students aging 12-14 years were randomly assigned to 1 of 5 groups: ultrasound therapy (1), ultrasound therapy and 15 sec stretch (2), ultrasound therapy and 30 sec stretch (3), 15 sec stretch (4) and 30 sec stretch (5). The passive knee extension (degrees) was measured at 0 and 3 weeks. Data were analyzed using one-way ANOVA and t-paired tests. Passive knee extension increased from 160.2°±7.9° to 163.5°±7.5° in group one (p=0.001), from 161.1°±6.9° to 166.5°±5.9° in group two (p<0.0001), from 163.5°±6.7° to 171.2°±5.9° in group three (p<0.0001), from 161°±11.8° to 164.4°±11.3° in group four (p = 0.005) and from 166.1°±5.6° to 171.1°±4.8° in group five (p = 0.001). There was not significant difference between five groups before (p = 0.48) and after intervention (p = 0.059). Our results showed that hamstring muscle group flexibility was increased in all groups. The gains achieved in range of motion of knee extension with the ultrasound therapy and 30 sec stretch were greater than to those made by ultrasound and 15 sec stretch methods. No advantage was apparent in using any of these protocols with respect to others to increase hamstring muscle group flexibility.

Key words: ROM, ultrasound, flexibility, hamstring, stretch

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INTRODUCTION

Adequate mobility of soft tissues and joints is also thought to be an important factor in prevention of injury or reinjury to soft tissues (Kisner and Colby, 2002). Elasticity of normal tissues was decreased following diseases and injuries and a change in the length-tension relationship of the muscle also occurs. As the muscle shortens, it no longer is capable of producing peak tension and tight weakness develops. Loss of flexibility, for whatever reason, can also cause pain arising from muscle, connective tissue, or periosteum (Hardy, 1989; Tillman and Cummings, 1992). Lack of motion also results in increased cross bonding or adherence between collagen fibers (Cummings and Tillman, 1992; Cummings *et al.*, 1983).

Hamstring shortening was seen after a variety of diseases and conditions such as lumbar dysfunction, neural syndromes, contractures, sport injuries and prolonged bed rest (Hertling and Kessler, 1996; Bandy *et al.*, 1998). Loss of flexibility of hamstring may lead to decrease in lumbar lordosis, reduction of muscle strength and quadriceps dysfunction during gait (Zachazewski, 1989). Lumbar pelvic rhythm was disturbed and as a result, anterior pelvic tilt was restricted and lumbar motion was increased. Excessive mobility of lumbar spine leads to over stretching of lumbar ligaments and consequently pain and instability (Levangie and Norkin, 2001). With regard to important role of hamstrings flexibility, restoration of its normal length is necessary. In this reason, different methods such as ultrasound therapy and stretching were studied. (Guffy and Knaust, 1997; Haar, 1978). Also, different duration of stretching in flexibility training programs range from 5 to 60 sec was recommended (Sady *et al.*, 1982). Beaulien (1981) showed that stretch duration lower than 30 sec did not increase muscle flexibility. However, Etnyre and Lee (1988) and Gajdosik (1991) found that 9 or 15 sec hamstring stretching result in greater improvement in hip and knee joints ROM. Madding *et al.* (1987) reported that sustaining a stretch for 15 sec was as effective as 120 sec. Feland *et al.* (2001) reported that longer hold times during stretching of the hamstring muscles resulted in a greater rate of gains in ROM. On the other hand, Researchers were emphasized on the thermal effects of continuous ultrasound compared to other heating modalities in increasing flexibility (Lehmann *et al.*, 1968; Sonnen, 1997; Reed and Ashikage, 1997; Middlemast and Chtterjee, 1978). Folconer *et al.* (1992) showed that ultrasound increases soft tissue extensibility and may be an effective adjunct in the treatment of knee contractures secondary to connective tissue shortening.

It is clear that there are different opinions in the therapeutic ultrasound efficacy and stretch duration on the flexibility of hamstring. As well, shortness of hamstring was seen in majority of the patients which were referred to rehabilitation centers (Norkin and White, 1985). Therefore, we examined the effects of therapeutic ultrasound and duration of stretching with or without using ultrasound on the hamstring flexibility. The purpose of this study was to determine passive knee extension before and after intervention with five protocols. We hypothesized that passive extension was increased after treatment with all protocols, but application of therapeutic ultrasound in conjunct with 30 sec stretching are more effective in increasing passive knee extension.

MATERIALS AND METHODS

Subjects: This randomized clinical trial was performed in Zabol in 2005. Boy students from guidance school aging 12-14 years participated in the study through simple non-probability sampling. The volunteers met 4 requirements. First, each subjects exhibited tight hamstrings. The shortness of hamstring muscles was determined by measuring passive hip flexion (degrees) while the knee was maintained in extension using a double-armed goniometer. The arms of the goniometer were 12 in length. For this purpose, subjects lay supine with the contra lateral leg and pelvis strapped to the bed. Anatomical landmarks were identified and the goniometer then positioned. The greater trochanter of the femur was palpated and the goniometer was centered over it. The lateral condoyle of the femur and mid auxiliary line were then marked. The arms of the goniometer were aligned with the proximal and distal landmarks. One researcher held the goniometer, the readings of which were concealed from the other researcher with piece of paper, while the second researcher passively moved the hip toward flexion while the knee was maintained in extension (Levangie and Norkin, 2001). Tight hamstrings were defined as a SLR lower than 70°. Second, subjects not involved in a regular exercise program and agreed not to start a program for the duration of the study. Third, not having any history of trauma and surgery on the lower extremities and lumbar spine. Fourth, lack of any neuromuscular disorders in lower extremities and spinal column. Subjects were excluded if they had not shortening of hamstring muscle; or were unable to tolerate stretch or to complete the study. Subjects voluntarily participated and a parent signed each subject's informed consent form approved by Zabol University of Medical Sciences, Zahedan.

Measurement of hamstring muscle flexibility: Fifty boy students from guidance school were selected according to above mentioned criteria and measurement. Passive knee extension of both legs (degrees) as indicator of hamstring muscle flexibility was measured using the goniometer. For this purpose, subjects were positioned supine with the hip and knee flexed to 90°. Then, the lateral malleolus of the tibia and greater trochanter of the femur were marked. One researcher held the goniometer, the readings of which were concealed from the other researcher with piece of paper, while the second researcher passively moved the leg toward terminal knee extension. Terminal extension was determined as the point at which the researcher felt a firm resistance to movement. Once terminal extension was reached, the researcher holding the goniometer ensured proper alignment and the blinded goniometer was revealed to assisting examiner for the measurement to be read and recorded. Zero degrees of knee extension were considered full hamstring muscle flexibility. Subjects were assigned randomly to 1 of 5 groups: ultrasound therapy, ultrasound therapy and 15 sec stretch, ultrasound therapy and 30 sec stretch, 15 sec stretch, or 30 sec stretch.

Ultrasound therapy: The ultrasound therapy device used was a Sonopuls 434 Enraf-Nonius, with 3 W cm^{-2} peak power and 1 and 3 MHZ frequency. In three ultrasound therapy groups, continuous therapeutic ultrasound was administered three times per week for three weeks. The ultrasound treatment was administered with a power of 2 W cm^{-2}, a frequency of 1 MHZ, continuously, 5 min daily on the medial and lateral hamstrings (2 min for each tendons) and between two tendons (1 min). After ultrasound therapy stretching was applied immediately in the second and the third groups.

Stretching procedure: Stretching of the hamstring muscle was performed by primary researcher. After oral and written instruction, stretching was carried out four times as a self applied active static stretching of 15 sec with 10 sec rest between stretches in the second and fourth groups. Subjects in the third and fifth groups received two stretches for 30 sec with a 10 sec rest between stretches. The first group received only therapeutic ultrasound. After receiving the instructions, the hamstrings were stretched in the standing position with the heel resting on a chair. The subject was instructed to lean the trunk forward with spine upright and pelvis pressed backwards to obtain a stretch over both the knee and the hip. The spine was kept upright and the pelvis pressed backwards all the time to avoid compensation. The written material contained an illustration of the position, the instructions, a time table and the figure of person from the front and from behind on which the subject was told to indicate where the stretch was felt. In addition, a watch with second hand was placed in front of the subject so that the stretch could be performed with an interval of 10 sec.

The duration of this study was 10 days and the study involved every other day. After ten sessions of treatment and training, all subjects were retested using the same procedures and personnel described for the pretest.

Statistical analysis: Data were analyzed using SPSS10. Kolmogorov-Smirnov test for normality were performed for all outcome variables. A one-way analysis of variance was used to determine differences between groups. A Tukey Honestly Significant Difference post hoc analysis was performed to interpret the findings. A paired t-test was used for comparison between pretest and posttest measurements. An alpha level of $p<0.05$ was the level of significance.

RESULTS

Fifty boy students aging 12-14 years completed all requirements for this study. All subjects correctly stretched hamstring muscle. The data were assessed for group differences in passive knee extension between and within each group. Table 1 presents the means and standard deviation for pretest and posttest measurements and gain scores (difference between pretest and posttest) of passive knee extension in five groups.

We performed 3 statistical analyses. First, 5 paired t tests were calculated on the pretest to posttest change for each group. The paired t tests indicated significance increases in hamstring flexibility in the ultrasound therapy group ($t = 4.98$, $p = 0.001$), in the ultrasound therapy and 15 sec stretch group ($t = 7.22$, $p< 0.0001$), in the ultrasound therapy and 30 sec stretch

Table 1: Pretest, post test and gain scores for passive knee extension (Degrees) in five group

	Ultrasound	Ultrasound+15 ss*	Ultrasound+30 ss	15 ss	30 ss
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
N	10.0	10.0	10.0	10.0	10.0
Pretest	160.2±7.9	161.1±6.9	163.5±6.7	161.0±11.8	166.1±5.5
Posttest	163.3±7.9	166.5±5.9	171.2±5.9	164.4±11.3	171.1±4.8
Gain	3.1	5.4	7.7	3.4	5.0

*ss = seconds stretch

group (t = 7.61, p< 0.0001), in the 15 sec stretch group (t = 3.74, p = 0.005) and in the 30 sec stretch group (t = 4.79, p = 0.001).

Second, we calculated one-way ANOVA to assess whether any significant differences existed in the pretest scores across the groups and found none ($F_{4,\ 45}$ = 0.89, p = 0.47). Therefore, the range of passive knee extension was quite similar in all groups before intervention and the groups were matched in terms of passive knee extension. Then, a one-way ANOVA was calculated to assess the posttest scores of the five groups and did not find any significant difference ($F_{4,\ 45}$ = 2.46, p = 0.059). Despite lack of significant difference among posttest scores of five groups, p-value of post-intervention (p = 0.059) was lower than p-value of pre-intervention (p = 0.47). As well, Tukey Honestly Significant Difference post hoc analyses did not show any significance differences between five groups in terms of passive knee extension. Table 2 presents p-value of these analyses between the means of pretest and posttest measurement of five groups.

Finally, gain scores between pretest and posttest measurements for each group were calculated. In an attempt to summarize the data, we conducted a one-way ANOVA on gain scores, revealing a significance differences between groups ($F_{4,\ 45}$=4.37, p = 0.005). Post hoc analysis with a Tukey Honestly Significant Difference test indicated a significant difference between the gains in the ultrasound therapy and 30 sec stretch group (7.7±3.2) and the 15 sec stretch group (3.4±2.9) and the ultrasound group (3.1±1.96) with p = 0.005 and p = 0.01, respectively. However, No significant difference was found between the gains in the ultrasound therapy and 30 sec stretch group and the 30 sec stretch group (5±3.3) and the ultrasound therapy and 15 sec stretch group (5.4±2.4). As well, Post hoc analysis with a Tukey test did not show any significance difference among other groups. Table 3 presents p-value of these analyses between the means of gain scores of five groups.

DISCUSSION

We rejected the first null hypothesis that no difference would be seen in range of passive knee extension after 10 sessions of intervention. The findings showed that the passive knee extension and consequently flexibility of hamstring muscles was significantly increased following static stretching of hamstring with 15 or 30 sec stretch and a combination of therapeutic ultrasound and 15 or 30 sec stretch and therapeutic ultrasound alone. The second null hypothesis was not rejected. Given the lack of significant difference in range of passive knee extension among five groups. However, the gains in range of passive knee extension obtained in therapeutic ultrasound and 30 sec stretch group (7.7) were significantly greater than both therapeutic ultrasound (3.1) and 15 sec stretch groups (3.4).

It is necessary that the results of this study are carefully interpreted. Although, all methods were effective in increasing ROM, but we did not find any significant difference among five protocols. Despite results of one-way ANOVA among posttest scores, we found that gain made with therapeutic ultrasound and 30 sec stretch group was significantly increased compared to ultrasound and 15 sec stretch groups. The main explanation may be found in the pretest scores of these groups. In spite of lack of significant difference among pretest scores of these groups, the scores in therapeutic ultrasound and 30 sec stretch group (163.5) was greater than therapeutic ultrasound (160.2) and 15 sec stretch groups (161). Thus, on these findings, we can not affirm that ultrasound and 30 sec stretch method is an appropriate technique as compared to therapeutic ultrasound and 15 sec stretch methods.

There are two explanations for increases flexibility with ultrasound. One explanation may be found in examining the possible vascular mechanism that occurs due to thermal effects of continuous ultrasound. Second,

Table 2: p-value of Tukey post hoc analyses between five groups. The means of pretest and posttest measurement (Table 1) between groups were compared

Group	Ultrasound		Ultrasound +15 s		Ultrasound +30 s		stretch 15 s		stretch 30 s	
Ultrasound			0.99	0.87	0.9	0.14	0.99	0.99	0.49	0.15
Ultrasound+15 sec	0.99	0.87			0.96	0.62	1.00	0.97	0.64	0.64
Ultrasound+30 sec	0.9	0.14	0.96	0.62			0.96	0.26	0.95	1.00
15 sec stretch	0.99	0.99	1.00	0.97	0.96	0.26			0.62	0.28
30 sec stretch	0.49	0.15	0.64	0.64	0.95	1.00	0.62	0.28		

p<0.05 is significant

Table 3: p-value of Tukey post hoc analyses between five groups. The means of gain scores (Table 1) between groups were compared

Group	Ultrasound	Ultrasound+15 sec	Ultrasound+30 sec	15 sec stretch	30 sec stretch
	Gain scores	Gain scores	Gain scores	Gain scores	Gain scores
Ultrasound		0.36	0.005*	0.99	0.55
Ultrasound+15 sec	0.36		0.36	0.5	0.99
Ultrasound+30 sec	0.005*	0.36		0.01*	0.21
15 sec stretch	0.99	0.5	0.01*		0.7
30 sec stretch	0.55	0.99	0.21	0.7	

*p<0.05 is significant

tissues can be characterized by their acoustic impedance, the product of their density and the speed at which ultrasound will travel through it. Low absorption of ultrasound waves is seen in tissues that are high in water content (e.g., fat), whereas absorption is higher in tissues rich in protein (e.g., skeletal muscle) (Dyson, 1987; Low and Reed, 1990). Ziskin *et al.* (1986) stated that an increasing in tendons length following continuous ultrasound therapy is due to change of their viscosity and plasticity. The effects of heating with ultrasound for increasing ROM have been noted in other studies (Lehmann *et al.*, 1968; Sonnen, 1997; Reed and Ashikage, 1997). Only a few studies emphasized on the non-thermal and sclerotic effects of therapeutic ultrasound in increasing connective tissue flexibility (Kahn, 1994; Young, 1996). Does therapeutic ultrasound without stretching techniques, like our study, result in increasing flexibility? In accordance with our results, Reed *et al.* (2000) showed that heating with continuous ultrasound did not augment the effects of stretching. Coakley (1978) stated that ultrasound at a frequency of 1 MHZ is absorbed primarily by tissues at a depth of 3-5 cm and is therefore recommended for deeper injuries and in patients with more subcutaneous fat. Elevation of collagen tissue temperature affects on the mechanical and physical characteristics of tissues and facilitates deformation of the collagen. Thus, pain and discomfort was reduced during stretching and collagen fiber ability to tolerate greater forces was increased.

We showed that static stretching increased muscle flexibility. The effects of statically stretching the hamstrings for a variety of durations were examined and controversial results have been reported (Bandy and Irion, 1994; Bandy *et al.*, 1998). Static stretching may be effective in increasing the length of muscle due to the prolonged stretching, which may allow the muscle spindle to adapt over time and cease firing (Gordon and Ghez, 1991). Robert and Wilson (1999) found that holding stretches for 15 sec as opposed to 5 sec, may result in greater improvements in active ROM. However, sustaining a stretch may not significantly affect the improvements gained in passive ROM. The researchers speculated that 15 sec of static stretching was sufficient to elicit a Golgi tendon organ response and therefore provide an effective flexibility training stimulus. Madding *et al.* (1987) showed that the effects of 15 sec stretch on the hip abductors flexibility were similar to the effects of 120 sec stretch. As well, Borms *et al.* (1987) did not find any significant difference in hip rang of motion following different stretch duration (10, 20 and 30 sec).

Our findings showed that simple stretching techniques results in greater ROM and consequently hamstring flexibility. The role of hamstring muscle in lumbar-pelvic rhythm was identified. Inflexible hamstring muscles by their attachment from the posterior knee region to the ischial tuberosity of the pelvis prevent full rotation and as a result the pelvic rhythm was disturbed. In total body flexion, once the pelvis has reached its maximum rotation, if total flexion has not been reached, further bending may be forced by more lumbar curving. Subsequently, abnormal stresses superimposed on the normal structures especially, lumbar spine. Thus, we daily met patients with low back pain or knee pain originated from tight hamstrings. These pain and discomfort easily managed with stretching. With regard to our results and high prevalence of tight hamstring, to regulate a prophylaxis program in primary schools for prevention of hamstring muscle shortness was recommended. The high prevalence of tight hamstrings and its high economic costs make the reduction of tightness- related pain as a health care priority.

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