ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

*International Journal of Development Research*
*Vol. 08, Issue, 02, pp.19012-19021, February, 2018*


ORIGINAL RESEARCH ARTICLE OPEN ACCESS

# A STUDY TO EVALUATE THE EFFECTIVENESS OF A SINGLE APPLICATION OF MUSCLE ENERGY TECHNIQUE COMPARED WITH PASSIVE STRETCH ON HIP EXTENSION RANGE OF MOTION IN ATHLETES

***[1]Dr. Deepshikha Beniwal, [2]Dr. Ajeet Kumar Saharan and [3]Dr. Vishal Bhardwaj**

[1]Jr. Physiotherapist, Medanta The Medicity, Gurgaon, Haryana, India
[2]Asso. Prof. Department of Physiotherapy, Maharaj Vinayak Global University, Jaipur, India
[3]MPT (Musculoskeletal & Sports) GTL, Artemis Hospital, Dwarka, Delhi, India

## ARTICLE INFO

***Article History:***
Received 12th November, 2017
Received in revised form
16th December, 2017
Accepted 23rd January, 2018
Published online 28th February, 2018

***Key Words:***

Muscle Energy Technique (MET),
Range of Motion (ROM).

## ABSTRACT

**Aim of the Study:** To evaluate the effectiveness of a single application of MET in comparison to passive stretch on hip extension ROM over a 30 minute follow up period.

**Material & Methodology: Study Design-** Experimental trial using a controlled crossover design, **Sample size-**Total of 30 subjects i.e, n=30 (15 in each group), **Type of sampling-**purposive sampling with alternatively allocation to the experimental group. **Study Duration-**A total of 8 weeks were included to conduct the study. **Inclusion criteria-** healthy adult male athletes aged between 18-23 years, the athletes giving informed consent were included in the study, healthy athletes exhibited a "positive" Thomas test, athletes not having any mental illness or any psychiatric problem, athletes not currently receiving any manual therapy treatment or undertaking a flexibility training regime. **Exclusion Criteria-** Participants were excluded if they had history of hip, pelvic or lower back pain, congenital hip joint dysplasia, pathology or trauma, psychological illness, unconsciousness or uncooperative or unresponsive, open wounds, had a known musculoskeletal or neurological disorder; or were taking medications that affect the musculoskeletal system (e.g. muscle relaxants), severe sprain and strain. Goniometer was used both in diagnosis and in assessing the results of the treatment. A goniometer purpose to measure accurately the movements present in a simple or composite joint. **Procedure -** This study was a 8 week study including the selection and assessment and desired athletes involved in the study. Data collection took place within the MDU Sports complex, Rohtak, Haryana undertaken by the researcher who was a registered physiotherapist, and was instructed in the specific experimental protocol for the MET intervention. All participants completed both an MET and a passive stretch protocol. Group allocation was determined by logistical factors primarily on the basis of the availability of the practitioner performing the MET procedure. Assessment and testing took place at the same day, with 7 days between sessions. Participants were asked to retrain from vigorous exercise and stretching their hip flexors during the 7 day interval between both intervention trials. A table was placed in the field used in the assessment procedure. **Pre intervention -** All participants undertook a warm-up exercise consisting of walking for 5 minutes at moderate speed immediately prior to commencement of the intervention. Following the warm-up, the participant was asked to sit with their sacrum at the very edge of the end of the table, they were then instructed to draw up their left knee and holding it with both hands, slowly rollback into a lying position while the researcher assisted with guiding the right leg up, simultaneously pulling the second (mobile) treatment table into place so that the participant was able to lie fully supine. The height of the second table was adjusted to be level with the first so that the participant could lie comfortably. The greater trochanter of the proximal femur and the lateral epicondyle of the distal femur of the right limb were palpated and marked with an indelible marker and overlaid with adhesive markers. The participant was then asked to bend their left hip and knee and hold the leg in the fully flexed position to maintain a flat lumbar spine and prevent pelvic tilt which was checked by the physical therapist. The physical therapist then removed the mobile treatment table while supporting the participant's right leg by cupping their heel, and slowly lowering it, allowing the leg to extend at the hip and hang in are laxed manner.

**Results: Participants -**The sample consisted of 30 male participants who were allocated to group A (*n*=15) or group B (*n*=15). The mean age of participants was 21.3 years (±1.6); the mean weight 64kg (±2.8); mean height 172.5cm (±3.6) and the mean hip extension at baseline was 20.16 degrees (±4.96).

****Corresponding author:***
**Dr. Deepshikha Beniwal,**
Jr. Physiotherapist, Medanta The Medicity, Gurgaon, Haryana, India.

Immediate effect of intervention, Five minutes post intervention at 5 min, Ten minutes post intervention at 10 min, Fifteen minutes post intervention at 15 min, Twenty minutes post intervention at 20 min, Twenty five minutes post intervention at 25 min, and Thirty minutes post intervention at 30 min.

**Conclusions:** The findings of this study indicate a "more significant" effect for increasing hip extension range of motion immediately following a single application of muscle energy technique to improve hip extension, and a "less significant" effect following passive stretch. Five minutes following the intervention the observed increase was "significant" for both groups and was maintained at 30 minutes. There was no evidence that an effect of either intervention was maintained following the 7-day interval. Therefore both MET and passive stretch appears to have a significant effect in increasing hip extension ROM for duration of up to 30 minutes.



**Citation: Dr. Deepshikha Beniwal, Dr. Ajeet Kumar Saharan and Dr. Vishal Bhardwaj. 2018.** "A study to evaluate the effectiveness of a single application of muscle energy technique compared with passive stretch on hip extension range of motion in athletes", *International Journal of Development Research*, 09, (02), 19012-19021.

## INTRODUCTION

Hip extension range of motion (ROM) is an important component of independent mobility. Basic functions such as standing from sitting and walking, as well as more complex tasks are dependent on coordination between the trunk and lower extremity for which hip joint flexibility is necessary (Eland *et al*., 2002). A restriction of hip extension ROM is common (Magee 2006), can lead to altered biomechanical relationships and functional compromise (Shimada, 1996; Hurwitz *et al*., 1997; Lee *et al*., 1997;Cristopoliski *et al*., 2009), and may be associated with lower back and lower extremity pain (Winters *et al*., 2004; Tyler *et al*., 2006). The hip joint has been identified as a key joint of interest for initial research by the Sports Advisory Group. This group was formed in 2013 of sports medicine experts including the chief medical officers from the national governing bodies of football, rugby, cricket, golf, horse racing, tennis, athletics, dance, para-olympic sport, English Institute of Sport and the Ministry of Defense. The group advises the Arthritis Research UK Centre for Sport, Exercise and OA on key areas for sports related research (Jackson *et al*., 2015). Hip extension ROM has been investigated in relation to gait function in the elderly (Cristopoliski *et al*., 2008), and persons with central nervous system disorders such as cerebral palsy (Lee *et al*., 1997), athletic performance (Young *et al*., 2003), sufferers of low back pain (Stodolny and Mazur, 1989; Winters *et al*., 2004), patella-femoral pain (Tyler *et al*., 2006; Winters *et al*., 2004) and osteoarthritis of the hip joint (Hurwitz *et al*., 1997).

A restriction of joint range of motion and a loss of flexibility may be attributed to a number of different causes including inactivity and immobilization (Alter, 1996; Trudel and Uhthoff, 2000; Prentice and Voight, 2001; Lederman, 2005; Magee *et al*., 2007), myoelectric hyperactivity related to central nervous system disorders (Shimada, 1996; Lee *et al*., 1997; Spruit and Fabry, 1997; Novacheck *et al*., 2002; Westhoff *et al*., 2003) and degenerative joint disorders (Shimada, 1996; Hurwitz *et al*., 1997; Porth, 2002). Sedentary lifestyles and a habitual seated posture are likely contributing factors in reduction of hip extension ROM.A range of treatment options for hip flexion contracture have been reported in the literature. Surgical lengthening of iliopsoas muscle and tendon has been performed in cases of spastic contraction associated with cerebral palsy (Hoffer 1986; Spruit and Fabry 1997 Novacheck *et al*., 2002), and for "internal snapping hip syndrome" (Hoskins *et al*. 2004; Byrd, 2005; Flanum *et al*., 2007). Injection of Botulinum toxin A into the psoas muscle has also been reported (Molenaers *et al*., 1999; Westhoff *et al*., 2003) as well as self stretch of the hip flexors and exercise (Winters *et al*., 2004; Tyler *et al*., 2006; Cristopoliski *et al*., 2007). Muscle energy technique (MET) and its variants of contract-relax (CR) stretch techniques such as proprioceptive neuromuscular facilitation (PNF) are commonly employed by osteopaths and other manual therapists in order to improve musculoskeletal function (Chaitow, 2006), effect fluid dynamics, stretch muscles perceived to be "tight", and increase ROM (Kuchera and Kuchera, 1994; Greenman, 1996; Goodridge, 1997).

Potentially MET could be employed as a treatment option for a restriction in extension ROM in the hip joint. The immediate effect of MET on ROM has been studied in arrange of different joints by a number of researchers who have found immediate positive effects on cervical spine ROM (Schenk *et al*., 1994; Fryer and Ruszkowski, 2004; Burns and Wells 2006), thoracic spine ROM (Lenehan *et al*., 2003), lumbar spine ROM (Schenk *et al*., 1997) and hamstring extensibility (Ballantyne *et al*., 2003; Smith and Fryer, 2008; Shadmehr *et al*., 2009). To date the reappears to be only one published study investigating the effect of MET on hip extension range of motion. Stodolny and Mazur (1989) examined the effect of post-isometric relaxation in conjunction with kinesio therapy (a prescribed exercise regime) compared with kinesio therapy alone over a 16-day period on participants with low back pain (LBP) diagnosed as disc pathology. One other study, an unpublished master's thesis (Milliken, 2003) investigated the effect of a single application of MET targeting the psoas major muscle on asymptomatic participants. Both these studies indicated an immediate positive effect on hip extension ROM. Neither study included a longer term follow-up. There is also a lack of research investigating the longer term effects of MET targeting muscle groups other than hip flexors. Spernoga *et al*., (2001) investigated the effect of a single application of PNF on hamstring extensibility over a 30 minute period and results indicated that a significant ($p<0.05$) effect lasted a maximum of six minutes. Trampas *et al*., (2010) measured passive knee extension immediately, and at10 and 30 minutes following a CR PNF stretch on the hamstring muscles. A "moderate" effect size was maintained at 10 minutes which diminished to a "small" effect size by 30 minutes post application of the CR stretch. Smith and Fryer (2008) reported a mean (±SD) increase of 2.49 degrees (±7.19; $p$=0.04) in active knee extension one week following application of an MET protocol and the authors suggested lasting effects of the technique. There appear to be few investigations into the duration of the effect of MET on hip extension ROM.

**Aims & Objectives - Rationale of the study**

Considering the serious importance of muscle energy technique on hip extension ROM. There is a growing concern about the limited hip extension range of motion due to some of the condition, disorder and post fracture etc. Although muscle energy technique has strong evidence to increase in the hip extension range of motion, but still the evidences for its effectiveness is unclear. This study is sought to compare and to find out the effect of single application of MET on hip extension range of motion.

**Aim of the Study**

To evaluate the effectiveness of a single application of MET in comparison to passive stretch on hip extension ROM over a 30 minute follow-up period.

**Hypothesis:** Application of Muscle energy technique is beneficial in the improvement of hip extension movement in comparison to passive stretch in athletes.

**Null Hypothesis:** Application of Muscle energy technique is not beneficial in improvement of hip extension movement in comparison to passive stretch in athletes.

**Operational definitions: Hip extension**: backward motion of the hip from the zero standing position.

**Muscle energy technique**: a manual medicine treatment procedure which involves voluntary contraction by the patient, against a directly executed counterforce applied by the operator.

**Thomas test:** The Thomas test (TT), named after Dr. Hugh Owen Thomas, was created to rule out hip flexion contracture (Thomas, 1878), meaning that a positive TT is indicative of hip flexion contracture.

**Modified Thomas test:** The modified Thomas test (MTT) was developed to assess the presence of hip flexion contracture and to measure hip extensibility.

## MATERIALS AND METHODS

Study Design- Experimental trial using a controlled crossover design (Hopkins, 1997), Sample size-Total of 30 subjects i.e, n=30 (15 in each group), Type of sampling-purposive sampling with alternatively allocation to the experimental group. Study Duration-A total of 8 weeks were included to conduct the study.

**Inclusion Criteria-** healthy adult male athletes aged between 18-23 years, the athletes giving informed consent were included in the study, healthy athletes exhibited a "positive" Thomas test, athletes not having any mental illness or any psychiatric problem, athletes not currently receiving any manual therapy treatment or undertaking a flexibility training regime.

**Exclusion Criteria-** Participants were excluded if they had history of hip, pelvic or lower back pain, congenital hip joint dysplasia, pathology or trauma, psychological illness, unconsciousness or uncooperative or unresponsive, open wounds, had a known musculoskeletal or neurological disorder; or were taking medications that affect the musculoskeletal system (e.g. muscle relaxants), severe sprain and strain. Goniometer was used both in diagnosis and in assessing the results of the treatment. A goniometer purports to measure accurately the movements present in a simple or composite joint.

**Procedure -** This study was a 8 week study including the selection and assessment and desired athletes involved in the study. Data collection took place within the MDU Sports complex, Rohtak, Haryana undertaken by the researcher who was a registered physiotherapist, and was instructed in the specific experimental protocol for the MET intervention. All participants completed both an MET and a passive stretch protocol. Group allocation was determined by logistical factors primarily on the basis of the availability of the practitioner performing the MET procedure. Assessment and testing took place at the same day, with 7 days between sessions. Participants were asked to retrain from vigorous exercise and stretching their hip flexors during the 7-day interval between both intervention trials. A table was placed in the field used in the assessment procedure.

**Pre intervention -** All participants undertook a warm-up exercise consisting of walking for 5 minutes at moderate speed immediately prior to commencement of the intervention. Following the warm-up, the participant was asked to sit with their sacrum at the very edge of the end of the table, they were then instructed to draw up their left knee and holding it with both hands, slowly rollback into a lying position while the researcher assisted with guiding the right leg up, simultaneously pulling the second (mobile) treatment table into place so that the participant was able to lie fully supine. The height of the second table was adjusted to be level with the first so that the participant could lie comfortably. The greater trochanter of the proximal femur and the lateral epicondyle of the distal femur of the right limb were palpated and marked with an indelible marker and overlaid with adhesive markers. The participant was then asked to bend their left hip and knee and hold the leg in the fully flexed position to maintain a flat lumbar spine and prevent pelvic tilt which was checked by the physical therapist. The physical therapist then removed the mobile treatment table while supporting the participant's right leg by cupping their heel and slowly lowering it, allowing the leg to extend at the hip and hang in are laxed manner.

**Passive stretch protocol -** The participant maintained the extended hip position described above for 60s which was equivalent to the length of time spent in this position during the MET protocol. The physical therapist then lifted the extended leg up by supporting the participant's heel, while drawing the mobile treatment table back into place, enabling the participant to return to the supine position.

**MET protocol -** The MET intervention used for this study was based on the description by Chaitow (2006)[6] and was clearly explained in simple language to each participant immediately prior to commencement. The participants were instructed to follow the prompts given by the practitioner and during the contraction phase of the stretch to "push their right leg up to meet the practitioner's resistance with approximately 5-10% of their perceived strength". The participant was also asked not to allow their lumbar spine to lift off the table, and to indicate if at any time during the procedure they experienced pain or discomfort.

**The MET intervention proceeded as follows**

- The participant was assisted into the extended hip position as previously described in the pre-intervention protocol.
- The practitioner stood adjacent to the participant at the end of the table facing the participant's right leg.
- The practitioner then placed their left hand over the participant's distal thigh just above the right knee and the aright handover the participant's right iliac crest to stabilize the pelvis
- The practitioner then gently pushed down on the thigh to stretch the hip joint to the first stretch barrier as perceived by the practitioner.
- The participant was then requested to "gently push up".
- The contraction phase was maintained for the duration of 5 seconds as recommended by Fryer and Ruszkowski (2004).
- The participant was then instructed to "relax" (duration 3seconds).
- The practitioner then gently pushed down on the thigh to stretch the hip joint to the next stretch barrier as perceived by the practitioner.
- This process was repeated for a total of five contraction phases (Greenman, 1996).
- The physical therapist then lifted the extended leg up by supporting the participant's heel, while drawing the mobile treatment table back into place, enabling the participant to return to the supine position.

**Post intervention**

Following the intervention, measures of hip extension were recorded immediately, and at intervals of 5 minutes and up to 30 minutes post intervention ($t$= 0, 5, 10, 15, 20, 25, 30 min). For the repeated measurements, the physical therapist assisted the participant into the extended leg position (as previously described) and instructed the participant to "relax". This position was maintained for 2s, then the leg was lifted back onto the treatment table by the physical therapist and the participant returned to the supine position for the time interval between each measurement. Following the first session the participants were each given an indelible ink pen and asked to maintain the markings on the anatomical reference points for the subsequent session.

**Data Analysis**

The raw data was tabulated using the Microsoft Office Excel 2010, was then explored and descriptive statistics were calculated. Pre-intervention (baseline) measures of degrees of hip extension ROM were compared with post- intervention measures for both passive stretch and MET using paired t-tests which were performed to calculate $p$ values. 95% confidence intervals were constructed for the mean differences. SPSS v20 (SPSS Inc, Chicago, IL) was used for the descriptive and inferential data analysis. The comparison and correlation between various items was assessed using a series of data analyses test. Mean and standard deviation were used to prepare summary statistics. Paired t-test is used to compare various parameters used in the study. The following statistical tools were used:

**Formulas Used are as Follows: Descriptive Statistics:** The mean, standard deviation and standard error were calculated to describe the data.

1. **Arithmetic Mean $(\overline{X})$:** It gives the average value of the whole

$$\bar{X} = \frac{\sum X}{N}$$

Where - $\bar{X}$= Arithmetic Mean, N= Total Number of Individuals, ΣX= Sum of all variables

2. **Standard Deviation (S. D.):** It gives the degree of dispersion or deviation of the recorded data from the mean. It is given by the formula:

$$\text{S. D.} = \frac{\sqrt{\Sigma(X-\overline{X})^2}}{N}$$

Where - X= Individual variable, N= Total Number of variables, S.D. = Standard Deviations, $X - \bar{X}$ = Deviation of variables from the mean.

3. **Standard Error (S.E.):** It enables the measurement of magnitude of the sampling error. It is calculated by using the following formula:

$$\text{S.E.} = \text{S.D} / \sqrt{N}$$

Where - S.E. = Standard error, S.D. = Standard deviation, N= Total number of variables.

4. **Student's 't' test:** It gives the difference between the two independent random samples of size N1 and N2 with mean X1 and X2 and S.E. of X1 and S. E. of X2. It is calculated by the following formula:

$$t = \sqrt{\frac{\bar{X}_1 - \bar{X}_2}{(SE_{X1})^2 + (SE_{X2}{}^2)}}$$

Where - t='t' test, $X_1$= mean of 1st variable, $X_2$= mean of 2nd variable, $SE_{X1}$= SE of 1st variable, $SE_{X2}$= SE of 2nd variable.

## RESULTS

**Participants:** The sample consisted of 30 male participants who were allocated to group A ($n$=15) or group B ($n$=15). The mean age of participants was 21.3 years (±1.6); the mean weight 64kg (±2.8); mean height 172.5cm (±3.6) and the mean hip extension at baseline was 20.16 degrees (±4.96).

**Immediate effect of intervention:** Immediately following the MET intervention a mean increase of 4.13 degrees (±2.27) of hip extension was observed (95%CI=3.28 to 4.98 ;$p \leq 0.001$) This was compared with the passive stretch (control) procedure for which a mean increase of 1.80 degrees (±2.39; 95%CI=0.90 to 2.69; $p \leq 0.001$) was measured. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph 1,2. While comparing MET intervention with passive stretch (control), there was mean increase of 3.93 degree (±5.69) of hip extension was observed (95%CI=1.80 to 6.05 ; $p \leq 0.001$). The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graphs 3.

**Five minutes post intervention**

At 5 min post MET intervention a mean increase of 2.70 degrees (±2.16) of hip extension was observed (95%CI=1.89 to 3.51; $p \leq 0.000$) This was compared with the passive stretch (control) procedure for which a mean increase of 2.26degrees (±1.89; 95%CI=1.56 to 2.97; $p \leq 0.000$) was measured. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph 1, 2.

**Table 1a. Raw data for passive stretch procedure group A**

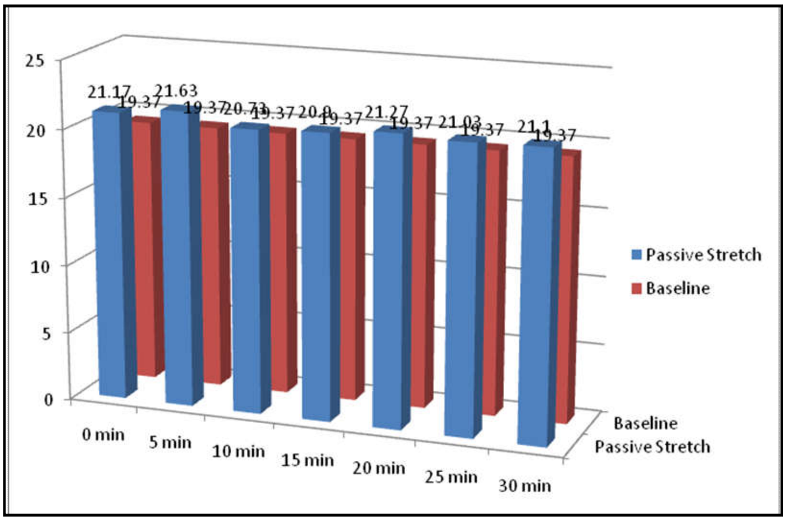
| Subjects | Group | AC Pre | AC 0 min | AC 5 min | AC 10 min | AC 15 min | AC 20 min | AC 25 min | AC 30 min |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 20 | 20 | 20 | 16 | 16 | 18 | 16 | 18 |
| 2 | A | 27 | 28 | 28 | 27 | 27 | 27 | 27 | 28 |
| 3 | A | 27 | 26 | 27 | 27 | 27 | 29 | 25 | 27 |
| 4 | A | 18 | 20 | 22 | 21 | 22 | 22 | 23 | 21 |
| 5 | A | 25 | 25 | 24 | 26 | 21 | 24 | 21 | 20 |
| 6 | A | 12 | 10 | 12 | 12 | 12 | 13 | 13 | 13 |
| 7 | A | 19 | 20 | 22 | 20 | 20 | 21 | 20 | 19 |
| 8 | A | 15 | 19 | 18 | 16 | 16 | 16 | 17 | 17 |
| 9 | A | 23 | 25 | 25 | 27 | 26 | 26 | 28 | 28 |
| 10 | A | 24 | 25 | 26 | 25 | 24 | 25 | 26 | 28 |
| 11 | A | 19 | 18 | 21 | 19 | 19 | 20 | 20 | 20 |
| 12 | A | 16 | 22 | 22 | 20 | 22 | 22 | 22 | 21 |
| 13 | A | 15 | 16 | 18 | 15 | 17 | 15 | 17 | 18 |
| 14 | A | 19 | 23 | 22 | 22 | 22 | 22 | 23 | 23 |
| 15 | A | 12 | 21 | 17 | 17 | 18 | 20 | 19 | 19 |

Notes: AC = Group A Control (Passive Stretch)

**Table 1b. Raw data for passive stretch procedure group B**

| Subjects | Group | BC pre | BC 0 min | BC 5 min | BC 10 min | BC 15 min | BC 20 min | BC 25 min | BC 30 min |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 16 | 20 | 19 | 18 | 22 | 21 | 19 | 20 |
| 2 | B | 15 | 20 | 17 | 19 | 19 | 18 | 19 | 17 |
| 3 | B | 17 | 18 | 18 | 17 | 19 | 17 | 15 | 13 |
| 4 | B | 15 | 19 | 19 | 16 | 16 | 16 | 17 | 17 |
| 5 | B | 23 | 25 | 25 | 27 | 26 | 26 | 28 | 28 |
| 6 | B | 24 | 26 | 26 | 25 | 24 | 25 | 27 | 28 |
| 7 | B | 15 | 17 | 17 | 15 | 17 | 17 | 17 | 18 |
| 8 | B | 19 | 22 | 22 | 22 | 22 | 22 | 23 | 23 |
| 9 | B | 27 | 27 | 27 | 27 | 28 | 27 | 27 | 28 |
| 10 | B | 27 | 28 | 28 | 27 | 27 | 28 | 25 | 27 |
| 11 | B | 19 | 23 | 23 | 23 | 22 | 22 | 23 | 21 |
| 12 | B | 25 | 24 | 24 | 26 | 21 | 24 | 21 | 21 |
| 13 | B | 12 | 11 | 12 | 12 | 13 | 13 | 13 | 14 |
| 14 | B | 19 | 21 | 20 | 20 | 20 | 21 | 20 | 18 |
| 15 | B | 17 | 20 | 19 | 18 | 22 | 21 | 20 | 20 |

Notes: BC = Group B Control (Passive Stretch)




**Graph 1. The mean values for hip extension range of motion for the Passive stretch intervention for each time intervals is displayed as follows**

**Table 2a. Raw data for MET procedure group A**

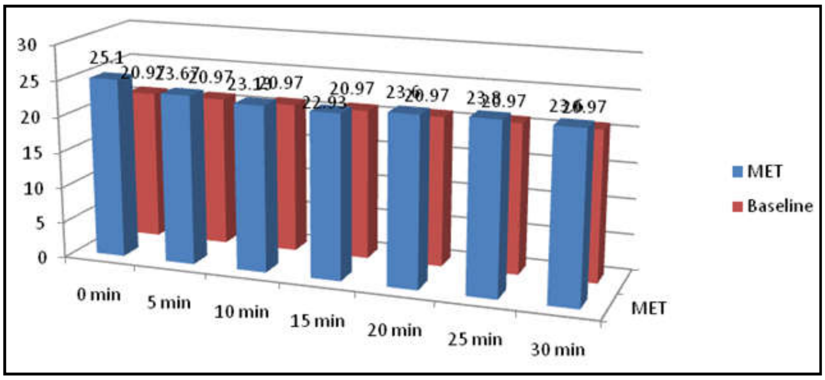
| Subjects | Group | AT Pre | AT 0 min | AT 5 min | AT 10 min | AT 15 min | AT 20 min | AT 25 min | AT 30 min |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 18 | 21 | 16 | 17 | 16 | 17 | 16 | 16 |
| 2 | A | 26 | 33 | 31 | 30 | 31 | 31 | 31 | 31 |
| 3 | A | 24 | 31 | 28 | 30 | 29 | 30 | 30 | 30 |
| 4 | A | 16 | 21 | 22 | 20 | 22 | 23 | 24 | 22 |
| 5 | A | 18 | 28 | 24 | 27 | 25 | 26 | 25 | 23 |
| 6 | A | 14 | 19 | 18 | 18 | 19 | 16 | 17 | 8 |
| 7 | A | 20 | 24 | 24 | 23 | 23 | 23 | 22 | 22 |
| 8 | A | 15 | 18 | 19 | 17 | 15 | 18 | 21 | 22 |
| 9 | A | 26 | 27 | 27 | 27 | 28 | 28 | 28 | 28 |
| 10 | A | 28 | 30 | 30 | 31 | 31 | 32 | 31 | 33 |
| 11 | A | 19 | 22 | 20 | 20 | 21 | 20 | 19 | 18 |
| 12 | A | 17 | 17 | 16 | 16 | 16 | 16 | 17 | 17 |
| 13 | A | 17 | 18 | 17 | 16 | 15 | 15 | 16 | 15 |
| 14 | A | 17 | 22 | 21 | 22 | 22 | 23 | 23 | 23 |
| 15 | A | 16 | 20 | 19 | 16 | 17 | 15 | 17 | 18 |

Notes: AT =Group A Treatment (MET)

**Table 2b. Raw data for MET procedure group B**

| Subjects | Group | BT Pre | BT 0 min | BT 5 min | BT 10 min | BT 15 min | BT 20 min | BT 25 min | BT 30 min |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 27 | 30 | 26 | 26 | 26 | 27 | 29 | 27 |
| 2 | B | 19 | 22 | 19 | 16 | 16 | 15 | 16 | 18 |
| 3 | B | 27 | 27 | 28 | 24 | 22 | 24 | 20 | 22 |
| 4 | B | 26 | 28 | 27 | 27 | 28 | 28 | 28 | 28 |
| 5 | B | 28 | 31 | 30 | 31 | 31 | 32 | 31 | 32 |
| 6 | B | 15 | 17 | 17 | 16 | 15 | 15 | 16 | 16 |
| 7 | B | 17 | 22 | 21 | 22 | 22 | 23 | 23 | 22 |
| 8 | B | 16 | 19 | 18 | 16 | 17 | 28 | 17 | 16 |
| 9 | B | 26 | 31 | 28 | 26 | 26 | 27 | 29 | 28 |
| 10 | B | 27 | 33 | 31 | 30 | 31 | 31 | 31 | 30 |
| 11 | B | 26 | 32 | 29 | 30 | 29 | 31 | 30 | 31 |
| 12 | B | 16 | 24 | 23 | 20 | 22 | 23 | 24 | 23 |
| 13 | B | 25 | 31 | 27 | 26 | 26 | 27 | 29 | 27 |
| 14 | B | 28 | 33 | 32 | 30 | 31 | 31 | 30 | 30 |
| 15 | B | 17 | 22 | 22 | 22 | 22 | 23 | 23 | 22 |

Notes: BT = Group B Treatment (MET)




**Graph 2. The mean values for hip extension range of motion for the MET interventions for each time intervals is displayed as follows**

While comparing MET intervention with passive stretch (control), there was mean increase of 2.03degree (±5.11) of hip extension was observed (95%CI=0.12 to 3.94; *p*≤0.038). The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graphs 3.

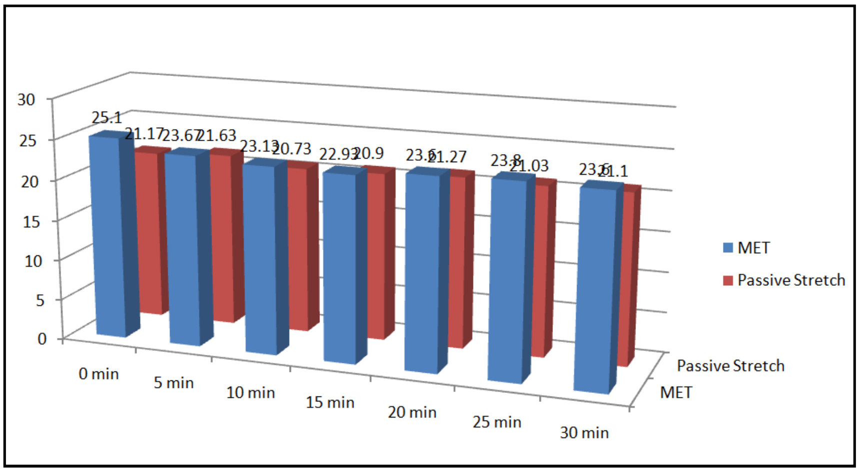
**Ten minutes post intervention**

At 10 min post MET intervention a mean increase of 2.16 degrees (±2.24) of hip extension was observed (95%CI=1.18 to 3.15; *p*≤0.000) This was compared with the passive stretch (control) procedure for which a mean increase of 1.36degrees (±1.90; 95%CI=0.65 to 2.07; *p*≤0.000*)* was measured. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph 1, 2. While comparing MET intervention with passive stretch (control), there was mean increase of 2.40degree (±4.76) of hip extension was observed (95%CI=0.62 to 4.18; *p*≤0.010). The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graphs 3.

**Fifteen minutes post intervention:** At 15 min post MET intervention a mean increase of 1.96 degrees (±2.68) of hip extension was observed (95%CI=0.96 to 2.96; $p \leq 0.000$) This was compared with the passive stretch (control) procedure for which a mean increase of 1.53degrees (±2.66; 95%CI=0.53 to 2.52; $p \leq 0.004$*)* was measured. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph 1, 2. While comparing MET intervention with passive stretch (control), there was mean increase of 2.03degree (±5.01) of hip extension was observed (95%CI=0.16 to 3.90; $p \leq 0.034$). The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graphs 3.

**Thirty minutes post intervention**

At 30 min post MET intervention a mean increase of 2.63degrees (±2.93) of hip extension was observed (95%CI=1.53 to 3.72; $p \leq 0.000$) This was compared with the passive stretch (control) procedure for which a mean increase of 1.73 degrees (±2.85; 95%CI=0.66 to 2.79; $p \leq 0.002$*)* was measured. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph 1,2. While comparing MET intervention with passive stretch (control), there was mean increase of 2.76degree (±5.45) of hip extension was




**Graph 3. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed as follows**

observed (95%CI=0.73 to 4.80 ;$p \leq 0.009$). The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph.

**Twenty minutes post intervention**

At 20 min post MET intervention a mean increase of 2.63 degrees (±3.06) of hip extension was observed (95%CI=1.48 to 3.77; $p \leq 0.000$) This was compared with the passive stretch (control) procedure for which a mean increase of 1.90degrees (±2.13; 95%CI=1.10 to 2.69; $p \leq 0.000$*)* was measured. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph 1, 2. While comparing MET intervention with passive stretch (control), there was mean increase of 2.33degree (±5.28) of hip extension was observed (95%CI=0.36 to 4.30; $p \leq 0.022$). The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graphs 3.

**Twenty five minutes post intervention**

At 25 min post MET intervention a mean increase of 2.83degrees (±3.30) of hip extension was observed (95%CI=1.60 to 4.06; $p \leq 0.000$) This was compared with the passive stretch (control) procedure for which a mean increase of 1.66 degrees (±2.95; 95%CI=0.56 to 2.76; $p \leq 0.004$*)* was measured. The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graph 1, 2. While comparing MET intervention with passive stretch (control), there was mean increase of 2.76degree (±5.45) of hip extension was observed (95%CI=0.73 to 4.80; $p \leq 0.009$). The mean values for hip extension range of motion for both the MET and passive stretch interventions for each time interval are displayed in Graphs 3.

**Reliability of hip extension**

The test-re-test reliability the of hip extension measurement across the 7 day trial interval was assessed by calculating the intra-class correlation coefficient (ICC) of the pre-intervention ROM measurement (ICC=0.66; 95%CI=0.29 to 0.86) which indicated a "high" degree of reliability (Hopkins 2002) [26]and that hip extension ROM is a reasonably stable measurement.

## DISCUSSION

The aim of this study was to evaluate the assessment of a single application of MET compared with passive stretch on hip extension range of motion over a 30 minute period on asymptomatic participants with a restriction in hip extension. The results indicated that MET produced a "significant" increase and that passive stretch doesn't produced "significant" increase on hip extension flexibility immediately following intervention. A "significant" effect was maintained up to thirty minutes following both interventions.

**Changes in Range of motion:** The immediate effect observed in this present study was similar to effects observed by both Stodolny and Mazur (1989), and Milliken (2003). Stodolny and Mazur (1989) described an investigation in which post–isometric relaxation (PIR) was either self performed or applied to the hip flexors in the modified Thomas position as was used in this current study. The PIR stretch was performed in addition to unspecified "kinesio therapy" (a prescribed exercise program), and was compared to a group who performed kinesio therapy alone over a 16 day period. Stodolny and Mazur (1989) reported immediate positive gains in hip extension ROM for the PIR group of 11.9 degrees (±10.5) compared with 2.8 degrees (±7.4) in the non PIR group. Although the effect size was not reported, however, using the data supplied, it was calculated to be "large". The participants in the Stodolny and Mazur (1989) study were all symptomatic with low back pain (LBP) and had all been diagnosed with disc pathology, however, no outcome measures or assessments were made in relation to their pain or functional abilities which would have been useful information in assessing clinically relevant outcomes of the technique.

Milliken's unpublished thesis investigating hip extension ROM following a single application of MET to hip flexor muscles in asymptomatic participants reported an immediate increase of 6.5 degrees following intervention and 2.8 degrees for the control group (Milliken, 2003). These results appear to be consistent with the immediate findings in the present study; however, no standard deviations or effect sizes were reported. Using the raw data supplied in the appendix of the Milliken study, further analysis revealed a "very large" effect of MET (6.5 degrees, ±3.7; 95% CI=4.4 to 8.6; $p<0.01$; $d=2$) and "small" effect in the control (no treatment) group (2.8 degrees; ± 2.5; $p = 0.0001$; $d = 0.55$). Both the Stodolny and Mazur (1989) and the Milliken (2003) studies achieved greater immediate increases of hip extension ROM than in the current study. Reasons for this are most likely to be due to greater restriction of hip extension ROM of the participants of these two studies at baseline than in this current study. Another explanation may relate to methodological differences, namely contraction duration and the duration of the post-isometric stretch phase. However this is a less likely explanation as these factors were consistent between this current study and that of Milliken (2003) and although longer duration times were employed for both these phases in the Stodolny and Mazur (1989)[56] investigation neither contraction duration (Fryer & Ruszkowski, 2004) nor the duration of the post isometric stretch phase (Smith & Fryer, 2008) appear to influence the efficacy of MET.

**Temporal effect of MET**

The reappear to be no other studies investigating the effect of MET, PNF or other related CR stretch techniques on hip extension ROM either with immediate or longer term follow-up. Only two studies were found investigating the effect of CR PNF over time, however, neither investigated hip extension ROM; in these studies the hamstring muscle was targeted and assessment was made measuring knee extension ROM with the hip joint in 90˚of flexion. Spernoga *et al*., (2001) measured the duration of a single application of PNF (using maximal isometric contraction) on the hamstring muscles over a period of 32 minutes and found that a significant increase in active knee extension only lasted 6 minutes. Although this finding may appear to contrast with the present study in which a "small" but significant effect of intervention was still evident at 30 minutes, the reduction in the effect size was evident at the 5 minute interval following the intervention. Trampas *et al*., (2010) measured passive knee extension immediately, and at 10 and 30 minutes following a CR stretch protocol. A "moderate" ($d$=0.6) effect size was maintained at 10 minutes which diminished to a "small" ($d$=0.2) effect size by 30 minutes post application of the CR stretch, findings that are more consistent with the present study. In this present study a "small" but non-significant reduction of hip extension ROM was observed 7 days following both the MET (mean difference - 4.13 degrees, ± 5.454 ; 95% CI = 0.9 to 6.7; $p = 0.001$; $d = 0.59$) and passive stretch (mean difference -1.4degrees (±2.55; 95% CI = 0.5 to 3.40 ; $d = 0.26$; $p$=0.128) procedures. Smith and Fryer (2008) noted a significant ($p$=0.04) increase of 2.49 degrees (±7.19) in active knee extension one week following application of an MET protocol. Differences in the findings between Smith and Fryer (2008) and the present study may be due to differences in the characteristics of the target tissues (hamstrings compared with hip flexors). However, in view of the standard deviation reported in Smith and Fryer's (2008) study, which was nearly 3 times greater than the mean increase reported, the small increase is probably not clinically meaningful. Furthermore, although Smith and Fryer (2008) reported "very high" reliability of repeated measures of active knee extension (ICC=0.99), the authors derived the ICC from two measures within the same session and not across the same interval (7 days) as used for the main experiment. In the present study the ICC was derived across the 7-day interval over which the experiment was conducted.

**Physiological mechanism of MET**

The changes in ROM observed in the present study appear to be consistent with a viscoelastic tissue response within the elastic range where the stretched tissue does not immediately return to its original length (Lederman 2005; Magee *et al*., 2007). Ballantyne *et al*., (2003) suggest that if increases in ROM following MET were due to changes in viscoelastic properties alone, allowing greater muscle extensibility, this would be achieved using a constant torque or force of stretch. In this current study, the passive hip extension ROM measured pre and post interventions were "assisted" by gravity, a constant force. Therefore the immediate increases in ROM measured for the MET stretch compared with the passive stretch protocol were assessed with a constant force of stretch, thus supporting Lederman's (2005) theory that increased gains in ROM for CR stretch techniques may be due to the focus of the stretch being directed on to the stiffer in-series connective tissue elements of the muscle tissue, as well as the more elastic parallel connective tissues primarily targeted during passive stretch. A more favored explanation however, is that an increase in stretch tolerance occurs as a result of CR procedures (Magnusson *et al*., 1996; Ballantyne *et al*., 2003). It is possible that an increase in stretch tolerance may have allowed for greater relaxation of the participants in the modified Thomas test position used for intervention and assessment and thus achieve a greater degree of hip extension.

**Limitations of the study**

The maximum range of hip extension has been reported to be up to 15 degrees of active extension (Magee, 2006), up to 20 degrees for passive extension and 30 degrees with assisted stretch (Kapandji, 2011). Harvey (1998) and Ferber *et al*.,(2010) measured the hip extension ROM of athletes in the modified Thomas test position and found the mean hip extension ROM to be 11.9 degrees (±5.6) and 10.6 degrees (±9.6; 95% CI=9.5 to 11.7) respectively. Although Schache *et al*., in 2000 measured a mean hip ROM of 17.4 degrees (range 7.5˚ to25˚), the mean baseline ROM in this current study was

19.2 degrees (±5.1), which was larger than expected, particularly as the participants tested "positive" for the Thomas test. Two primary explanations are suggested:

Firstly, some of the participants in this present study may have tested falsely 'positive' to the Thomas test. Kendall *et al*.,(2005) suggests a 'false-positive' result for the Thomas test may occur if the non-test leg is flexed excessively, flexing the lumbar spine and sacrum, posteriorly rotating the pelvis and lifting the tested limb off the table and therefore giving the appearance of a restriction in hip extension. To increase reliability, Peeler and Anderson (2006) suggest more specific criteria, particularly regarding the amount of flexion of the non tested leg, are required for the Thomas test. Secondly, Harvey (1998) noted that if the contra-lateral hip (non test leg) is not held maximally to the chest, the angle of extension in the test leg appears greater. Although in the present study the non test leg was flexed and held so that the lumbar spine remained flat on the treatment table to prevent lumbar spine extension and an anterior rotation of the pelvis exaggerating hip extension range, the participants were not instructed to hold the leg maximally to their chest. This may have allowed anterior rotation of the pelvis to occur and falsely increasing the recorded range. Although the current study indicated a "significant" effect in mean increase in hip extension ROM of 4.13degrees (95% CI = 3.6 to 6.9) for MET immediately following this intervention, in light of the calculated SEM (3.0 degrees) and the SDD (8.32 degrees) the results of the present study do not represent a convincing positive benefit. The size of the SDD appears to be due to the level of variability of the outcome measure which is reflected in the ICC (0.66) for repeated measures and therefore an improvement in experimental reliability in the repeated measure of hip extension ROM would be desirable. Gabbe *et al*., (2004) also reported similar ICC scores (0.63 - 0.75; 95%CI =0.20 to 0.95) for test-retest reliability, however, Harvey (1998) reported 'extremely high' reliability (ICC= 0.91-0.94) although both these studies instructed their participants to hold their contra lateral leg in maximal flexion while measuring hip extension ROM.

There are two primary sources of measurement variability or error, namely technical error in measurement, and biological variability. Biological factors leading to a variation in ROM include the participants' recent physical activity, lumbopelvic stabilization and muscle temperature. These factors were controlled for by requesting the participants refrain from vigorous exercise and stretching activities prior to and between sessions, a warm-up procedure prior to the intervention, and conducting the trial at the same time of day (7 days apart) in a warm room for both intervention sessions for each participant.

Possible sources of technical error for the experimental trial include; positioning of the markers on the participant's skin; the position of the participant's sacrum at the edge of the table; the degree of flexion in which the non-test hip was held; and the operators ability to accurately extract data. Reliability of data extraction was "almost perfect" (ICC=0.99; 95% CI=0.99to 1.0). The most likely source of technical error is a variation in the range of flexion in which the participant held their non test hip which would have affected the consistency of the angle measured across all the time intervals as it may have differed each time the participant assumed the test position. A strap (adjustable for each individual) to hold the non-test hip and leg in a constant position that maintains a neutral lumbar spine and pelvis should be considered in future investigations. It is clear that meticulous attention in controlling variables involved in ROM measurement is required when conducting a experimental trial such as this. In randomized controlled experimental designs participants are typically allocated to groups in a random fashion, with the aim of making each group sample representative of the population and minimizing group bias (Hopkins, 2010). Randomised controlled designs are considered to be optimal in investigation of cause and effect relationships (Hicks, 2004; Hopkins, 2010). Random selection, however, does not guarantee equality of characteristics in a population at baseline and non-random allocation aimed at minimizing differences in group means may be a superior method particularly when the effect of a treatment depends on a group characteristic (Scott *et al*., 2002).

A potential limitation of this study is that random allocation was not used; participants were allocated to groups as they were recruited, depending on availability of the practitioner performing the technique, and in order to achieve even group numbers. Pre & post controlled cross over experiments, however, have the smallest errors arising from group mean participant characteristics (Hopkins, 2010) due to groups receiving both intervention and control procedures. In this study no differences were observed between group characteristics and therefore it is less likely a lack of randomisation impacted on the outcome in anyway. A suitably powered study enables the detection of a real difference and that the findings are not merely a result of chance. More specifically, adequate power is required to avoid the statistical error of concluding there is no difference when a difference may actually exist (Thomas *et al*., 2005). Therefore, there is insufficient evidence to conclusively determine that no difference exits between the effect of MET and passive stretch at 30 minutes.

**External validity**

The technique protocol used in this study was consistent with how MET may be applied in a clinical situation and the technical approach to delivery was intended to be similar to how the technique may be delivered in clinical practice (e.g. no constraints). The participants in this study, males between the age of 18 and 23 years who exhibited a restriction in hip extension ROM, were asymptomatic.

**Recommendations for further study**

Prolonged effects of treatment are clinically desirable, therefore studies investigating how best to achieve longer outcomes of treatment term would be of clinical interest. Investigations into the prolonged effect of repeated applications of MET (e.g. multiple sessions over 4 weeks), are recommended as well as the efficacy of "self applied" (Chaitow, 2006) versus practitioner applied MET, aimed to improve hip extension ROM is also advisable if repeated applications are required for long term changes to occur. Comparison of MET with other manual techniques designed to improve biomechanical function and joint movement, as well as the use of functional and pain related assessments on symptomatic subjects pre and post application of MET would also contribute to an informed approach to the use of MET within clinical practice. How to best obtain immediate and lasting improvements in joint range of motion are desirable.

## Conclusion

The findings of this study indicate a "more significant" effect for increasing hip extension range of motion immediately following a single application of muscle energy technique to improve hip extension, and a "less significant" effect following passive stretch. Five minutes following the intervention the observed increase was "significant" for both groups and was maintained at 30 minutes. There was no evidence that an effect of either intervention was maintained following the 7-day interval. Therefore both MET and passive stretch appears to have a significant effect in increasing hip extension ROM for duration of up to 30 minutes.

## REFERENCES


Alter, M.J. 1996. Science of Flexibility (3rd ed.). United states of America: Human Kinetics Publishers Inc; p.32-35, 54-55.

Andrew, D. Vigotsky, Gregory J. Lehman, Chris Beardsley, 2016. Bret Contreras, Bryan Chung and Erin H. Feser The Modified Thomas test is not a valid measure of hip extension until pelvic tilt is controlled. *Peer J.,* 4:e2325; DOI 10.7717

Ballantyne, F., Fryer, G., McLaughlin, P. 2003. The effect of muscle energy technique on hamstring extensibility: the mechanism of altered flexibility. *Journal of Osteopathic Medicine,* 6(20):59-63

Benjamin, K., Robroy, L. 2012. Martin, The Hip Complex: Joint Structure And Function 5th ed. p.356.

Burns, D.K., Wells, M.R. 2006. Gross Range of Motion in the Cervical Spine: The Effects of Osteopathic Muscle Energy Technique in Asymptomatic Subjects. *The Journal of American Osteopathic Association,* 106(3): 137-142.

Byrd, J.W.T. 2005. Snapping hip. Operative Techniques in Sports Medicine, 13(1): 46-54. Chaitow L. Muscle Energy Techniques. 3rd edition. London: Churchill Livingstone; 2006.p. 1, 152.153.

Christopher M. Norris, Exercise Therapy: Managing Sport Injuries 4th ed. 2011, p.91-93.

Christopher M. Norris, The Hip: Managing Sport Injuries 4th ed. 2011, p.143- 163.

Cristopoliski, F., Barela, J. A., Leite, N., Fowler, N.E., Rodacki, A.L.F. 2009. Stretching exercise program improves gait in the elderly. *Gerontology,* 55:614-620.

Derrick, T.R., Hamill, J., Caldwell, G.E. 1998. Energy absorption of impacts during running at various stride lengths. *Medicine and Science in Sports and Exercise* 30:128–135.

Edwards, W. B., Taylor, D., Rudolphi, T. J., Gillette, J.C., Derrick, T.R. 2009. Effects of stride length and running mileage on a probabilistic stress fracture model. *MedicineandScienceinSportsandExercis*e41:21772184DOI 10.1249/MSS.0b013e3181a984c4.

Eland, D.C., Singleton, T.N., Conaster, R.R., Howell, J.N., Pheley, A.M., Karlene, M.M., Robinson, J.M. 2002. The "iliacustest": New information for the evaluation of hip extension dysfunction. *Journal of the American Osteopathic Association*, 102(3): 130- 142.

Ferber, R., Kendall, K.D., McElroy, L. 2010. Normative and critical criteria for iliotibial band and iliopsoas muscle flexibility. *Journal of Athletic Training*, 45(4): 344-348.

Flanum, M.E., Keene, J.S., Blankenbaker, D.G., De Smet, A.A. 2007. Arthroscopic treatment of the painful "internal"snapping hip. American Journal of Sports Medicine., 35(5): 770.779

Franz, J.R., Paylo, K.W., Dicharry, J., Riley, P.O., Kerrigan, D.C. 2009. 2008. Changes in the coordination of hip and pelvis kinematics with mode of locomotion. Gait and Posture29:494–498 DOI 10.1016/j. gaitpost, 11.011

Fryer, G., Ruszkowski, W. 2004. The influence of contraction duration in muscle energy technique applied to the atlanto, axial joint. *Journal of Osteopathic Medicine*, 7(2): 79-84.

Gabbe, B.J., Bennell, K.L., Finch, C.F. 2006. Why are older Australian football players at greater risk of hamstring injury? *Journal of Science and Medicine in Sport* 9:327–333DOI 10.1016/j.jsams.2006.01.004.

Gabbe, B.J., Bennell, K.L., Wajswelner, H., Finch, C.F. 2004. Reliability of common lower extremity musculoskeletal screening tests. Physical Therapy in Sport 2004; 5:90-97.

Goodridge, J.P. 1997. Muscle Energy Procedures. In: Ward RC. (Ed) Foundations of Osteopathic Medicine. Philadelphia: Lippincott Williams & Wilkins; p. 692.

Greenman, P.E. 1989. Principles of manual medicines, Baltimore: Williams and Wilkins.

Greenman, P.E. Principles of manual medicine (2nd ed.). Maryland: Williams & Wilkins; 1996. p. 93, 96.

Harvey, D. 1998. Assessment of the flexibility of elite athletes using the modified Thomas test. British Journal of Sports Medicine, 32: 68-70.

Hicks, C. 2004. Research Methods for Clinical Therapists (4th ed.). Edenburgh: Churchill Livingston., p. 93.

Hoffer, M.M. 1986. Management of the hip in cerebral palsy. *The Journal of Bone and Joint surgery* 1986; 68:629-631.

Hopkins, W.G. 1997 A New View of Statistics: Generalizing to a population: Repeated measures Model. Retrieved from: http://www.sportsci.org/resource/stats/index.html (last accessed 15 March 2011)


*******