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Close kinematic strengthening of gluteus maximus is more effective than rectus femoris in improving dynamic and static balance in asymptomatic population

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Abstract

Question: Is there any significant difference in strengthening of gluteus maximus and rectus femoris on dynamic and static balance? **Design:** Experimental design comparative in nature. **Participants:** Thirty asymptomatic participants (mean age 21.39±1.99) of Sardar Bhagwan Singh Institute, Dehradun, India, with normal body mass index and right dominant lower extremity, were divided randomly in three groups of 10 participants in each. **Intervention:** Two week (5 sessions a week) close kinematic chain strengthening program of gluteus maximus (group c) and rectus femoris (group b) where gluteus medius (group a) is controlled. **Outcome measures:** Single limb stance time, star excursion balance test (sebt) in eight (Anterior, Anteriomedial, Medial, Posteriomedial, Posterior, Posteriolateral, Lateral, Anteriolateral) directions. whereas in sebt improvement for group c was greater (8.26±4.30, 7.13±4.48, 7.25±4.0, 10.62±5.31, 6.9±6.05, 8.38±3.11, 6.38±3.54) compare to group b (4.63±4.47, 6.63±3.81, 5.63±3.81, 4.5±1.85, 10.5±5.78, 7.5±5.4, 5.13±4.36, 4.5±3.02) and group a (2.25±3.57, 2±3.02, 2±3.30, 1.75±5.36, 2±5.04, 3.25±5.25, 2.62±5.85, 3.25±2.66) in all eight (Anterior, Anteriomedial, Medial, Posteriomedial, Posterior, Posteriolateral, Lateral, Anteriolateral) directions. **Conclusion:** This study provides idea that the strengthening program of rectus femoris and gluteus maximus has the effect on static as well as dynamic balance as the improvement of single limb balance and SEBT was documented in both the groups. Data analysis revealed that improvement was more in group in comparison to group B and group A (C>B>A) which stated that gluteus maximus strengthening has better effect on static (single limb stance) and dynamic (SEBT) balance in comparison to rectus femoris strengthening.

Introduction

Balance is a generic term to describe a dynamic process through which the body's position is maintained in equilibrium (Anne D. Kloos, 2004). balance has two basic component static balance and dynamic balance; functional task requires static balance to maintain a stable antigravity position while at rest such as during sitting, dynamic balance to stabilize the body when support surface is moving, thus Basic activities of daily living (like walking sitting etc.), require the background of a normal balance (Frances E Huxham, 2001).Maintenance of balance is complex task which involves various system of human body, these includes nervous system, contextual system, somatosensory system, visual, auditory, vestibular and musculoskeletal system, Interplay among these systems is required to maintain balance (Anne D. Kloos, 2004).

Musculoskeletal system is an important factor in the balance control as balance control requires a complex and significant change in muscle length and muscle tone (Anne D. Kloos, 2004), normal balance requires control of acceleration forces to maintain equilibrium, which is done by musculoskeletal system (Frances E Huxham, 2001).balance control requires an adaptability to counter act any changes in body's equilibrium (Frances E Huxham, 2001).muscular contribution is an important factor for the maintenance of balance during stance phase(static balance)

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and swing phase (dynamic balance) (Woollacott Mh, Tang P-I, 1997).

Musculature surrounding hip and knee joints plays an important role in maintaining balance as they work to counter act the external force acting up on the body, specifically Hip and knee extensors (gluteus maximus and rectus femoris) are the major group which works to control balance (Allison S. Arnolda, 2005), these two are the major muscles group, responsible for hip strategy of maintaining balance (L. M. Nashner, 1986),which plays an important role in maintaining balance when supporting surface is short in relation to foot length[6],during single limb stance anterior and posterior body sway are the main reason of misbalance, by counteracting the anterior and posterior body sway hip strategy helps in maintaining balance in Saggital plane around hip and knee joint (Anne D. Kloos, 2004).during posterior body sway gluteus maximus activation takes place to maintain balance, whereas during anterior body sway rectus femoris activation maintains the balance (L. M. Nashner, 1986).

Research Question

Is the gluteus maximus strengthening has better effect then the rectus femoris strengthening, on the improvement of static and dynamic balance on asymptomatic population controlled with gluteus medius strengthening?

Method

Design

Experimental design- comparative in nature.

Participants, Therapists, Centers

Inclusion Criteria

1). Students of SBSPGI of age 18-25 yrs.

2). Normal body mass index (18.5-24.9) (P.Halun, 2006).

3). Normal range of motion around hip and knee joint.

4). Muscle strength >3 around hip and knee joint.

5). Normal pattern of gait (Sandra J Olney, 2006).

Exclusion Criteria

1). History of any kind of systemic disease for which subject is on medication or any kind of other therapy. 2). Past or present history of hip, knee, ankle joint dysfunction. 3). History or complaint of any kind of back pain with duration more than six weeks (Suraj Kumar, 2010). 4). History of spinal injury or disorder. 5). Any kind of foot deformity (pes cavus or pes planus) (Jay Hertel, 2002). 6). Known history of hypertension, or hypotension.

Intervention

Hip Hiking (Group A)

Position of the subject was with one leg (testing extremity) on a 2-4 inch block or step raise, another leg hanging out of the block. Body was straight and both the hand on pelvis or on the shoulder of the therapist for support (initially) (Carylon Kisner, 2006). Subject asked to alternatively lower and elevate the pelvis on the side of unsupported leg. (Fig 5)

Single Leg Partial Squatting (Group B)

Subject standing on one leg (targeting extremity), both hand across the chest or on the chair for support (initially).Subject asked to flex his knee 30-40 degree then extend alternatively. (Fig 6)

Unilateral Bridging (Group C)

Subjects were positioned in hook lying position with one lower extremity (hip flexed abducted, externally rotated and knee flexed to form figure of four position) rested on the other knee (targeted extremity). Subjects were asked to press the upper back and foot in to the mat, elevate the pelvis, and extend the hips. (Fig 7)

Outcome Measures

Star Excursion Balance Test

The SEBTs are functional tests that incorporate a single-leg stance on one leg with maximum reach of the opposite leg. The SEBTs are performed with the subject standing at the center of a grid placed on the floor, with 8 lines extending at 45° increments from the center of the grid (Allison S. Arnolda, 2005). The 8 lines positioned on the grid are labeled according to the direction of excursion relative to the stance leg: anterolateral (AL), anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), and lateral (L) (Rasool, K. George, 2009). The grid was constructed in an athletic training facility using a protractor and 3-in (7.62-cm)-wide adhesive tape and was enclosed in a 182.9-cm by 182.9-cm square on the hard tile floor.

A verbal and visual demonstration of the testing procedure was given to each subject by the examiner (L.C.O.). Each subject performed 6 practice trials in each of the 8 directions for each leg to become familiar with the task (Rasool, K. George, 2009) after the practice trials, subjects rode a stationary bike for 5 minutes at a self-selected pace and then stretched the quadriceps, hamstrings, and triceps surae muscle groups before testing. To perform the SEBTs, the subject maintained a single-leg stance while reaching with the contralateral leg (reach leg) as far as possible along the appropriate vector. The subject lightly touched the furthest point possible on the line with the most distal part of the reach foot. The subject was instructed to touch the furthest point on the line with the reach foot as lightly as possible in order to ensure that stability was achieved through adequate neuromuscular control of the stance leg (Allison S. Arnolda, 2005). The subject then returned to a bilateral stance while maintaining equilibrium. The examiner manually measured the distance from the center of the grid to the touch point with a tape measure in centimeters. Measurements were taken after each reach by the same examiner.

Three reaches in each direction were recorded. Subjects were given 15 seconds of rest between reaches. The average of the 3 reaches for each leg in each of the 8 directions was calculated. Reach leg (right, left), order of excursions performed (clockwise, counterclockwise), and direction of the first excursion (A, M, L, P) were counterbalanced to control for any learning or order effect (Allison S. Arnolda, 2005), All trials were then performed in sequential order in either the counterclockwise or clockwise directions.

Trials were discarded and repeated if the subject (1) did not touch the line with the reach foot while maintaining weight bearing on the stance leg, (2) lifted the stance foot from the center grid, (3) lost balance at any point in the trial, or (4) did not maintain start and return positions for one full second. If a subject was judged by the examiner to have touched down with the reach foot in a manner that caused the reach leg to considerably support the body, the trial was discarded and repeated. In other words, if the reach foot was used to widen the base of support, the trial was not recorded. The base of support was the stance foot for the entire trial with the fraction of a second in which the reach foot very lightly touched the ground. It was atypical for subjects to have discarded trials, and none reported fatigue during or after the testing session.

Single Leg Stance

Single limb stance is a tool to assess the balance variables (static balance) (Eva Ageberg, 2003).single limb stance time is one of the four tasks to assess the balance and gait (Richerd W Bohanon, 1993). Single limb stance denotes the stance phase of gait as well as static balance (Frances E Huxham, 2001). Criteria to assess single limb stance; instruction for the subject according to the criteria were, "Stand on one leg, place your arms across your chest with your hands touching your shoulders and do not let your legs touch each other. Look straight ahead with your eyes open and focus on an object about 3 feet in front of you". Instructions to stop the criteria were, if the legs touched each other, the feet moved on the floor, their foot touches down, or the arms moved from their start position. Subjects were barefooted and eyes were opened (O'loughllin J, 1993). procedure was performed for 3 times and mean were noted down.

Data analysis

One way annova (analysis of variance) test has been performed to compare the improvement of single limb stance time and SEBT in 8 directions in all the 3 groups.

Post hoc scheffe's test has been performed to find out which group has the more effect in improvement of single limb stance and SEBT.

The significance (probability) level has been selected as 0.05.

Results

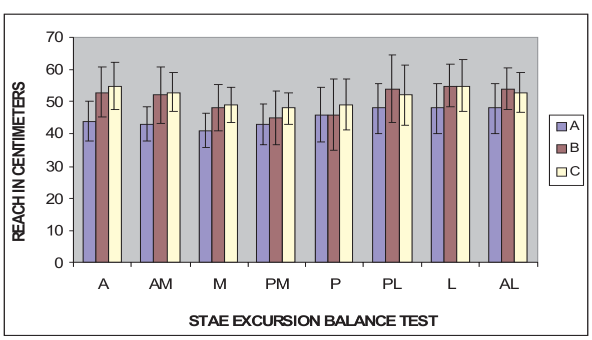
In this study, 30 subjects (mean age 21.36 ± 1.29) were selected and were divided into three groups A (Mean age 21±1.63), B (Mean age 21.4±0.8) and C (Mean age 21.7±1.33) with 10 subjects in each group.

Mean values of all 8 directions A, AM, M, P, PM, P, PL, L, AL, (Graph:1) and single limb stance at week 0 (Graph:3) were, 44.6±6.20, 43.6±5.35, 41±4.69, 43.1±6.26, 46.3±8.6, 48.1±7.75, 48.3±6.7, 48±5.8 and 34.47±17.85 respectively for group A, 56.3±7.70, 52.1±8.9, 48.2±7.09, 45.3±8.27, 46±10.91, 54.6±10.52, 55.7±6.76, 54.6±6.38, and 34.27±13.85 respectively for group B, 55.9±7.21, 53.1±5..87, 49.8.±75.4, 48.2±5.01, 49.5±7.98, 52.5±9.57, 55.4±8.07, 53.4±6.18 and 54.17±12.91 respectively for group C (Table:1). One way anova were applied to compare the difference, It shown the significant difference in single limb stance and anterior, anterio-medial, medial, components of SEBT.

As the result was significant for baseline, data were and analyzed with mean difference of week 2and week0 (table:2), (graph:2), (Graph 4). The mean values were, 2.25±3.57, 2±3.02, 2±3.30, 1.75±5.36, 2±5.04, 3.25±5.25, 2.62±5.85, 3.25±2.66 and 2.82±11.34 respectively for group A, 4.63±4.47, 6.63±3.81, 5.63±3.81, 4.5±1.85, 10.5±5.78, 7.5±5.4, 5.13±4.36, 4.5±3.02 and 7.37±8.02 respectively for group B, 8.26±4.30, 7.13±4.48, 7.25±4.0, 10.62±5.31, 6.9±6.05, 8.38±3.11, 6.38±3.54 and 14.72±7.32 respectively for group C. One way anova were applied to compare the mean difference value. Result was statically significant for single limb stance and A, AM, M, PM, P and L component of star excursion balance test.

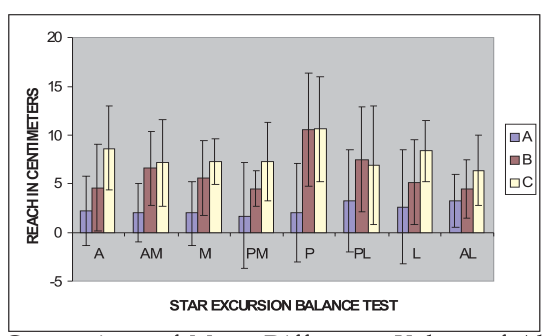
Post hoc scheffe's test was performed on the significant values of one way annova on single limb stance time and SEBT (Table 3). It shows the significant value for A-C group in single limb stance, anterior, anterio-medial, medial, posterior-medial, posterior, lateral component of SEBT. It also shows the significant value for A-B group in posterior component of SEBT.

Graph 1



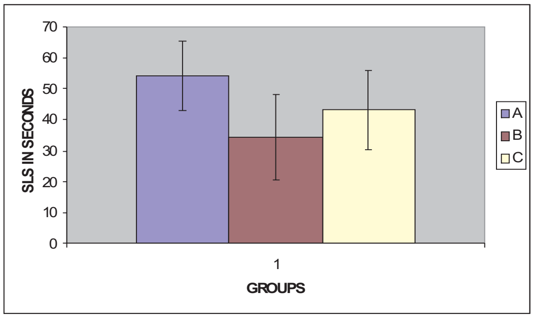
Star Excursion Balance Test (Mean ±S.D) at week 0

Graph 2



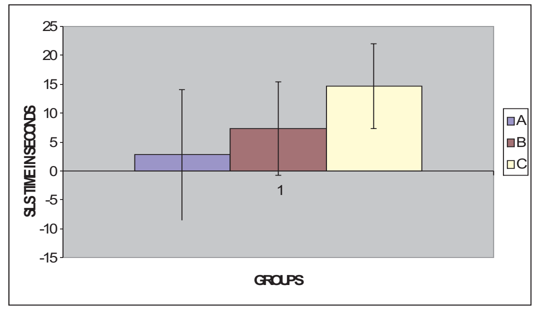
Comparison of Mean Difference Values of All 8 Directions of SEBT (Week2-0)

Graph 3



Single Limb Stance (Mean ±S.D) At Week 0

Graph 4



Comparison of Mean Difference Values of Single Limb Stance Time (Week2-0)

Table 1. Comparison of Mean Values of All 8 Directions of SEBT and Single Limb Stance Time- One Way Annova (Week 0)

GROUPS	A	AM	M	PM	P	PL	L	AL	SLST
GROUP A	44.6	43.6	41.0	43.1	46.3	48.1	48.3	48.0	34.17
	±6.20	±5.35	±5.35	±6.26	±8.6	±7.75	±7.75	±7.75	±11.34
GROUP B	53.3	52.1	48.2	45.3	46.0	54.6	55.7	54.6	34.27
	±7.70	±8.9	±7.09	±8.27	±10.91	±10.52	±6.76	±6.38	±13.85
GROUP C	55.9	53.1	49.8	48.2	49.5	52.5	55.4	53.4	54.17
	±7.21	±5.87	±5.47	±5.01	±7.98	±9.57	±8.07	±6.18	±12.91
F VALUE	8.6	5.7	6.40	1.47	0.4	1.25	3.35	3.26	5.8
SIGNIFICANCE	S	S	S	NS	NS	NS	NS	NS	S

Table 2. Comparison of Mean Difference Values of All 8 Directions of SEBT and Single Limb Stance Time- One Way Annova (Week 2-Week 0)

GROUPS	A	AM	M	PM	P	PL	L	AL	SLST
GROUP A	2.25	2	2	1.75	2	3.25	2.62	3.25	2.82
	±3.57	±3.02	±3.30	±5.36	±5.04	±5.25	±5.85	±2.66	±11.34
GROUP B	4.63	6.63	5.63	4.5	10.5	7.5	5.13	4.5	7.37
	±4.47	±3.81	±3.81	±1.85	±5.78	±5.4	±4.36	±3.02	±8.02
GROUP C	8.62	7.13	7.25	7.25	10.62	6.9	8.38	6.38	14.72
	±4.30	±4.48	±2.43	±4.00	±5.31	±6.05	±3.11	±3.54	±7.32
F VALUE	4.9	4.6	5.5	3.8	6.5	0.3	5.7	2.06	3.5
SIGNIFICANCE	S	S	S	S	S	NS	S	NS	S

Table 3. Post Hoc Scheffe's Test on the Significant Values of One Way Annova on SEBT and Single limb stance time (Week 2-Week 0)

GROUPS	VALUES	A	AM	M	PM	P	L	SLST
A VS B	P	1.32	6.26	5.29	1.99	27.79	2.17	1.004
	SIGNIFICANCE	NS	NS	NS	NS	S	NS	NS
B VS C	P	3.76	0.07	1.00	1.90	0.01	3.56	2.63
	SIGNIFICANCE	NS	NS	NS	NS	NS	NS	NS
A VS C	P	9.48	7.54	10.56	7.6	28.98	11.04	6.9
	SIGNIFICANCE	S	S	S	S	S	S	S

S: Significant (p>0.05)
NS: Non significant (p<0.05)
The significance (probability) level has been selected as 0.05.

Discussion

Data analysis revealed that the improvement of balance is greater in the group which undergone the strengthening of gluteus maximus (c) than the other group. As discussed earlier that hip strategy is an important factor in maintaining balance because it counteracts the anterior and posterior body sway (Vleeming A, 1989), impairment in hip strategy can lead to an impaired balance. Gluteus maximus strengthening was more effective because, Hip extensors are the major muscles which counteract the posterior body sway thus help in maintaining balance. Among the hip extensors gluteus maximus is the most efficient muscle due its muscle properties (large cross sectional area, angle of penetration, moment arm) (Sandra J. Shultz, 2001). Gluteus maximus is the largest muscle of the human body and it has a important role in walking.[39] During normal walking gluteus maximus has a role of providing stabilization to the sacro iliac joint and it also has an important role in the rehabilitation which is been proved in previous literatures by Judy Wilson et al, 2005. G. Nemeth et al, 2009 sated that in the anatomical position of hip joint the moment arm of gluteus maximus to the bilateral motion axis was 79 mm, which was greater than any other muscle surround hip joint (F Fryssebech, 2009), thus it has greater influence in maintaining hip joint position in neutral. Gluteus maximus is a part of core musculature, weakness of which can lead to impaired hip strategy adding to this Nicola W Mok et al, 2004, stated that efficacy of hip strategy reduced in people with low back ache and also added that the main reason behind low back ache is the weekness of core musculature (Papadopoulus S Emmanual, 1987), which indicates a greater influence of gluteus maximus on hip strategy in comparison to rectus femoris. It has greater role in controlling single limb stance (static balance) in compare to rectus femoris which is supported by Allison.s.Arnolda et al, 2004 who stated that during single limb stance, per unit force, gluteus maximus has the more potential than the quadriceps muscle group). During the process of rehabilitation following an injury, recovery of gluteus maximus is faster than other muscle to control hip extension which is also been supported previous literature by Gerogery. J. Leheman et al, 2006.

Major function of gluteus maximus as during running, is to control flexion of the trunk on the stance-side and to decelerate the swing leg; contractions of the stance-side gluteus maximus may also help to control flexion of the hip and to extend the thigh (Daniel. E. Lieberman et al, 2006). Along being an extensor gluteus maximus is also a weak abductor of hip thus it also helps to maintain frontal plane balance of hip joint, (Signe Brunnstrom 1983), but rectus femoris has contribution only in Saggital plane maintenance of balance thus gluteus maximus has more influence on balance. Gluteus maximus also works as a dynamic stabilizer as it is thought to cause tightening of hip joint ligaments thereby reducing mobility, suggested by Vleeming et al, 1989.

Contraction of hip extensors significantly reduces the sacral mobility and thus produces the stability to the trunk and as well as the hip joint (J.G. Wilson, Judy Wilson, Emma Ferris, 2005). Gluteus maximus contributes most significantly to support the lower limb via the vertical ground reaction force during the early stance phase from foot flat to just after contralateral toe off that how it contributes an effective functioning to the normal cycle of gait pattern (Anderson et al, 2003).

Future research

1). A larger sample size can be taken for the study.

2). Study can be carried out on symptomatic population (stroke rehabilitation, post immobilization etc.

3). Study can be carried out on specific population like athletes.

4). Specific work group can be taken for the study eg. Desk job population, as they are prone to develop low back ache and are prone to impairment in hip strategy.

5). Old age group can be taken for the study as balance is an important factor of injurious falls in older people.

6). More objective method can be use to assess the static balance.

7). Study can be carried out with larger duration of 6-8 week as hypertrophic changes can be seen after 6 weeks of strengthening.

Relevance to clinical practice

Balance is an important factor of injurious falls. As health professionals; physiotherapists have a specific interest in recognizing and treating balance problems. People with balance difficulties constitute a large proportion of all neurological and musculoskeletal workloads. To be effective, physiotherapists therefore need ways to assess patients, measure the outcome of treatment and predict which people, particularly amongst the older population, are at risk of falling. However, selecting an appropriate regimen for the improvement of balance among individuals with musculoskeletal deficit is difficult, as there are many regimens available to treat the impaired balance. In this study it has been proved that the gluteus maximus strengthening regimen has the greater effect on improving static and dynamic balance than the rectus femoris strengthening regimen, and the reason is the physiological properties of the gluteus maximus. Through this regimen emphasis on both static balance as well as on dynamic balance can be given and it can be applied as a treatment protocol among the patient with impaired balance due to musculoskeletal reasons, as well as on the asymptomatic population.

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