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EFFECT OF FOOT ASYMMETRY ON POSTURAL STABILITY BEFORE AND AFTER FATIGUE.

Physiotherapy

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ABSTRACT

Background & Purpose - Numerous studies found that static and dynamic balance to be adversely affected by changes in peripheral input secondary to joint injury and changes in stability of the surface on which one is standing but far less attention has been focused on whether more subtle alterations in the surface, stability or peripheral input of the foot may also affect balance. Furthermore the detrimental effect of fatigue on static and dynamic postural control have been studied in chronic ankle instability patients but effect of different foot types and lower extremity fatigue on static and dynamic postural control has yet to be studied . Therefore the purpose of this study was to understand the potential influence of anatomical alignment (foot asymmetry) and fatigue on measures of postural stability (static and dynamic balance) before and after fatigue of lower extremity.

Methodology - 30 female subjects of mean age 20.8±2.05 years were included as per inclusion and exclusion criteria. Further they were divided into three groups depending on the scores of Foot Posture Index (FPI-6) i.e., Group A – Pronated Foot (n=10; mean age = 21.2±1.87 years); Group B- Normal Foot (n=10; mean age = 21.1±2.60 years) and Group C- Supinated Foot (n=10; mean age = 20.1±1.59years). Static and Dynamic Postural Stability was assessed in standing position using Balance Error Scoring System (BESS) and Star Excursion Balance Test (SEBT) respectively before and after inducing fatigue. Lower limb fatigue was induced through lunging task and it was quantified through Borg's 15- Point Scale (RPE score-15).

Results - One – way Analysis of Variance has been done to pre-fatigue and post-fatigue mean values of Static Balance (double limb, single limb and tandem stance on firm and foam surfaces) and of Dynamic Balance for right and left foot in 8 different directions (anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral) between Groups A, B &C. No significant difference (p>0.05) was there in static postural stability and reach distance in different foot types in 8 directions in three different foot types before and after fatigue.

Conclusion - This study showed that there was no change in postural stability (static and dynamic) because of foot asymmetry before and after lower limb fatigue when three foot types are compared.

KEYWORDS

Foot Asymmetry, Postural Stability, Fatigue

INTRODUCTION

Balance is the ability to maintain equilibrium or the ability to maintain the center of gravity over the base of support. It requires the ability to maintain a position to stabilize during voluntary activities and to react to external perturbations[1]. Balance in closed kinetic chain relies on integrated feedback and movement strategies among hip, knee and ankle and can be disrupted by diminished afferent feedback or deficiencies in strength and mechanical stability of any joint or structure along lower extremity kinetic chain[2]. Aspects of neuromuscular control may be quantified through measures of postural control; classified as either static i.e.; attempting to maintain a stable base of support with minimal movement or dynamic i.e., attempting to maintain a stable base of support while completing the prescribed movement[3]. Standing weight bearing assessments are more functional and have more clinical relevance when evaluating proprioception in relation to fall, chronic ankle sprains; as they involve all of the cutaneous, articular and muscular proprioceptors that act in concert during normal everyday activity[4]. Freeman and associates suggested the use of Rhomberg's test to examine decrease in proprioception of ankle and to evaluate functional instability[5].

Weight bearing force is a significant factor in the structure and function of the feet, which are the foundations of the human posture[6]. The foot serves to support and move the body and to absorb ground reaction forces during locomotion. The integrity of its many functions depends largely on the plantar vault, formed by the longitudinal medial and transverse arches[7]. Important role is played by cutaneous foot sole sensors and foot muscle proprioceptors which monitor the amplitude and direction of contact forces exerted by the body onto the ground. Experiments which support these conclusions have shown that replacing a firm surface by foam surface or cooling the foot sole results in postural instability.[8]

The implications of hypermobile and hypomobile foot and associated neuromuscular changes on peripheral input and balance have received little attention to date.[9] For healthy adults, the preferred sensory input for balance control is somatosensory information from feet in contact with support surface.[9,10] Excessively supinated or pronated foot posture may influence somatosensory input via changes in joint mobility and surface contact area and through changes in muscular strategies to maintain a stable base of support.[11] Poor foot position sense hinder accommodation between plantar surface of foot and support surface, thus requiring postural adjustments more proximally to maintain upright posture and balance.[9] Disruptions to one joint may create altered neural activity and compensatory muscle recruitment at other joint complexes, resulting in disrupted movement pattern and ultimately altering joint stability.[3] Postural deficits secondary to excessive pronation or supination would be magnified in static stance with greater challenge to support surface via loss of visual feedback i.e., eyes closed, relying more on somatosensory input, which still has not been explored.[9]

Fatigue may impair the proprioceptive and kinesthetic properties of the joints. It increases threshold of muscle spindle discharge, which disrupts afferent feedback, subsequently altering joint awareness. The detrimental effect of fatigue on static postural control has been explored, but effects on measures of dynamic postural control are unknown.[3] Although joint abnormalities, such as chronic ankle instability have often been assessed relative to static and dynamic balance; whether structural foot alignment alone may represent foot abnormality that could alter proprioception and postural control has yet to be determined.[9] Therefore the purpose of the study was to determine whether asymmetry in foot posture affects postural stability before and after fatigue.

METHODOLOGY:

The cross-sectional study was conducted in Research Laboratory of Department of Physiotherapy; Balawala, Dehradun. 30 female subjects of mean age 20.8 ± 2.05 years were included from Mata Gujri Girl's Hostel, Balawala, Dehradun as per inclusion and exclusion criteria (History of injury to either ankle, knee and hip joints; cerebral concussion; vestibular disorders, lower extremity injuries for 3 months before testing; any ear infection or upper respiratory tract infection at time of study; Prior balance training). Ethical committee approval was taken and all of them signed a consent form after procedure was explained to them in detail. They were divided in 3 groups; Group A (Pronated foot), Group B (Normal foot) and Group C (Supinated foot) based on Foot Posture Index scores (FPI-6) [14]. All the three groups were assessed in standing position for Static Balance using Balance Error Scoring System (BESS) [13] in which all subjects stood in 3 different stances i.e; double limb stance, single limb stance and tandem stance on two different surfaces with eyes closed for 20 seconds in each stance. Six errors i.e; hands lifted of the iliac crest; opening eyes; step, stumble, or fall; moving hip into more than 30 degrees of flexion or greater than 6 inches (15.24 cm) off the ground, lifting forefoot or heel and remaining out of test position for more than 5 seconds were looked for and each error was scored 1 point. At the end of 20 seconds total numbers of errors were counted. Dynamic Balance was checked using Star Excursion Balance Test (SEBT) [9,12] for each leg with foot being tested placed in center of grid and other foot was used to excurse in 8 different directions without losing balance. Lower Limb fatigue was induced using lunging task with test limb forward. Subjects lunged forward the distance equal to the individual leg length that had been measured at the beginning of the session. A lunge cycle was defined as having the subject reach to the target achieve approximately 90 degree of hip and knee flexion in lunging leg while maintaining an upright trunk and return the reaching leg back to the point of origin. Fatigue was quantified using Borg's Rate of Perceived Exertion (RPE). After fatigue was induced again postural stability was checked using BESS and SEBT.

DATA ANALYSIS & RESULTS:

One – way Analysis of Variance was used to compare pre-fatigue and post-fatigue mean values of Static Balance (double limb, single limb and tandem stance on firm and foam surfaces) and of Dynamic Balance for right and left foot in 8 different directions (anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral) between Groups A, B & C. Significance level has been selected as p< 0.05.

Table 1: Subject information

S. No	GROUPS	No. of Subjects	AGE (years) (Mean ± S.D.)
1	Pronated foot (Group- A)	10	21.2±1.87
2	Normal foot (Group-B)	10	21.1±2.60
3	Supinated foot (Group-C)	10	20.1±1.59

Table 2 - Comparison of mean Balance Error Scoring System on firm surface of post-fatigue between group A, B and C.

Groups	Double Limb Mean (SD)	Single Limb Mean (SD)	Tandem Mean (SD)
A	0.1 (0.32)	8.5 (2.41)	4.2 (1.98)
B	0.0 (0.00)	6.7 (2.16)	5.1 (3.17)
C	0.0 (0.00)	8.5 (2.41)	5.7 (1.76)
F-value	- (NS)	1.98 (NS)	0.95 (NS)

S→Significant (p<0.05) N.S.→Non-Significant (p>0.05)

Table 3 - Comparison of mean Balance Error Scoring System on foam surface of post-fatigue between group A, B and C.

Groups	Double Limb Mean (SD)	Single Limb Mean (SD)	Tandem Mean (SD)
A	0.2 (0.42)	10.6(2.41)	6.1(3.41)
B	0.3 (0.58)	9.7(2.05)	5.8(3.32)
C	0.2 (0.40)	11.0(2.0)	6.7(2.31)
F-value	- (N.S)	-0.92 (N.S)	-4.18(N.S)

S→Significant (p<0.05) N.S.→Non-Significant (p>0.05)

Table 4: Comparison of mean distance reached in 8 directions on Star Excursion Balance Test for right foot pre-fatigue between Group A, B and C.

Groups	ANT Mean (SD)	AM Mean (SD)	M Mean (SD)	PM Mean (SD)	P Mean (SD)	PL Mean (SD)	L Mean (SD)	AL Mean (SD)
A	83.3 (13.7)	86.8 (14.8)	83.4 (18.2)	76.9 (16)	67.8 (17.6)	67.9 (13.8)	61.1 (10.4)	80.8 (11.7)
B	81.9 (16.1)	83.4 (18.4)	77.5 (25.8)	71.1 (20.7)	70.5 (22.3)	71 (15)	64.2 (8.4)	80.7 (13.7)
C	82.5 (12.3)	85.9 (11.8)	82.3 (12.7)	77.7 (11.9)	65.1 (9.5)	65.1 (11.4)	61.4 (9.8)	79.8 (9.9)
F-value	0.18 (NS)	0.69 (NS)	1.32 (NS)	1.11 (NS)	0.23 (NS)	-0.098 (NS)	0.94 (NS)	0.087 (NS)

Table 5 - Comparison of mean distance reached in 8 directions on Star Excursion Balance Test for right foot post-fatigue between group A, B and C.

Groups	ANT Mean (SD)	AM Mean (SD)	M Mean (SD)	PM Mean (SD)	P Mean (SD)	PL Mean (SD)	L Mean (SD)	AL Mean (SD)
A	77.7 (11.7)	83.3 (16.2)	80.1 (14.9)	74.5 (13.3)	58.5 (16)	59.4 (16)	49.8 (14.5)	75.5 (13.1)
B	75.4 (14.1)	82.4 (19.7)	71.3 (26.7)	65.3 (18.9)	62.4 (14.9)	63 (9.5)	56.0 (10.1)	73.3 (10.0)
C	76.9 (7.03)	82.03 (8.3)	80.2 (6.8)	67.7 (8.6)	57.7 (9.1)	59.1 (39.1)	56.7 (10.4)	74 (8.7)
F-value	-0.002 (NS)	0.017 (NS)	0.80 (NS)	1.13 (NS)	0.34 (NS)	0.33 (NS)	1.04 (NS)	0.11 (NS)

S→Significant (p<0.05) N.S.→Non-Significant (p>0.05)

DISCUSSION:

The study was experimental in design, with aim of understanding the effect of foot asymmetries on postural stability before and after fatigue. In most of studies, the method for inclusion of three different foot types was based on navicular drop measures [9,11] which quantified foot posture in only one plane but present study used Foot Posture Index[14] which measured foot posture in all three body planes and provide information on rearfoot, midfoot and forefoot segments. Moreover, instrumented measures of postural control i.e.; force platforms (center of pressure excursion area and velocity) were used in most research settings [9,11] very few researches have used non- instrumented measures i.e.; error scoring systems and star excursion balance test [3,10] to assess static and dynamic postural stability. According to Cote et al in 2005, supinated foot has less sensory information to rely than a rectus and planus foot and in excessive pronation there was flattening of medial arch and hypermobile midfoot place greater demands on neuromuscular system to stabilize the foot and maintain upright stance[9].To understand this relationship it was hypothesized that foot asymmetry has some effect on postural stability (static and dynamic) before and after fatigue of lower extremity.

One way ANOVA were used to do compare 3 different groups i.e., A, B & C for all conditions of Balance Error Scoring System i.e.; double limb stance, single limb stance and tandem stance on firm and foam surface, before and after fatigue. No significant difference (p>0.05) was there in static postural stability in three different foot types before and after fatigue. The results were supported by study done by Hertel et al in 2002, which compared postural control during single leg stance in healthy individuals with cavus, rectus and planus foot type using force platform and found no significant COP excursion velocities among different foot types.[11] Similar study done by Cote et al. [9] in 2005 compared static postural stability in different foot types during single limb stance under eyes open and eyes closed conditions on Chattecx Balance System and found no difference in center of balance or postural sway as a function of foot type.

Similarly, one way ANOVA were used to compare dynamic stability between Groups A, B & C using Star Excursion Balance Test before and after fatigue. The result showed no significant difference (p>0.05) in reach distance in different foot types in 8 directions before and after fatigue. Gribble and Hertel (2003) in their study has examined the role of foot type, height, leg length and range of motion measurements on excursion distances while performing Star Excursion Balance Test and found no statistically significant relations between foot type and ROM measurements and excursion distances which supports our results.[12]

Hence, the result showed that there was no difference in postural stability (static and dynamic) before and after fatigue of lower limb between three different foot types, therefore experimental hypothesis has been rejected and null hypothesis proved true. The reasoning may be well explained by simplified model of distal lower extremity used by Kirby (1989) to describe rotational equilibrium about subtalar joint axis. Medial and lateral deviation of subtalar joint axis causes alteration in lengths of moment arms of extrinsic muscles of foot.[15]In pronated foot type there is medial deviation of subtalar joint axis, leading to increase in pronatory torque from muscular contraction of peroneus brevis and causes subtalar joint pronation motion. There is progressive increase in ground reaction force under medial forefoot and progressive decrease in ground reaction under lateral forefoot. Because of increased ground reaction force under medial metatarsal heads, it tends to cause frontal plane inversion moment on plane of metatarsal head that ultimately is translated into retrograde supination moment on rearfoot by way of midtarsal joint.[15] In supinated foot type there is lateral deviation of subtalar joint axis, leading to increase in supinatory torque from muscular contraction of posterior tibial muscle and causes subtalar joint supination motion. There is progressive increase in ground reaction force under lateral forefoot and progressive decrease in ground reaction under medial forefoot. Because of increased ground reaction force under lateral metatarsal heads, it tends to cause frontal plane eversion moment on plane of metatarsal head that ultimately is translated into retrograde pronation moment on rearfoot by way of midtarsal joint.[15]

Once pronation moment has been exactly counterbalanced by supination moment, the foot will stop pronating and when supination moment has been exactly counterbalanced by pronation moment ,the foot will stop supinating and rotational equilibrium at subtalar joint is maintained.[15] Gray (1969) in his study on normal subjects show marked EMG muscular activity only in soleus muscle to maintain standing position whereas subjects with flatfoot show activity in all muscles tested (soleus, tibialis anterior, tibialis posterior, peroneous longus) to control the subtalar and transverse tarsal joint in order to resist further flattening of arches and pronation of foot. These extrinsic muscles are used primarily to maintain the anterposterior balance of center of mass of body over the weight bearing structures of foot.[18]

Structure of foot may influence leg stiffness i.e.; ability of entire lower extremity to attenuate excessive force generated during stance phase,[16] through mechanical coupling of foot and knee. High arched individuals exhibit decreased pronation throughout stance phase resulting in decreased knee flexion excursion and associated higher stiffness.[16] Low arched individuals exhibit greater knee external rotation, associated with similar tibial internal rotation and greater femoral internal rotation with respect to tibia resulting in increase in dynamic quadriceps angle and lateral patellar translation. There was increase in quadriceps muscle force to prevent further knee flexion.[17]

No significant change in dynamic postural stability was well explained by findings from study done by Padua et al in 2006. Study concluded that vertical leg stiffness was unaffected by lower limb closed kinetic fatigue protocol in order to sustain functional performance, but use different control strategies[19].Three fatigue induced muscle activation strategies were (1) ankle dominant, (2) antagonist- inhibition strategy and (3) quadriceps dominant stategy.[19] Individuals using ankle dominant strategy place greater reliance on ankle musculature e.g. squat exercises primarily facilitates knee and hip extensor musculature with little stress on gastrocnemius and soleus, so after fatigue greater reliance is on less fatigued musculature. Gastrocnemius activity was increased by 38% in females.[19] Antagonist inhibition strategy represent compensatory mechanism to offset fatigue by maximizing mechanical efficiency of joint, by shifting to antagonist inhibition strategy, would maximize efficiency in transferring agonist muscle force to produce joint moments[19]. Quadriceps dominant strategy after fatigue attempts to compensate quadriceps muscle fatigue and maximize internal knee extension moment generated by quadriceps. Quadriceps: Hamstring co-activation ratio in females is 2.6 post fatigue and peak quadriceps activity was more than 2.5 times that hamstring.[19]

CLINICAL RELEVANCE

Altered balance and biomechanical deviations are one of the factors for ankle injuries, so these non-instrumented measures of postural stability for static and dynamic balance can be used to assess potential biomechanical risk factors predisposing to ankle instability. Non instrumented measures of postural stability can be used to assess the effectiveness of various rehabilitative protocols and methods used for lower extremity injuries to check improvement in proprioceptive and postural control for example after ACL reconstruction and in knee osteoarthritis. Moreover we can detect direction specific postural control deficits due to various lower limb biomechanical deviations and muscle imbalances and design a specific protocol to correct them and reassess the improvement.

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