Comparison of Core Stability in Individuals with Flexible Flat Foot and Normal Foot

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Abstract: ***Objectives**: 1) To study the core stability in individuals with Bilateral Flexible flat foot in the age group of 19-35 years. 2) To study the core stability in individuals with Normal foot in the age group of 19-35 years 3) To compare the core stability in the individuals with Bilateral Flexible flat foot and Normal foot in the age group of 19-35 years. **Research design**: Cross-sectional study. **Method**: In this study 30 subjects for Bilateral Flexible flat feet and 30 subjects for Normal arched feet were selected by using the sit to stand navicular drop test (SSNDT), to measure the Core stability back extensor endurance test, flexor endurance test and the side bridge test were used, the Means and the standard deviation for each group was calculated and compared. **Results**: Extremely significant mean differences in core stability tests were found in the individuals having Bilateral Flexible flat feet (p<0.0001).*

Keywords: Flexible flat foot, Core stability, Navicular drop test, Kinetic chain, muscle imbalances

1. Introduction

Foot posture plays an important role in the quality of daily living. The ankle/foot complex is made up of 28 bones that form 25 component joints. The structure of the feet is such that it permits the functions of both the stability and the mobility depending on the tasks which are imposed on it. The feet have to be stable to provide an adequate base of support and function as a rigid lever for the push off phase during walking, running or jumping. The feet also have to be mobile to adapt to uneven terrain and absorb shock when the feet hit the ground.[1], [2] Flat foot is also called as Pes planus, Plano valgus or Calcaneo valgus. This term describes an abnormally low medial longitudinal arch, which causes the Plantar fascia to be excessively stretched resulting in the Subtalar joint pronation, Rearfoot valgus posture, calcaneal eversion and Navicular depression. Flexible Flat foot is the commonest type in which the medial longitudinal arch appears to be normal in a non-weight bearing position, but the arch drops excessively on weight bearing. This deformity would be associated with other structural abnormalities and compensations.[1], [2] A recent study done in India in the year 2017 found that the prevalence of flexible flat foot was 13.6% (males-12.8%, females-14.4%).[5]

2. Core Stability

The Lumbopelvic-Hip Complex, or “Core, ” is composed of Spine, Hips, Pelvis, Proximal lower limb, and Abdominal structures that either produce or restrict movement of these segments. The stability of any system is the ability to limit displacement and maintain structural integrity. Therefore, core stability can be defined as the ability of the Lumbopelvic-Hip Complex to prevent buckling of the Vertebral Column and return it to equilibrium following perturbation by using Strength, Endurance and Motor Control in a functional manner through all the planes of motion and action despite changes in the center of gravity.[7, 8, 9]

Effect of flexible flat foot on the kinetic chain of the body

Every activity involves movements of joints and limbs in a coordinated way to perform a task. Individual body segments and joints, collectively called "links, " have to be moved in certain specific sequences to allow the accomplishment of the tasks. The sequencing of the links is called the "kinetic chain”. Each kinetic chain has its own sequence but the basic organization includes proximal to distal sequencing, a proximal base of support or stability, and successive activation of each segment of the link and each successive link. The net result is generation of force and energy in each link, summation of the developed force and energy through each of the links. and optimal transfer of the force and energy to the terminal link. Injuries or adaptations in some areas of the kinetic chain can cause problems not only locally but distantly, as distal links must compensate for the lack of force and energy delivered through the more proximal links. This phenomenon, called "catch-up” is both inefficient in the kinetic chain, and dangerous to the distal link because it may cause more load or stress than the link can safely handle. These changes may result in anatomical or biomechanical situations that increase injury risk, perpetuate injury patterns, or decrease performance.[7]

Bilateral flat foot cause more proximal lower limb dysfunctions, which lead to an altered lumbopelvic hip stability (core stability) and hence contribute to a wide range of lower limb injuries affecting the lower back, hip, knee, lower leg, ankle and foot.[8], [10]The kinetic chain of the lower limbs will be affected in individuals with flexible flat foot resulting in increased pronation of the Subtalar joint causing internal rotation of the Tibia, and Femur, increased valgus at the Knee joint, increase in the Q angle and Anterior pelvic tilt, this increases the pressure on the posterior structures of the spine and lumbar lordosis, there is an associated strain on the muscles of, hip, lumbar, sacral region, which may cause wedging of the intervertebral discs, sciatic nerve stress, all these changes cause lumbopelvic hip complex or core instability.[12], [15], [17-23], [26] An altered core stability causes dysfunction in terms of reduced flexibility, strength, and motor control of the lumbopelvic hip complex. Core stability deficits have been known to contribute to the development of various injuries like the Anterior cruciate ligament (ACL) injuries, Lower back dysfunctions, patellofemoral pain syndrome, Iliotibial band syndrome.[10]

3. Literature Survey

1) **Amir Letafatkar, Shahrzad Zandi, Majid Khodayi (2013)** Studied the relationship between flat foot deformity with Q angle and knee pain in Iranian freestyle wrestlers. 20 subjects from Iranian national wrestlers with mean age 19.11 ± 0.86 yrs, weight 70.5 ± 18.4 kg, height 173.2 ± 9.1 cm, were selected for the study and it was found that there was a significant relationship between flat foot deformity and knee pain in wrestlers. Based on the results of the study, authors concluded there is an existence of kinetic chain system and flat foot deformity may result in patella lateral rotation and increased Q angle and that these agents resulted in knee pain.

2) **Alex Barwick, Josephine Smith, Vivienne Chuter (2012)** Conducted a review of literature to study the relationship between foot motion and lumbopelvic–hip function and found that foot Pronation is associated with reduced Gluteus Medius activity and an altered Lumbopelvic hip complex stability this resulted in increased number of lower limb pathologies and injuries, also females are more prone to such injuries due to the structure of their wider pelvis. Functional foot orthosis (FFO) have been prescribed successfully to treat such overuse injuries due to gluteus medius dysfunction and Pronation, the rationale behind FFO is that it has an effect on the proximal structures (Gluteus Medius, Lumbopelvic hip complex) therefore preventing the occurrence of lower limb injuries and pathologies.

3) **Mohamed Taher Eldesoky, Enas Elsayed Abutaleb (2015)** Conducted a Cross sectional study to investigate influence of bilateral and unilateral flatfoot on Pelvic Alignment in which 56 subjects, aged 18–40 years, were allocated to three groups: 20 healthy subjects, 19 subjects with bilateral flexible second-degree flat foot, and 17 subjects with unilateral flexible second-degree flatfoot. 3D assessment of the pelvis was done digitally to evaluate pelvic alignment in the frontal and sagittal planes by measuring pelvic inclination and pelvic tilt angles. It was observed that unilateral and bilateral second-degree flatfoot produced significant pelvic anteversion, in comparison to the healthy subjects. But the bilateral flatfoot subjects had a more anteversion than the unilateral subjects. Unilateral flatfoot caused a significant lateral pelvic tilt in the direction of the affected side in comparison to the healthy and bilateral flatfoot subjects. It was concluded from the study that the bilateral and unilateral second-degree flatfoot changes pelvic alignment. Both of them lead to increases of pelvic anteversion while the unilateral one caused lateral pelvic tilt toward the affected side. Thus, foot posture should be considered when assessing patients with pelvic misalignment and disorders.

4) **Sam Khamis, Gali Dar (2015)** conducted a cross sectional study to determine the relationship between foot and pelvic alignment while standing. 35 healthy subjects in the age group of 23-33 were recruited for the study, the study was conducted at a gait and motion analysis laboratory, each participant underwent a detailed examination that included lower extremity range of motion, anthropometric and skeletal alignment measurements. Three - dimensional motion analysis was done using VICON1three-dimensional motion analysis system. Participants were made to stand on different wedges at angles to induce hyper pronation. It was concluded that hyper pronation resulted in internal tibia rotation, internal hip rotation and anterior pelvic tilt was identified. Due to the interaction of the foot and pelvis based on the Kinetic chain the alignment of the entire lower extremity up to the pelvis can be changed due to hyper pronation clinicians must know that while addressing pelvis and lower back dysfunction, foot alignment should be examined as a contributing factor.

5) **Khatere Farokhmanesh, Toraj Shirzadian (2014)** conducted a study of “Effect of Foot Hyper pronation on Lumbar Lordosis and Thoracic kyphosis in standing position using 3-dimensional ultrasound-based motion analysis system. In this study 35 healthy subjects age ranging from 18-30 years were asked to stand on 4 positions including a flat surface (normal position) and on wedges angled at 10, 15, and 20 degrees. Measurements were made by a motion analysis system. The eversion created by the wedges caused a significant increase in lumbar lordosis and thoracic kyphosis. It was concluded from the study that with increased bilateral foot pronation, lumbar lordosis and thoracic kyphosis increased as well. In fact, each of these is a compensation phenomenon.

6) **Rafael Z.A. Pinto, Thales R. Souza (2008)** conducted a study to establish relationship between calcaneal eversion and pelvic alignment. In this study 14 young healthy subjects participated in the study. A Motion Analysis System was used to obtain pelvic and calcaneal positions. Subjects were filmed in a relaxed standing position during three trials, under three conditions: bilateral stance, unilateral stance with calcaneal eversion, bilateral stance with calcaneal eversion. Calcaneal eversion was produced by a 10-degree medial wedge. Unilateral and bilateral calcaneal eversion produced an increased pelvic anteversion. Thereby it can be concluded from this study that an excessive calcaneal eversion during standing, changes pelvic alignment and therefore, it should be considered while treatment.

7) **Kellie C. Huxel Bliven and Barton E. Anderson (2013)** Conducted a narrative review on core stability training for injury Prevention. This review stated that Core stability focuses on maintaining neutral spinal alignment, optimal trunk position, and the efficient transfer of loads along the kinetic chain. When the core stability is altered it can give rise to distal joint injuries for e.g. ACL injuries at the knee joint, a variety of assessment tools

can be utilized to evaluate core stability. A multifaceted approach is recommended utilizing tests for muscle recruitment, endurance, neuromuscular control, and fundamental functional movement patterns. Core stability should be trained in a progressive manner, starting with local muscle recruitment, moving to core stabilization in a variety of postures, and then transitioning into total body dynamic movements.

8) **John D. Willson, Christopher P. Dougherty, Mary Lloyd Ireland et al (2005)** conducted a study to determine core stability and its relationship to lower extremity function and injury. The study stated that core stability dysfunctions can lead to various problems affecting the distal segments in the kinetic chain ranging from a reduced back extensor endurance resulting in low back pain, ankle sprains, inadequate firing of Gluteus Medius and Maximus, various knee injuries involving ACL and the patellofemoral joint. Therefore, it was implicated that optimal Core stability may provide protective benefits to the musculoskeletal system, from maintenance of low back health to preventing knee ligament dysfunctions. Core stability is the ability of the lumbopelvic hip complex to prevent buckling and to recover to equilibrium after a perturbation. The static elements (bone and soft tissue) contribute to some extent, but core stability is predominantly maintained by the dynamic function of muscular elements. There is a clear relationship between trunk muscles and lower extremity functions. Current evidence suggests that decreased core stability may cause injuries and that appropriate training of core may reduce injury. Appropriate rehabilitation may result in decreased rates of back and lower extremity injury.

9) **McGill, Aaron Childs (1999)** in a study of the “Endurance holding times and the ratios between torso extensors, flexors, and lateral flexors (stabilizers), for clinical assessment and rehabilitation targets for Low Back Stabilization Exercises. The study included 75 young healthy subjects (31 men, 44 women) and they were made to perform isometric endurance tests (back extensor, flexor, side bridge tests) It was concluded from the study that Women had longer endurance times than men for torso extension, but not for torso flexion or for the "side bridge" exercise, which challenges the lateral flexors (stabilizers). Men were able to sustain the "side bridge" for 65% of their extensor time and 99% of their flexion time, whereas women were able to sustain the "side bridge" for 39% of their extensor time and 79% of their flexion times. The tests were proved to be reliable, with reliability coefficients of >.97 for the repeated tests on 5 consecutive days and again 8 weeks later.

Problem definition: Is the core stability in individuals with Bilateral Flexible flat foot altered as compared to individuals having normal arched feet?

4. Methodology/Approach

1) **Study design** – Cross sectional study
2) **Study setting and place of study**- Tertiary health care center, community set up.
3) **Study population-** Individuals in the age group of 19-35 years.
4) **Study duration**- 6 Months
5) **Method of selection of subject**

Inclusion criteria –

- Individuals in the age group of 19-35 years
- Individuals who gave written consent to participate in the study.
- Bilateral Flexible flat foot (Sit to stand NDT >10mm)
- Normal foot (Sit to stand NDT 6-8 mm)

Exclusion criteria –

- Neurological conditions - foot drop, stroke, spinal cord injuries, parkinsonism.
- Rigid flat foot
- Pregnancy
- Prolapse intervertebral disc, spondyloarthropathies, Lumbar canal stenosis, Spondylolisthesis, fractures of the spine, low back pain etc.
- limb length discrepancy due to scoliosis
- BMI>30
- Individuals who are exercising regularly, individuals who participate in recreational sports activities

6) **Sample size -** was calculated using open epi software as follows from pilot study which was done on 16 individuals, sample size of 30 was considered in each group, the total sample size including dropout in both the groups = 60.

7) **Type of sampling-** consecutive sampling
   - Any lower limb injuries -ankle sprains, knee instability, fractures of lower limb, pelvis etc.

8) **Methods for data collection: –**
   - Approval was obtained from the ethics committee.
   - Informed consent was taken from all subjects.
   - The demographic data was collected as per the data record sheet.
   - The subjects were evaluated for sit to stand navicular drop test (SSNDT) and core stability tests were performed by each subject.

Core stability tests

a) **<u>The trunk flexor test</u>-** began with the participant in the sit-up position with their trunk supported at 60° of trunk flexion. Knees and hips were flexed at 90°, arms crossed over chest, and feet secured. The support of the trunk was then removed, and the participant held the position for as long as possible. The test was terminated when the participant was no longer able to hold the position. The time in seconds was noted.[7], [8]

Figure 1: Flexor Endurance test (starting position)

Figure 2: Flexor endurance test (end position)

b) **<u>The trunk extensor test</u>** - was performed with the participant lying prone on treatment tables. Their pelvis, hips, and knees were secured to the treatment table, while a chair at the same height as the surface of the table supported the trunk and upper extremities. The chair was removed, and the individual held a horizontal body position for as long as possible with arms crossed over chest. The test was discontinued when the participant fell below the horizontal position. The time in seconds was noted.[7], [8]

Figure 3: The trunk Extensor test (start position)

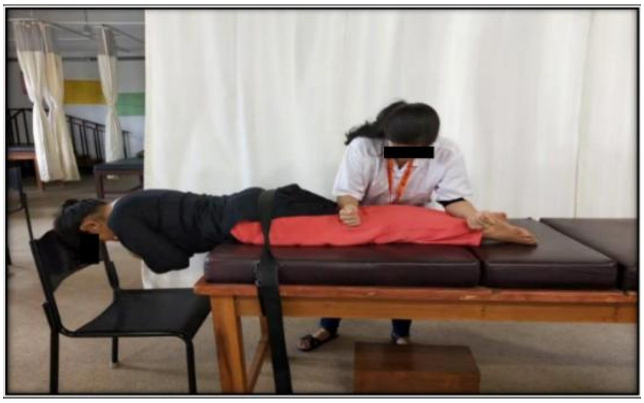


Figure 4: The trunk Extensor test (end position)

c) **<u>The side bridge tests</u>** (right, left) were performed in the side-lying position on a treatment table. The participant supported their weight only on their lower elbow and feet while lifting their hips off the mat. The subjects were asked to hold the position for as possible. The test was stopped when the side-lying position was lost. The time in seconds was noted.[7], [8]

Figure 5: Side Bridge test

5. Results

1) The data was entered using MS-EXCEL 2007 and analyzed using GraphPad instat version 3.1.
2) Descriptive analysis of numerical data was expressed in Mean and Standard Deviation for various parameters.
3) Frequencies of categorical data were expressed in percentages.
4) Normality of data was assessed using Kolmogorov Simonov test
5) Since the data was not Normally distributed (Kolmogorov Simonov test) non- parametric Mann-

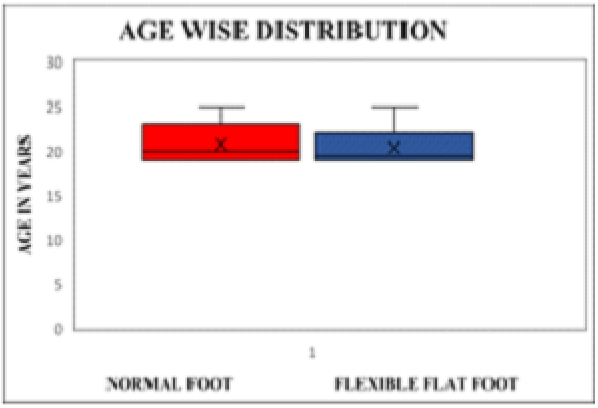
Whitney U test was used for comparison of means between two groups.

6) p value less than 0.05 was considered to be statistically significant.
7) The data obtained was Quantitative and Continuous in nature hence graphical representation was done using Box plots and Bar graphs.

Age

Table 1: Comparison of Age in both the groups

Groups	n=60	Minimum	Maximum	Median	Mean	SD	Test	P Value	Significance
Normal Foot	30	19	25	20	20.76	2.128	Mann-Whitney U Test	0.538	Not Significant
Flexible Flat Foot	30	19	25	19.5	20.4	1.793	Mann- Whitney U Test		

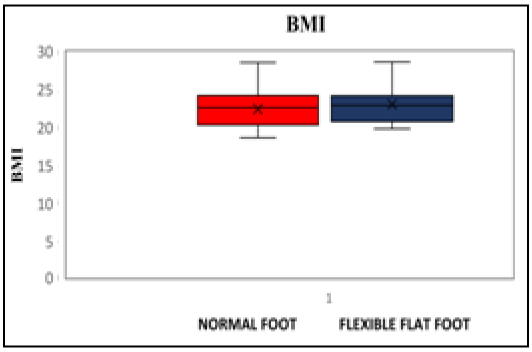


Inference – There is equal distribution of age in both groups.

BMI

Table 2: Comparison of BMI in both the groups

Groups	n=60	Minimum	Maximum	Median	Mean	SD	Test	P Value	Significance
Normal Foot	30	18.6	28.6	22.6	22.43	2.48	Mann-Whitney U Test	0.382	Not significant
Flexible Flat Foot	30	19.8	28.7	22.9	23.04	2.43	Mann-Whitney U Test		



Inference -BMI was equally distributed between both the groups.

Gender

Table 3: Distribution of Gender

Gender	Normal Foot		Flexible Flat Foot	
	Frequency	%	Frequency	%
Females	23	0.76	23	0.76
Males	7	0.23	7	0.23
Total	30	100	30	100

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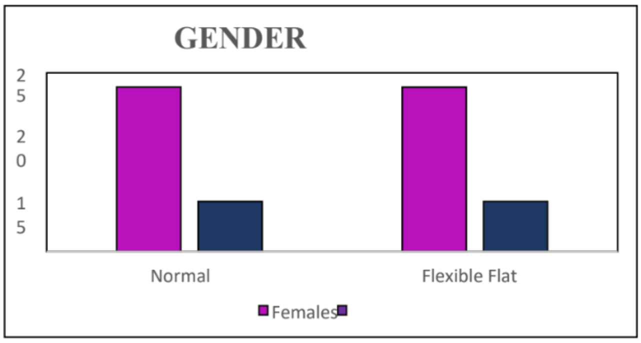


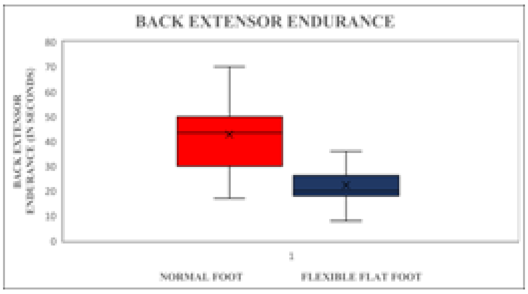
Graph 3: Showing age distribution in both the groups

Inference – Equal distribution of males and females in both groups.

Back Extensor Endurance Test

Table 4: Comparison of Back Extensor Endurance in both the groups

Groups	n=60	Minimum	Maximum	Median	Mean	SD	Test	P values	Significance
Normal Foot	30	17	70	43.5	42.86	15.211	Mann-Whitney U Test	<0.0001	Extremely significant
Flexible Flat Foot	30	8	36	20	20	7.476	Mann-Whitney U Test		



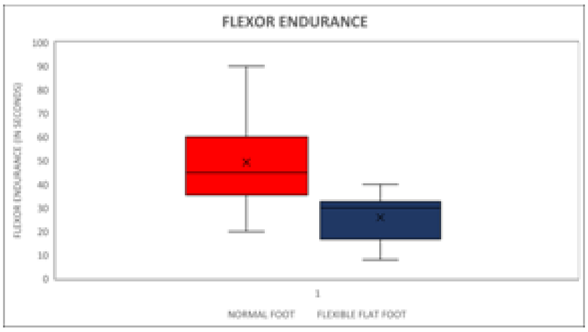
Graph 4: Showing Back extensor endurance in both groups

Inference: There was an extremely significant difference between the scores of the two groups showing reduced back extensor endurance in the individuals with flexible flat foot.

Flexor Endurance Test

Table 5: Comparison of flexor endurance test in both the groups

Groups	n=60	Minimum	Maximum	Median	Mean	SD	Test	P values	Significance
Normal Foot	30	20	90	45	49.2	18.75	Mann-Whitney U Test	<0.0001	Extremely significant
Flexible Flat Foot	30	8	40	30	26	9.830	Mann-Whitney U Test		



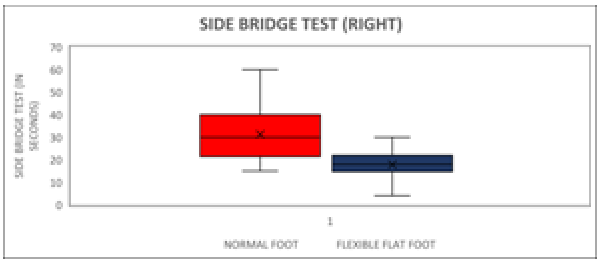
Graph 5: Showing Flexor Endurance in both groups

Inference: There was an extremely significant difference between the scores of the two groups showing reduced flexor endurance in the individuals with flexible flat foot.

Side Bridge Test (Right)

Table 6: Comparison of side bridge test (right side) in both the groups

Groups	n=60	Minimum	Maximum	Median	Mean	SD	Test	P values	Significance
Normal Foot	30	15	60	30	31.266	10.625	Mann-Whitney U Test	<0.0001	Extremely significant
Flexible Flat Foot	30	4	30	18	17.866	6.152	Mann-Whitney U Test		



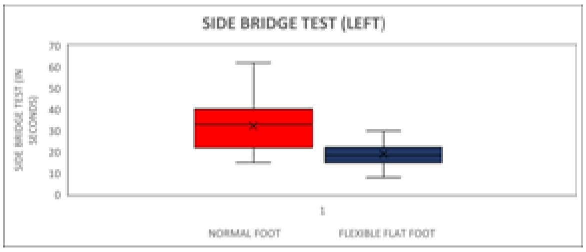
Graph 6: Showing Side Bridge Endurance (right) in both groups

Inference: There was an extremely significant difference between the scores of the two groups showing reduced side bridge endurance of the right side in the individuals with flexible flat foot.

Side Bridge Test (Left)

Table 7: Comparison of Side bridge test (Left)

Groups	n=60	Minimum	Maximum	Median	Mean	SD	Test	P values	Significance
Normal Foot	30	15	62	33	32.433	10.744	Mann- Whitney U Test	<0.0001	Extremely significant
Flexible Flat Foot	30	8	30	18.5	19.133	5.829	Mann-Whitney U Test		



Graph 7: Showing Side Bridge Endurance in both groups

Inference: There was an extremely significant difference between the scores of the two groups showing reduced Lateral bridge endurance of the left side in the individuals of flexible foot.

Descriptive Statistics

Normal foot

Test	Minimum	Maximum	Mean	SD	Median
Back extensor endurance test	17	70	42.86	15.211	43.5
Flexor endurance test	20	90	49.2	18.735	45
Side bridge test (right)	15	60	31.266	10.625	30
Side bridge left (left)	15	62	32.433	10.744	33

Flexible flat foot

Test	Minimum	Maximum	Mean	SD	Median
Back extensor endurance test	8	36	22.33	7.476	20
Flexor endurance test	8	40	26	9.830	30
Side bridge test (right)	4	30	17.866	6.152	18
Side bridge left (left)	8	30	19.133	5.829	18.5

6. Discussion

The main objective of this research was to study the comparison of core stability in individuals with flexible flat foot and normal foot.

Based on the inclusion and exclusion criteria 60 individuals were selected for the study post screening. There were 2 groups which were normal foot group consisting (n=30) of 23 females and 7 males with mean age of 20.76 ±2.128 years and mean BMI of 22.43 ±2.48, and flexible flat foot group consisting (n=30) of 23 females and 7 males with mean age of 20.4 ±1.793 and mean BMI of 23.04 ±2.43.

Individuals included in the study were assessed using sit to stand Navicular drop test. Core stability tests were performed in both the groups. Statistical significance was considered when p value was less than 0.05.

The results from statistical analysis of the present study rejects the null hypothesis. There was an extremely significant difference in Core stability (Flexor endurance test, Back extensor endurance test, Side bridge (Right, Left)) in individuals with flexible flat foot in the age group of 19-35 years.

The reasons to the above findings are-Flexible flat foot causes changes in the kinetic chain of the entire lower extremity upto the lumbar, pelvic and the hip region.

A study which was done by Sam Khamis, Ziva Yizhar (2007) stated that flexible flat foot is characterised by hindfoot pronation (calcaneal eversion). The changes in the structure of the feet induce malalignment in the entire lower extremity as there is an interaction of the distal segments with the proximal segments based on the concept of kinetic chain theory these changes lead to structural and functional deficits in the knee, hips, pelvis and the lumbar spine due to abnormal forces which act on the body. Foot pronation causes internal rotation of the Tibia and Femur, changes in the patellofemoral joint, abnormal acetabular orientation, femoral anteversion, exaggerated anterior pelvic tilt and compensations at the lumbar spine along with the affection of the soft tissues around these joints.[26]

The study done by Mohamed Taher Eldesoky, Enas Elsayed Abutaleb (2015) confirmed the kinematic chain that exists between the feet and the pelvis, and stated that any changes in the structure of the feet will cause abnormal forces acting on the body, the bilateral flatfoot changes the pelvic alignment it leads to increase of pelvic anteversion these alterations of the pelvis and spinal alignment resulted from the additional stress placed on the ligaments, joints, and muscles engaged in preservation of the normal alignment of the body, therefore it can be implicated that as a result of flatfoot the alignment of lower extremity is affected, this will also affect the surrounding soft tissue structures and their ability to function optimally.[19]

The findings of the study done by Neveen Abdel Raoof, Dalia Kamel (2017) confirmed the postural changes associated with flatfeet, that the presence of flatfoot altered the limb posture and affected the orientation of the pelvis and lumbar spine. These postural alterations resulted from the additional stress placed on all of the joints, ligaments and muscles involved in maintaining upright posture.[36]

Rahele Khamooshi, Samaneh Mohammadi et al. (2017) found that core Stability training exercises and stretching and strengthening exercises of bilateral flexible flat feet for a period of 8 weeks was found to be more effective than the conventional treatment alone. [16]

A study done by Hamideh Khodaveisia, Haydar Sadeghia (2016) stated that Over pronation of the feet can change the position of hip, pelvis and trunk and upper extremities, Over pronation is accompanied by internal rotation of tibia and femur, knee valgus and pelvis anterior tilt producing more pressure and stress while disturbing the ability of muscles responsible for pelvic stability and increasing pathologic pressures on supporting tissues of sacroiliac joint. As external oblique muscle is the greatest abdominal muscle controlling the rotation to front of pelvis, in the case of stability in spine, the activity of external muscle activity increases, therefore it can lead to imbalance of the muscle, and this way it can alter the core stability in subjects with altered feet alignment.[37]

Farzaneh Yazdani, Mohsen Razeghi, et. al. (2018) conducted a study “The influence of foot hyperpronation on pelvic biomechanics during stance phase of the gait” It was found that hyperpronation group had greater Anterior Pelvic Tilt during 20%–80% of the stance phase. Thus, the study concluded that, in persons with hyperpronation, the role of the pelvic segment was mainly to maintain postural balance in the sagittal plane by increasing anterior pelvic inclination. The anterior pelvic tilt may be associated with low back symptoms and lumbopelvic dysfunctions. This study implicated that foot hyperpronation will affect the hips, pelvis and the lumbar joints and also the structures around it and this can give rise to lumbopelvic hip dysfunctions altering the core stability of such individuals.[64]

In a study done by Mohammad Sadegh Ghasemi, Jalil Koohpayehzadeh et al (2017) confirmed the postural instabilities associated with flat feet, the pelvis bone is an important segment situated in the centre of the body and connects the movements of the lower limbs to the segmental motion of the spine, and is a functional link through which loads are transferred in a proximal and distal manner. When the posture is optimal, the muscles and ligaments have to contract minimally to maintain stability, with altered posture commonly associated with foot hyperpronation, the soft tissue structures will have to contract more to maintain the postural stability thus can give rise to dysfunctions of the core. the study concluded that pronation increases anterior pelvic tilt, lumbar lordosis, and thoracic kyphosis all are compensatory changes.[17]

Another study which was conducted by Alex Barwick, Josephine Smith (2012) was to investigate the effect of Functional foot orthosis in preventing lower limb injuries in individuals with pronated feet, the study confirmed that the coupling between the feet and the hips could give rise to the dysfunction of musculature of the Lumbopelvic–hip complex. Thus, this study confirms the interdependence of feet and the core stability.[23]

Amir Letafatkar, Shahrzad Zandi (2013) had proven that based on the concept, of kinetic chain wrestlers with flat feet had laterally rotated patella, increase in Q angle which resulted in increased knee pain, thus the study implicated that when flat feet give rise to structural malalignments affecting the lower limbs, due to abnormal forces acting on the body.[22]

A study done by Khatere Farokhmanesh, Toraj Shirzadian, (2014) to investigate the effect of foot hyperpronation on Lumbar Lordosis and Thoracic Kyphosis in standing position, was conclusive of bilateral feet hyperpronation affecting the proximal structures, each increase is a compensatory Samah Saad Zahran, Nadia Abdul Azim Fiyaz (2016) conducted a study to investigate Iliopsoas flexibility in subjects with Bilateral Flexible Flatfoot. And it was concluded from the study that there is an interdependence of hip muscle function and foot alignment. Reduction of flexibility of the iliopsoas muscle which has a direct attachment to the spine, pelvis and the femur will cause a dysfunction of the lumbopelvic-hip complex.[35]

With such musculoskeletal malalignments, repeated abnormal movements and sustained abnormal postures will cause adaptations in the muscle length, strength and stiffness this would lead to movement impairments causing an altered lumbopelvic hip complex stability or the core stability. Therefore, from the above studies it can be concluded that in an altered position of the Lumbopelvic region which is commonly observed in individuals with flat foot, there is an increase in the lordosis and Anterior pelvic tilt, causing an increased tightness in the hip flexors, lumbar extensor muscles and stretched and weak abdominals (Transversus Abdominis, Internal and External obliques, Rectus Abdominis) and the hip extensor muscles (Gluteus Maximus and Hamstrings). This altered posture has an effect over the passive structures causing narrowing of posterior disc space, intervertebral foramen and approximation of the articular facets. Greater percentages of Type 1 fibres than Type 2 fibres are seen in all the back muscles which show that their major function is of stabilization and postural control. Since posture is maintained by a tonic muscular contraction it should be noted that muscular endurance might be more important than muscular strength in maintaining posture, therefore in cases of postural alterations there would be a negative effect on strength and endurance.[6] Change to return body's centre of gravity to its stable position within the base of support. With increased anterior tilt of the pelvis, lumbar vertebrae are deviated anteriorly and cause an increase in lumbar curvature, lumbar curvature increases and results in kyphosis to compensate for increased lumbar curvature.[21]

All these structural abnormalities would give rise to muscular imbalances in the lumbopelvic-hip complex region trying to compensate for the structural changes. These changes can be observed by the following studies.

It was proven by Josephine Key (2010) that the length tension relationship of the muscles due to an increased Anterior pelvic tilt and lumbar lordosis would be affected, leading to the pelvic crossed syndrome, in which there is tightness and facilitation of the iliopsoas and rectus femoris (hip flexors), thoracolumbar extensors (trunk extensors), while there is weakness and inhibition of the abdominal muscles (trunk flexors) and gluteus maximus and medius (hip extensors).[25]

Also, a study done by Pooja Mulchandani, Trupti Warude, Amrutkuvar Pawar (2017) to find out the efficacy of gluteal muscle exercise on individuals with flat feet, their rationale for the treatment was that the Gluteal muscles stabilize the hip by counteracting gravity's hip adduction torque and maintain proper leg alignment by eccentrically controlling adduction and internal rotation of the thigh. Gluteal muscle weakness internally rotates the hip joint inducing foot pronation. This study proves that flat feet have an influence on the proximal segments of the body causing muscular imbalances.[14]

Sho Takai, Koji Kaneoka (2016) confirmed with studies that analysed the muscle work in anterior pelvic tilt that the local muscles may be related to anterior and posterior pelvic tilting. In other words, the local muscles may control motion in the pelvic sagittal plane During anterior pelvic tilting, the Erector spinae and the Multifidi exhibited significantly larger activities.[31]

Samah Saad Zahran, Nadia Abdul Azim Fiyaz (2016) conducted a study to investigate Iliopsoas flexibility in subjects with Bilateral Flexible Flatfoot. And it was concluded from the study that there is an interdependence of hip muscle function and foot alignment. Reduction of flexibility of the iliopsoas muscle which has a direct attachment to the spine, pelvis and the femur will cause a dysfunction of the lumbopelvic-hip complex.[35] Such musculoskeletal malalignments, repeated abnormal movements and sustained abnormal postures will cause adaptations in the muscle length, strength and stiffness which would lead to movement impairments, thereby causing an altered lumbopelvic hip complex stability or the core stability. Hence, from the above studies it can be concluded that, in an altered position of the Lumbopelvic region which is commonly observed in individuals with flat foot, there is an increase in the lordosis and Anterior pelvic tilt, causing an increased tightness in the hip flexors,. lumbar extensor muscles and stretched and weak abdominals (Transversus Abdominis, Internal and External obliques, Rectus Abdominis) and the hip extensor muscles (Gluteus Maximus and Hamstrings). This altered posture has an effect over the passive structures causing narrowing of posterior disc space and intervertebral foramen and approximation of the articular facets. Greater percentages of Type 1 fibers as to compared Type 2 fibers are seen in all the back muscles, showing that their major function is of stabilization and postural control. Since posture is maintained by a tonic muscular contraction it should be noted that muscular endurance might be more important than muscular strength in maintaining posture, therefore in cases of postural alterations there would be a negative effect on strength and endurance. [66]

The core stability has three components which are passive (inert structure/bones/ligaments), active (muscles) and neural control. If any one of the components is not providing support it will affect the stability of the whole structure. Therefore, it can be concluded that core stability will be affected in individuals with flat feet.[66]

7. Conclusion

1) Individuals with flexible flat foot will have an effect on the proximal segment through the kinetic chain phenomenon of the body, affecting the core stability.
2) Individuals with flexible flat foot have reduced core stability.
3) Thus, core stability must be assessed while treating individuals with flexible flat foot and interventions that address core stability must be included in the treatment of flexible flat foot.

8. Future Scope

Limitations

1) Study was conducted in a limited Geographical area.
2) Results of this study cannot be generalized in a population over 35 years of age.

Suggestions

Research can be conducted in participants of different age groups.

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