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Correlation between Core and Hip Abductor Endurance in Overweight and Obese Students with Flexible Flat Feet

Dr. Pramod J. Palekar[1], Luvai M. Karimjee[2], Dr. Tushar J. Palekar[3]

[1]Pimpri, Pune, Maharashtra, Pimpri, Pune-411018
Email id: physiopramodj@gmail.com
[2]Intern, Dr. D.Y. Patil College of Physiotherapy, Pimpri, Pune- 411018
Email id: luvaimkarimjee@gmail.com
[3]PhD, Principal and Professor,Dept of Musculoskeletal sciences, Dr. D.Y. Patil College of Physiotherapy, Dr. D. Y. Patil Vidyapeeth, Pimpri, Pune, Maharashtra
Email id: tusharjpalekar@gmail.com, Email id: principal.physio@dpu.edu.in

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ABSTRACT

Flexible flatfoot is a common foot deformity that can lead to altered biomechanics and excessive pronation during weight-bearing activities. Prior studies have linked proximal weakening of the hip abductor muscles and core to flatfoot. Additionally, a greater incidence of flatfoot deformity and decreased hip and core strength have been connected to obesity. Nevertheless, not much research has been done on the connection between obesity, flatfoot, hip abductor endurance, and core endurance.

The aim of this study was to analyse the correlation between core muscular endurance and hip abductor endurance among overweight and obese students between 18-25 years of age with flexible flatfeet.

This was an observational study carried out in a tertiary health care centre. Convenience sampling was used for selecting a sample of 75 overweight and obese college students, ages 18 to 25, who had flexible flatfoot (navicular drop ≥10mm, positive Jack's test and Tiptoe Standing test). The Biering-Sorensen test, the Plank hold test, and the Side Plank hold test were used to measure core endurance. The Hip Abductor Isometric Endurance Test was used to assess hip abductor endurance. Pearson's correlation coefficient was used to examine the relationship between core and hip abductor endurance measures. Mean differences between overweight and obese groups were compared.

In obese students with flexible flatfoot, positive correlations were observed between hip abductor endurance and all core endurance tests (Biering-Sorensen, Plank Hold, Side Plank Hold). However, there was a negative correlation seen in the overweight flatfoot group between hip abductor and core endurance. No statistically significant differences in mean core or hip endurance were noted between the overweight and obese cohorts.

The findings suggest that proximal muscular endurance impairments among individuals with flatfoot deformity may be exacerbated by increased obesity levels. Assessing hip and core function may aid in determining risk factors and directing exercise programs intended to prevent musculoskeletal issues in this population.

Keywords: *Core endurance, Flexible flat feet, Hip abductor endurance, Obese, Overweight*

1. INTRODUCTION

Pes planus (Flat Feet) is a medical condition in which the medial longitudinal arch curvature of the foot is more flat than regular and the whole sole of the foot comes into near total or complete contact with the ground[1]. There are two types of Flat Feet observed; the first, rigid or congenital, and the second, Flexible flat feet which is commonly observed in individuals which is presented with an absent medial longitudinal archon weight-bearing and reformation during non-weight bearing. Additionally, there is forefoot abduction, internal rotation, and plantar flexion of the talus, as well as calcaneal eversion.Commonly used method to measure flatfeet is the Navicular Drop Test with a prevalence of 13.6%. Jack's test and Tiptoe Standing test is commonly used to measure flexible flat feet[1, 2, 3].

In healthy people, the instability caused by flat feet during weight-bearing and movement activities causes patho-mechanical compensatory issues within the closed kinematic chain of the lower extremities. This includes, tibial and femoral medial rotation, anterior pelvic tilting, increased lumbar lordosis and thoracic kyphosisindicating presence of a distal to proximal kinematic chain.The altered pelvic posture puts more strain on hip and pelvic muscles like the piriformis, iliopsoas, and gluteal muscles[4].

Due to this influence, very commonly weakness of the core musculature is observed in adolescents with flexible flat feet.The complete transmission of forces generated from the bottom through the lower extremities, the torso, and finally to upper extremities is made possible by a strong core. Gains in core muscular strength and endurance are essential to lowering impairment because they maintain and support the spinal segments both during exercise and against external loads. Particularly during vigorous exercise, the core is crucial for lowering the risk of damage and stabilizing peripheral joints[2].

A recent study on the impact of flexible flat feet on the core endurance of healthy individuals discussed the involvement of hip abductor weakness leading to reduced lateral core endurance in this population [4]. The abductors of the hip, mainly the Gluteus Medius is responsible for maintaining the pelvic stability in the frontal plane as well as preventing excess load on the hip adductor and internal rotator muscles by controlling the movement of the femur on the pelvis as well as the pelvis on the hip [5]. Hollman et al. (2006) stated that medial arch collapse causesgreater foot pronation during weight-bearing activity leading totibial internal torsion and knee valgus, along with femur adduction and internal rotation, which is related with reduced hip-abductor strength[6].

Along with the impact that flexible flat feet have on the core and the hip abductor strength, there is an almost equal impact of Obesity on the core, hip abductors, and flexible flat feet. Obesity has been a worldwide health problem since many years affecting individuals in countries that are developed and still developing. A more recent systematic review indicated that obesity is highly related with non-specific foot discomfort in the general population, indicating that the foot is not immune to the effects of obesity[7]. One possible explanation for the relation of obesity and flexible flat feet is that; an individual with a higher body mass and a weak musculature will often complaint of pain or discomfort because of greater mechanical load on the foot which places the musculature of the foot in additional stress eventually weakening the muscles and potentially leading to collapsed arches on weight bearing [8, 9].

Different studies conducted on the effects of individuals with higher BMI ($\geq$25.0 kg/m^2) on flexible flat feet or different foot postures have observed a relevance of weaker core muscles strength. There is an association of excessive adipose tissue accumulation at the abdominal region which weaken the abdominal musculature around [9, 10]. It's also important to note that in overweight and obese people, the rectus abdominal muscle exhibits the most fatty infiltration, followed by the lateral abdominal muscle and the erector spinae[11]. This gradually causes altered biomechanics such as anterior pelvic tilting reducing strength of the oblique muscles along with the gluteal and tight hip flexors causing aggravating low back pain [12].

A few studies have examined the relationship between the strength of the hip abductors in normal weighted and overweight/obese individuals. The findings indicate that, when the hip abductors score was normalized to bodyweight, the gluteus medius strength was significantly higher in the former group than in the latter. This difference in strength may account for increased hip adduction movement during normal gait and functional activities, suggesting that obesity may be a contributing factor to reduced hip abduction in these individuals [13, 14].

Studies have proven that there is a significant impairment of core muscles endurance and hip abductors endurance because of flat feet; there is a directly proportional relationship of obesity to the reduction of core and hip abductor strength; as well as shown the effect ofBMI on the foot posture alignment and development of collapsed arches.

The purpose of this study was to investigate the correlation between core and hip abductor endurance in overweight and obese students aged 18-25 with flexible flat feet. The objectives of this study were to assess the correlation between core endurance using the tests (Biering Sorensen, Plank hold, Side Plank hold) and hip abductor endurance using Hip Abductor Isometric Endurance test and to assess correlation between core and hip abductor endurance in each overweight and obese students with flexible flat feet.

2. METHODS AND METHODOLOGY

This was an observational study conducted on 75 samples of overweight and obese category using convenience sampling method. A tertiary health care centre was used as the study setting which was Dr. D.Y. Patil College of Physiotherapy, Pimpri, Pune. The participants were taken from the same setting and written consent was signed by all. The inclusion criteria consisted of willing to participate overweight and obese studentswith BMI between 23.0 to $\geq$ 30 kg/m^2 (according to ASIAN classification), Navicular drop $\geq$10mm, Jack's test and Tiptoe standing test positive for flexible flat feet.Subjects were excluded from the study if they didn't present with flat foot, presented with rigid or congenital flat feet, if they had a history of low back pain or any injury or damage to the spine, lower extremities or back, if they had any congenital deformities or cardiovascular impairments.Ethical approval was taken from the institutional ethical committee of Dr. D.Y. Patil Vidyapeeth, Pune. The sample size was calculated using G*Power V 3.1.9.4 Software (n=75).

Assessment of Flexible Flat Feet-

1. Navicular Drop Test (NDT): It assesses the degree of pronation/lowering of the medial longitudinal arch. Higher navicular drop values are associated with a more pronated foot and lower arch. Lower navicular drop values indicate a more supinated foot and higher arch. An ND of ≥10 mm was considered in this investigation for diagnosis of flat feet. The NDT has shown moderate to good correlation with other clinical measures of arch height like the arch angle (r=-0.64), Staheli index (r=0.63) and Chippaux-Smirak index (r=0.61) from footprint measures[15].
2. Jack's test: used to assess and determine whether the Flat Foot is of rigid/structural type or the flexible type. It involves passive dorsiflexion of the great toe (1st metatarsal joint). Positive result of flexible flat feet will be seen as elevation of the MLA, due to tightening of the plantar fascia. Negative result will be seen as no elevation on dorsiflexion of the hallux.
3. Tip toe standing test: It involves asking the patient to stand on the toes; an apparent medial arch along with heel varus indicates flexible flat feet.

Assessment of Core Endurance-

1. Biering- Sorensen Test: -Often known as the prone isometric back extension endurance test, this is a frequently used test for assessing the back extensors endurance. The test participant was suspended over the edge of the plinth while lying prone during the procedure. The ASIS is in contact to the edge of the table. The lower body was secured to the table with straps. The subject maintained the upper body in an unsupported horizontal, neutral spine position as long as possible while the examiner used a stopwatch to record the time till failure. When the subject was unable to stay in the horizontal position any longer, the test is over. Longer hold periods suggest more muscle endurance in the back extensors. Comparing it to other back endurance tests carried out in flexion, the Biering-Sorensen test is seen to be more demanding and functional and has shown good to excellent reliability[2, 4, 16, 17]. Based on study done by Latimer et al. (1999) the average holding time for patients who had no symptoms of low back pain was 132.6 ± 42.2 seconds. This was significantly longer compared to subjects with current nonspecific low back pain (94.6 ± 33 sec) and those with previous episodes of back pain (107.7 ± 36.4 sec)[18].
2. Plank Hold Test: - For this test the subject was prone on a mat with only the elbows and forearms in contact with the ground as well as the toes of the feet. The upper body was elevated so that the back is in a straight line along with the hip and legs [4]. Studies have demonstrated good interrater, intrarater, and retest reliability of timed plank hold tests. For this study, plank was done by the subjects without a specific time limit till failure.This test provides a practical and standardized method to quantify core muscle endurance [16, 19, 20]. According to research done on older and younger adults, the overall mean plank holding time was 145.3 seconds, with younger adults demonstrating longer holding times than older adults on average[21].
3. Side Plank Hold Test: - The side plank hold test, evaluates the endurance of the lateral core muscles.For this test the participant must elevate their hips off the mat to maintain a straight line from their head to their feet while lying on their side, supported by one elbow and their feet. When the subject can no longer maintain the position and lowers their hips to the ground, the test is over. The test has been shown to have good reliability for measuring lateral core endurance. One study found high intra- and inter-tester reliability for the side plank test. Another study showed good test-retest reliability with an intraclass correlation coefficient of 0.91 [2, 4, 17, 22].

Assessment of Hip Abductor Endurance-Using the Hip Abductor Isometric Endurance Test (HAIET)which commonly targets the Gluteus Medius muscle. For this test, the participant was placed in a side-lying position with the hip to be assessed placed superiorly with the knee and hip extended and internally rotated with the ankle dorsiflexed and inverted. The contralateral limb was put into hip and knee flexion. The therapist should make sure that the pelvis is squared. The hand of the ipsilateral upper limb is placed on the pelvis. The patient was then instructed to isometrically hold the leg in a horizontal position with the knee in extension and the pelvis, trunk, and the scapula in the same alignment upon vocal command. The investigator records the time during which the participant holds the limb straight and time till failure or fatigue of this movement is recorded. This test has a good validity and test-retest reliability, ICC (0.73) [23, 24].

3. STATISTICAL ANALYSIS

Data analysis and interpretation was done using the statistical package SPSS. Mean and Standard deviation were calculated for all the variables. Pearson correlation was used to find the correlation between core endurance and hip abductor endurance tests in overweight and obese population.

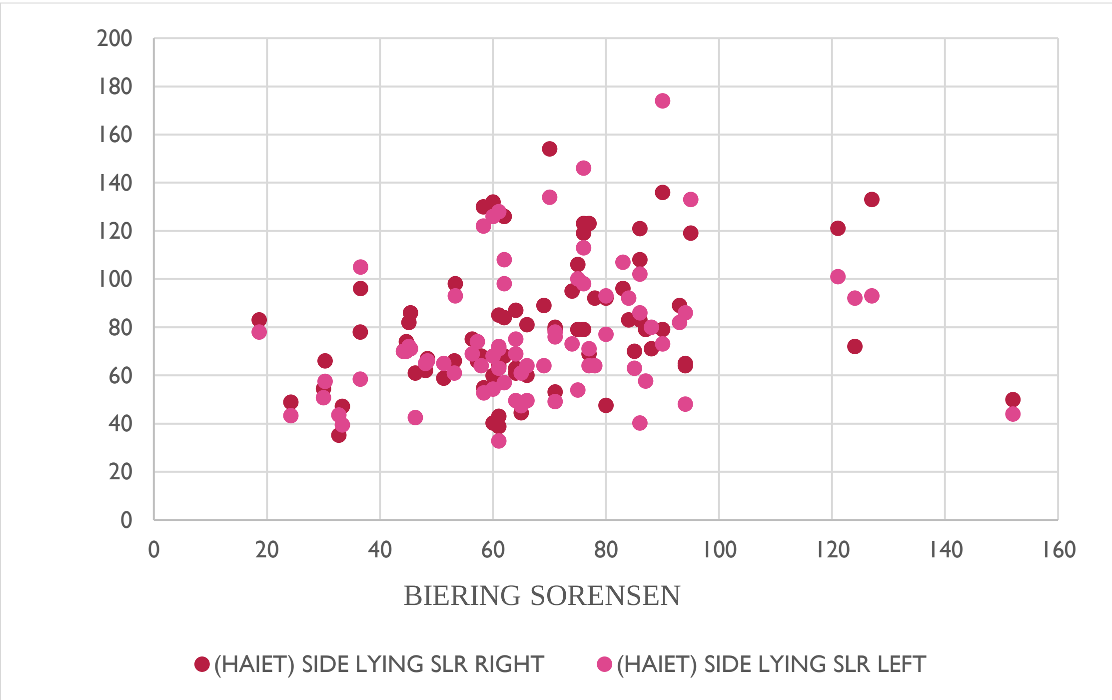
TABLE NO. 1- Mean values of core endurance and hip abductor isometric endurance tests with standard deviation for overweight and obese students.

VARIABLE	OVERALL MEAN AND STANDARD DEVIATION
Biering Sorensen Test	67.94 +/- 23.40
Plank Hold Test	44.96 +/- 28.11
Side Plank Hold Right	21.95 +/- 15.90
Side Plank Hold Left	19.83 +/- 13.22
(HAIET) Side Lying SLR Right	80.17 +/- 26.32
(HAIET) Side Lying SLR Left	76.46 +/- 27.34

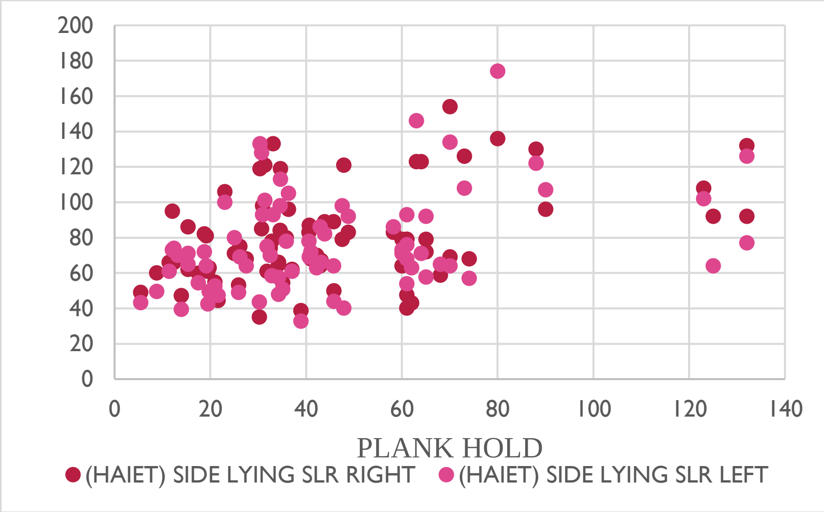
TABLE NO. 2– Correlation between core endurance tests and hip abductor endurance test.

CORRELATION (Pearson Correlation [r])	(HAIET) SIDE LYING SLR RT.	(HAIET) SIDE LYING SLR LT.
BIERING SORENSEN	0.304	0.253
PLANK HOLD	0.398	0.382
SIDE PLANK HOLD RT.	0.276	0.304
SIDE PLANK HOLD LT.	0.235	0.246

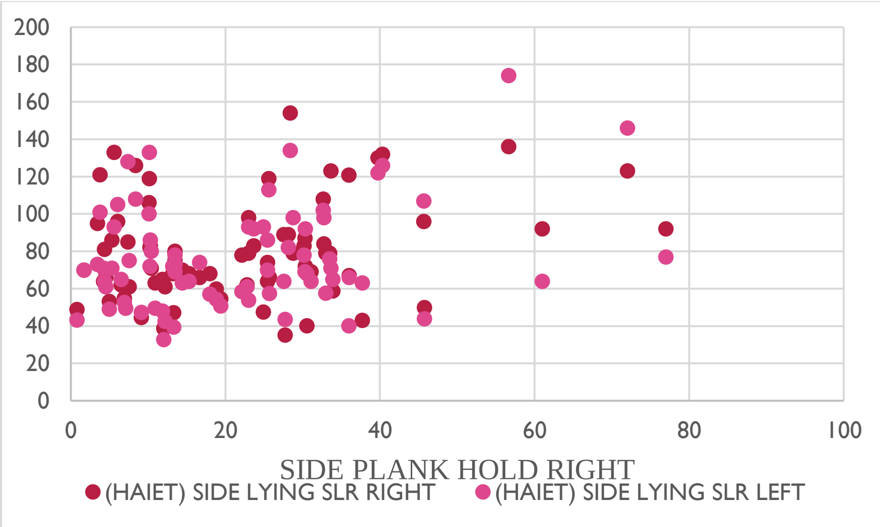
GRAPH NO. 1 –Correlation between Biering-Sorensen test and (HAIET) Side lying SLR Right and Side lying SLR Left.



GRAPH NO. 2- Correlation between Plank Hold test and (HAIET) Side lying SLR Right and Side lying SLR Left.



GRAPH NO. 3 - Correlation between Side Plank Hold TestRight and (HAIET) Side lying SLR Right and Side lying SLR Left.



GRAPH NO. 4 - Correlation between Side Plank Hold Test Left and (HAIET) Side lying SLR Right and Side lying SLR Left.

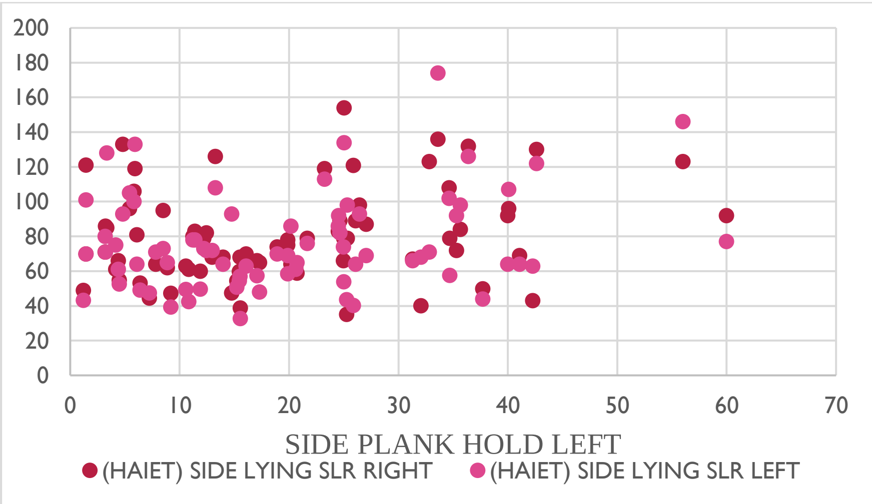
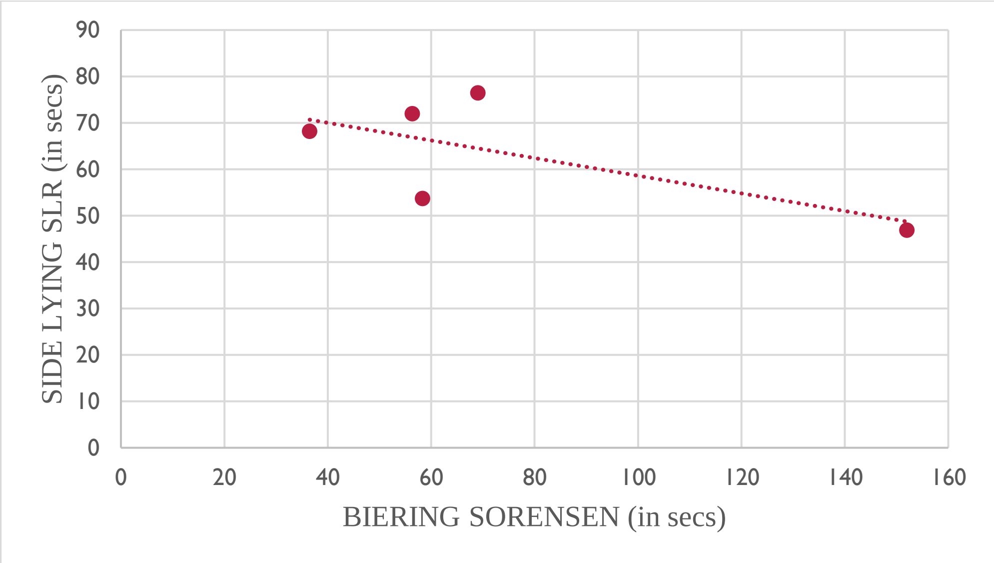


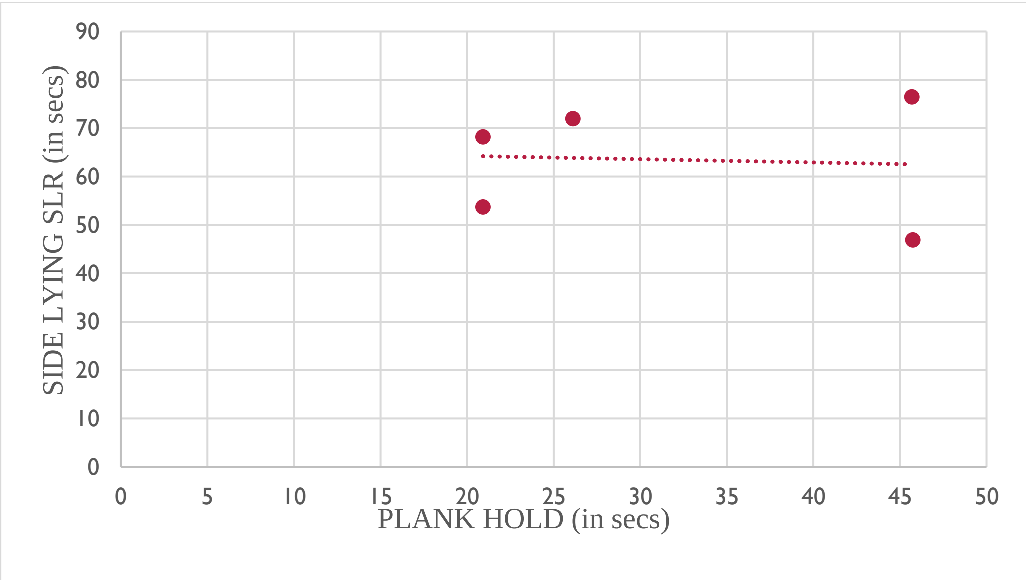
TABLE NO. 3– Correlation between core endurance tests and hip abductor endurance test in overweight students.

CORRELATION (Pearson correlation [r]) IN OVERWEIGHT STUDENTS	[HAIET] SIDE LYING SLR (MEAN)
BIERING SORENSEN	-0.678
PLANK HOLD	-0.068
SIDE PLANK HOLD (MEAN)	-0.232

GRAPH NO. 5 - Correlation between Biering Sorensen Test and (HAIET) Side lying SLRin overweight students.



GRAPH NO. 6 - Correlation between Plank Hold Test and (HAIET) Side lying SLR. in overweight students.



GRAPH NO. 7- Correlation between Side Plank Hold Test and (HAIET) Side lying SLR. in overweight students.

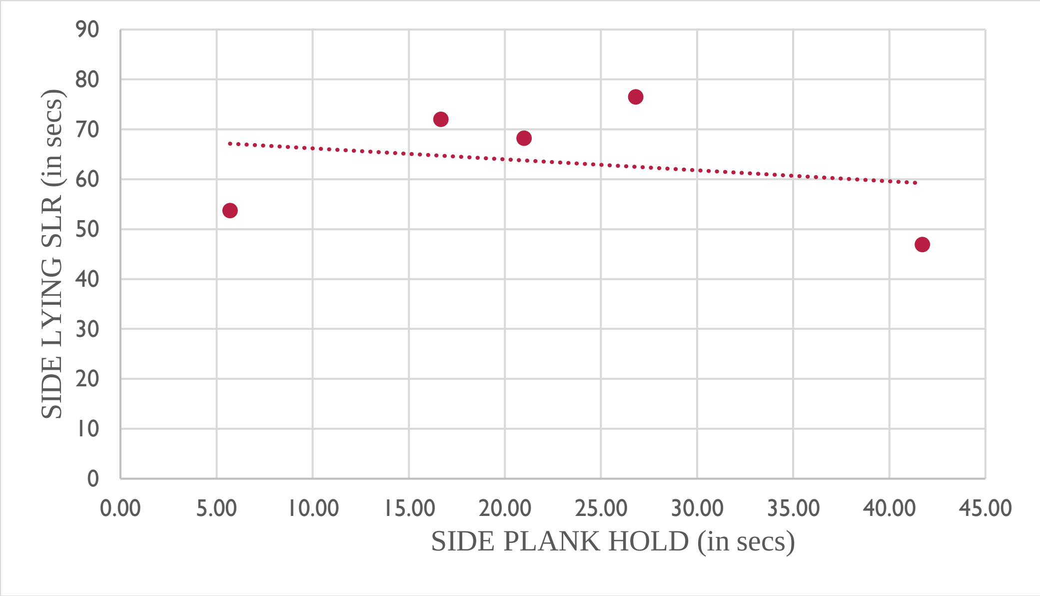
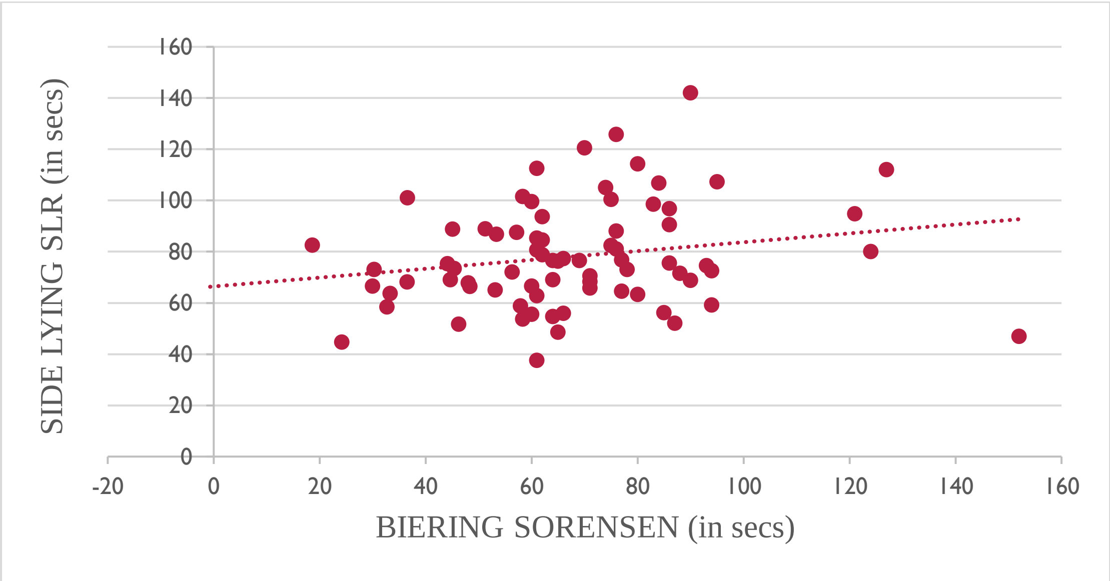


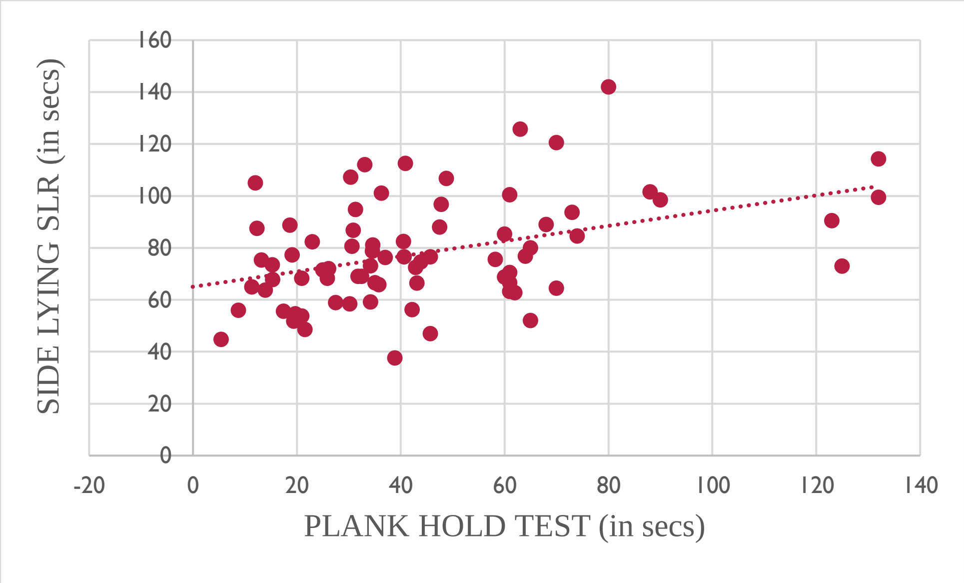
TABLE NO. 4– Correlation between core endurance tests and hip abductor endurance test in obese students.

CORRELATION (Pearson correlation [r]) IN OBESE STUDENTS	SIDE LYING SLR
BIERING SORENSEN	0.298
PLANK HOLD	0.402
SIDE PLANK HOLD	0.354

GRAPH NO. 8- Correlation between Biering Sorensen Test and (HAIET) Side lying SLRin obese students.



GRAPH NO. 9- Correlation between Plank Hold Test and (HAIET) Side lying SLR in obese students.



GRAPH NO. 10- Correlation between Side Plank Hold Test and (HAIET) Side lying SLR in obese students.

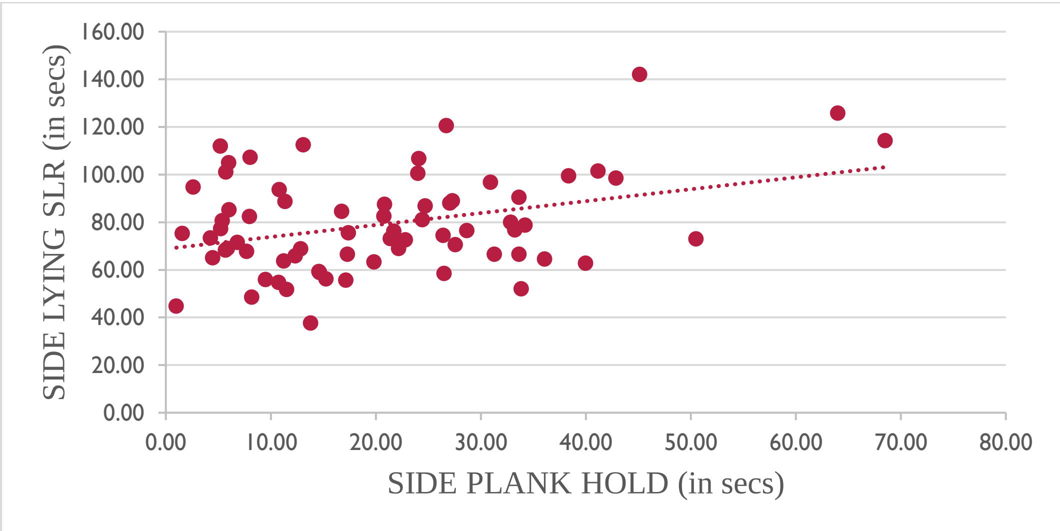


TABLE NO. 5 -shows the Mean difference of the values of each test performed between Obese and Overweight population.

VARIABLES		N	Mean	Standard Deviation	Standard Error Mean	P Value
Biering Sorensen	Obese	70	67.48	21.61	2.58	0.524
	Overweight	5	74.44	44.92	20.09	
Plank Hold	Obese	70	45.72	28.83	3.45	0.382
	Overweight	5	34.26	11.27	5.04	
Side Plank Right	Obese	70	21.87	16.07	1.92	0.863

	Overweight	5	23.15	14.90	6.66	
Side Plank Left	Obese	70	19.70	13.37	1.60	0.758
	Overweight	5	21.61	12.03	5.38	
(HAIET) Side lying SLR Right	Obese	70	80.95	26.80	3.20	0.344
	Overweight	5	69.34	16.45	7.36	
(HAIET) Sidelying SLR Left	Obese	70	77.81	27.72	3.31	0.111
	Overweight	5	57.59	9.80	4.38	

4. RESULTS

According to the statistical analysis done, there was found to be a positive correlation between the core endurance tests i.e. Biering Sorensen, Plank Hold, Side Plank Hold (Right and Left) and the Hip Abductor Endurance Test (Side lying SLR Right and Left) in obese students as compared to overweight students with Flexible Flat Feet.

Biering Sorensen Test–

The mean value of **Biering Sorensen Test** between the obese and overweight were 67.48 +/- 21.61 and 74.44 +/- 44.92. There was found to be a positive correlation between Biering Sorensen test and Hip Abductor isometric endurance test right andleft with r=0.304 and r= 0.253 respectively in overweight and obese students.

In overweight students there was a negative correlation found between Biering Sorensen and HAIET with r=-0.678. However, in obese students, there was a positive correlation found between the sametests with r= 0.298.

The mean difference between obese and overweight population were insignificant with p value 0.524.

Plank Hold Test–

The mean value of **Plank Hold Test** between the obese and overweight were 45.72 +/- 28.83 and 34.26 +/- 11.27.There was found to be a positive correlation between Plank Hold test and Hip Abductor isometric endurance test right and left with r= 0.398 and r= 0.382 respectively in overweight and obese students.

In overweight students there was a negative correlation found between Plank Hold and HAIET with r= -0.068. However, in obese students, there was a positive correlation found between the same tests with r= 0.402.

The mean difference between obese and overweight population were insignificant with p value 0.382.

Side Plank Hold Test–

The mean value of **Side Plank Hold Test (Right)** between the obese and overweight were 21.87 +/- 16.07 and 23.15 +/- 14.90. The mean difference therefore between obese and overweight population were insignificant with p value 0.863.

The mean value of **Side Plank Hold Test (Left)** between the obese and overweight were 19.70 +/- 13.37 and 21.61 +/- 12.03. The mean difference therefore between obese and overweight population were insignificant with p value 0.758.

The correlation values for the Side Plank right with the HAIET right and left were positive with r= 0.276 and r= 0.304 respectively in overweight and obese students.

The correlation values for the Side Plank left with the HAIET right and left were positive with r= 0.235 and r= 0.246 respectively in overweight and obese students.

In overweight students there was a negative correlation found between Side Plank Hold and HAIET with r= -0.232. However, in obese students, there was a positive correlation found between the same tests with r= 0.354.

Hip Abductor Isometric Endurance Test (Side lying SLR)–

The mean value of **[HAIET] Side lying SLR (Right) Test** between the obese and overweight were 80.95 +/- 26.80 and 69.34 +/- 16.45. The mean difference therefore between obese and overweight population were insignificant with p value 0.524.

The mean value of **[HAIET] Side lying SLR (Left) Test** between the obese and overweight were 77.81 +/- 27.72 and 57.59 +/- 9.80. The mean difference therefore between obese and overweight population were insignificant with p value 0.111.

5. DISCUSSION

The study aimed to determine the correlation between core muscular endurance and hip abductor endurance among 75 overweight and obese adults with flexible flatfoot deformity (70 obese, 5 overweight). BMI, navicular drop test, Jack's test, and tiptoe standing test were used for assessment. Core endurance was measured using Biering Sorensen, plank hold, and side plank hold tests, while hip abductor endurance was assessed with the hip abductor isometric endurance test (side-lying straight leg raise). The study revealed positive correlations between core endurance and hip abductor endurance in obese college students with flexible flat feet, but negative associations in overweight students, aligning with previous research on lower extremity strength deficits and core dysfunction in this population.

The findings of this study support prior research indicating that flexible flat foot deformity can lead to compensatory motions up the kinetic chain to absorb forces. Specifically, the collapse of the medial longitudinal arch results in greater ankle pronation, tibial internal torsion, and knee valgus during weightbearing activities. Greater tibial rotation and knee valgus resulting from arch collapse necessitates greater recruitment of hip abductors and rotators to centre the femoral head within the acetabulum [6]. The gluteus medius plays a particular role as it controls hip adduction and internal rotation on the stance leg. These alterations may represent the body's attempt to stabilize and absorb forces in the presence of arch dysfunction. However, the compensations can increase demands on proximal musculature around the hip and pelvis to control alignment and stability such as the hip abductors [4, 5]. This can explain why flexible flat foot patients often demonstrate weakness in hip abductor strength and endurance compared to normal arched individuals.

The core musculature, consisting of the abdominal musculature anteriorly and paraspinals and gluteal muscles posteriorly, works as a cylinder to offset perturbations from the lower limbs [2]. Impaired foot arch integrity in flexible flatfoot may challenge core capacity to properly stabilize the body.

This study found that among overweight and obese students with flexible flat feet, there was a moderatecorrelation between hip abductor endurance and the core endurance measured by theirrespective tests. More specifically, lower hip abductor endurance test scores were associated with lower core muscular endurance. It was also observed that there was evident decrease in the side plank hold scores indicating impaired lateral core endurance. The kinetic chain theory, which depends on stability and mobility from foot to trunk for optimal force transfer, can explain these associations [2].

Furthermore, having excess body mass puts more strain on the hip abductors to stabilize the stance limb's lever arm during gait. Hip abduction demands increase as the arch collapses in a flexible flatfoot, causing the medial structures that resist pronation to fail [6, 25]. This explains why navicular drop and decreased hip abductor endurance have been observed to positively correlate.

These biomechanical changes may explain why people who are obese or overweight and have flat feet frequently have foot, hip, and low back discomfort [8, 9]. The persistent pain might then increase musculoskeletal suffering by lowering activity levels and encouraging weight gain [8]. Despite reduced hip and core endurance in our samples, there were no appreciable variations according to the ASIAN classification for BMI in obese and overweight. It is possible that even mild obesity places significant demands on this proximal muscle groups' ability to compensate for joint stress.

Due to changed length-tension relationships of the lower leg and plantar intrinsic muscles brought on by medial longitudinal arch collapse, flexible flatfoot deformity may impair hip abductor endurance and core strength[26]. Additionally, Due to the decreased production of force for dynamic stability, proximal muscles may be recruited in compensation, which could result in early fatigue. Furthermore, arch strain results in adjacent stabilizers' localized inflammation and muscle inhibition, which may be a factor in the endurance capacity deficit that was seen[27, 28].

Appropriate conservative treatment strategies that focus on the intrinsic muscles of the foot and enhance arch stiffness via bracing or orthoses may lessen compensatory demands on the proximal musculature [29]. Furthermore, there may be therapeutic advantages to using weight training to specifically target hip and core weakness.It has been shown in earlier research that lumbopelvic stability facilitates force dissipation in dynamic tasks [2]. It's feasible that greater structural alignment and better absorption of ground reaction forces in people with flat feet are made possible by increased proximal stability resulting from core/hip strengthening.

The results of this study show that in overweight and obese students with flexible flat feet, hip abductor and core strength and endurance are significantly reduced. Thus, more attention should be given in training these sets of muscles taking the kinetic chain into account comprehensively. Programs for conservative therapy that include lumbopelvic, hip stability, movement pattern correction, and arch strengthening may help reduce dysfunction in this population.

Limitations to this study include: 1) The sample size used in this study consisted of 75 samples, which lacked equal gender distribution, predominantly having females more than males, 2) The age group only consisted of 18–25-year-old students in the college, 3) The screened overweight and obese students included in the study, had more number of students in the obese category than the overweight (70 obese and 5 overweight).

Future scope includes conducting researchto see if assessing the whole kinetic chain, specific exercise programs targeting muscle and movement dysfunction from hips to feet, can improve arch function and reduce pain in people with flexible flat feet.

6. CONCLUSION

To conclude, this study found evident positive correlations between core endurance tests and hip abductor endurance test in 18-25 years overweight and obese students with flexible flat feet, indicating a reduction of core and hip abductor endurance in this population. The findings suggested that foot arch integrity plays an important role in force absorption and neuromuscular control along the kinetic chain and additional weight will play a major role causing musculoskeletal and neuromuscular impairments further down the line.

ADDITIONAL INFORMATION

Conflicts of interest: No conflict of interest.

Depiction of Biering- Sorensen test to assess back muscles endurance.

Depiction of a Plank Hold test timed till failure.

Demonstration of a Side Plank Hold Test

Demonstration of a Side lying Hip Abductor Isometric Endurance Test

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