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Comparison of the effect of 4 weeks core stability training and foot intrinsic muscle training on foot posture

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***Abstract*---**Persons with pronated feet may be prone to more injuries than these with normal feet. As it disrupts the body's natural alignment and causes increased impact when the foot strikes the ground. The purpose of the present study was to compare the effects of 4-week core stability training and foot intrinsic muscle training on foot posture in females. Twenty-six females with pronated feet were randomly divided into two groups. The group A performed the core stability training (n=13) and the group B performed the foot intrinsic muscle training (n=13) for four weeks with frequency of 5 sessions per week. Foot Posture Index, McGill protocol, weight distribution and foot load response were assessed at the baseline and at the end of four weeks. Dependent t-test was used to check the differences within the group before and after the program. Independent t-test was used to compare the differences between groups after the intervention. Results: In Group A after the intervention there was a significant difference in posture of both feet ($p < 0.001$) whereas, no significant difference in weight distribution on forefoot and backfoot, and load response of both the feet was found. Group B showed a significant difference only in right foot posture ($p<0.001$) after 4-weeks intervention. When both the groups were compared after the intervention there was a significant difference only in posture of left foot. Core stability training was more effective than the foot intrinsic muscle training on the foot posture after 4-week intervention. Therefore, the rehabilitation programs may incorporate a combination

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of core stability and foot intrinsic muscle training rather than foot alone to obtain effective results.

***Keywords*---**pronated foot, FPI-6, McGill Protocol, Zebris FDM-T treadmill.

Introduction

Foot receives whole body weight and allows movement. Arch is one of most important components that provides body weight support and force distribution. It is important for foot stability and resilience. The medial longitudinal arch (MLA), comprises of the first metatarsal, medial cuneiform, navicular, talus, and calcaneus bones, and is a primary weight-bearing and shock-absorbing structure (Neumann, 2011). The MLA plays a crucial role for shock attenuation and its flexible component enables proper function. Therefore, disorders of the medial longitudinal arch may affect foot function. Flatfoot (pes planus or fallen arch) is commonly seen due to decreased medial longitudinal arch. This deformity induces calcaneus bone in the valgus position and talus bone in plantar flexion with adduction producing excessive pronation of the foot when bearing full weight (Pandey et al., 2013). Flatfoot can be categorized as flexible and rigid types (Helfet et al., 1980). In rigid flatfoot there is permanent flattening of medial longitudinal arch in both weight bearing and non-weight bearing situations. While in flexible flatfoot the arch is flat only during weight bearing situations and it disappears during non-weight bearing positions. Flexible flatfoot can be due to tibialis posterior dysfunction, abnormalities of the foot bones, ligament laxity, shortened Achilles tendon, calf muscle tightness or contracture, and weakness of the foot muscles (Huang et al., 1993; Leung et al., 1998 & Murley et al., 2009). Abnormal peripheral information from the foot affects muscle performance necessary for body posture and position control (Shumway-Cook and Horak, 1986) and stable maintenance on the base of support (Franco, 1987). Such abnormalities in the MLA leads to loss of the functional stability of the foot (Franco, 1987), which in turn causes balance problems (Hertel, 2002; Hillstrom et al, 2013; Tsai et al, 2006).

Foot posture is categorized into neutral foot, flatfoot, and high-arched foot. Flat and high-arched foot postures are more commonly associated with increased risks of lower limb injuries when compared with the neutral foot posture (Tong and Kong, 2013). Specifically, flatfoot posture is a risk factor for medial tibial stress syndrome and patellofemoral pain syndrome (Neal et al., 2014), while high-arched foot has been associated with a high risk for overuse injuries of the foot or ankle (Cain et al., 2007). Previous reports have suggested associations of foot posture with lateral ankle sprain (Morrison and Kaminski, 2007) and anterior cruciate ligament injury (Loudon et al., 1996). Although the mechanisms underlying links between foot posture and increased risk of lower limb injury remain unclear, changes in lower limb biomechanics (Hollander et al., 2019), neuromuscular controls (Murley et al., 2009), and postural stability (Cote et al., 2005; Kim et al., 2015) are considered to be among the mechanisms. The plantar intrinsic foot muscles play a crucial role in supporting the medial longitudinal arch, providing the foot stability and flexibility for shock absorption. These muscles also have an influence on the range of foot pronation (Ferber et al., 2009). When the plantar intrinsic foot muscles were fatigued, there may be a change in foot posture towards pronated position (Cowley et al., 2013; Escamilla et al., 2013). Excessive pronation transmitted to internal rotation of the tibia, may also reason overloading of the knee joint or can be the reason of different adjustment in proximal part of the lower extremity (Ferber et al., 2009 & Hintermann et al., 1998). Excessive pronation in pes planus causes ground reaction forces to deviate medially during stance phase of the gait (Song et al., 1996). Thus, altered dynamic function and related foot deformities result in abnormal plantar pressure pattern in pes planus (Buldt et al., 2018). It has been reported that, pes planus leads to higher pressure under the big toe, central forefoot and the medial midfoot; lower pressure in the medial and lateral forefoot compared to neutrally aligned feet (Buldt et al., 2018; Ledoux et al., 2002; Forghany et al., 2018). Integration of the active and passive structures of the foot supports MLA and contributes dynamic foot control (McKeon et al., 2013). Extrinsic and intrinsic foot muscles act as the main components of foot function and the intrinsic foot muscles are considered to have a more important role in dynamic foot control (McKeon & Fourchet., 2015). Evidence suggests that strengthening intrinsic muscles enhances dynamic support of MLA and foot stability (Sudhakar et al., 2018 & Mulligan et al., 2013 & Sulowska et al., 2016). Several recent studies have focused on the capacity of the plantar intrinsic foot muscles (PIFMs) to support the MLA (Fiolkowski et al., 2003; Headlee, et al., 2008 & Kelly et al., 2014). The extrinsic foot muscles, such as the posterior tibialis, are strong MLA supporters; however, in individuals with pes planus, the PIFMs are atrophied compared with those in individuals with a normal arch (Angin et al., 2014). Moreover, smaller cross-sectional areas of the PIFMs, such as the abductor hallucis and flexor hallucis brevis, are correlated with more severe pes planus alignment (Angin et al., 2018). Therefore, PIFM hypofunction may be a cause of pes planus alignment and related injuries.

The lower kinetic chain includes a series of joints, such as the ankles, knees, hips, and trunk that facilitates the transmission of forces into the trunk and hips during running, jumping, kicking, and throwing. Dysfunction of any one of the joints within the lower kinetic chain linkage system may result in dysfunction elsewhere within the chain. Kinetic chain injuries may result from muscle imbalances, joint restrictions, and inadequate rehabilitation of previous injuries. Beckman and Buchanan noted a significant delay in latency of the gluteus medius muscle in patients with chronic ankle instability as compared with normal controls. Core stabilization is important because base of the body vector shifts during ambulation to the supporting foot while controlling the centre of gravity. Proximal core weakness at trunk, pelvis and hip can affect athlete's postural stability and ability for shock absorption as Gluteus medius, upper gluteus maximus and posterior TFL provides lateral stabilization of pelvis over the hip in the frontal plane during rapid transfer of body weight on the loading leg during running. However, none of these studies provides an absolute conclusion regarding the direct effect of core stabilization on foot posture. So, this study aims to: 1) To check the effect of the core stability training on foot posture. 2) To check the effect of the foot intrinsic muscle training on foot posture. 3) To compare the effect of the core stability training and foot intrinsic muscle training on foot posture.

Methods

Subjects

This study was approved by Institutional ethical committee of the University. Twenty-six females (age: 23.76±1.3years) with pronated feet were included in the study, after obtaining the informed consent. The demographic characteristics of the subjects is mentioned in Table-1, and the selection criteria included: Healthy female subjects in the age group of 18-25 years with pronated foot, subjects with no history of lower limb injury in the past one year, completed consent form. The exclusion criteria for the study subjects were those that had FPI-6 score <6 points, where a score ≥ 6 was used to identify individuals with pes planus alignment (Redmond et al., 2006), any sign of pain in the lower limbs, current orthopedic treatment, ligamentous hyperlaxity, serious illness, osteoarticular surgery of the foot.

Table 1
Demographic Characteristics of Subjects in both groups

Parameter	Core Stability Training Group (A) Mean ±SD n =13	Foot Intrinsic Muscle Training Group(B) Mean ±SD n =13
Age	23.38 ± 1.32	24.15 ± 1.28
Height (cm)	159.46 ± 6.77	160.4 ± 5.56
Weight (kg)	57.80 ± 8.92	60.2 ± 11.03
BMI	22.74 ± 3.40	22.9 ± 3.98

Procedure

The participants visited MYAS-GNDU department twice, during the first visit after collection of subjective data foot posture was determined using FPI 6. This was followed by a warm up session of 2 minutes at an average speed of 1.6 m/s on Zebris FDM-T treadmill (Zebris Medical GmbH, Isny, Germany) and then weight distribution (%) & foot load response (%) was measured for the stance and dynamic analysis respectively. All the subjects were randomly divided into group A and group B. Core stability was measured using McGill protocol for group A, post which a four-week intervention program of core stability and foot intrinsic muscle was proposed for Group A and B respectively. After 4-weeks intervention, all the subjects of both groups were reassessed.

The foot posture index

Foot posture was assessed using the Foot Posture Index. The subjects stood in their relaxed stance position with double limb support. They were then instructed to stand still with their arms by the side and looking straight ahead. During the assessment, ensuring that the patient does not swivel to try to see what is happening was important as that would have significantly affected the foot posture (Redmond, 2005). The six clinical criteria employed in the FPI – 6 are:

- Talar head palpation
- Supra and infra lateral malleolar curvature
- Calcaneal frontal position
- Prominence in the region of the talonavicular joint
- Congruence of the medial longitudinal arch
- Abduction / Adduction of the forefoot on the rearfoot

McGill protocol

Core stability was assessed using the McGill Protocol (McGill, 2005):

- Trunk flexion (anterior musculature of the core)
- Trunk extension:
- Right and left side plank

Intervention

Core Stability Training (Group-A)	Foot Intrinsic Muscle Training (Group-B)
Bridges with Leg Lifts, Static Abs, Lower Trunk Rotation, Planks (Prone, Left, Right), Bicycles, Full Vertical Crunches, Bridges with Marching, Long Arm Crunches, Trunk Rotation with Weights, Bilateral Leg Lowering for six times a week for four weeks (Nicole Kahle.,2009).	Short Foot Exercise, Toes-Spread-Out Exercise, Towel Curl Exercise, Great Toe Extension, Reverse Tandem Walk (Sulowska et al., 2007 & Lynn et al.,2012).

Statistical analysis

The SPSS 17 IBM software was used for statistical analysis. Tabled data underwent an adherence or normality test (Kolmogorov-Smirnov) that identified all the variables as normally distributed. Whole data was described in terms of mean and standard deviation. Dependent t-test was used to see with in group differences in FPI-6, weight distribution of both feet, forefoot and backfoot, foot load response and McGill protocol (Group A only) before and after 4-week intervention in both groups. Independent t- test was performed to see the differences in between the two groups.

Results

Core Stability Training (Group-A)

When the FPI-6, McGill protocol, weight distribution on forefoot and backfoot, and load response of both the feet before intervention was compared with the after 4-weeks intervention significant increase in both feet FPI-6 ($p<0.005$); trunk flexion ($p<0.005$); trunk extension ($p<0.005$) and both side plank ($p<0.005$) was observed. There was no significant difference observed in weight distribution on forefoot and backfoot, and load response of both the feet.

GROUP A								
PARAMETERS	PRE		POST					
	Mean ±SD		Mean ±SD		Paired t-test		P- value	
	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
FPI-6	7.08± 1.38	8.15 ±1.62	6.00 ±1.08	6.69 ±1.60	6.062	7.98	0.0001	0.00000
FF%	56.00±11.87	51.23±14.34	56.23 ±4.62	51.31± 9.43	0.062	0.015	0.9518	0.9882
BF%	44.00±11.87	48.77±14.34	43.00 ±5.19	48.69± 9.43	0.282	0.015	0.783	0.9882
Weight Distribution in %	45.31±10.81	54.69±10.81	49.15 ±7.93	50.85 ±7.93	1.465	1.465	0.1687	0.1687
Foot load response in %	14.49±2.98	15.02±4.243	13.62±1.17	13.50±1.081	1.209	1.571	0.2499	0.1422
McGill (in secs)								
Trunk Flexion	90.77 ±28.25		189.38 ±118.57		3.184		0.0079	
Trunk Extension	44.78± 26.04		64.31 ±32.05		4.133		0.0014	
Side Plank	38.83± 16.08	41.52 ±16.89	52.28± 16.77	57.33± 18,.54	5.411	6.063	0.0002	0.0001

FPI – Foot Posture Index, FF – Fore Foot, BF – Back Foot

Foot Intrinsic Muscle Training (Group-B)

When the FPI-6, weight distribution on forefoot and backfoot, and load response of both the feet before intervention was compared with the after 4- weeks intervention significant increase in right foot FPI-6 ($p<0.005$) was observed. There was no significant difference observed in weight distribution on forefoot and backfoot, and load response of both the feet.

PARAMETERS	GROUP B							
	PRE		POST					
	Mean ±SD		Mean ±SD		Paired t- value		P-value	
	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
FPI-6	8.00±1.080	10.15±1.725	7.85±1.281	7.62±1.502	1.477	6.881	0.1654	0.0000
FF%	53.08±10.743	49.00±13.398	53.08±6.626	46.38±13.556	0.0000	0.702	1.0000	0.4962
BF%	46.92±10.743	51.00±13.398	46.92±6.626	53.62±13.556	0.0000	0.702	1.0000	0.4962
Weight Distribution in %	46.92±10.364	53.08±10.364	51.31±7.631	48.69±7.631	1.446	1.446	0.1739	0.1739
Foot load response in %	15.20±2.012	15.09±2.092	14.04±1.146	14.41±1.562	2.086	1.130	0.0590	0.2805

FPI – Foot Posture Index, FF – Fore Foot, BF – Back Foot

Independent t-test

When both the groups were compared for post data, FPI-6, weight distribution on forefoot and backfoot, and load response of both the feet after 4- weeks intervention significant increase in both feet FPI-6 ($p<0.005$) was observed in group -A and only right foot showed significant increase in group-B. There was no significant difference observed in weight distribution on forefoot and backfoot, and load response of both the feet in both the groups.

PARAMETERS	GROUP A				GROUP B			
	POST				POST			
	Mean ±SD		P-value		Mean± SD		P- value	
	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
FPI-6	6.00± 1.080	6.69± 1.601	0.0001*	0.0000*	7.85± 1.281	7.62± 1.502	0.1654	0.0000*
FF%	56.23± 4.622	51.31± 9.437	0.9518	0.9882	53.08± 6.626	46.38±13.556	1.0000	0.4962
BF%	43.00± 5.196	48.69± 9.437	0.7830	0.9882	46.92± 6.626	53.62±13.556	1.0000	0.4962
Weight Distribution in %	49.15± 7.936	50.85± 7.936	0.1687	0.1687	51.31± 7.631	48.69±7.631	0.1739	0.1739
Foot load response in %	13.62± 1.178	11.15± 4.538	0.2499	0.0236	14.04± 1.146	11.81±4.417	0.0590	0.6185

FPI – Foot Posture Index, FF – Fore Foot, BF – Back Foot

Discussion

The aim of the present study was to compare the effects of core stability and foot intrinsic muscle training on foot posture, weight distribution during standing and load response in walking. The results showed that there was a significant change in the bilateral foot posture of the subjects in core stability training group, whereas no significant changes were observed in weight distribution and load response. In the foot intrinsic muscle training group, a significant change on foot posture was observed only in right foot and no significant changes were found in other parameters. The significant changes in the foot posture in the core stability group in accordance with the findings of Khamooshi and colleagues (2016) where they reported that the core stability exercise were effective in improving the foot arch in female children.

The core stability of the body helps in optimally distributing and transferring the force of the body by stabilizing the spinal column (Hill & Leiszler, 2011). The exercises targeting the core stability are effective in preserving body balance while performing dynamic moves (McCaskey, 2011). The results obtained in the present study explains that the core stability training effective in significantly improving the foot posture there only the foot intrinsic muscle training where no significant improvement in foot posture was found. The stability exercises of the trunk improve the balance and stability of the body (Marshall & Murphy, 2005). The previous studies found that the core stability training improved the balance, gait ability and foot pressure distribution (Kim, 2005; Yoon et al., 2015). In the present study, although changes in the weight distribution in standing and load response in walking was seen after 4 weeks of core stability training but the changes are not significant. This might be due to the lower duration of training which is four weeks, unlike that of eight weeks training in the study where they found significant changes (Yoon et al., 2015).

In this study the foot intrinsic muscle training produced a significant change in foot posture of right foot while no such change was observed in left foot posture, weight distribution and load response. The present study showed no statistically significant difference in FPI-6 after a 4-week foot intrinsic muscle training. However, study by Okamura et al., (2019) showed an improvement in FPI-6 after 8-week foot intrinsic muscle intervention. This study does not support the aforementioned study due to a shorter period of intervention. Banu Unver et al., (2019) showed that six weeks Short Foot Exercise was effective in decreasing Navicular Drop, enhancing foot posture, reducing foot pain, disability and increasing plantar force in midfoot. However, Navicular Drop, FPI, pain, disability, maximum plantar pressure did not change in six weeks. This study reveals that intrinsic muscle activity provides support to maintain MLA. Another study by Mulligan and cook demonstrated a decreased ND and increased arch height index in subjects with neutrally aligned foot after 4-weeks Short Foot Exercises.

Lee et al., (2016) and Panichawit et al., (2015) investigated the effects of ankle and intrinsic foot muscle strengthening on weight distribution in pronated foot. One of these studies revealed that weight distribution of medial heel reduced after six-week tibialis posterior and foot intrinsic muscle strengthening while the other demonstrated no significant differences in weight distribution after eight-week foot muscle training which is similar to the findings of this study. Escamilla-Martinez et al., 2013, evaluated the foot posture using the Foot Posture Index and weight distribution in 30 runners before and after a run at a moderate pace (3.3m/sec), for 60 minutes. They observed the tendency towards foot pronation. The total score in FPI-6 increased by 2 points in both feet, the weight distribution under the medial heel and the second metatarsal head increased, and the longitudinal arch decreased. However, the present study showed no statistically significant difference in FPI-6 after 4 weeks of intervention.

On comparing the effect of core stability training alone between foot intrinsic muscle training on foot posture we found a significant difference in foot posture. On comparing both core stability and foot intrinsic muscle with each other, we observed a greater improvement in the foot posture in core stability group. Since foot intrinsic muscle group had a lower improvement in foot posture. Further from our result we can conclude that core stability training is more effective than the foot intrinsic muscle group on foot posture. A limitation of this study was that we use a small sample size was taken. Also, the sample population was female. The present study was conducted in four weeks; thus, it is suggested that the future researches to be carried out on longer periods so that the results could be compared with the results obtained herein.

Conclusion

The findings of this study suggest that core stability training is more effective than the foot intrinsic muscle training on the foot posture after 4-week intervention. The future studies can be directed to explore the effectiveness of the core stability training and foot intrinsic muscle training on the foot posture with the larger sample size and longer period of intervention. Also, the rehabilitation programs can incorporate a combination of core stability and foot intrinsic muscle training rather than foot alone to obtain effective results and quicker recovery.

Suggestions for future research

From the analysis of results, discussion and conclusion drawn from the study, the following suggestions can be made for future studies:

- Study to observe the effects of the exercise program on the foot posture.
- Follow-up of subjects after the completion of the exercise program.
- Study with a larger sample size.
- Addition of a control group to compare results.

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Conflict of interest

The authors declare no conflict of interest.

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