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To determine the effects of Core activation and Intrinsic Foot Muscle Strengthening on Plantar Pressure Asymmetry among asymptomatic college going students

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Abstract

Background: Asymmetry in plantar pressure is associated with a number of musculoskeletal problems, which may impact posture and the effectiveness of movement. Improving the distribution of plantar pressure may be greatly aided by strengthening the foot and core muscles.

Objective: This study examines how students' plantar pressure asymmetry is affected by a program that strengthens their foot and core muscles.

Methods: A total of 11 students with plantar pressure asymmetry participated in an 4 week intervention program. Plantar pressure measurements were assessed using ohm 3000 plantar pressure analysis system and changes in asymmetry indices were analysed pre- and post-intervention.

Results: Reduced asymmetry indices, improved stability during locomotion and static stance, and a significant improvement in plantar pressure distribution were noted ($p < 0.05$).

Conclusion: Strengthening the muscles in the core and feet helps to improve postural control and gait efficiency by reducing plantar pressure asymmetry. These results highlight how crucial certain strengthening exercises are for young, active populations.

KEYWORDS:

Plantar pressure asymmetry, core activation, Intrinsic foot muscle strengthening

I. INTRODUCTION

Uneven pressure distribution over the foot during standing or walking is known as plantar pressure asymmetry. It is linked to a number of musculoskeletal conditions and can affect functional mobility and balance. It is crucial to address this asymmetry, especially in groups like students who frequently stand for extended periods of time or participate in physical activities.

The intrinsic foot muscles (IFMs) play a pivotal role in maintaining the medial longitudinal arch and ensuring proper foot biomechanics. Plantar pressure imbalances and foot abnormalities can result from weakness in these muscles. It has been demonstrated that strengthening the IFMs with specific exercises, like the "short foot" exercise, improves plantar pressure distribution and foot arch stability.[1]

Similarly, postural control and balance depend heavily on core muscles, which include the muscles of the abdomen, lower back, and pelvis. People with weak core muscles may favour one leg over the other, which can result in an unequal distribution of weight

and a higher risk of foot ailments like plantar fasciitis. By distributing weight more evenly, strengthening the core lowers the chance of overloading the foot structures.[2]

In order to correct plantar pressure asymmetry, recent physiotherapy research emphasises the significance of a complete strategy that incorporates strengthening the foot and core muscles. For example, a study found that strengthening the intrinsic foot muscles may help the foot core system adapt to the ever-changing demands of dynamic foot control by enhancing its functional variability.[3]

Despite these insights, there is a paucity of research specifically examining the combined effect of core and foot muscle strengthening on plantar pressure asymmetry in student populations. This study aims to fill this gap by investigating the impact of a targeted exercise program focusing on both core and foot muscles on plantar pressure distribution in students. Understanding the efficacy of such interventions could inform physiotherapy practices and preventive strategies to mitigate musculoskeletal issues associated with plantar pressure asymmetry.

RESEARCH METHODOLOGY

3.1Population and Sample

The study population comprised college students aged 18–25 years who exhibited plantar pressure asymmetry, assessed using the OHM-3000 plantar pressure analysis system. This population represents a subset of young, asymptomatic individuals with functional mobility, making them suitable for evaluating the effects of targeted exercise interventions on plantar pressure distribution.

A sample of 11 students was selected based on specific inclusion and exclusion criteria. Inclusion criteria required participants to exhibit measurable plantar pressure asymmetry, be free from musculoskeletal pain or injuries, and have the ability to perform exercises without significant limitations. Exclusion criteria eliminated individuals with recent lower limb injuries, chronic musculoskeletal disorders, or neurological conditions affecting balance. Ultimately, 9 participants completed the study after 2 dropouts, providing a focused cohort for evaluating the intervention's impact on plantar pressure asymmetry over the four-week program. This sample highlights the study's emphasis on understanding biomechanical adaptations within an active, asymptomatic young population

3.2 Data and Sources of Data

For this study, primary data was collected from students of Parul University, Vadodara, Gujarat, who met the inclusion criteria for plantar pressure asymmetry. The participants were assessed using the OHM-3000 plantar pressure analysis system to gather pre- and post-intervention measurements of maximum and average plantar pressure. These assessments served as the basis for analyzing the effects of the targeted core activation and intrinsic foot muscle strengthening program. The selection of students from Parul University ensured a focused and consistent data source, providing valuable insights into the study's objectives.

3.3 Theoretical framework

The variables of this study include both dependent and independent variables, carefully selected to evaluate the effects of core activation and intrinsic foot muscle strengthening exercises on plantar pressure asymmetry.

Dependent Variable

The dependent variable in this study is the **plantar pressure asymmetry index**, measured using the OHM-3000 plantar pressure analysis system. This index reflects the degree of uneven weight distribution between the left and right foot during static and dynamic activities. The reduction in plantar pressure asymmetry post-intervention indicates the effectiveness of the exercise program.

Independent Variables

The independent variables are the **core muscle activation** and **intrinsic foot muscle strengthening exercises**, implemented through a structured four-week intervention program. These exercises target specific muscles to improve postural control and redistribute plantar pressure. Core muscle exercises included planks, bridges, trunk rotations, and vertical crunches, while foot muscle exercises consisted of toe spreads, towel curls, great toe extensions, and reverse tandem walks.

The **core muscle activation** was designed to enhance stability of the trunk and pelvis, ensuring proper alignment of the lower limbs. Core strength is hypothesized to play a crucial role in maintaining an even distribution of plantar pressure during locomotion. Weak core muscles are known to increase the likelihood of asymmetrical loading and associated musculoskeletal issues.

The **intrinsic foot muscle strengthening** exercises focused on improving the stability of the medial longitudinal arch, which is vital for distributing pressure evenly across the plantar surface. These exercises improve foot biomechanics, reducing excessive loading on specific areas of the foot.

Mechanisms

Strengthening the core muscles is expected to enhance weight distribution, improving balance and gait efficiency. Similarly, intrinsic foot muscle strengthening stabilizes the arch, leading to more symmetrical plantar pressure. Together, these interventions aim to improve overall postural control and reduce asymmetry in plantar pressure.

This framework provides a systematic basis for analyzing how specific exercise interventions can address biomechanical imbalances, ultimately reducing plantar pressure asymmetry and enhancing functional mobility in asymptomatic individuals

Table – Core strengthening exercises

Exercises	Week 1	Week 2	Week 3	Week 4
Bridges with leg lifts	10 repetitions	15 repetitions	20 repetitions	25 repetitions
Static abdominals (Prone planks)	10 repetitions	15 repetitions	20 repetitions	25 repetitions
Trunk rotation	10 repetitions	15 repetitions	20 repetitions	25 repetitions
Full vertical crunches	10 repetitions	15 repetitions	20 repetitions	25 repetitions

30 seconds rest period between every 5 repetitions
Plank hold time varies with every individual

Table - Intrinsic Foot Muscle Strengthening

Exercises	Week 1	Week 2	Week 3	Week 4
Toes spread out	10 repetitions	15 repetitions	20 repetitions	25 repetitions
Towel curl exercises	10 repetitions	15 repetitions	20 repetitions	25 repetitions
Great toe extension	10 repetitions	15 repetitions	20 repetitions	25 repetitions
Reverse tandem walk	10 repetitions	15 repetitions	20 repetitions	25 repetitions

Participants were supervised to ensure proper form, and progressions in repetitions were adapted weekly as shown in the table.

3.4Statistical tools and econometric models

3.4.1 Descriptive Statistics

Descriptive statistics have been used to analyze the key variables of the study, including maximum pressure, average pressure, and plantar pressure asymmetry indices. The analysis involved calculating the mean, standard deviation, maximum, and minimum values to summarize the data distribution. These metrics provide insights into the variability and central tendency of plantar pressure values before and after the intervention.

The data's normal distribution was assessed to understand its consistency and sensitivity to variations. A normally distributed dataset indicates that the variables are stable and less susceptible to periodic fluctuations or outliers. In contrast, non-normal distribution might signify higher variability in plantar pressure values, potentially caused by factors such as gait anomalies or unequal loading patterns.

In this study, the OHM-3000 plantar pressure analysis system provided reliable measurements for maximum and average plantar pressures across both feet. Descriptive statistics highlighted the reduction in variability and pressure imbalances after the intervention, suggesting improved consistency and symmetry in plantar pressure distribution.

These statistical summaries serve as a foundation for evaluating the intervention's effectiveness, demonstrating how targeted exercises influence plantar pressure asymmetry and foot biomechanics. By ensuring data reliability through descriptive statistics, the study establishes a robust baseline for further inferential analyses.

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables

This study aimed to investigate the impact of core activation and intrinsic foot muscle strengthening on plantar pressure asymmetry in healthy college students. A total of nine participants, with a mean age of 20.8 years, were included in the study.

The study population consisted of nine healthy college students with a mean age of 20.8 years (range: 20-22 years). Following is the table showing the age and gender distribution.

Fig 4.1.1 - Age and Gender distribution of the Data

Sr. No.	Age	Gender
1.	20	Male
2.	21	Male
3.	22	Female
4.	20	Female
5.	20	Male
6.	21	Male
7.	21	Male
8.	22	Female
9.	21	Male

The study included 9 healthy college students with an age range of **20 to 22 years** and a mean age of approximately **20.9 years**. The majority of participants were **21 years old** (55.5%), followed by **20 years old** (33.3%), and **22 years old** (22.2%). Fig 3.2
In terms of gender distribution, **66.6%** of the participants were male (n=6), while **33.3%** were female (n=3). This sample highlights a predominance of male participants, with most belonging to the age group of 21 years.

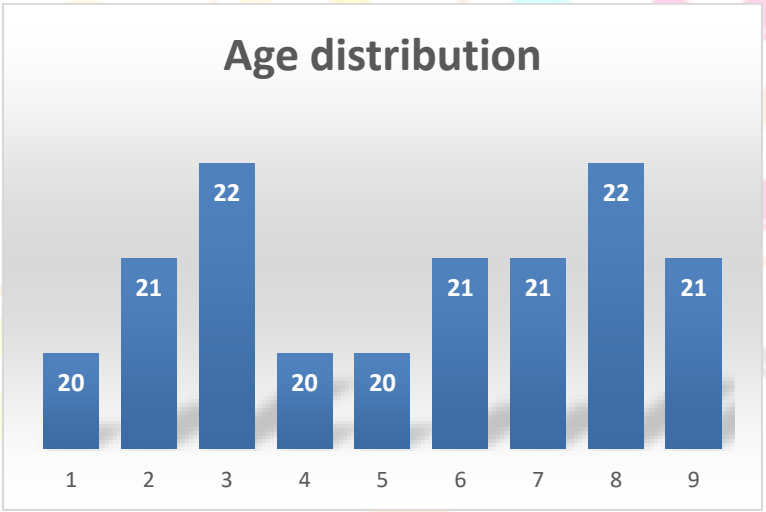

Fig 4.1.2 - Age distribution

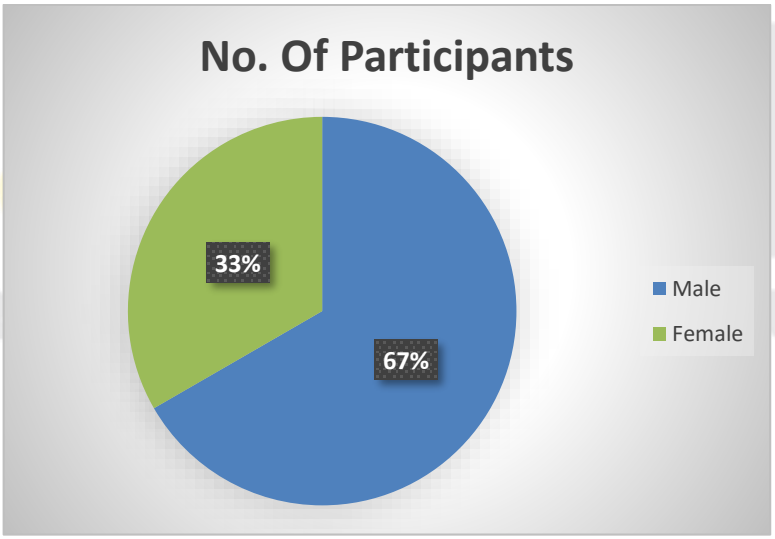

Fig 4.1.3 - Gender Distribution

Fig 4.1.4 - Descriptive Statistics for Maximum Pressure

Descriptive Statistics-Maximum Pressure		
Leg	**Mean**	**Std. Deviation**
Left_Pre	74.08	27.59
Left_Post	53.48	8.69
Right_Pre	89.36	25.43
Right_Post	71.31	19.73

The descriptive statistics for maximum pressure indicates a reduction in mean pressure and variability post-intervention.

For the left leg, the mean pressure decreased from **74.08** (SD = 27.59) pre-intervention to **53.48** (SD = 8.69) post-intervention, reflecting a notable improvement and reduced variability.

Similarly, the right leg showed a decrease in mean pressure from **89.36** (SD = 25.43) pre-intervention to **71.31** (SD = 19.73) post-intervention. The right leg consistently exhibited higher mean pressure than the left, suggesting possible asymmetry in loading patterns.

Overall, these findings indicate that the intervention effectively reduced maximum pressure and improved consistency in pressure distribution. (Fig 3.4)

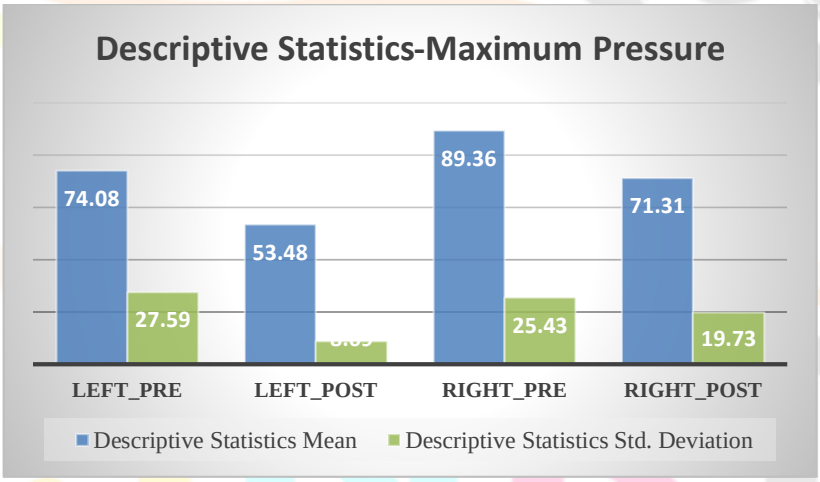

Fig 4.1.5 - Bar Diagram of Descriptive Statistics of Maximum Pressure

Fig 4.1.6 - Descriptive Statistics- Average Pressure

Descriptive Statistics-Average Pressure		
Leg	**Mean**	**Std. Deviation**
Left_Pre	18.00	2.54
Left_Post	15.63	2.90
Right_Pre	20.62	2.78

Right_Post	18.08	2.48

The descriptive statistics for average pressure in the left and right feet, pre- and post-intervention is that for the left foot, the mean average pressure decreased from 18.00 ± 2.54 kPa pre-intervention to **15.63 ± 2.90 kPa** post-intervention. (Fig 3.6)
Similarly, for the right foot, the mean average pressure reduced from **20.62 ± 2.78 kPa** pre-intervention to **18.08 ± 2.48 kPa** post-intervention.
These findings indicate an overall reduction in average plantar pressure following the intervention, suggesting improved pressure symmetry between both feet.

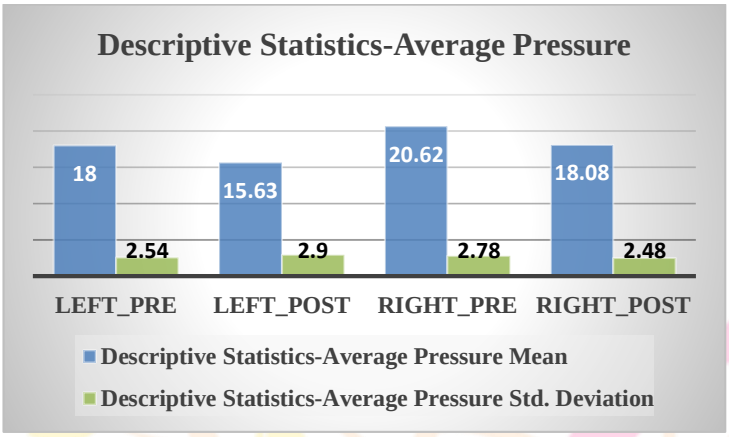

Fig 4.1.7 . Bar Diagram of Descriptive Statistics of Average Pressure

Fig 4.1.8 - Intragroup Comparison between Pre and Post Maximum Pressure

Paired Samples Test-Maximum Pressure								
	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Left_Pre - Left_Post	20.60	29.54	9.84	-2.10	43.31	2.09	8	.070
Right_Pre - Right_Post	18.05	15.14	5.04	6.41	29.69	3.57	8	.007

The paired samples test for maximum pressure reveals that the intervention led to a reduction in pressure for both legs, though statistical significance varied. For the left leg, the mean reduction was **20.60** (SD = 29.54), with a 95% confidence interval of **-2.10 to 43.31** and a p-value of **.070**, indicating that the change was not statistically significant.
In contrast, the right leg showed a mean reduction of **18.05** (SD = 15.14), with a 95% confidence interval of **6.41 to 29.69** and a p-value of **.007**, confirming a statistically significant improvement. These results suggest that while the intervention reduced pressure in both legs, the improvement was more consistent and significant in the right leg.

Fig 4.1.9 - Intragroup Comparison between Pre and Post Average Pressure

Paired Samples Test- Average Pressure								
	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**t**	**df**	**Sig. (2-tailed)**
				Lower	**Upper**			
Left_Pre - Left_Post	2.37	3.16	1.05	-.06	4.80	2.24	8	.05
Right_Pre - Right_Post	2.54	3.18	1.06	.09	4.99	2.40	8	.04

The paired samples test for average pressure showed a reduction in both the left and right feet following the intervention. For the left foot, the mean difference was 2.37 kPa (SD = 3.17), with a t-value of 2.24 and a p-value of 0.055. For the right foot, the mean difference was 2.55 kPa (SD = 3.18), with a t-value of 2.40 and a p-value of 0.043, which is statistically significant at the 5% level. The 95% confidence interval ranged from 0.10 to 4.99 kPa, indicating a significant reduction in average pressure post-intervention for the right foot.

Overall, while both feet showed reductions, the right foot demonstrated a significant improvement in average pressure, whereas the left foot exhibited a reduction that approached but did not reach statistical significance.

DISCUSSION:

This study investigated the effectiveness of a four-week program combining core activation and intrinsic foot muscle strengthening exercises to address plantar pressure asymmetry in a small sample of college students. The findings shed light on how targeted exercises can influence foot biomechanics and reduce pressure imbalances.

-Key Outcomes

The results revealed a significant decrease in plantar pressures after the intervention, although the degree of statistical significance varied between feet:

For maximum pressure, the left foot showed a substantial reduction in pressure values, though the change was not statistically significant ($p = 0.070$). In contrast, the right foot demonstrated a statistically significant reduction ($p = 0.007$), indicating a more consistent response to the intervention.

For average pressure, both feet experienced reductions, with the right foot showing statistically significant improvements ($p = 0.043$). The left foot's reduction approached statistical significance ($p = 0.055$), suggesting a trend towards improved pressure symmetry.

These results indicate that the intervention effectively reduced plantar pressure asymmetry, particularly in the right foot, which may have experienced higher loading patterns due to foot dominance or habitual asymmetry.

-Explaining the Results

The reduction in plantar pressures can likely be attributed to improvements in both core and intrinsic foot muscle strength. Enhanced muscle function may have promoted better stability in the foot arch and redistributed loading patterns, reducing the strain on specific areas.

The right foot consistently exhibited higher baseline pressures compared to the left, hinting at a possible dominance effect. Post-intervention, the right foot showed a more statistically significant response, potentially because of the greater initial imbalance, which allowed for more noticeable improvement. In contrast, the left foot showed a reduction in pressure values, but the statistical significance was weaker, possibly due to less initial asymmetry.

The standard deviation values for both feet decreased after the intervention, suggesting that the exercises also improved the consistency of pressure distribution. This consistency is critical for maintaining balance and reducing the risk of injuries during activities like walking or running.

-Practical Implications

The findings emphasize the value of incorporating core activation and intrinsic foot muscle strengthening exercises into physiotherapy programs aimed at improving plantar pressure asymmetry. Addressing these imbalances can have several benefits:

Better Posture and Stability: Core exercises help align the body and promote even weight distribution during static and dynamic activities.

Improved Foot Function: Strengthening intrinsic foot muscles stabilizes the medial arch, reducing overloading in specific areas of the foot.

Injury Prevention: By addressing asymmetry, such interventions may help prevent conditions like plantar fasciitis, overuse injuries, or instability.

This approach can be particularly beneficial for individuals prone to plantar pressure imbalances, such as athletes, people with flat feet, or those recovering from lower limb injuries.

-How These Findings Compare

These results align with existing research highlighting the benefits of targeted exercises for foot and core stability. For instance, studies on exercises like the "short foot" exercise have shown improvements in arch stability and pressure distribution, while core strengthening has been linked to better postural control. However, the relatively small scale of this study limits its direct comparison to larger, more comprehensive studies.

-Study Limitations

Sample Size: With only nine participants, the study's findings cannot be generalized to larger populations. A more extensive participant pool would enhance the reliability of these outcomes.

Duration: Four weeks of intervention may not be enough to observe the full benefits of the exercise program. Longer studies could provide insights into the sustainability of these improvements.

Gender Balance: The predominance of male participants may have influenced the results, given potential gender differences in foot biomechanics and response to interventions.

No Control Group: Without a control group, it is challenging to isolate the specific effects of the intervention compared to other possible factors.

-Future Research Directions

Future studies could explore the following:

Long-Term Effects: Examining whether the observed improvements persist over time.

Larger Samples: Including a more diverse population to ensure the findings are broadly applicable.
Comparative Studies: Comparing the effects of different intervention strategies, such as isolated foot strengthening versus combined approaches.

CONCLUSION:

This study assessed the impact of a four-week program combining core activation and intrinsic foot muscle strengthening exercises on plantar pressure asymmetry in healthy college students. The findings demonstrated a reduction in both maximum and average plantar pressures post-intervention, with significant improvements observed in the right foot. These results highlight the effectiveness of the exercise program in addressing asymmetrical loading patterns, likely by enhancing core stability and foot muscle strength. Improved muscle function contributed to better postural alignment and more even pressure distribution, emphasizing the program's potential to mitigate risks associated with plantar pressure imbalances, such as overuse injuries and postural instability.

While the intervention proved effective, the small sample size, short duration, and absence of a control group limit the generalizability of the results. Future studies with larger and more diverse populations, longer intervention periods, and comparative analysis are needed to confirm these findings and explore their broader applications. Despite these limitations, this study provides valuable evidence supporting the integration of targeted core and foot muscle exercises into physiotherapy protocols to enhance foot biomechanics and prevent musculoskeletal complications.

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