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Correlation Of Pronation Of Feet With Balance And Agility In Bharatnatyam Dancers.

A Correlational Study

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Abstract: Bharatnatyam is one of the ancient Indian classical dance form performed till today. In Bharatnatyam dance rhythmic stamping performed barefoot at varying speed may influence the height of medial longitudinal arch of the foot, causing pronation of feet. Balance, strength, co-ordination and agility are major demands for dancers. Any structural alteration in foot complex may have an impact on these components which might affect their performance and can cause foot injuries. Therefore, this study aims at finding correlation of pronation of feet with static and dynamic balance and agility.

Aim: To correlate pronation of feet with balance and agility in Bharatnatyam dancers.

Methodology: A correlational study was done in which 60 Bharatnatyam dancers with age group of 15 to 30 years, having 5 or more years of experience in Pune using purposive sampling as per inclusion and exclusion criteria. Navicular drop test was used to include dancers with flat foot. Three tests Stork stand test, Modified bass test and Hexagonal agility test were used to assess static balance, dynamic balance and agility respectively. Each test was explained and demonstrated and best results were noted. Data was collected, statistical analysis was done and results were tabulated.

Data Analysis and Result: Data analyzed through non-parametric test using Graphpad Prism version 10.2.1. In Stork stand test, 43% dancers had fair grade and 57% dancers had poor static balance. In modified bass test, 55% had good, 26.6% had moderate and 18.2 % had fair dynamic balance. In Hexagon Agility test clockwise direction, 68% had fair, 9% had good, 18% needs improvement and 5% had poor agility. In Hexagon Agility test anti-clockwise direction, 73% had fair, 10% had good, 9% needs improvement and 8% had poor agility. Study found that there is no correlation (p-value>0.05) between pronation of feet with dynamic balance, non-significant (p-value>0.05) weak negative correlation was found between pronation of feet with static balance of right side and agility and there is significant (p-value<0.05) weak negative correlation between pronation of feet with static balance of left side.

Conclusion: This study concluded that there is weak negative correlation between pronation of feet with static balance and there is no correlation between pronation of feet with dynamic balance and agility in Bharatnatyam dancers, but agility was fair to poor.

***Index Term*– Bharatnatyam dancers, Pronation of Feet, Flat foot, Static Balance, Dynamic Balance, Agility.**

I. INTRODUCTION

Indian Classical dance forms are one of the most diverse and oldest dance forms in the world.[1] In all these forms, dynamic postures range from shortening of the body, wherein knees are bent with flat feet (Aramandi), to lengthened postures characterized by knee extension and erect spine with shoulder elevation (Thaat).[1] Dance increases total body movement, which helps to improve circulatory, respiratory, skeletal, and muscular systems.[2] Indian classical dance involves a constant change of base of support from stance to low jumps and spins along with intricate footwork.[1] Graceful movement of torso, shifting from side to side and turning around the axis of the spine, challenges balance.[1]

Balance is the ability to maintain the centre of gravity of the body while minimizing the postural sway.[3] Balance is achieved through the coordination of multiple body systems- motor and sensory (visual, vestibular and somatosensory), cognition, task, environment, and other extrinsic factors.[3] Maintaining balance isn't a matter of staying rigid or in one place, but by making small shifts and adjustments continually.[3] Defining the balance skill scientist described the static balance as "the ability to keep a good

base and a steady position with less moves" and the dynamic balance as "the ability to execute a movement while keeping a stable position of the body.[4] It has been speculated that during rhythmic stamping of the feet (Tatkara) a dancer receives constant proprioceptive feedback from proprioceptors located in the plantar surface of the foot that relay information about the dance surface to higher centres, thereby activating the ankle and hip activity during body sway under static and dynamic conditions and effectively improving postural stability.[1] Long-term practice of any dance form is likely to be reflected in better postural control, as greater postural stability and muscle strength are known outcomes of dance training.[1]

Agility skill is defined in many ways most of them sound like the quick movement of the body in response to a stimulus as well as the ability to rapidly change the movement direction or the ability to start and stop quickly.[4] Motor skills that affect the agility are balance, coordination, explosive strength and flexibility.[4] Agility is not just about the speed with which an individual can change direction. Agility movements involves perceptual component like decision making and anticipation in all processes of dance.[4] Dancers requires strength, control and coordination while you move in all different directions, jump, twist and turn.[4]

Bharatanatyam dance incorporates a lot of one leg positional holds (for poses), spins (single-legged or double), quick movement transitions, changes in positions and stances ('araimandi', 'mandi', 'samam', lunge potions, full sit, side sits etc.).[3] Bharatanatyam dancers constantly change bodily stances, thus challenging balance.[3] Bharatnatyam involves 'TATTA ADAVU' means tapping of the foot against the floor, this is usually done in two positions one being ARAIMANDI which is half squatting with heels joined and feet pointing in opposite direction.[5] Other being MUZHUMANDI which is sitting on toes with knee bent, heels joined and hands behind the waist.[5]This demands dancers to achieve various positions which demands great flexibility and tremendous stress on the musculoskeletal system.[5] High demand placed on the foot of these dancer leads to injuries over period of time than spontaneous and this can be attributed to overuse injuries, fatigue of the foot muscles.[5]

Foot is the only the part of human body that provides interface between body and surface where the human stands on in an upright posture. It has two distinct characteristics that make human foot functionally unprecedented. As a weight bearing structure, it must be stable enough to bear body weight and resist the external forces, works like a catapult that exert force to push body up and forward during walking.[6] The ankle-foot complex is the third most common site of pain in Indian dancers.[7]
In Bharatnatyam dance rhythmic stamping performed barefoot at varying speeds may influence the height of medial longitudinal arch, causing structural alteration of ankle-foot complex.[7] The altered biomechanics could lead to abnormal rolling of ankle and landing to the foot.[5] In reduced medial arch the ankle roll laterally stressing the lateral aspect of the foot.[5] The other factors that could be responsible are the ground reaction forces, the dancing surface, hours of dancing years of dancing and whether the dancer is professional dancer or is pursuing it as a recreational activity.[5] This might have an effect on performance of the dancers and ankle and foot injuries. Thus, there is a need to assess foot posture and to understand the effect on dancing and prevent development of musculoskeletal injuries.

Balance, co-ordination and agility are major demands for Indian classical dancers. Impairment in any of these three components may have an impact on their routine. Agility is mainly checked in athletics rather than dancers.[4] There are not much studies on agility in Bharatnatyam dancers. Therefore this study would assess the correlation of pronated feet on static, dynamic balance and agility in Bharatnatyam dancers. By correlating the effect of foot posture on balance and agility we can train the dancers more efficiently to improve their balance and agility. Also, some of the positions or postures of Bharatnatyam dance form can be used for patient with pathology but with better cognition level as a dance therapy.

II. METHODOLOGY

This study was conducted on 60 Bharatnatyam Dancers with 5 or more years of experience, age 15-30 years old in Pune. Ethical committee clearance was obtained. Written consent was taken from the subjects who fulfill the inclusion and exclusion criteria. Testing procedure was explained and demonstrated to the subjects. Participants were given 2 trials for each test and best results were noted.

II.A INCLUSION CRITERIA

- Dancers >5yr of training[8]
- Age group 15-30 yr
- Pronated Foot with positive Navicular drop test

II.B EXCLUSION CRITERIA

- Any recent lower limb injury[3]
- Foot deformity other than pes planus

II.C OUTCOME MEASURE

1.Navicular Drop Test (NDT)
Participant's position : Sitting and Standing
Using semirigid ruler, height of the navicular tuberosity from the floor was measured in Weight Bearing (WB) and Non-Weight Bearing (NWB) positions.
Difference >10mm : Test is positive.

Fig. no.1: Performing Navicular drop test.

Fig no.2 & 3: NDT: 5mm in NWB position to 3mm in WB position.

2. Stork Stand Test

Patient position : Hands on hip and eyes open

Participant stands on dominant ball of the foot by raising the heel from the floor on signal start. Participants have to maintain the balance as long as possible, without moving the ball of the foot from its initial position.

As soon as the subject loses balance either by touching the heel to the floor or by the movement the foot's initial position, the time stops.

Interpretation	Score (seconds)
Excellent	>50
Good	40-50
Average	25-39
Fair	10-24
Poor	<10

Fig no.4: Participant performing Stork stand test.

3. Modified Bass Test

Course is marked as illustrated in diagram.

The subject begins by standing stationary on the right foot on the starting point square. The subject then hops to 1st tape mark with left foot on and immediately holds the position for 5 sec. Subject hops with alternate foot and holds the position. This continues till 10th tape mark.

Successful Landing :- 5 points
Holding the position :- 1 point/sec
No. of box covered :- 1point/box
Total :- 100 points

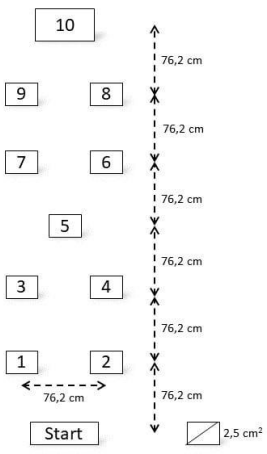


Fig no.5: Markings for Modified Bass Test

4. Hexagonal Agility Test

Hexagon of 24 inch side and 120^{o} angle

Subject stands in centre on hexagon with both the feet together facing the front line. On the command 'go', they jump ahead across the line, then back over the same line in centre. This pattern is continued for 3 revolutions. Test is performed both clockwise and anti-clockwise.

Seconds	Interpretation
5sec and below	Excellent
6-10 sec	Very Good
11-15 sec	Good
16-20 sec	Fair
21-25 sec	Needs Improvement
>25 sec	Poor

Interpretation of Hexagon Agility Test

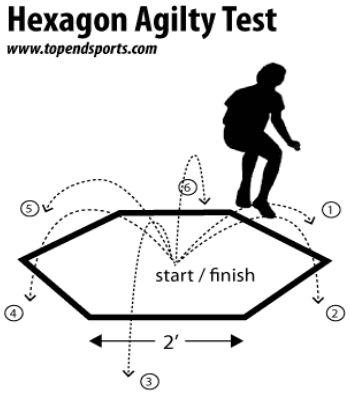
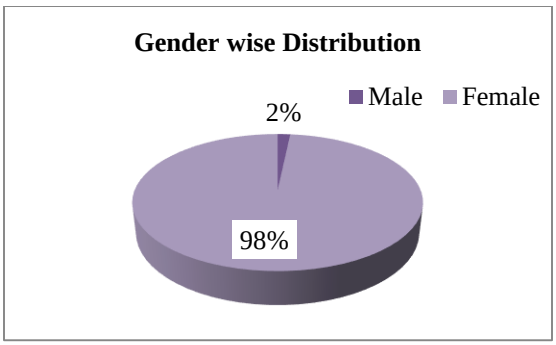


Fig no. 6 – Marking for Hexagon Agility Test

III. STATISTICAL ANALYSIS AND RESULT

Statistical analysis was performed using Graphpad Prism version 10.2.1 and Microsoft Excel 2007. Normality test (Shapiro Wilk) was applied to see the normality of the data. Non-parametric test Spearman's correlation coefficient was applied for data which was not normally distributed. Level of significance was considered to be 0.05.

Total of 60 participants with mean age 21 years with pronation of feet (Mean of right foot NDT: 12.38mm and left foot NDT: 3.44mm) were included.

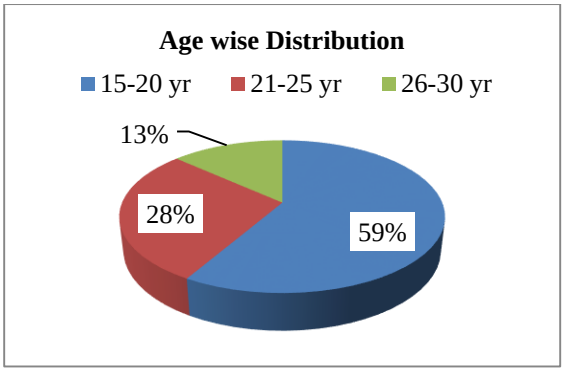


Graph: 01

	No. of subjects
Male	1
Female	59

Table: 01

Interpretation: Out of 60 participants 2% were male and 98% were female.



Graph: 02

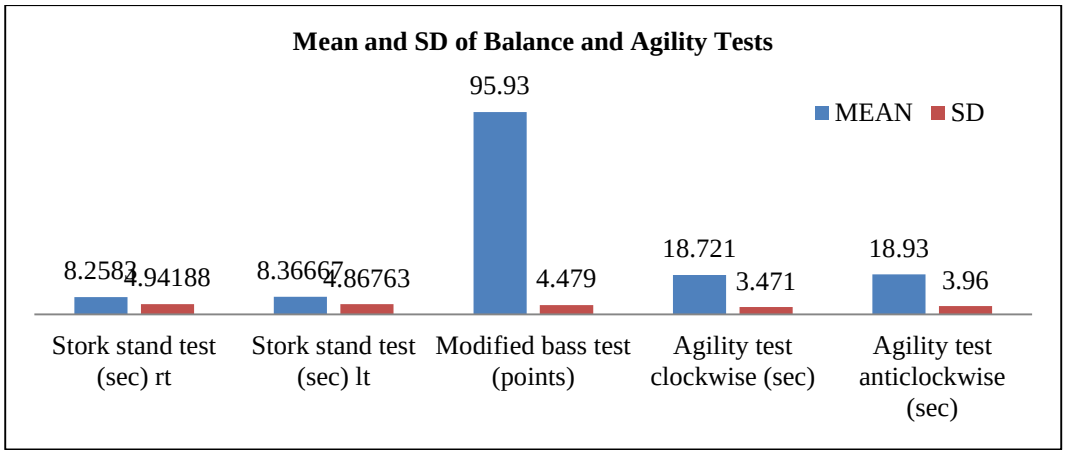
Age	No. of subjects
15-20 yr	35
21-25 yr	17
26-30 yr	8

Table: 02

Interpretation: Out of 60 subjects 59% were between 15 to 20 years, 28% were between 21 to 25 years and 13% were between 26 to 30 years.

	MEAN	SD
Stork stand test (sec)	8.675	4.94188
Modified bass test (points)	95.93	4.479
Agility test clockwise (sec)	18.721	3.471
Agility test anticlockwise (sec)	18.93	3.96

Table no. 03



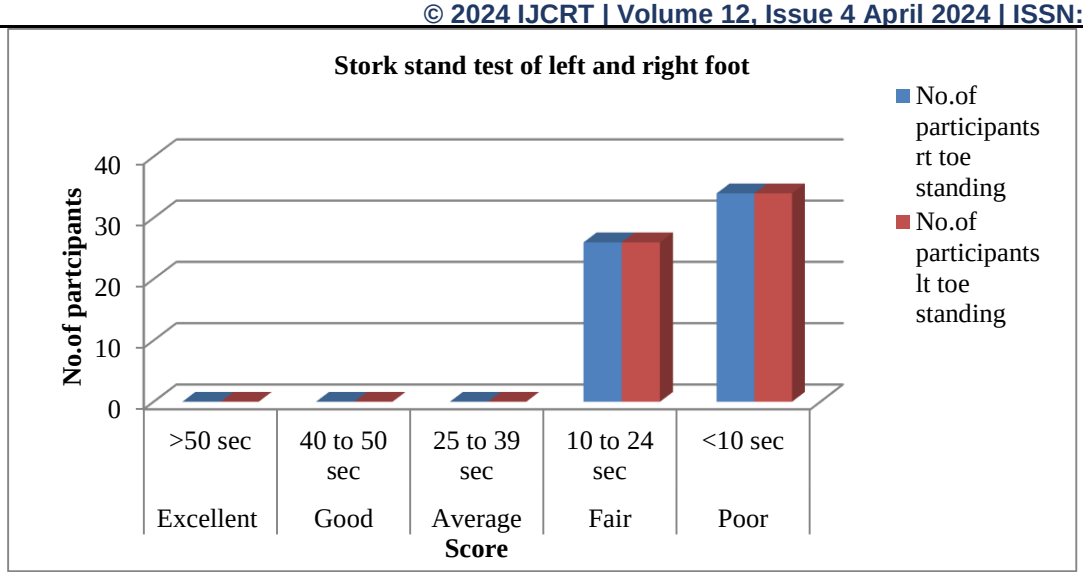
Graph no.: 03

Interpretation: Graph shows mean and SD of balance and agility tests.

STORK STAND TEST

Stork stand test interpretation	Score	No. of participants	
		Right Foot	Left foot
Excellent	>50 sec	0	0
Good	40 to 50 sec	0	0
Average	25 to 39 sec	0	0
Fair	10 to 24 sec	26	26
Poor	<10 sec	34	34

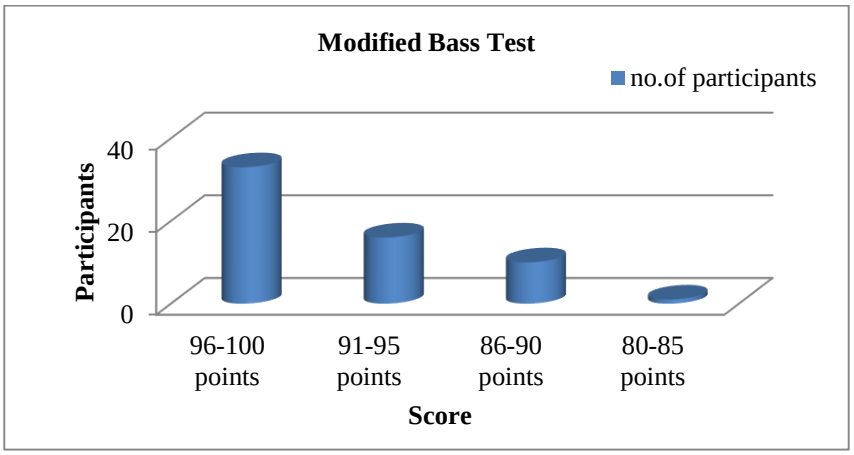
Table no.: 04



Graph no.: 04

Interpretation: Out of 60 subjects; 43% subjects have fair grade of static balance and 57% subjects have poor static balance.

MODIFIED BASS TEST



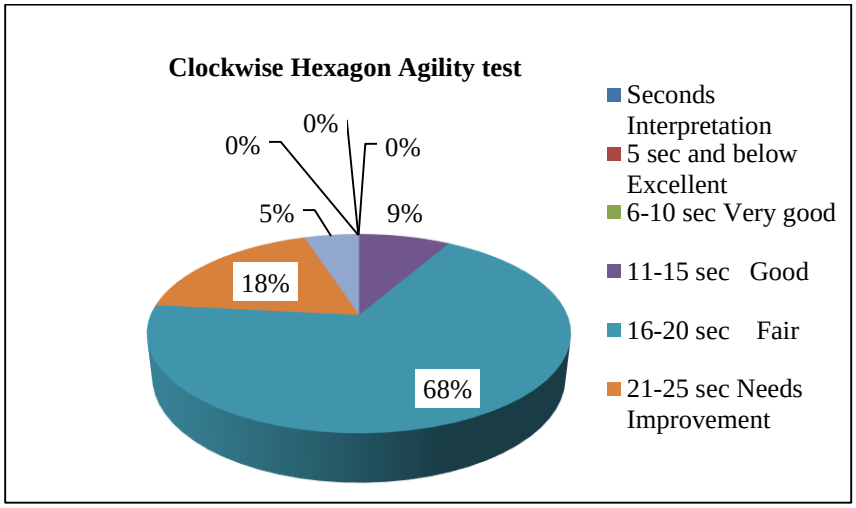
Graph: 05

MBT points	No. of participants	
96-100	33	55%
91-95	16	26.60%
86-90	10	16.60%
80-85	1	1.60%

Table no.: 05

Interpretation: Out of 60 subjects 55% had good dynamic balance, 26.6% had moderate dynamic balance 18.2% had fair dynamic balance.

HEXAGON AGILITY TEST- CLOCKWISE



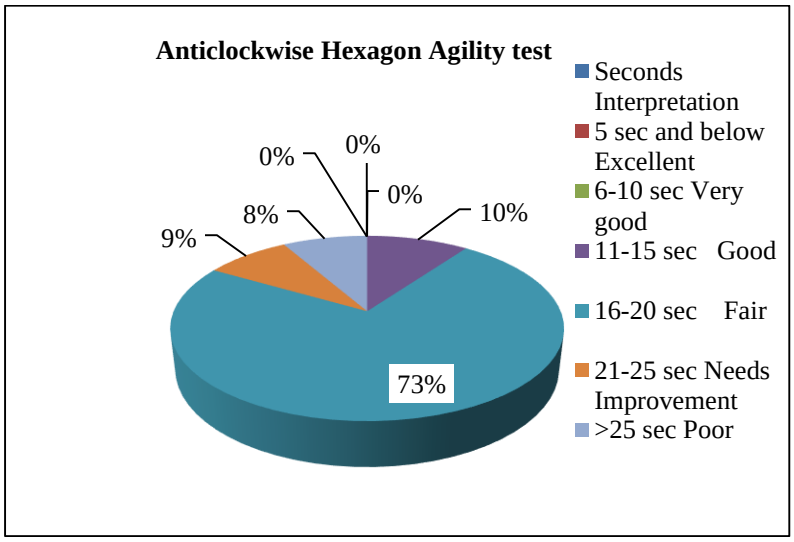
Graph: 06

Seconds	Interpretation	No. of subjects
5 sec and below	Excellent	0
6-10 sec	Very good	0
11-15 sec	Good	5
16-20 sec	Fair	41
21-25 sec	Needs Improvement	11
>25 sec	Poor	3

Table no.: 06

Interpretation: Out of 60 subjects in clockwise hexagon agility test 68% subjects have fair agility, 18% needs improvement, 9% subjects have good agility & 5% have poor agility.

HEXAGON AGILITY TEST- ANTICLOCKWISE



Graph: 07

Seconds	Interpretation	No. of subjects
5 sec and below	Excellent	0
6-10 sec	Very good	0
11-15 sec	Good	6
16-20 sec	Fair	44
21-25 sec	Needs Improvement	5
>25 sec	Poor	5

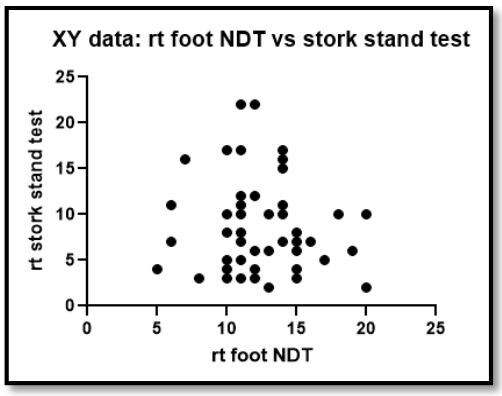
Table no.: 07

Interpretation: Out of 60 subjects in anticlockwise agility test 73% have Fair agility, 10% have good agility, 9% subjects needs improvement & 8% subjects have poor agility.

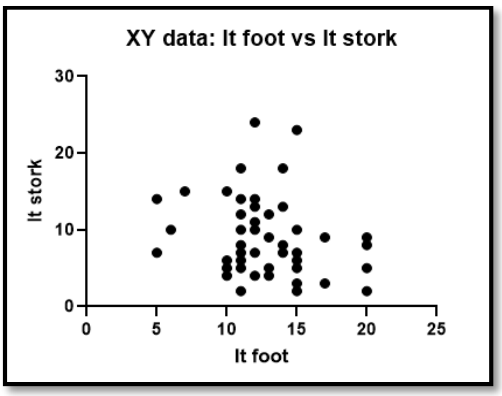
Correlation of Pronation of Feet with Stork Stand Test

	Stork stand test	
	Right foot pronation	Left foot pronation
SPEARMAN r	-0.07236	-0.3228
P-value	0.5827	0.0119

Table no.: 08



Graph: 08



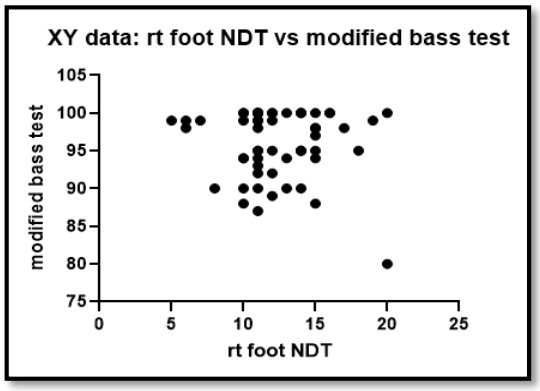
Graph: 09

Interpretation: Graph 8 shows that there is non-significant negative correlation between pronation of feet with static balance of right side (p-value>0.05). Graph 9 shows that there is significant negative correlation of pronation of feet with static balance (p-value<0.05).

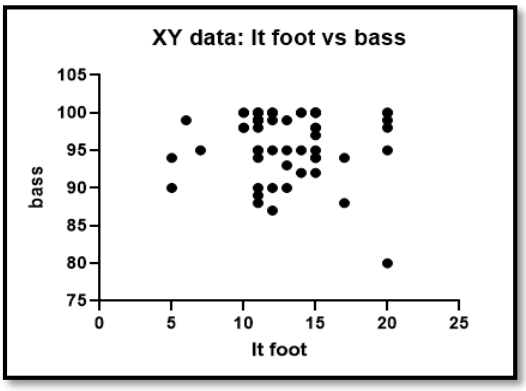
Correlation of Pronation of Feet with Modified Bass Test

	Modified bass test	
	Right foot pronation	Left foot pronation
SPEARMAN r	0.06055	0.01953
P-value	0.6458	0.8823

Table no.: 09



Graph: 10



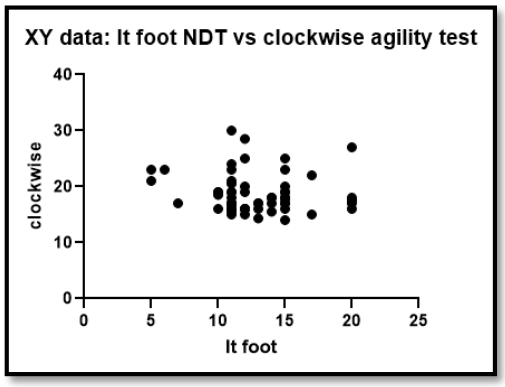
Graph: 11

Interpretation: Graph 10-11 shows that there is no significant correlation between pronation of feet with dynamic balance (p-value >0.05).

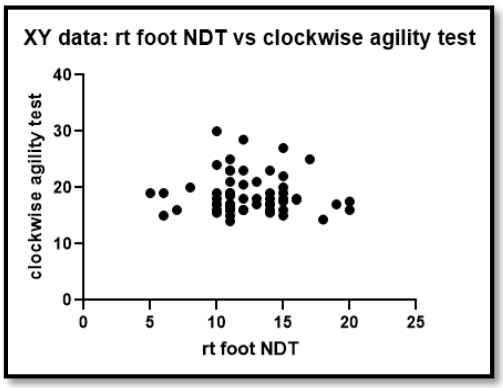
Correlation of Pronation of Feet with Hexagon Agility Test- Clockwise

	Hexagonal Agility test Clockwise	
	Right foot pronation	Left foot pronation
SPEARMAN r	-0.008791	-0.1198
P-value	0.9468	0.3618

Table no.: 10



Graph: 12



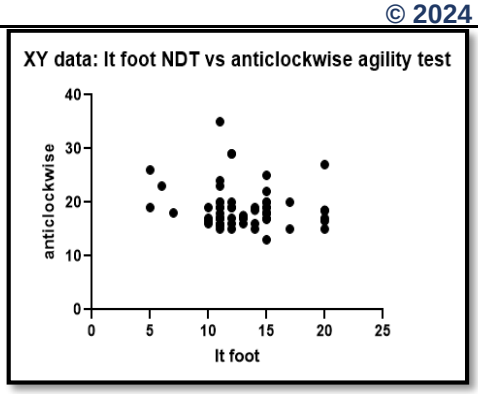
Graph: 13

Interpretation of Graph 12 & 13: There is non-significant weak negative correlation between pronation of feet with agility in clockwise direction (p-value >0.05).

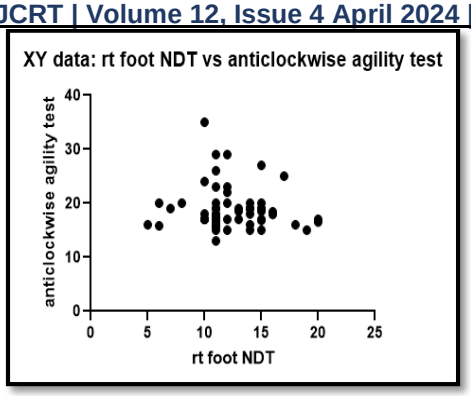
Correlation of Pronation of Feet with Hexagon Agility Test- Anti-clockwise

	Hexagonal Agility Test Anticlockwise	
	Right foot pronation	Left foot pronation
SPEARMAN r	-0.03897	-0.07248
P-value	0.7675	0.5821

Table no. : 11



Graph: 14



Graph: 15

Interpretation of Graph 14 & 15: Graph shows that there is non-significant weak negative correlation between pronation of feet and agility in anti-clockwise direction (p-value >0.05).

IV. DISCUSSION

As a dynamic art form, Bharatnatyam utilizes various poses for a depiction that have a unilateral stance, balancing on the toes in full squatting (Mandi pose), and quick changes in posture that require rapid weight shifts. Different steps require movements in and out of the base of support with different upper and lower limb movements, in turn causing continual shifts of the centre of gravity while dancing.[3]

This study aimed to correlate the effect of flat feet on balance and agility in Bharatnatyam dancers. Most of the bharatnatyam dancers had started Bharatnatyam practice at very young age between 6-7 years but, the full maturation of foot arch takes place at the age of 5-6 years. Therefore, excessive strain like loading on the foot with continuous foot tapping over the hard surface produces high level compressive force over the heel, tarsal and metatarsal joints, which may alter the integrity of foot arch structure thus leading to flat foot.[20] Posterior tibial tendon, abductor hallucis muscle, spring ligament and plantar fascia maintains the height of the navicular bone and medial arch of the foot. Dysfunction of any of these soft tissue lead to flat foot. The feet are located at the distal point of this chain and act as a base of support surface for kinematic chain. Based on this, it is believed that any small dynamic change in the feet affects the control of the body position.[21] The results of the present study showed that majority of the dancers had asymmetry in bilateral foot pronation. This can be because every individual has their dominant and preferred side in performing everyday activities, similarly dancers often have a dominant side in dance movements, which can affect how the feet pronate during various steps and sequences. According to the study of Amit Agarwal et al (2020), strength asymmetries for right and left ankle with weaker inverters in non dominant and strong invertors along with evertors of dominant limb may be the reason for pronation of feet more in non dominant foot.[24]

The main result of the present study showed that statistically pronation of right foot was having non-significant negative correlation with static balance (p-value >0.05) and on the other hand pronation of left foot was having significant negative correlation with static balance (p-value <0.05). Clinically static balance of Bharatnatyam dancers with flat feet was very poor. Maintenance of static posture is dependent upon the orientation and integrity of body segments, resting muscle tone and small magnitudes of muscle activation, visual, somatosensory and vestibular information. Reduced medial longitudinal arch affect the distribution of weight, shifts the centre of pressure on the foot and increases stress on midfoot and ankle. Lack of arch support in flat feet can lead to increased strain on the plantar fascia, achilles tendon and surrounding soft tissue can affect muscle activation patterns and joint stability which comprise balance and increase the risk of overuse injuries. Researchers Ziga et al (2021) concluded that small differences in static balance may exist between preferred and non preferred leg when the preference is determined based on manipulation task.[26] Therefore difference in static balance was seen in same individual for both the feet.

In Modified Bass Test, no significant correlation was found between pronation of feet with dynamic balance (p value >0.05). Dynamic movements allow for continuous adjustments in joint angles, muscle activation, and weight distribution, which may help reduce the effects of pronation of feet on balance. Individuals with flat feet may engage additional muscles or use different movement strategies during dynamic tasks to compensate for biomechanical limitations, thereby maintaining better balance compared to static standing. People suffering from the deformity of the flexible flatfoot due to the deficiency that has occurred in the proprioceptive system, the vestibular and vision systems are replacing the lack of sensory information of the sole to control the body position in a dynamic state.[20] According to the study done by Namrata Sojatra et al (2017), when the arch height is less, balance is better probably due to increased connection points of the foot with the ground, which in turn improves proprioception and balance.[27] Therefore, dynamic stability is not affected by pronation of the feet.

Also the research result showed that there is no significant correlation between pronation of feet with agility in Bharatnatyam dancers (p-value is >0.05). But clinically, subjects had fair agility. Pronation of the foot results in more toes being easily seen on the lateral side as the forefoot abducts. Depending on the types of foot posture the toe grip and toe strength also varies. The toes appear to play an important role in stabilizing the body when the centre of mass is displaced in standing, walking and running. This reduced grasping ability of the toes may contribute to loss of balance and falls.[28] The position of the forefoot and toes as a result of pronation or supination of the feet could thereby influence balance and agility.[28] In the study done by Shruti Kamble et al (2019) they found that static and dynamic balance was good but agility was good to fair in ballet dancers.[4] Therefore, foot posture, the force generation and muscular activity can be the reason to how foot alignment has a correlation with agility. It was also found that, dancers had weak and strong side while performing test in clockwise and anticlockwise direction. The dominant eye permits a priority treatment of the information on its visual field and thus allows faster reaction times on dominant side. The

supporting leg permits more reactive strength and a better motor control of push-off actions, thus allows turning faster on the opposite side.[4] Therefore each dancer had different scoring while performing hexagon agility test in both the directions.

From the observations it was seen that static balance was more affected by pronation of feet than dynamic balance and agility in Bharatnatyam dancers. It may be because flat feet can impact static balance due to altered foot alignment, weight distribution, and sensory feedback and the dynamic nature of activities allows for greater adaptability and compensation, reducing the perceived impact on dynamic balance compared to static standing tasks. Dancers with flat foot may rely more on proprioceptive feedback and muscle coordination to maintain balance and agility. But with progressing age overuse of plantar flexors, dorsiflexors, and foot invertors from repetitive foot postures on hard surface lead to ankle and foot pain. Therefore, all the Bharatnatyam dancers should be educated and trained about the foot problems and their prevention.

V. CONCLUSION

The study thereby concludes that there is weak negative correlation between pronation of feet with static balance and no correlation between pronation of feet with dynamic balance and agility in Bharatnatyam dancers, but agility was fair to poor.

VI. LIMITAION OF THE STUDY

Male population was not found.

Years of experience can be taken into consideration.

VII. FUTURE SCOPE OF THE STUDY

In future research can be done on male classical dancers.

VIII. CLINICAL IMPLICATION

Since the study concludes that there is decreased static balance in Bharatnatyam dancers with pronation of feet and fair agility, training for intrinsic muscle strengthening can be given to improve foot arch, static balance and agility.

IX. ACKNOWLEDGEMENT

I express my deep sense of gratitude to my project guide Dr. Gargi Bhalekar, professor of Neuro Physiotherapy department at LSFPEF's College of Physiotherapy, for her guidance, precious time and contributions made during the course of the study. I express my sincere thanks to all the subjects who participated and gave their full cooperation for the study.

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