

## Morphometric Analysis of Ankle and Foot in Classical Bharathanatyam Dancers Using Foot Posture Index (FPI) And Plantar Scan Images (PSI)

K.Vijayakumar<sup>1</sup>, Dr.S.Senthil kumar<sup>2</sup>,

<sup>1</sup>(Research scholar, Department of Anatomy, Sri Ramachandra University, Chennai, India)

<sup>2</sup>(Professor of Anatomy, Sri Ramachandra University, Chennai, India)

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**Abstract:** Ankle and foot problems not only affect the general population, it also affects the dancers and athletes community. Bharathanatyam is one of the ancient classical dances in India which is a part of natya shastra a bible of classical dances. A total of 50 female bharathanatyam dancers were participated in this study. Arches of the foot were analyzed using plantar scan images (PSI) and the ankle and foot deviation are analyzed using foot posture index (FPI) scale. The parameters Clarkes angle (CA), Staheli index (SI), Chippaux index (CI), and Arch index (AI) from PSI was measured using Autocad 2010 software. The study had shown a high significance that 70% of the bharathanatyam dancers had flattened arch foot, 20% high arched foot, and ankle foot deviations. Due to repetitive loading of the ankle and foot complex during dance practicing and performance from younger age, increases stress over the foot arches and lead to flattening of arch (Pes planus) and that causes the ankle and foot rolling medially "pronated foot" and laterally "supinated foot". Along with this body mass index (BMI) and physical activity plays a major role in the ankle and foot problems. Sedentary dancers had shown a high level of flatness of the foot arch along with pronated foot. The ankle and foot problems can be reduced by regular diagnosis and assessment, proper warm up and stretching techniques and foot wear modifications should be made to prevent deformities.

**Keywords:** Ankle, foot posture, flat foot, pronated foot, supinated foot, dancers foot.

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### I. Introduction/Background

Dance is one of the healthiest activity which enhances the quality of life [1]. Primarily dance is a form of unique art, and secondarily it is a form of physical activity. Dancers have proved to have a significant strength in jumping movements, enormous muscular endurance and maintaining a very low level of body fat [2]. Bharathanatyam is a very ancient famous classical dance, balasaraswathi described that bharathanatyam as natya yoga and it is based on the natya shastra which is the bible of classical Indian dance [3]. In bharathanatyam one of the step "tatta adavu" means tapping the foot against the floor according to the music, in "araimandi" (half sitting posture) "muzhumandi" (full sitting posture) with knees bend and placing the hands behind the waist with palm facing outward position [12]. Dance is also a one of the high risk physical activity and the incidence of musculo-skeletal problems are high in dancers, most of the bharathanatyam dancers begins their practice at a very younger age and that leads to negative impact over the musculo-skeletal system in dancers and athletes [1]. Professional dancers have a high competition in executing the difficult steps during performing a stage dance for that they have to liberate an enormous energy; as a consequence most of the dancers are suffering with overuse stress injuries over the joints and repetitive wear and tear lesions [5]. Musculoskeletal problems and pain are the major reason which affects the dancers participating in competitions thus making them loss of salary, temporary unemployed and poverty which leads to quit the dance career. About 60%-90% of dancers are affected with overuse injuries of their back and lower extremities [6]. Several degenerative modifications takes place during the aging process in the foot arch, and it is one of the structure which undergoes changes significantly. The football players, wrestlers, power lifters, gymnastics and handball players have shown lower foot arch indices [4]. Prolonged stress over the joints, increased body mass and laxity of ligaments can leads to flatness of foot [8]. Most of the sports and dance related injuries in the body are in concert with neglecting the warm up and flexibility training this leads the misalignment of the joint complex and causes the deformation [9]. Osteoporosis, amenorrhea, obesity and eating disorders affects the female dancers thus leading to a condition called "female athletic triad", similar to gymnasts dancers also starts their training at a early age during their growth and development period, status of an elite dancer can be achieved only by years of intense practice, dedication and perseverance. When compared the physical profile of the unconditioned individuals with dancers, the dancers had a high level of cardiac and muscular endurance, good flexibility and explosive power for performing dance movements [10]. The relation between the body structure, practicing and the occurrence of musculoskeletal problems were studied to only a little extent in bharathanatyam dancers. Most of the researches and publications was done on incidence and prevalence of injuries in ballet dancers and other modern dancers,

Hence there is a lack of knowledge concerning the biomechanical problems of ankle and foot in bharathanatyam dancers, therefore the aim of the study is to evaluate a relationship between the ankle and foot problems based on the body composition and physical activity in bharathanatyam dancers. So this study was conducted to analyze the foot posture index (FPI) and foot plantar scan (PSI) in dancers to evaluate the patho-mechanical effects of on ankle and foot.

## II. Study Design

This study includes Bharatanatyam dancers from Saraswathi Naatiya Palli, Chennai. An observational study was made on 50 professional female dancers between the age group of 18 -45 years who started dancing at the age of 4 – 7 years. This research excludes dancers with open wound, undergone foot surgery and with neurological disorders. All the participants were explained about the need and purpose of the study and were obtained by an informed consent and the study was approved by the Institutional Ethics Committee (IEC).The following information was collected and categorized based on the duration of dance in hours/day/month, based on this information the dancers were classified into three groups:

1. Group - A Regularly practicing : (1½ - 2 hours /session , 3-4 sessions /week )
2. Group - B Sporadically practicing : (1½ - 2 hours / session, 5-6 sessions /month)
3. Group - C Sedentary dancers : (1½ - 2 hours / session, once in a month or not even dance)

### Assessment tools:

Standard height and weight checking apparatus, self designed scanner equipment, computer and AutoCAD 2010 software.

## III. Methodology

### Measurements

Height (cm) and weight (kg) were measured using a standard apparatus for all the dancers in 3 groups and the BMI is calculated according to world health organization (WHO).

### Foot posture index (FPI) [7]

FPI was an inference from a search of literature providing the details of clinical assessment from more than 140 papers and it is an essential and best tool in analyzing the segments of forefoot, midfoot and hindfoot.

- Curves above and below lateral malleolus
- Palpation of talar head
- Inversion and eversion of calcaneus
- Bulging in the talo-navicular region
- Congruence and height of medial longitudinal arch
- Abduction and adduction of forefoot on rearfoot

### Reference values:

Normal = 0 to +5

Pronated = +6 to +9, highly pronated 10+

Supinated = -1 to -4, highly supinated -5 to -12

### Plantar scan image (PSI)

A self designed equipment made with wood, toughened glass and a document scanning machine, individuals stood over the equipment and the scanning procedure was done. The equipment can able to withstand upto 200kgs. The scanned plantar surface images are transferred to the computer and the parameters (Clarke's angle, Staheli index, Chippaux index, and arch index [11]) were measured using Autocad 2010 software.

## IV. Outcome Measures

**Arch (Clarke) index** (ABC angle) : Line A is the angle at the medial most margin of the forefoot and hindfoot, line B connects the medial side of the foot to the medial most part of the metatarsal region [25].

**Chippaux-Smirak index** ( $100 \cdot CD \setminus AB$ ) : The ratio between  $CD/AB$ , Line AB is the wider zone of forefoot and line CD is the narrowest width of the midfoot [25].

**Staheli index** ( $CD/EF$ ): The ratio between  $CD/EF$ , line CD is the narrowest width of the midfoot and line EF is the wider zone of the hindfoot [25].

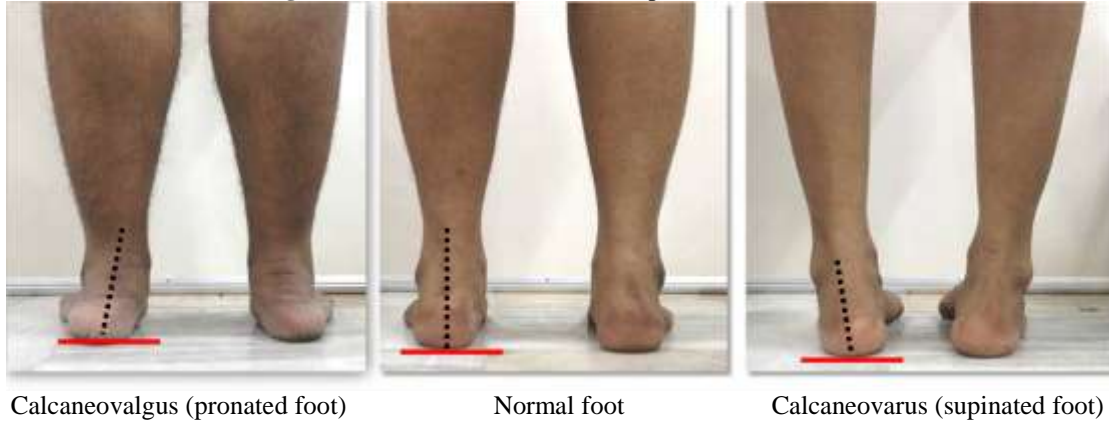
**Arch index**  $E/(D+E+F)$ : This is the ratio of the area of toeless footprint, a line joining the middle of the 2<sup>nd</sup> toe to the posterior most midpoint of the heel. Two perpendicular lines to this line divides the footprint into 3 equal parts [25].

**Table: 1** difference between normal foot and flat foot

Parameters	Normal range	Flat foot
Clarks index	31° - 45°	<31°
Chippaux-smirak index	25% - 45%	>50%
Staheli index	0.5 - 0.7	> 0.7
Arch index	0.21 - 0.28	>0.28

**V. Observation And Results**

**Fig: 1** Foot and ankle based on foot posture index (FPI)



Calcaneovalgus (pronated foot)

Normal foot

Calcaneovarus (supinated foot)

**Fig: 2** Foot arch from plantar scan image (PSI)



Flat arch (Pes planus)

Normal arch

High arch (Pes cavus)

**Table: 2** Mean and Standard deviation parameters of bharathanatyam dancers

	AGE (years)	WT (kgs)	HT (Cms)	BMI	FPI	PLANTAR SCAN IMAGES			
						CI	SI	CSI	AI
MEAN	29	70.6	161	27.4051	5.62	34.55	0.664	39.51	0.2696
STD DEVIATION	6.1	10.1	4.8	3.79	4.623	7.113	0.139	10.67	0.05

**Table: 3** Different types of arches of foot in bharathanatyam dancers

		BMI	FPI	CI	SI	CSI	AI
BMI	Pearson Correlation	1	.711**	-.629**	.597**	.591**	.607**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	50	50	50	50	50	50
FPI	Pearson Correlation	.711**	1	-.872**	.881**	.835**	.846**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	50	50	50	50	50	50
CI	Pearson Correlation	-.629**	-.872**	1	-.873**	-.785**	-.818**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	50	50	50	50	50	50
SI	Pearson Correlation	.597**	.881**	-.873**	1	.875**	.841**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	50	50	50	50	50	50
CSI	Pearson Correlation	.591**	.835**	-.785**	.875**	1	.869**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	50	50	50	50	50	50
AI	Pearson Correlation	.607**	.846**	-.818**	.841**	.869**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	50	50	50	50	50	50

Group – A \*\*Correlation is significant at the 0.09 level (2-tailed).

Group – B \*\*Correlation is significant at the 0.06 level (2-tailed).

Group – C \*\*Correlation is significant at the 0.04 level (2-tailed).

The observations were statistically analyzed using SPSS 20 version, for analyzing interval data between the dancers groups the ordinal FPI data were converted to Rasch transformed scores. Linear correlations were performed to identify the strength of the relationship between the FPI and PSI the entire dancers of all three groups. Correlation values for FPI and PSI in bharathanatyam dancers above 0.08 were considered as very strong correlation and between 0.03 – 0.06 were moderate, and values below 0.03 are considered to be a weak correlation [19]. In our study around 79% of the bharathanatyam dancers are affected with Pesplanus and 58% of population had calcaneovalgus (pes planus with pronated foot), 11% of the dancers with pescavus and 4% had calcaneovarus (pescavus with supinated foot).

## VI. Discussion

The study was designed to analyze the prevalence of ankle and foot problems among bharathanatyam dancers. As hypothesized the incidence of foot problems was high among the bharathanatyam dancers. Since many type of musculoskeletal injuries and problems including psychological factors affects the dancers, our study limits the focus mainly over the ankle and foot complex. In our study ankle and foot of 50 bharathanatyam dancers were studied it showed that 79% of the dancers in our study are affected. After discussing with bharathanatyam dance teachers, and choreographer we found a lot of complaints from students learning bharathanatyam regarding the foot and ankle pain during practicing in araimandi and muzhumandi postures, continuous tapping of the floor with foot leads to pain in the ankle and foot region. Araimandi and muzhumandi posture resembles the posture in western ballet, where there is a increased torsion in the tibia and also excessive rotational movement over the talocalcaneal joint [22] [23]. The arches of the foot are not present at birth, and it progress to develop during the age of 5-6 years. Gould et al examined the flattened longitudinal arches of children between 11- 14 months of age [13]. The etiological factors of lower extremity injuries in dancers are muscle weakness, improper footwear, high impact torsion during jumping movements and also some environmental factors. Around 68% of dancers are affected with ligament strain, fractures, flat arch foot and tendinitis [15]. Preston J. Smith studied the pathological effects among 1000 dancers and found that 64% of the individuals are affected by overuse injuries [20]. Happiness Anulika Aweto stated that around 86.1% of professional dancers had severe musculoskeletal pain and injuries in lagos state Nigeria, from that study he analyzed that the most commonly affected sites are the lowback, hip, knee, ankle and foot [21]. Most of the ballet dancers are affected with patellofemoral knee pain, and ligament injuries over the ankle and foot, and the break dancers are severely affected with low back pain known as “back syndrome” and “alopecia break dancia” which is caused by the head spin during break dance motions, spinous process fracture, cervical region injuries, and life threatening injuries like quadriplegia may occur, in a study with 354 break dancers showed that around 68.13% of the dancers are affected with spine problems. Aerobic dance is a form of health exercise but the practice may vary widely in duration and intensity, jumping movements bouncing and hopping involves a high-impact and repetitive stress over the spine and lower extremity around 75.9% of aerobic dancers are affected with low back and knee injuries. Literature have shown that all type of dances have its some own negative effects towards the musculoskeletal system [24] in our study bharathanatyam dancers shown a high level of flat foot (0.04) in the sedentary group – C, like the ballet dancers in our study also the bharathanatyam dancers have raised BMI and in overall 79% of the dancers are affected with ankle and foot problems.

### Interpretation

The basic and major dancing postures in bharathanatyam dance are



Fig : 3



Fig : 4



Fig : 5

1. Samapadam (fig: 3) – It is the most simple and basic posture in which the dancer has to tap the floor with foot which will be facing forwards with spine straight.
2. Araimandi (fig: 4) – In this posture the dancer has to tap the floor with foot in (half-squatting) position with the heels of both feet together, and toes of both foot pointed to the opposite direction, a diamond shape will be maintained between the thighs and legs for a best araimandi posture.
3. Muzhumandi (fig : 5) – In this posture the dancer sits down completely (full squatting) with both heel are joined as close as possible.

Most of the bharathanatyam dancers in our study have started their practice at a very young age between 4-7 years but, the full maturation of the foot arch takes place at the age of 5-6 years, therefore the high impact external forces during the bharathanatyam interferes with the growth and development of arches of the foot by changing the anatomical structure that may leads to flattening of the arches of foot. Therefore excessive strain like loading the foot with continuous foot tapping movements during dancing over the hard surface produces a high level of compressive force over the heel, tarsal and metatarsal joint complex may alter the integrity of the structure of the foot arch thus leading to flatness of foot. Individuals with raised BMI had a flattened longitudinal arches with a broader midfoot area associated with a pronation of the foot complex [16-18]. Hence the sedentary dancers with raised BMI had a collapsed foot arch structure. when the medial arch collapses the stability of the talonavicular complex is affected and this causes to roll over of the ankle complex medially thus leads to Calcaneovalgus (pronated foot). The raise in the medial arch leads to roll over of the ankle complex laterally thus leads to Calcaneovarus (supinated foot) [14]. Pronation and supination are the normal triplanar movement which occurs in the foot during walking and running. The term foot pronation refers to a combination of abduction of the forefoot, eversion of hindfoot and dorsiflexion. Supination refers to a combination of adduction of the hindfoot, forefoot inversion and plantarflexion. The normal range for pronation is 15<sup>o</sup>- 30<sup>o</sup> and the supination range is 45<sup>o</sup> - 60<sup>o</sup> excessive pronation and supination of the foot beyond the normal range is termed as pronated and supinated foot respectively [15].

## VII. Conclusion

Bharathanatyam is known for its cultural, graceful, purity, tenderness, expressive and sculpturesque poses which needs high levels of physical and psychological power during performance. Improper dancing techniques, muscular imbalance, overuse and hyper mobility of the joints yields the high prevalence of ankle and foot injuries in bharathanatyam dancers. Due to intensive practicing and training for hours together over the hard surface leads to pathomechanical changes in the foot arch structure. Musculoskeletal injuries and problems, eating disorders, obesity, psychological stress are the major problems seen in dancers; all these factors are interlinked to one another. The lack of the knowledge about the problems in bharathanatyam dancers need to be addressed, the incidence of problems in bharathanatyam dancers in under-reported. Early screening and assessment should be done to prevent or reduce the problems. Dancers need to do regular health assessment for their medical condition and safety precautions should be taken care before involving in any type of physical activity.

In conclusion, further research is to be needed to rule out the musculoskeletal problems of other anatomical regions like shoulders, hip, low back and knee among bharathanatyam dancers. Proper diagnosis, effective treatment and precautive measures should be taken to prevent the ankle and foot problems in dancers.

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