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Analysis of Lower Extremity Muscle Flexibility among Indian Classical Bharathnatyam Dancers

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Abstract**—**Musculoskeletal problems are common in high performance dance population. This study attempts to identify lower extremity muscle flexibility parameters prevailing among bharatanatyam dancers and analyze if there is any significant difference exist between normal and injured dancers in flexibility parameters. Four hundred and one female dancers and 17 male dancers were participated in this study. Flexibility parameters (hamstring tightness, hip internal and external rotation and tendoachilles in supine and sitting posture) were measured using goniometer. Results of our study it is evident that injured female bharathnatyam dancers had significantly ($p < 0.05$) high hamstring tightness on left side lower extremity compared to normal female dancers. The range of motion for left tendoachilles was significantly ($p < 0.05$) high for the normal female group when compared to injured dancers during supine lying posture. Majority of the injured dancers had high hamstring tightness that could be a possible reason for pain and MSDs.

Keywords**—**External rotation (ER), Internal rotation (IR), Musculoskeletal disorder (MSD), Range of motion (ROM)

I. Introduction

DANCE involves the body, emotion and mind: it is both a physical activity and a means of expression and communication. Dance is a conscious effort to create visual designs in space by continuously moving the body through a series of poses and pattern training. The movements must also be in symmetric and should follow a particular rhythm. Bharatanatyam, according to Balasaraswati, is a natya yoga that reveals spirituality through the physical and emotional body. It is the most popular of the Indian classical dance forms in South India, and the most ancient of all the classical Indian dance styles in India, which are all based on Natya Shastra, the Bible of the classical Indian dance.

There is a huge lacuna in the area of dance medicine in relation to Indian classical dance. Though practiced over centuries, Indian classical dance has undergone enormous change along with passage of time. Today it stands facing new challenges in order to meet the demands of the present world. Injuries have become a great threat to the dancers just as in the case of athletes and sports persons. The population of dancers is unique because they are not merely athletes whose work intensity is no less than one football player but also they are artists who constantly strive to perfect the subtle and aesthetic details in their performance. In relation to this transition of the dancing style we need to evaluate the consequential changes happening in the human body, thereby preventing further damages.

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Flexibility is considered as an essential element of normal biomechanical functioning in sport [1]. Lack of flexibility may lead to produce early muscle fatigue or alter the normal biomechanics of movement predisposing to injury. The literature report shows a number of associated benefits of flexibility including improved athletic performance, reduced injury risk, prevention or reduction of post exercise soreness and improved co-ordination [1] – [4]. Some studies have shown that decreased hamstring flexibility is a risk factor for the development of patellar tendinopathy and patellofemoral pain [5], [6].

Musculoskeletal problems occur more frequently among the classical ballet dancers [7]. It has been estimated that approximately 90% of professional dancers will suffer at least one musculoskeletal injury during their career. In a study performed by Hincapie, Morton, and Cassidy, it was discovered that the point prevalence of minor injury occurrence in a group of university and professional ballet, modern, and theatrical dancers was 74% [8]. A similar study from New Zealand determined the point prevalence of pain related to chronic injuries in professional ballet and modern dancers to be 48 % [9].

The demands placed on dancers' lower extremities leave them at risk of musculoskeletal injuries. Several literatures shows that 64 - 80% of ballet injuries happen in the lower extremity such as muscles strain and tear [10], about 64 - 75% of these injuries affect the muscles and soft tissues. Looking at lower extremities, dancers may expect a high numbers of foot and ankle injuries. The most common site for stress fractures in the dancer is the shafts of the 3 central metatarsals (63%), and stress fractures (7%) on anterior tibial cortex [11]. A five year analysis at Alvin Ailey American Dance Center identified 58% of all dancer injuries as occurring in the lower extremity with 34% occurring at the foot and ankle and 17% occurring in the low back and pelvis [12].

Araimandi is the most basic of bharathnatyam dance, which is similar to demiplie position used in the ballet. This dancing posture has a closed chain knee flexion with hip abduction and external rotation. To maintain the balance (stability), dancers need adequate flexibility in their lower extremity muscles. The term flexibility is the range of motion to joint through its normal plane of motion and static flexibility is the range of motion available to a joint or series of joints. The dynamic flexibility refers to the ease of movement within the obtainable range of motion [3].

Knee injuries are quite common in ballet dancers and are estimated to account for approximately 14% to 17% of the injuries seen in this patient population. Epidemiological studies of ballet dancers' show that 90% of professional and 63% of student dancers have a dance related injury in his/her career [13]. During professional training (age < 18 years) 36 % of the dancers have experienced chronic injuries. Dancers perceive injuries are partly caused by faulty technique and

body structure with 28% citing these factors as causative [14]. Vicki Negus (2005) reports that 93.1% of non traumatic injury and 41.4% of traumatic injury are occur for dancer. Extension of the pelvis or hyperlordosis of the lumbar spine are to be avoided. But, many dancers creating such a posture they are able to achieve greater external rotation [15].

Bennell et al, (1999) study reported that there was no significant increase in dorsiflexion range after giving periodical stretching exercise for 3 years. They also conclude that dorsiflexion range is largely fixed, and this would be consistent with it being limited by bone to bone apposition (tibiotalar) rather than soft tissue [16]. Ballet dancers require extreme degrees of hip external rotation (ER) and abduction to perform dance steps such as the demi plie. Performance of the demiplie, damage to the inert and contractile tissue allied with the knee joint lead to anterior knee pain. Ilio-tibial band (ITB) tightness may be a contributing factor to patellofemoral pain for dancers [17]. Hamstring injuries are common in sprinting, dancing, martial arts, hockey, and kicking sports such as soccer [18].

Overuse knee injuries occurring most often among female dancers include patellofemoral joint syndrome, patellar tendon disorders such as "Jumper's knee", iliotibial band syndrome (ITBS), and medial collateral ligament (MCL) sprain [19], [20]. A study by Reid addressed a few of these injuries, discovering distribution of knee problems to be about 50% patellar knee pain, 11% ITBS, and 10% ligamentous injury [20]. According to Reid, about 20% of patellar knee pain is due to chondromalacia patella in conjunction with patellofemoral joint syndrome. Patellofemoral joint syndrome in dancers is usually due to weakened medial and overactive lateral knee stabilizers that lead to biomechanical imbalances of the patellofemoral joint. In dancers who force turnout by overstretching medial musculature and internal rotators, this is an even more likely injury.

Forced lower extremity external rotation, ballet dancers have been found to have significantly increased iliotibial band (ITB) tightness when compared with other athletes. A tightened lateral component and excessive amounts of time spent in full lower extremity external rotation, many dancers begin to have patellofemoral issues arise as well. Increased tension laterally usually causes medial over-stretching or laxity in dancers. Like many people with patellofemoral issues, many dancers have been found to have weak vastus medialis obliquus muscles which fail to properly stabilize the patella [20].

There is lack of research work done specifically on Indian classical dancers and in their own context and it acts as a great impediment in providing a scientific recommendation to prevent injuries and offer the right treatment. Though dance medicine has branched out as a speciality under sports medicine, there is much to be studied in order to apply or translate it on the Indian classical dancers. The want of careful and in depth study and analysis of the Indian classical dancers with regard to their training and practice patterns is the main reason for this scenario. Since flexibility plays a pivotal role in the range of performance of a dancer, much need to be studied on this aspect of Indian classical dancers. The traditional practices of the dancers need to be carefully studied and juxtaposed with the modern system of physical training. This study attempts to identify the lower extremity MSD problem among south Indian dancers. The objective is to find the flexibility parameters between normal and injured south Indian bharathnatyam and analysis if there is any significant difference between normal and injured dancers in terms of flexibility parameters.

II. Methods and Materials

A. Participants

In this study, 401 female dancers (177 – Normal, 224 – Injured) and 17 male dancer (13 – Injured, 4 – Normal) were involved where all the participants who had no recent traumatic lesion due to other external cause were not taken. The average hours practiced per week was 11.57 hours and had total dancing experience of 7.7 years. The dancers has the following physical characteristics

- ✓ Age: 17.85 years (mean)
- ✓ Weight: 47.63 Kgs (mean)
- ✓ Height: 156.698 cms (mean)

B. Inclusion Criteria

- Indian classical dancers (both male and female)
- Minimum of four year of regular dance experience.
- Current dance activity must be 8 hours per week.
- Age between 13 - 35 years.

C. Exclusion Criteria

- Subjects with recent injury within 1 year.
- Subjects who have undergone any surgery in lower limb.
- Subjects with neurological deficit and medical problems.

III. Experimental Design and Protocols

All the dancers are given a questionnaire and the subjects who meet the criteria are selected as samples. All the data were done in the dance institute of the respective groups namely

1. Natyasankalpa, Chennai
2. Mahalakshmi dance school, Chennai
3. Ashram, Puduchery
4. Lavanya shankar's dance institute, Coimbatore
5. Kalamandalam, Kerala
6. Kalaikaviri, Trichy

The study was performed at different dance institutes and as per the guidelines of the hospital Ethics Committee of Ortho One Hospital for human volunteer research. All volunteers also read and signed an informed consent before participating. It is a retrospective, single session, observational and comparative study design.

Flexibility variables (joint angle) were measured using a 3m plastic goniometer of 360° movements with movable arm fixed at an axis of 6 inch as shown in fig 1. This device has been shown to be reliable (intra and inter rater reliability) for measuring knee extension, plantar flexion and dorsiflexion of

ankle, hip rotational movements. Cooperation was obtained from the dance institutes to interview and measure the flexibility. The standard warm up and flexibility training portion of several classes were observed and visually analyzed. Each dancer was given a questionnaire to know their age, years of experience and duration of dancing per week also those who had pain were asked to describe its quality, nature duration and associated disability. The range of motion was measured prior warm up and stretching in order to maintain uniform procedure.

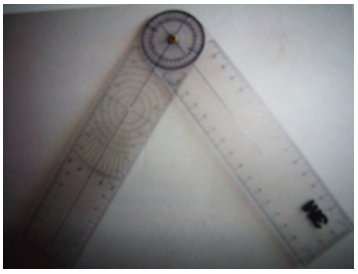

Fig. 1 Goniometer Instrument

A. Measurement of Flexibility Variables

Hamstring [21]: The subjects were positioned in supine lying such that the lower extremity to be measured was in 90° of hip flexion and full knee extension. The contralateral lower limb was strapped down to the table to control any accessory movements as shown in fig 2. The bony landmarks marked were greater trochanter of femur, lateral epicondyle and lateral malleoli using marker. Assistance taken to maintain the hip in 90° of flexion and subjects were asked to do knee extension actively and no verbal encouragement was given to the subjects.

Fig. 2 Method of Measuring Hamstring Flexibility

Tendoachilles [22]: Ankle dorsiflexion was measured in full knee extension as well as in 90° knee flexion in high sitting. The axis of the goniometer was placed over the lateral malleoli; the stationary arm placed vertically along the mid shaft of fibula and the movable arm was along the fifth metatarsal. It was ensured that the subjects did not actively dorsiflex the ankle during measurement. While dorsiflexing the ankle and heel was held such that the hind foot was pulled distally and the ankle lightly dorsiflexed with a magnitude of torque which caused a slight stiffening of tendoachilles.

Hip Internal and External Rotation (IR & ER) [15]: Passive range of motion in internal and external rotation for hip was measured in supine, with both knees flexed and extended over the end of treatment plinth. The supine position was chosen because of the better ability to stabilize the pelvis and lumbar spine. Hip was positioned in neutral and the thigh was secured to the plinth with a belt to avoid any active or passive hip movement other than ER and IR. The pelvis was secured to the plinth in a neutral position in all planes using another belt; padding was done for the lumbar spine and thigh shown in fig 3. The contralateral lower limb was abducted slightly to allow free movement of the tested limb, but it was not allowed to rest on the outside of the plinth. The axis of the goniometer was placed on the tibial tuberosity located by manual palpation. The moving arm of the goniometer was aligned along the longitudinal axis of the lower leg and the stationary arm was aligned vertically with the table leg. Passive hip internal and external rotation was measures at the point of the resistance.

Fig. 3 Hip Internal and External Rotation Measurement

Observational Study: Flat foot was a very common problem among the dancers. Flat foot, iliotibial band and quadriceps muscle tightness was quantified through observational method. Following techniques were used to quantifying the observational parameters.

Iliotibial Band Tightness (ITB) [23]: Measured in side lying, where hip is stabilized and the knee joined is extended, abducted and allowed to fall in internal rotation. If the leg falls in internal rotation it is considered normal, if the leg touched the midline it is mild tight. If the leg doesn't touch the midline then it is considered to be very tight.

Ellys Method: To find the quadriceps muscle tightness. Which the patient is prone lying position with knee is flexed and thigh is extended. Care is taken in order to avoid thigh abduction and pelvis lift. If the heel touches the buttock and the thigh is lifted freely it is considered to be free flexible. If the hip just touches the buttock and unable to lift the thigh then it is considered mild tight and if the heel also does not touch the buttock it is considered as very tight muscle.

Measure Flatfoot: In this measurement patient to stand in single leg and observe the medial arch position. If the foot musculature is weak then the medial arch collapses.

B. Statistical Analysis

The flexibility features such as hamstring, IR, ER measured using goniometer for normal and injured female dancer were statistically analyzed. Similarly, abnormal dancer gender wise comparison for flexibility parameters were also statistically analyzed. Normality test (Skewness–Kurtosis test) on the data-to-be-assessed yielded a positive result, and hence an unpaired students -t test (a parametric test) was performed on the features to evaluate the level of significant. SPSS 12.0 for Windows (SPSS Inc., Chicago) was used for the statistical calculations.

IV. Result

From the results it was evident that injured female bharathnatyam dancers have significantly ($p < 0.05$) high hamstring tightness at left side as of lower extremity compared to normal female dancer as shown in table I. Normal female dancers the range of motion (ROM) for left tendoachilles joint was significantly ($p < 0.05$) high when compared to injured dancers during supine lying posture as shown in fig 4.

TABLE I
Significant Statistical Results For Flexibility Parameters Among Indian Classical Bharathnatyam Dancers

	Left Hams	Left-IR	Right-TA - Sup	Left TA - Sup	Right TA -Sit
FM Normal Vs Abnormal	0.035	-	-	0.005	0.022
Abnormal M Vs FM	-	0.05	0.0001	0.001	-

Note: Shows results with significant p – values (< 0.05). FM – Female, M – Male, L. IR – Left hip internal rotation, R. TA / L. TA - Sup – Right / Left tendoachilles in supine posture, R. TA -Sit - Right tendoachilles in sitting posture

In sitting posture, right tendoachilles flexibility values were significantly high ($p < 0.05$) for normal female dancers as compared to injured dancers (Fig 4). It was observed that injured female dancers have low ROM at left and right tendoachilles, due to this most of dancers have severe musculoskeletal disorders (MSDs) in lower extremity region. Hip internal and external rotation of flexibility parameters (ROM) doesn't show any significant difference between normal and injured female dancers.

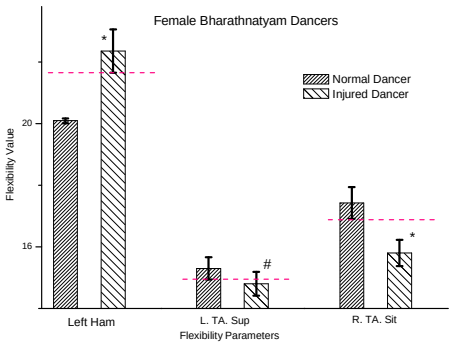

Fig. 4 Shows mean and one SEM of flexibility parameter between normal and injured female bharathnatyam dancers. Acronyms used are Left Ham – Left hamstring, L. TA. Sup – Left Tendo Achilles supine Lying Position, R. TA. Sup – Right Tendo Achilles Supine Lying Position. Note * $p < 0.05$, # $p < 0.1$

In gender wise comparison of injured dancers, it was found that left internal rotation (IR) was significantly ($p < 0.05$) high for injured female when compared to male injured person. During supine lying posture flexibility parameter of left and right tendoachilles joint ROM was significantly ($p < 0.05$) high for injured female dancers as compared to injured male as shown in fig 5.

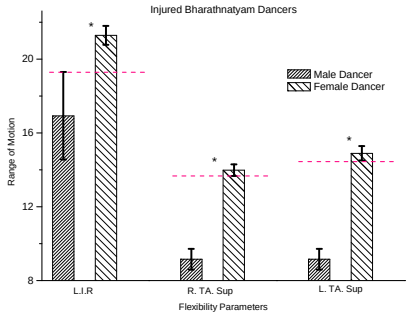

Fig. 5 Shows mean and one SEM of flexibility parameter between Male and Female injured bharathnatyam dancers. Acronyms used are L. I. R – Left Internal rotation, L. TA. Sup – Left Tendo Achilles supine Lying Position, R. TA. Sup – Right Tendo Achilles Supine Lying Position. Note * $p < 0.05$

There is no significant difference between male and female injured dancers for flexibility parameters such as hamstring, ROM during sitting position etc. Lower Extremity Muscle Flexibility problem arising from musculoskeletal disorders (MSDs) in injured and normal dancers have been well-documented among south Indian Bharatanatyam dancers.

A. Observational Result

Observation results show that a flat foot complaint was high for injured dancers as compared to normal. Iliotibial Band (ITB) muscle tightness was high and quadriceps muscle tightness was low in normal male and female dancer when compared to injured dancers as shown in table II & III. T his result concluded that injured dancers have flat foot and muscle tightness problem which may lead to MSD during his/her dancing carrier.

TABLE II
Observational Result For Flat Foot And Muscle Tightness Complaint For Female Dancers

	Normal Dancers		Injured Dancers	
	Right	Left	Right	Left
Pes planus (flat foot)	55	55	62	63
ITB Muscle Tightness	55	55	59	59
Quadriceps Muscle Tightness	74	78	101	101

TABLE III
OBSERVATIONAL RESULT FOR FLAT FOOT AND MUSCLE TIGHTNESS COMPLAINT FOR MALE DANCERS

	Normal Dancers		Injured Dancers	
	Right	Left	Right	Left
Pes planus (flat foot)	0	0	1	1
ITB Muscle Tightness	0	0	1	1
Quadriceps Muscle Tightness	1	1	9	9

V. DISCUSSION

Generally dancers had a routine warm up sessions and all the movements were dance specific posture including full squat (muzhumandi jumps) and full jumps, lateral lunges. Many dancers attend yoga sessions. The majority of body regions complaint that was found among the female bharathnatyam dancers was knee (48.8%), LBA (24%), ankle (12.4%), shoulder and neck (7.5%) and shin (2.6%), hip pain (0.8%) which was already found by a survey study [24]. Some of the previous study observed that knee injuries are more pronounced in ballet dancers. It was also evident that bharathnatyam dancers were significantly affected by knee injury during his/ her dance life. This could be due to the demi plie like position adopted in bharathnatyam which is known as aramandi.

The muscle flexibility measured among normal and injured dancers for hamstring muscle and we found that the tightness is greater which indicates that painful group had severe hamstring tightness. Johns (1993) studied the epidemiology of injuries associated with physical training among young men in the army and it has been concluded that athletes with tight muscles (low flexibility) are more susceptible to muscle strains [26]. But the left side tendoachilles was found to be tight among the normal subjects.

The right side TA was found tight in sitting position. Some study of professional ballet dancers found an average dorsiflexion deficit of 10° in both position. A tight gastroc-soleus complex in a ballet dancer contributes to hindfoot inversion during plie. This in turn may provoke the peroneal muscles to contract in an effort to evert the hindfoot and counteract the powerful gastroc-soleus. Such excess stresses on the foot and ankle musculature, combined with the decreased cushioning effect of equinus may contribute to the development of tendoachilles and peroneal tendonitis, metatarsal and fibular stress fracture and additional injuries more proximal in the leg [13]. This variation was not found in both the sides of the leg among bharathnatyam dancers and this variation can possible be due to balancing action of one leg on the other.

Also the majority of the dancers who were taken as subjects in this study were in their teen age (average age 17.9). According to Dalton [25] rapid bone growth during growth spurt can create tightness or muscle imbalance across the joints. A large group of sports participants are the adolescents. During rapid bone growth, such as the adolescent growth spurt, this creates tightness and inflexibility across the joints as the lengthening of the musculo-tendinous unit lags behind that of the bone itself. This inflexibility creates imbalance across the joints and increased stresses are applied to joint during sports or play activity. At this stage more stretching exercises can be advised in order to prevent the imbalance in muscle group.

Internal and external rotation angle did not show any significance between the normal and injured subjects. From the observations made we find that tightness were also found among the ITB and quadriceps muscle groups. Though it was not quantified due to lack of timing these observed values are noteworthy inorder to bring about further study. Pes planus or flatfoot was also found in larger population. The dancers reported that to produce resonance pressure along the medial foot was used and dancers felt resonance helps them to keep in pace with the rhythm. Though many senior dancers said resonance should be gentle and forced resonance is not recommended or needed. The risks of patellofemoral syndrome, shin splints, and stress fractures may also be increased by hyperpronation in ballet [27].

Gender-wise: Comparison between male and female dancers shows significant results in calf muscle in supine lying both the right and left side. All female dancers have range of motion greater than the male dancers. Internal rotation range of motion on the left side also shows significance. But this cannot be generalized since the male population was less compared to female dancers.

VI. CONCLUSION AND SUGGESTIONS

Injured dancer have high hamstring tightness that lead to pain and MSD. Tendoachilles range of motion was low in both positions i.e. supine lying and sitting for injured dancers. Though the result did not show much variation among the muscle group, good flexibility is a part of dancers well being. All the dancers are recommended to do regular yoga stretch (hatha yoga). The yoga, hatha yoga in particular is integral part of bharathnatyam. Over centuries this has been forgotten or ignored. It is note-worthy that every stretching exercises necessary for the body, for any athletic event or bharathnatyam is well documented in hatha yoga.

Every dance teacher must be aware of the anatomical variations that exist among the students. There is a large group of dancers who had complaints of pain, though the pain level was not severe enough to stop their dancing career. Lack of stretches and muscle tightness may lead to overuse injury or even produce early wear and tear changes in the weight bearing joints. The other possible internal and external factors are to be checked in-order to prevent injuries among this group.

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Dr. David V Rajan

Graduated from the most famous Christian Medical college, Vellore and obtained his Post Graduate degree from Madras medical college, Chennai, India. Presently, he is an exclusive Arthoscopic surgeon, practicing Orthopaedic Sports Medicine in Coimbatore and Chennai, India. He is the past President of the Indian Arthroscopic Society and the past Secretary of the Shoulder Society of India. He is the Honourable member of Arthposcopy association of North America. At present he is the president of sports medicine association of Tamilnadu, India. He has been a faculty member of many leading medical institutions in India for several courses in Artroscopic surgery. Inspite of his busy sports med practice he has lot of time in applying sports medicine skills in bharathnatyam. His ambition has been to apply sports med principles in bharathnatyam and thereby reduce the risk of injury to the dancers.

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