BASICS OF BHARATHANATYA AS A MEANS FOR IMPROVING BALANCE

Indira C P

Register Number: 12AUD009

A Dissertation Submitted in Part-Fulfilment of Final Year

Master of Science (Audiology)

University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE – 570006

MAY-2014

CERTIFICATE

This is to certify that this dissertation entitled **'Basics of Bharathanatya as a means for improving balance'** is a bonafide work submitted in part-fulfilment for the Degree of Master of Science (Audiology) of the student (Registration No.: 12AUD009). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

May, 2014

Dr. S. R. Savithri
Director
All India Institute of Speech and Hearing,
Manasagangothri, Mysore -570 006.

CERTIFICATE

This is to certify that this dissertation entitled **'Basics of Bharathanatya as a means for improving balance'** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Diploma or Degree.

Mysore

May, 2014

Dr.Sandeep M.
Guide
Reader in Audiology
All India Institute of Speech and Hearing
Manasagangothri, Mysore - 570 006.

DECLARATION

This is to certify that this dissertation entitled **'Basics of Bharathanatya as a means for improving balance'** is the result of my own study under the guidance of Dr. Sandeep M., Reader in Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

Mysore Register No.: 12AUD009

May, 2014.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

To My Years at AIISH…

Acknowledgement

"'Thank You' is the best prayer that anyone could say"

-Alice Walker

First and foremost, I would like to express my gratitude to my guide, Dr. Sandeep, for his constant support and guidance throughout the course of this study. This study would have remained a dream, had it not been for your guidance… Dear Sir, you are the coolest guide and a wonderful teacher!! I wish I could some time manage as many things as you do and still remain calm! ☺

Dear Sujit Sir… thank you very much for all the time you have spent for me clearing my doubts time after time… not even once have you refused to do so, even in the middle of your very busy schedule…. Thank you very much sir!!

To my darling subjects…. (Nayana, Reshli, Anagha, Divya, Farzeena, Rashmi, Priya, Jijina, Serooya, Salome, Anitha, Deepthy, Swathy, Merlin,Thanzeem, Preeti, Ashitha, Vindhya, Ansu, Jyoti, Liji …. And my gang :P) TONNES OF THANKS for the time you have spent for me ☺ I enjoyed being at the training sessions a lot ☺ ☺ . Hope it was enjoyable for you too….

Dear Litna! Thank you very very much for letting me use your photos in my dissertation ☺ hmmm.. Nice modelling ;)

Dear Animesh sir, you are the best teacher ever! The lessons from your introduction to audiology classes are the reason that I liked audiology in the first place… thank you!!

Dear Ajith Sir, Vijay Sir, Manjula Ma'm and Asha Ma'm, ….. Thank You for being amazing teachers ☺

To Nike Sir, Prashanth Sir and Sreekar Sir, thank you for being the lovely seniors who created interest in a first BSc's mind towards Audiology. Hope you continue teaching people around you all the while….

To Vasanthalakshmi mam… Thank you ma'm, for helping me understand statistics and specifically the statistics required to analyze the data of this particular study ☺

To Sandeep Sir's Family… thank you very much for all the hospitality ☺ To Ganapathy Sir, Nike Sir, Sharath Sir and Dhatri akka… You guys have a knack of making place of work fun to be in!! Thanks a lotttt !!!

From now on it is not 'Acknowledgements' as such… below written are a few lines from me to the most important people in my life.

All my BSc and MSc classmates :D Can't ever forget the years of fun, classes, trips, movies, learning, and fights :P Love you guys!!! And sorry if I have hurt anybody.. Just wanted to say it was never intentional…..

Irfanatha and Rakesh…!I am writing for you both together as you have many things in common… ;) I'll always feel bad for getting to know you both very late… you are two wonderful human beings and I just love your energy, sincerity, caring and talkative nature ☺ Love you both…

Divya and Shreyank ☺ You guys are wonderful friends to be with…. And you do justice to the proverb 'A friend in need is a friend indeed'.. ;) You are two juniors who have been with me for all the work, enjoyment and fun… And DARE YOU STOP the creative works you do… Alllllll the very best for your future ☺

Yo Yo Veepeeee ☺.. I love the spirit and enthusiasm you possess for anything you do…. I have had lovely times being with you and your group ☺ and working with you is always enjoyable, thanks to your sincerity and sense of responsibility… You have a lot of potential and talents… just dream and achieve whatever you want in life !!! Thank you for being a lovely sister :*

Abhi ☺… What can I say?? We got to know each other very late, true….. but you became part of my family within AIISH and outside AIISH in no time ☺ Stay the same friendly, cool, enthusiastic and pampered boy.. thank you for being a wonderful brother!

Sabarish…. I admire you for your energy, passion, love for people around you, and sincerity in the work you do, my friend!!! We seriously missed you in our BSc classes! All the best for your future☺…

Ramiz, Merin and Chithrechi….. You guys are the best!!! I just love your company….. thanks for being such amazing friends!!

Ansu, Sandhya, Neethu, Lappi, Pavi, and Supritha….. You guys ARE my family at AIISH !!! Can't ever forget the times we have spent together….. We have had times of fun, enjoyment, work, fear, sorrow and anger… and I shall remember those moments throughout my life….. Love you all !!

Ansu, my sweetheart! You are the most selfless in our class, and let me tell you, the cutest !! ☺. Love you loads!

Sandhya.. you ARE very beautiful ☺. You are an extremely strong person and I am sooo lucky to be your friend! I sincerely hope that you achieve anything and everything you want in life (including becoming a counsellor ;)). All the very best!

Neets… You are the best girl I've known!! Stay the same… Don't change --- anymore :P.. I can't ever forget all the time we have spent discussing our language, movies, stories and ideas….. I 'll always cherish your company!

Pavi…. You are a wonderful person and an excellent friend…… Never lose your enthusiasm in life and always encourage your crazy ideas… !!! Stay happy, my dear.. wherever you go!!

Supritha.. all credits to you for bringing dance back into my life ☺ … thanks for having been a wonderful friend… You are the first person to make me realize that I can be a good friend, and you are the first friend who promised never to leave me alone… it means a lot to me… thank you☺ and I know that you will be a famous dancer we shall all be proud of ☺. Good luck!! YOU ARE AWESOME !!!

To Lappi.. You must be the calmest person on this earth! I guess you are the only person who can manage a person like me with a soft touch, a sweet smile and an interesting story… Love all the hours we have spent discussing our weird ideas, and principles in life :D…

Kuttan ☺… Thank you for being a brother who was always available to fight with when bored and turn to for help in the times of need… ;) I always enjoy your presence and have always admired your work…. All the best for all your future ventures ☺

The persons responsible for my joining MSc: Achchan, Amma and Pavan

To Pavan ☺.. Hmm… Now it is my turn to return your words for me… ;) You are an incredible asset and I am lucky to have you in my life… and I mean it ☺… Thank you for staying with me through all my temper tantrums and mood swings… You are my source of strength and happiness…

To my dear parents… Thanks a lot for trusting in me and bringing me up with all the freedom to choose whatever I wanted in life… Had it not been for your support and guidance, I would not have been able to reach till here… Love you a lot, Amma, for all the trust and inspiration; for being the most beautiful woman in my life.. You literally taught me how to be a 'Good' person... Love you a lot, Achcha, for teaching me to stay unique, be frank, help others and work sincerely… For providing a hand to hold on to whenever I feel lost…. Love you loaadsss… ☺

Chapter 1

INTRODUCTION

One of the most important tasks of the human postural control system is that of balancing the body over a small base of support provided by the feet (Fay, 2007). Maintaining accurate balance is required not only while moving and shifting the body, but also while staying rigidly in one spot. This process of balance requires continuous adjustments and changes in the body posture to stay in the required equilibrium state (Schafer, 1987).

Balance is accurately maintained by the coordination of three systems: the vestibular system, the proprioceptive system and the visual system (Riemann, 2002; Lephart, 2002; Gaerlan, 2010; Kiefer, 2009; Gribble & Hertel, 2004). Of these three systems, the vestibular system is the sensor of gravity (Fay, 2007) and therefore provides most important input to the nervous system for postural control. The vestibular system, as a sensory system, provides the information about position and motion of the head, and the direction of gravity- to the central nervous system. The central nervous system integrates this information with the inputs from other sensory systems and constructs 'schema' or an 'internal representation' of the position and movement of the entire body and the surrounding environment (Fay, 2007).

The process of balance is a skill and can be improved with training. It has been shown in the literature that dancers exhibit extraordinary skill in balancing, wherein they are capable of maintaining balance in different difficult to maintain postures, as well as numerous movements which occur in a sequence (Batson, 2010; Crotts, Thompson, Nahom, Ryan, & Newton, 1996; Ambegaonkar, Caswell, Winchester, Shimokochi, Cortes, & Caswell, 2013). Dance training is reported to expand our body map's capabilities, promoting clarity and differentiation of body part relationships for skilful balance and coordination (Batson, 2010).

A couple of studies compared the balancing abilities of individuals with and without dance training (Crotts, Thompson, Nahom, Ryan, & Newton, 1996; Ambegaonkar, Caswell, Winchester, Shimokochi, Cortes, & Caswell, 2013). Crotts, et al. (1996) assessed the balance abilities of professional ballet dancers on select balance tests, which included one legged stance under six combinations of visual and support surface conditions. They found that dancers were capable of maintaining these stances for longer periods as compared to their age-matched controls in these tests. Based on these, the authors suggested that the balance strategies used by the dancers should be carefully analyzed to consider if these could be used to improve balance in injured dancers and in those individuals with balancing problems.

Ambegaonkar, et al. (2013) compared the balancing abilities between fifteen dancers and eighteen non-dancers on Balance Error Scoring System (BESS; error scores), the Star Excursion Balance Test (SEBT; per cent leg length), and the Modified Bass Test of Dynamic Balance. Results revealed that dancers had fewer errors in the BESS, and had greater SEBT reach distances in two directions- medial and posteromedial. They obtained similar BASS scores from both the groups. The findings of this study showed that dancers had greater skill in balancing than non-dancers, although not in all conditions.

Swathi and Sinha (2011) compared dancers and non-dancers on vestibular evoked myogenic potentials (VEMP), an objective test of vestibular pathway. They found a significant difference in VEMP amplitudes between the control group and dancers and concluded that dance practice would improve balance. Based on the findings, dance based therapy was recommended for individuals with balancing difficulties. These findings support the use of dance based therapies.

Numerous studies have also tried to find out the effectiveness of dance and, exercise programs based on dance for the improvement of balance and stability in the elderly population (Krampe, 2010; Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse, 2013; Krampe, Rantz, Dowell, Schamp, Skubic, & Abbott, 2010; Walls, 2010). All these studies have come to a conclusion that dance is a very useful means for improving their balance, stability, and have also shown that they have psychosocial benefits.

1.1 Justification for the Study

Literature reveals consensus in terms of the positive influence of dance on balance function. However, most of the reported studies are carried out on professional dancers who had undergone years of training in dance. Therefore it is not clear as to what minimum duration of training is necessary to evidence observable improvements in the ability to balance. If dance has to be recommended as means of improving balance in clinical population, the positive changes shall be noticeable within few weeks or atmost few months of the training.

In fewer studies where short-term dance-based therapy has been used (aerobics for 12 weeks-Crichton, 1997; Tango for 10 weeks-Corbin & Metal, 1983; and social dance-Cooper & Thomas, 2002), the whole body movements were involved which is difficult to be performed by individuals with balancing problems and therefore are questionable in their clinical utility.

Indian dance on the other hand has several advantages over the western dance. Indian dance and drama forms have several texts that are ancient and explain the rules for essential gestures and postures. Abhinayadarpanam, or 'Mirror of Gesture' is one such ancient treatise that deals with all essential gestures and postures used in Hindu dance and drama (Ghosh, 1957). It thus has a clear guideline for the different movements that have to be followed for training in dance. The exercises practiced by individuals during dance training include eye movements, whole body movements, neck movements, etc., carried out to a rhythm**.** Bharathanatyam, a dance form of South India is also a Hindu dance-form that uses Abhinayadarpana as a text book (Sathyanarayana & Gokak, 1968). The body movements in Abhinayadarpana are simpler, and in the initial stages involve only one body part, and therefore could be useful in individuals with balancing problems, if proved to be helpful.

Furthermore, from the previous literature it is not clear as to training in which body movement is more helpful in treating the balancing problems. That is, considering that the balance is attained through inputs from visual, vestibular and proprioceptive domains, different dance movements may show differential improvements. Training the individual body movements as detailed in Abhinayadarpanam may throw light into which among the three inputs systems is more receptive for training. Therefore the present study is taken up to derive the effect of short-term training on basics of Bharathanatyam on the balancing abilities and also to determine which body movement is more beneficial in the improving the balance system.

1.2 Objectives of the Study

Objectives of the present study are two folded. The primary objective was to investigate the effect of short-term training utilizing movements cited in

Abhinayadarpana (as used in Bharathanatyam) in improving balancing abilities of individuals. If the improvement is observed, the secondary objective was to compare which of the movements among the ones utilized for training (eye and head movements versus whole body movements and gaits) bring about greater improvement in balancing abilities.

Chapter 2

REVIEW OF LITERATURE

The present chapter provides details of the relevant literature in the mechanisms of body balance, balance disorders, dance as a means to improve body balance, Abhinayadarpana and its principles and tests to document the functions of body balance. For the clarity of understanding, the available literature is compiled under the following headings.

1. Anatomy and physiology of the balance system
2. Dysfunction of the balance system
3. Dance as a means to improve balance
4. Indian dance
5. Behavioural tests for balance assessment

2.1 Anatomy and Physiology of the Balance System

Maintenance of balance is a process achieved by the interaction of information obtained from coordinated and accurate functioning of the three sensory systems in the brain, namely- the vestibular system, proprioceptive system and visual system (Shaffer & Harrison, 2007). The relative weightage of the input provided by each of these sensory systems is differently explained by different authors. Allum and Pfaltz (1985) attributed vestibular information as the primary input for dynamic balance stability (65% contribution). But others (Colledge, Cantley, Peaston, Brash, Lewis, & Wilson, 1994; Hobeika, 1999; Merla & Spaulding, 1997; Poole, 1991; Uchiyama & Demura, 2009) showed proprioceptive and visual input as the primary inputs. While Colledge, et al. (1994) and Hobeika (1999) gave primary role to the proprioceptive information, and in its absence, to visual information in standing balance. However, the others (Merla & Spaulding, 1997; Poole, 1991; and Uchiyama & Demura, 2009) attribute the primary role in maintaining postural stability to visual system.

2.1.1 *Anatomy and Physiology of the Vestibular system*

The vestibular system is one among the three major sensory systems helping in the balance maintenance of the body. Knowledge of the anatomy and physiology of the vestibular system is necessary as this information shall provide an insight about the movements that can stimulate the system.

Vestibular system consists of peripheral and central parts. The peripheral vestibular system has three semicircular canals (Superior, Posterior & Inferior), the otolithic organs (utricle & saccule) and the vestibular nerve. Whereas, the central vestibular system consists of vestibular nuclei and the cerebellum (Hain & Helminski, 2007). The vestibular system enjoys 6 degrees of freedom by means of three semicircular canals and two otolithic organs. Angular acceleration (three planes) is monitored by three semicircular canals (SCCs), namely, the Lateral SCC, Superior SCC, and the Posterior SCC. Linear acceleration is sensed by the utricle in the medio-lateral and antero-posterior planes and by the saccule in the vertical plane (Hain & Helminski, 2007; Barber & Stockwell, 1976). Thus, the vestibular system is triggered by angular as well as linear movements of the head in space. Functionally the vestibular system mediates two important reflexes, the vestibulo-spinal reflex and vestibulo-ocular reflexes.

Vestibulo-spinal Reflex: Head acceleration is detected by the vestibular apparatus, and it results in an occulomotor response as well as a response from the upper and lower limbs of the body- the vestibulo spinal reflex. The vestibulo spinal reflex (VSR) functions to stabilize the body (Zee, 2007; Hain & Helminski, 2007). Whenever the head is tilted towards a side, the neural impulses are passed in such a manner that impulses are passed to the vestibular nuclei on both sides of the body. This is followed by impulses being sent to the medial and lateral vestibulo spinal tracts to the spinal cord. This in turn activates the extensor muscles on the side of the body towards which the tilt happened, and simultaneously activates the flexor muscles on the opposite side (Pompeiano & Allum, 1988). The VSR can be static, or dynamic, depending upon the timing involved.

Vestibulo-ocular Reflex: Stable vision during the movement of head is maintained by the Vestibulo ocular reflex (VOR). The semi-circular canals facilitate the maintenance of stable vision during angular motion, and the utricle and saccule, during the linear motion (Hain & Helminski, 2007).

Thus we can see that the vestibular system gets stimulated by angular as well as linear movements of the body and that these movements in turn evoke responses from the system sending impulses to the eyes, as well as muscles of the body. Moreover, literature evidences the phenomenon of ‘compensation’ in individuals with disorders of the vestibular system. VOR is the major contributor making this possible (Zee, 2007).

Studies by Fetter & Zee (1989) and Zee, Fetter, & Proctor (1988) on monkeys with induced unilateral loss of vestibular function with and without the occipital lobe demonstrated that VOR was capable of compensating for the loss, in spite of the loss of vision (Zee, 2007).

2.1.2 *Anatomy and Physiology of the Visual System*

Visual input to the balancing system contributes information regarding the direction of a moving object in the environment, which is an external phenomenon (Guerraz & Day, 2008). Steady gaze/vision during a movement is necessary for maintenance of balance, which is achieved by holding an image on the foveal region of the retina. An inability to achieve this would result in an illusory movement of the visual environment (Berencsi, Ishihara, & Inanaka, 2005).

Two kinds of eye movements that help an individual to maintain the image of the visual environment in a stable way on the retina (the fovea, which is the most sensitive part on the retina, to be more precise) are the vestibulo-ocular reflexes and the visually mediated reflexes. Movements of the head are sensed by the mechanoreceptors within the labyrinth and these mediate the vestibulo-ocular reflexes, as already seen in the anatomy of the vestibular system (section 2.1.1).

The visually mediated reflexes are dependent upon the ability of the brain to detect the speed at which an image is drifting off from the fovea. These are optokinetic and smooth pursuit tracking movements (Walls, 1962; Carpenter, 1988). These reflexes, together maintain the image stabilized at the fovea, regardless of the head movements. (Walls, 1962; Carpenter, 1988).

The intention of discussing the eye movements in this section is to understand how it helps in maintaining balance. Movement of the body is detected by the CNS by use of a static reference. This external reference, such as a wall is used by the visual system considering the movement of the body against that of this external reference (Merla & Spaulding, 1997). A sensory system assists an individual in their perception of the environment (afferent) as well as movements of their own eyes, body or head (efferent) (Kapuola & Thuan, 2006). The former is formed by the focal system and the ambient system which are two visual systems. The focal system helps one focus on an object in the environment. The ambient system, which is also known as peripheral vision is helpful in the detection of one's own movement as well as movement of the visual scene (Guerraz & Bronstein, 2008).

2.1.3 *Anatomy and Physiology of the Proprioceptive System*

The third input to the brain facilitating balance maintenance of the body comes from proprioception. It is the collective neural input to the Central Nervous System (CNS) from specialized nerve endings called mechanoreceptors, which are located in the joint, capsules, ligaments, muscles, tendons, and skin (Carpenter, Blasier, & Pellizzon, 1998; Ribeiro & Oliveira, 2007; Voight, Hardin, Blackburn, Tippett, & Canner, 1996).

Proprioception helps the brain perceive information about tension/force, body/joint movement, and relative position of limb (Riemann & Lephart, 2002). The specialized nerve endings, the 'mechanoreceptors' are located in the muscle, tendon, fascia, joint capsule, ligament and skin. These are the sensory neurons responsible for the perception of proprioceptive information (Carpenter, et al., 1998; Voight, et al., 1996). Of these mechanoreceptors, the muscle receptors (muscle spindles) are the ones that provide the primary information (Proske, 2005; 2006) to the CNS. They convert the mechanical events that are sensed by them at their host tissues into frequency-modulated neural signals and present it to the CNS (Grigg, 1994). Thus, it can be inferred that a movement of the body is sensed by the brain through impulses delivered by the sense of proprioception.

The inputs from the mechanoreceptors at different locations are utilized at three different levels in the CNS- at the spinal level, at the brainstem, and at the higher levels of the CNS such as the cerebral cortex and cerebellum which helps in bringing about voluntary movements (Myers & Lephart, 2000). Inputs from the mechanoreceptors are integrated at these levels of the CNS and errors in velocity and timing are avoided during the execution of the movement (Batson, 2009).

There is strong evidence that projects the importance of proprioception for maintaining normal body posture, controlling balance and posture, generating smooth and coordinated movements. It also influences motor learning and relearning (Ghez, Gordon, & Ghilardi, 1995; Ghez & Sainburg, 1995). These studies show that lack of proprioception results in delayed onset of movements and impaired movement trajectories. Thus proprioceptive input is seen to be necessary in learning as well as in coordination of movements.

Studies by Crotts, et al. (1996) and Ambegaonkar (2013) has reported better balancing skills in individuals trained in dance. Learning dance involves getting training in maintaining the static postures as well as in performing dynamic movements. Achieving the ability to do these tasks involves coordination of different body parts, and in effect, movement, or positioning of different body parts in a particular manner. Movements involving the head, neck and eyes may be expected to stimulate the vestibular and visual systems, whereas movements of the full body, like walking or jumping may be expected to stimulate the sense of proprioception also to a greater extent.

2.2 Dysfunction of the Balance System

Lesions within the central or peripheral balancing systems can result in dizziness, vertigo and impaired balance (McClure, 1986). These lesions can cause static disturbances or dynamic disturbances (Zee, 2007).

Individuals who exhibit balance problems due to vestibular/otological causes fall into two main categories: those that have specific diagnoses, like Menie`re's disease and benign positional paroxysmal vertigo, and those that have peripheral labyrinthine pathology, and no spontaneous vestibular compensation has taken place. Disorders that belong to the first category have standard established treatment regimens (Luxon, 2004). Management of dysfunction of the balance system can have 5 major wings:

- General medical evaluation, along with treatment of the associated conditions
- Pharmacological intervention
- Vestibular rehabilitation
- Psychological intervention
- Surgery

The central vestibular system is however characteristically plastic, meaning that it is receptive to changes – it can learn new behaviours. Vestibular pathologies result in sensory conflicts which lead to active neuronal changes in the cerebellum and brainstem (Shepard & Telian, 1995). Since the balance system is capable of learning new behaviours, there occurs a speedy recovery from the symptoms following peripheral vestibular pathology. This process is referred to as 'vestibular compensation' (Luxon, 2004). Vestibular compensation occurs as the result of adaptation/habituation, which in turn leads to recalibration of gain of the vestibular reflexes, substitution of sensory inputs as well as motor responses, and also alteration of strategies used for maintaining balance (Luxon, 2004).

The plan of vestibular rehabilitation therapy (VRT) is based on this compensation process, and these programs aim at taking advantage of the innate plasticity of the balance system to improve the compensation process that is natural (Shepard, Telian & Smith-Wheelock, 1990). The very first VRT was developed by Cawthorne and Cooksey, who in their studies, observed better recovery of the patients who practiced eye and head movements, which came to be known as the Cawthorne-Cooksey exercises (Han, Song, & Kim, 2011). It was originally used to treat those individuals who had labyrinthine injury resulting from surgery or head injury (Cooksey, 1946; Cawthorne, 1945). The population for which VRT is recommended are:

a) Individuals who have a stable vestibular lesion (Shepard, Telian, & Smith-Wheelock, 1990)
b) Individuals with a cortical lesion or mixed central or peripheral lesions (Shepard, Telian, & Smith-Wheelock, 1990)
c) Individuals who have suffered from head injury (Shepard, Telian, & Smith-Wheelock, 1990)
d) Individuals with psychogenic vertigo (Shepard, Telian, & Smith-Wheelock, 1990)
e) The elderly with dizziness (Hall, Heusel-Gillig, Tusa, & Herdman, 2010)
f) Individuals who suffer from vertigo with uncertain etiology (Shepard & Asher, 2010)
g) Individuals who have undergone treatment for BPPV (Blatt, Georgakakis, Herdman, Clendaniel, & Tusa, 2000)

The goals of VRT are to enhance gaze stability, to enhance postural stability, to improve vertigo, and to improve daily living activities (Herdman, 1997).

2.3 Dance as a Means to Improve Balance/ Therapeutic Tool

Exercise programs that are based on dance movements aiming at improving balance of the individuals following the programs have been created and researched upon by experimenters. Most of these researches focussed upon improving the balancing skills of the elderly (Krampe, 2010; Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse, 2013; Krampe, Rantz, Dowell, Schamp, Skubic, & Abbott, 2010; Walls, 2010). These studies report of benefits in terms of balance, stability as well as the psychosocial aspects of the participants.

Krampe (2010) aimed at investigating the use of dance therapy for improving the gait and balance of the elderly. Krampe carried out her research using The Lebed Method™ (TLM). A combination of low-impact dance steps that was choreographed to music was used for providing dance sessions that lasted for 45-minutes. The participants attended eighteen sessions over a period of two months. Her pilot study and the dissertation study reveal that the participants experienced improvements in gait and balance.

Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse (2013) investigated the effects of a dance class attended for duration of 1 hour per week for six months by a group of healthy elderly individuals. Their performance was compared to a control group. The participants' cognition, intelligence, attention, reaction time, motor, tactile, and postural performance, as well as subjective well-being and cardio-respiratory performance were assessed by the authors. The experimental group exhibited benefits in not only the dance related parameters like posture and reaction times, but also in cognitive, tactile, motor performance, and subjective well-being as compared to the control group. Correlation of baseline performance with the improvement following intervention revealed that those individuals who benefitted most from the intervention were the ones who showed the lowest performance prior to the intervention.

Walls (2010) in the evidence based review on effectiveness of dance for improving balance in healthy elderly adults, concludes that dance would improve balance in healthy elderly adults to a greater extent compared to other usual activities. This was putforth after comparing across different studies, which use different styles of dance. Such a utility of dance was said to be present for improving dynamic as well as static balance in healthy elderly adults.

Effectiveness of Tango dancing training program against that of a walking program was assessed by McKinley, et al. (2008). In their study, thirty individuals at risk for falls were randomly assigned to a tango class or a walk group. The participants attended the program for a duration of ten weeks. The results obtained from this study led the authors to suggest that tango classes might result in greater improvements than walking in balance skills and in walking speed in the 10-week intervention.

Hackney and Earhart (2010) presented a case study wherein the effects of tango dance classes on the balancing abilities of individuals with Parkinson's disease. Twenty one hour tango classes were attended by an 86 year old subject over a period of 10 weeks. Improved balance and endurance, confidence in balancing, and improvement in quality of life were reported by the participant and demonstration of improvement was also present on a questionnaire, and other behavioural tests like Berg balance scale, 6 minute walk test, and functional reach.

The influence of Greek traditional dance training program on the dynamic balance of individuals with mental retardation (MR) was evaluated by Tsimaras, et al. (2012). Seventeen individuals with mild or moderate degree of mental retardation participated in this study. They were assigned to either of the two groups- intervention or control groups. Pre-training and post-training exercise tests were executed to evaluate their dynamic balance ability (by means of a balance deck). The intervention group underwent a Greek traditional dance training program of three 45 minutes sessions per week, for a duration of 16 weeks. Post-training results showed that the individuals in the intervention group improved during treatment, from their baseline scores on dynamic balance measurements. In contrast, the control group did not show any improvement in the post-training measurements. It concluded that individuals with MR may be able to improve their dynamic balance by practicing a systematic and well-designed Greek traditional dance training program.

The authors of the above mentioned studies state several reasons for the improvements observed in these tests. As summarised by Keogh, Kilding, Pidgeon, Ashley, & Gillis (2009), in the elderly individuals, dance training shows in index of improvement due to increased aerobic power, stronger lower body muscles leading to better endurance and altogether contributing for improved strength, flexibility, agility, gait and balance. They state that in the elderly individuals, improvement in lower body bone-mineral content and muscle power will be improved by dance training, hence overall leading to reduction in the number of falls. This according to them may also reduce cardiovascular health risks.

In general, the studies state that the psychosocial improvements evidenced by the participants of their respective studies may have originated from improved motor control and balance leading to increased confidence which in turn helped them involve in a more active lifestyle.

In the study by Swathi & Sinha (2009) mentions of better Vestibular Evoked Myogenic Potentials from the vestibulo-collic pathway in the dancers are seen. This may be an evidence to state that he improvements/differences seen in the behavioural domains of those who undergo dance training is being reflected at the neural level also.

As can been inferred from the results of the research works stated in the previous section, there exists a positive influence of dance on balance function, and this influence can be utilized as a means to improve balance in individuals who have balancing difficulties. However, the studies mentioned above fail to provide evidence regarding the specific movements that bring about the observed improvements in balance. Also, there are no evidences from the Indian dance forms.

2.4 Indian Dance

Indian dance and drama forms have several texts that are ancient and explain the rules for the essential gestures and postures. Abhinayadarpanam, or 'Mirror of Gesture' is one such ancient treatise that deals with all essential gestures and postures used in Hindu dance and drama (Ghosh, 1957).

The above-mentioned Nandikeshwara's Ahinayadarpanam has made history. It is widely used as a guideline for the classical dances of India. It contains descriptions of extensive varieties of movements and gestures which can be traced in almost all forms of dance. It is divided into three sections:

1. Abhinaya- its meaning, which is in turn divided into 5 subparts.
2. Abhinaya- its history, that is divided again into three subparts
3. Abhinayadarpanam, which is further divided into nine subparts.

(Ghosh, 1957)

Subpart one of the section that contains Abhinayadarpana, talks about scope of the work. This treats in detail about angikaabhinaya, communicating with gestures. Through this book, the author discusses several gestures. Nandikeśvara describes 9 gestures of the head (*shirobheda*), 8 gestures of eyes (*drishtibheda*), 4 gestures of the neck (*greevabheda*), 28 gestures by one hand (a*samyuta hasta)* , 23 gestures by both the hands (*samyuta hasta),* gestures for representing gods, gestures for representing the 10 *avatārās* of *Viśṇu*, gestures for representing different castes, gestures for representing various relations, gestures of hand for dance in general, and the method of moving hands in dance and gestures for representing nine planetary deities (Navagraha gestures) (Ghosh, 1957).

After discussing about the gestures, *Nandikeśvara* moves on to descriptions about postures and gait (The descriptions depend principally on feet). These movements are 16 manners of standing and resting (*Maṇḍalas and sthānakas*), 5 kinds or leaping movements (*Utplavanas*), 7 kinds of spinning movements (*Bhramarīs*), 8 types of walks (*Cārīs)* and 10 types of gaits (*gati)* (Ghosh, 1957).

According to Sathyanarayana and Gokak (1968), considering the extensive details of the movements mentioned in Abhinayadarpana, it was considered as a manual of gesture and posture used in Hindu dance forms. They state that Bharathanatyam, a dance form of South India is also a Hindu dance-form that uses Abhinayadarpana as a text book.

The movements described in Abhinayadarpana are simpler and in the initial stages involves only one body part, and therefore could be useful in individuals with balancing problems, if proved to be helpful. However, no such outputs attempts have been made till date.

Moreover, apart from the trained body movements, rhythm of the music/dance has also been shown to have direct relationship with the vestibular system (Trainor, Gao, Jing-jiang Lei, Lehtovaara, & Harrisc, 2008). Trainor, et al. provided electric impulses to the vestibular system and made the subjects differentiate two rhythms, in the absence of tactile, proprioceptive or visual feedbacks. The results showed that the vestibular system plays a primal role in the perception of musical rhythm. Thus, dance movements, along with musical rhythm may be beneficial in stimulating the vestibular part of the balancing mechanism in the body.

2.5 Behavioural Tests for Balance Assessment

Assessment of balance using behavioural measures can be done using several tests, The Romberg test, Fukuda stepping test, Tandem gait test, Balance Error Scoring test, Star Excursion Balance test and Foam and Dome test, to name a few.

Behavioural tests are an integral part of the balance test assessment battery of those professionals who deal with individuals with balancing difficulties. These provide an easy to administer and simpler to interpret way to understand the deficits of the balancing system, with reference to the peripheral systems that provide input to the CNS. They are also useful in testing the involvement of the CNS.

These tests were developed by different professionals, and depending upon their administration, they are intended to provide information about the static or dynamic balancing ability of the individuals.

The Fukuda Stepping test, given by Fukuda (1959) is administered to find out the weaker of the two labyrinths. This test, however has shown to be having low sensitivity and specificity (Honaker & Shepard, 2009). Tandem gait test, which tests for the cerebellar consistency, again is reported to be having low specificity (Desmond, 2004). The BEST, according to the researchers who proposed the test, can detect difficulties in the balancing system, especially after a traumatic brain injury (University of North Carolina’s Sports Medicine Research Laboratory, Chapel Hill.). The Foam and Dome test tests for sensory integration of balance (Khattar & Hathiram, 2012). This test has applications as a clinical tool to identify an individual’s dependence on various sensory inputs during times of inter-sensory conflict with good sensitivity and specificity. (Shumway-Cook & Horak, 1986). The

SEBT assesses dynamic balancing skills of a person. For the purpose of assessing dynamic postural control the SEBT has been reported to be a reliable and valid instrument (Gray, 1995; Hertel et al., 2000; Kinzey & Armstrong, 1998; Olmsted et al., 2002). The most important advantage of behavioural assessments is in their simplicity and ease of administration.

Chapter 3

METHOD

A multiple group pre-test post-test control group design was used to test the null hypothesis that short-term dance training based on Abhinayadarpana will have no significant effect on the balancing abilities of individuals. The following method was used to test the relationship between dance and balance system.

3.1 Participants

Thirty two adults, with normal hearing sensitivity, normal vision, normal locomotor functioning and no significant history of balancing difficulties, participated in the study. All of them were adult females of age ranging from 18 to 25 years, and pursuing either graduation or post-graduation programs. They hailed from different parts of India. The individuals satisfied the following criteria and therefore qualified for the study.

a) Should be untrained in dance and should not have actively participated in any form of dance
b) Should not have involved themselves in sports activities
c) Should have been observed to have at least a ‘minimal sway’ (according to a five point rating scale) in the Fukuda stepping test
d) Should have the ability to perceive basic rhythm, as this would facilitate the dance training based on Abhinayadarpana. This ability was assessed based on their skill in following the rhythm of a particular song. Individuals had to either tap to the rhythm or walk to the rhythm.
e) The presence of balancing problems was formally ruled out on Fukuda stepping test (Fukuda, 1959). Falling upon performing the test was considered as the exclusion criteria.

The participants were divided into 4 subgroups, depending on whether they were given dance training or not, and depending on the type of movements taught to them. Group 1 to 3 were given dance training and were operationally termed as experimental groups. Group 4 was not given any dance training and thereby on the other hand served as the control group. Among group 1, 2 and 3, group 1 was trained only for body movements and gaits, group 2 was trained only for eye and head movements and group 3 was trained for both eye-head and body movements. All the participants were blindfolded to the purpose of the study. An informed consent was obtained from each participant prior to their participation in the study. In all the future mentions experimental group 1, 2 and 3 are also referred to as E1, E2 and E3 respectively. Groups E1 and E3 had 7 participants each, E2 had 8 participants and the control group had 10 participants.

3.2 Experimental Procedure

Experimental procedure involved three phases carried out in a span of 23 days; *pre-training assessment*, *dance training phase* and the *post training assessment*. Figure 3.1 is a block diagram representing the 3 phases of experimental paradigm and their sequence.

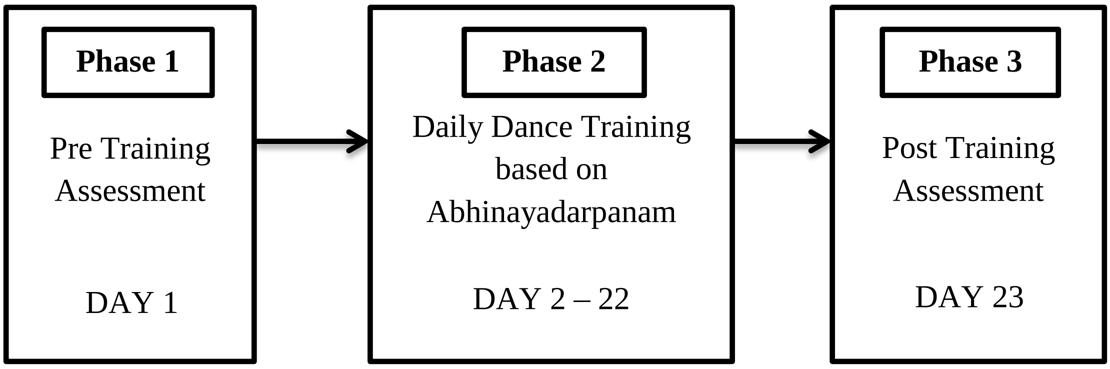


Figure 3.1: Block diagram showing the experimental paradigm.

3.2.1 Phase 1: Pre-training Assessment

In the phase 1, balancing abilities of each participant was documented on Fukuda stepping test, Foam-Dome test, Balance Error Scoring test (BEST) and Star Excursion Balance Test (SEBT). The details of the different input systems assessed in these 4 tests are given in Table 3.1.

Standardized procedures of each of these tests (Fukuda, 1959; Khattar & Hathiram, 2012; Gribble & Hertel, 2003; Bell et al., 2011 respectively) were used for the purpose. Specific procedural details follow.

Table 3.1: *List of input sensory systems assessed in different tests of balance function used in the present study*

Test of Balance Function	**Input Sensory Systems**
Fukuda stepping test	Vestibular
BEST	Vestibular & Proprioception
Foam and Dome test	Vestibular, Visual & Proprioception
SEBT	Vestibular, Visual & Proprioception

Fukuda Stepping Test: *P*articipants were made to stand at the centre of a circle with marked angles radiating from the centre. They were asked to close eyes, extend their hands in front and march at a spot. As recommended by Fukuda in 1959, a marching rate of 110 steps per minute was used, which was ensured by asking them to keep steps according to the metronome beats provided. After the test was performed, the distance and angle of deviation from the point of origin (centre of the circle) was calculated.

In this test, the individual was made to stand at the centre of the circle with the angles marked. At the end of the test, participant's position was marked. The linear displacement of the participant was measured using a measuring tape and the angular displacement was measured with the help of the drawn angles and a protractor. Figure 3.2 shows a picture of a participant performing Fukuda Stepping test.

Figure 3.2: A participant performing Fukuda Stepping test.

Balance Error Scoring Test (BEST): During the administration of this test, the participants were made to maintain three different postures on firm ground and on medium density foam. The postures that had to be maintained were:

- Double leg stance - The participant had to stand with feet side by side, hands placed on hips and the eyes closed.
- Single leg stance - The participant had to stand on the non-dominant foot (the leg opposite to the preferred leg for kicking). Hands were placed on the hips; the hip was flexed to approximately 30° and knee was to be flexed to approximately 45°. Eyes were to be kept closed.
- Tandem Stance - In this posture, the participant was made to stand placing heel to toe. Heel of the dominant foot is to be placed touching the toe of the non-dominant foot. The participant had to place hands on the hips and close their eyes.

These three positions were to be maintained with their feet on a firm surface as well as a foam pad, for a duration of 20 seconds each. A video of the participants' performance was made during the testing. This was later analyzed for the errors made by them. The total number of errors made was noted down, in each posture, in each surface and in each participant.

The participants were given one error score for making any of the following errors during the 20-second test duration: lifting hands off the iliac crest, opening eyes, step, stumble or fall, moving their hip into >30 degrees of abduction, lifting forefoot or heel or staying out of position for >5 seconds. Figure 3.3 shows photographs of a participant performing BEST.

Figure 3.3: Test positions of the Balance Error Scoring Test (Panel A: Double leg stance, Firm; Panel B: Single leg stance Firm; Panel C: Tandem stance Firm; Panel D: Double leg stance, Foam; Panel E: Single leg stance, Foam; Panel F:Tandem Stance, Foam).

Foam and Dome Test: During this test, the participants were given four postures to maintain: standing straight; standing on the non-dominant leg with the other leg placed on the thigh; standing on the non-dominant leg with the other leg lifted but hanging; standing on the non-dominant leg with the other leg's toe touching its toe. The participants had to maintain the postures in two conflicting proprioceptive (standing on terra firma and on a medium density foam) and three visual conflicting inputs (Eyes open, eyes closed & wearing a visual dome) to simulate the sensory organizational test. The postures were to be maintained for as long duration as possible, the maximum duration required being 30 seconds. The duration for which a person was able to maintain a particular posture was recorded as the response parameter. The difference in performance during pre- and post-test recordings was noted down. Figure 3.4 shows a representative participant undergoing Foam and Dome test.

Figure 3.4: Postures maintained during Foam and Dome test (Panels A, B, C and D). These postures were maintained on a foam surface (Panel E), and with eyes open, eyes closed and while wearing a visual conflicting dome (Panel F).

Star Excursion Balance Test (SEBT): The participants were made to stand in the middle of a grid formed by eight lines that extended out at 45° from each other. They were asked to reach as far as possible along the lines and return the extended leg back to the centre after making a light touch on the line when extended. This had to be accomplished while maintaining a single-legged stance. They were made to extend their leg in all the eight directions first, with the right leg being the base of support (Right-leg stance) and then the left leg being the base of support (left-leg stance). Three trials were taken in each direction (anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral) and the measurement of the excursion distance was done. A rest period of 5 minutes was given before starting the second leg stance.

The extent to which each individual is capable of extending their leg in each direction was recorded during the pre-training and post training assessments. The values were noted down in inches for the right-leg as well as left-leg stances. Figure 3.4 shows a representative participant performing SEBT.

Figure 3.4: SEBT performed with a left legged stance.

3.2.2 Phase 2: *Dance Training Phase*

This phase began on the day following pre-test. Only the participants in experimental groups (E1, E2 and E3) underwent dance training. The training was for a period of 21 consecutive days, and was provided by a qualified (Vidwat in Bharathanatyam) professional dancer. The training provided to the participants employed the movements mentioned in Abhinayadarpanam. Two different types of movements from Abhinayadarpanam were considered for training: movements that were perceived to be primarily stimulating the vestibular system and visual system and movements that involve proprioceptive stimulation as well. Nine movements of the head and 8 movements of the eyes, that is ***śirōbhēdāḥ*** *and* ***dṛṣṭibhēdāḥ*** were expected to stimulate the vestibular and visual systems. primarily. Exercises of the body that were taken up for therapy included the ***pādabhedaḥ*** **(***Leg movements***).** It consisted of 9 postures or the ***maṇḍalabhēdā,*** 6 resting postures or the ***sthānaka,*** 5 types of leaps or ***utplavanabhēdāḥ,*** 7 types of spins or ***bhramarī,*** 8 types of shifting positions ***or cārībhēdāḥ*** and 9 types of gaits or ***gati bhēdāḥ.*** These movements mentioned in the Abhinayadarpana were expected to stimulate the proprioceptive system also. (Movements of the neck were excluded as they are complicated and difficult to achieve in a short span of training as judged by the professional dancer who provided the training). Group 1 received training in the body movements- the *pādabhedaḥ.(constituted of maṇḍalabhēdā, sthānaka, utplavanabhēdāḥ, bhramarī, cārībhēdāḥ* and *gati bhēdāḥ***)**. Group 2 was trained in *śirōbhēdāḥ and dṛṣṭibhēdāḥ*. The third group received training in *pādabhedaḥ , śirōbhēdāḥ and dṛṣṭibhēdāḥ*. The details of the dance movements, along with the respective pictures are given in Appendix 1.

Of the twenty one days of training, initial seven days focused on making the participants learn the movements, and the following fourteen days focused on making them practice the movements. The dance movements were choreographed to a music (Tracks 2, 4, 8, 10 and 11 from the Album Wedding Bells by Vidwan Chitti Babu) and the same was used for training as well as practice.

Each dance training session was held for a duration of 30 minutes. The participants were trained as a groups and each subgroup (Group 1, 2 & 3) was trained separately. The control group (Group 4) did not participate in the training phase.

3.2.3 Phase 3: Post-training Assessment

On completion of training, on the 23rd day, each participant underwent a post-training assessment of balancing abilities. This assessment was done using the same tests as that in the pre-training assessment (Fukuda stepping test, BEST, Foam-Dome test & SEBT).

3.3 Data Analysis

The group and individual data was compared between pre and post training assessments to infer about the training related changes in the body balance. The following analyses were carried out.

1) Comparison of the performance in pre and post training phases, in experimental groups.
2) Comparison across the 3 experimental groups.
3) Comparison of the pre training performance with that of improvements seen, if any.

Chapter 4

RESULTS

The primary objective of the present study was to investigate whether short-term Abhinayadarpana based dance training would lead to observable changes on the body balance. Secondary objective was to analyze the differences, if any, across the three types of dance movements used, in terms of their influence on body balance.

The balancing abilities of the participants as documented on the 4 standardized behavioural tests were compared between pre and post-training phases to derive the effect of training. The differential effects of 3 different types of movements, if any, were inferred by comparing the balancing abilities across the three experimental groups. Attempt has also been made to depict the overall trend in the pre to post-training phases by representing the individual data. The following statistical tests were used for the purpose:

a) Descriptive statistics to derive mean, median and standard deviations
b) Wilcoxon Signed Rank test to compare the balancing abilities between pre and post training phases
c) Mann Whitney U test for between and across group comparison in their balancing abilities.
d) Pearson product moment correlation to find relationship between pretraining performance and the improvements seen.

The details of specific results obtained in the present study have been given under the following headings:

1) Results of the Fukuda Stepping test
2) Results of the Balance error scoring test
3) Results of the Foam and Dome test
4) Results of Star Excursion Balance test

4.1 Results of Fukuda Stepping Test

In the Fukuda stepping test, from each participant, distance and angle of deviation were noted down. Table 4.1 gives the mean, median and standard deviation of the two target parameters (distance of deviation in inches and angle of deviation in degrees) in the four groups, in pre and post training phases.

Table 4.1:*Mean, median and standard deviation of distance (in inches) and angle of deviation (in degrees)in the pre and post training phases, in the four groups,1, 2, 3 and 4*

Parameter	Group	Pre Training			Post Training		
		Mean	Median	SD	Mean	Median	SD
Distance moved from origin (inches)	E 1	56.8	40.1	68.1	32.6	30.0	17.1
	E 2	45.7	58.0	26.2	23.9	22.0	10.9
	E 3	46.1	30.0	50.1	23.5	20.0	16.6
	C	48.7	40.0	39.9	40.8	41.5	19.1
Angle of deviation (in degrees)	E 1	110.7	75.0	115.3	32.8	25.0	29.2
	E 2	42.8	25.0	44.4	39.3	42.5	27.1
	E 3	84.2	90.0	52.3	31.4	35.0	17.4
	C	50.0	45.0	17.6	48.5	47.5	18.5

4.1.1 Comparison between Pre and Post Training Phases

From the Table 4.1 it can be observed that the mean distance and angle of deviation was lesser in post training phase compared to pre training phase. This was true in all four groups. The mean difference between the pre training and post training phases was more in the experimental groups compared to control group.

To test whether the observed mean differences between pre and post training phases was statistically significant, Wilcoxon Signed rank test was used. The results of Wilcoxon signed rank test are given in Table 4.2.

Table 4.2: *Results of Wilcoxon Signed Rank test comparing the distance (in inches) and angle of deviation (in degrees) between pre and post training phases separately in the four groups of participants*

Group	Z	
	Distance	Angle of deviation
E 1	-1.352	-2.043*
E 2	-1.612	-0.169
E 3	-1.183	-2.197*
Control	-0.153	-0.570

*(Note: *p<0.05)*

The results showed that there is significant difference in the angle of deviation in group 1 and group 3. However there was no significant difference between pre and post training in the distance of deviation.

4.1.2 Between-group Comparison in Pre and Post Training Phases

A careful observation of Table 4.1 shows us that the distance of deviation was comparable in the pre training phase among the four participant groups. However in the post training phase the distance of deviation was much lesser in the experimental groups (1, 2 and 3) than in the control group (Group 4).

To statistically test this, experimental and control groups were compared on Mann Whitney U test separately in the pre and post training phases. In this, the three experimental groups were combined and compared against the control group. Results (Table 4.3) revealed that there was no significant difference across the two groups in pre training phase. This was true for distance as well as angle of deviation. However in the post training phase, there is a significant difference between the two groups in the distance of deviation while there was no significant difference in the angle of deviation.

Table 4.3: *Results of Mann Whitney U (Z scores) showing comparison between the combined experimental group and control group in terms of their distance and angle of deviation, in the pre and post training phases*

Distance		Degree	
Pre training	Post training	Pre training	Post training
-0.265	-2.07*	-0.593	-1.92

*(Note: *p<0.05)*

Because the combined experimental group significantly differed from the control group, the three experimental groups were separately compared (Group 1, 2 and 3) with the control group (group 4) on Mann Whitney U test. The results of Mann Whitney U test showed that there was a significant difference between experimental group 2 and the control group. But the experimental group 1 and 3 did not differ from the control group.

4.1.3 Across-Group Comparison of the Change Index

Further, in order to verify the presence of differential effect of the different types of movements of Abhinayadarpana (movements used to train experimental groups 1, 2 and 3), the difference in the distance and angle of deviation between pre and post training phases was computed. That is, the distance and angle of deviation obtained in the pre training phase was subtracted from that of post training phase.

These difference values (operationally termed as change index) were compared across the three experimental groups on Mann Whitney U test, the results of which are given in Table 4.4. The results showed that there was no significant difference across the three experimental groups either in distance or angle of deviation.

Table 4.4 Results of Mann Whitney U test *showing comparison across the three experimental groups in terms of their change index of distance and degree of deviation*

Parameter	Group 1 - 2	Group 1 - 3	Group 2 – 3
Distance	-0.46	-0.12	-0.46
Degree	-1.73	-006	-1.73

(Note: p values in all the above comparisons were more than 0.05)

4.1.4 Comparison of the Trend in Individual Data of Change Index

The individual data of the change index was plotted on a scatter plot separately for distance and degree of deviation and also separately for the four participant groups (Figure 4.1- Scatterplots of distance of deviation, Figure 4.2- Scatterplots of degree of deviation). In the scatterplots, a decrease in the distance and angle of deviation in the post training phase compared to pre training phase will be represented in the negative value. On the other hand, an increase in the distance and angle of deviation in the post training phase compared to pre training phase would lead to positive values. It can be observed from Figure 4.1 and 4.2 that most of the participants of the experimental groups (Panel A, B and C) showed decrease in the distance and angle of deviation in the post training phase compared to pre training phase. However, the individual change indices were equally distributed around zero in the scatterplot of the control group (Panel D).

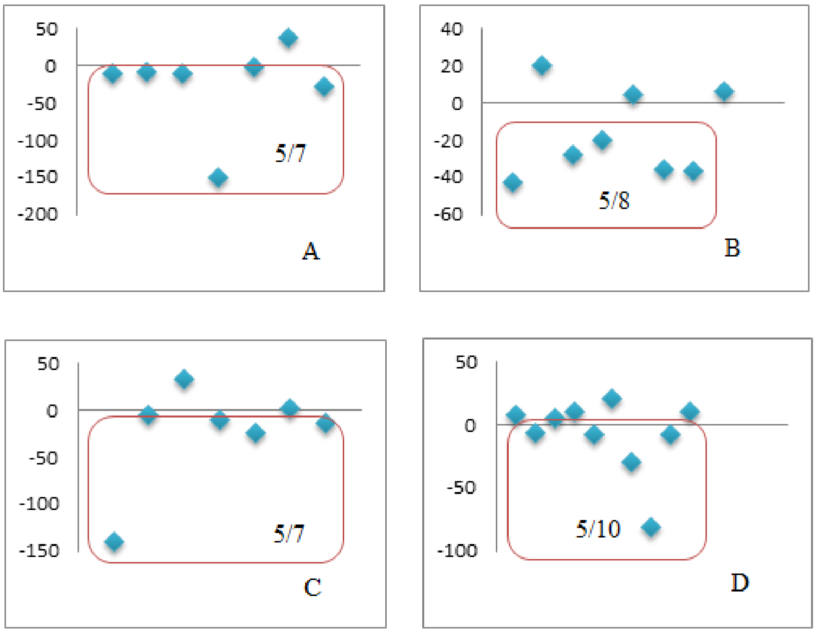


Figure 4.1: Scatterplots representing the individual change index of distance of deviation in the 3 experimental groups (Panel A-Experimental group 1, Panel B-Experimental group 2 and Panel C-Experimental group 3) and control group (Panel D).

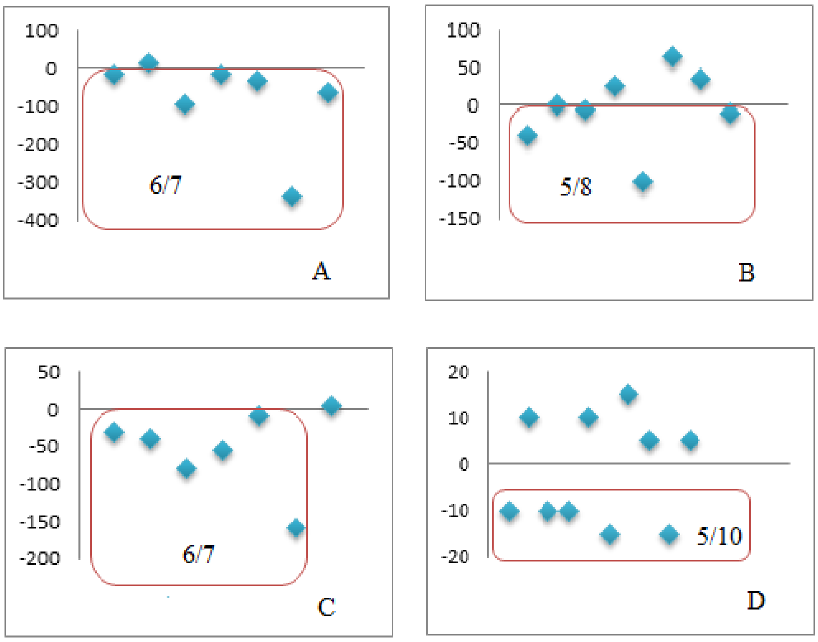


Figure 4.2: Scatterplot representing the individual change index of angle of deviation in the 3 experimental groups (Panel A-Experimental group 1, Panel B-Experimental group 2 and Panel C-Experimental group 3) and control group (Panel D).

4.1.5 Correlation between Pre Training Performance and Change Index

Figure 4.3 (for distance of deviation) and Figure 4.4 (for angle of deviation) are scatterplots showing the relationship between pre training performance and the respective change index in the experimental group (participants of all three experimental groups put together). It can be seen from the scatterplots that there was an inverse relation between pre training performance and the change index. The observed relationship was statistically tested using Pearsons' product-moment correlation, and the results showed a significant correlation ($p<0.01$) with a correlation coefficient of -0.924 for distance of deviation and -0.955 for angle of deviation.

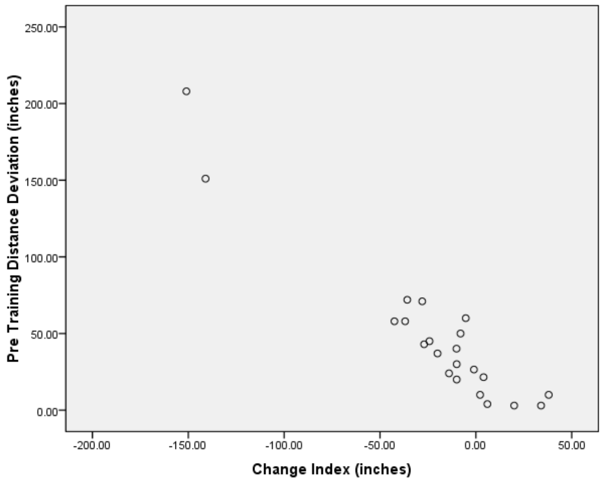


Figure 4.3: Scatterplot showing the relationship between pre training distance of deviation and the respective change index in the experimental group.

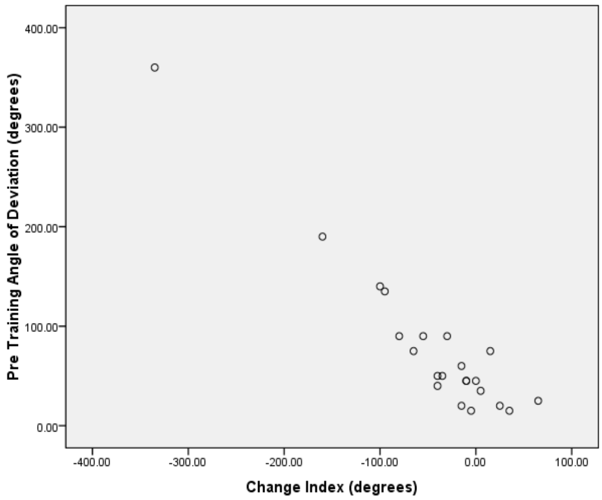


Figure 4.4: Scatterplot showing the relationship between pre training angle of deviation and the respective change index in the experimental group.

4.2 Results of Balance Error Scoring Test

In this test, total number of errors made while maintaining the three positions (single leg stance, double leg stance and tandem stance) on firm ground and on a foam surface were recorded from each participant. The mean, median and standard deviation of the number of errors are presented in Table 4.5. It can be observed from the table that there were no errors in the double leg stance on firm surface both in pre and post training phases. The errors however were seen in most of the other conditions. In test conditions where the errors were seen, the mean number of errors was lesser in the post training phase compared to pre training phase in all three experimental groups (group 1, 2 and 3). Such a trend however was not seen in the mean number of errors of control group.

Table 4.5: *Mean, median and standard deviation of number of errors (raw scores) in different stances obtained in the pre and post training phases, in the four groups of partcipants*

Stance	Group	Pre Training			Post Training		
		Mean	Median	SD	Mean	Median	SD
Double leg stance, Firm (DLS Firm)	E 1	0.00	0.00	0.00	0.00	0.00	0.00
	E 2	0.00	0.00	0.00	0.00	0.00	0.00
	E 3	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00
Single leg stance, Firm (SLS Firm)	E 1	3.14	3.00	0.89	0.71	0.00	1.11
	E 2	3.25	2.00	2.96	1.12	0.50	1.72
	E 3	2.28	1.00	2.69	1.00	0.00	1.91
	C	1.10	1.0	1.10	1.10	1.00	1.19
Tandem Stance, Firm (TS Firm)	E 1	2.14	2.00	1.34	0.57	0.00	0.78
	E 2	1.37	1.50	1.06	0.37	0.00	0.74
	E 3	0.85	0.00	1.21	0.42	0.00	1.13
	C	0.30	0.00	0.67	0.50	0.00	0.84
Double leg stance, Foam (DLS Firm)	E 1	1.71	1.00	1.79	0.14	0.00	0.37
	E 2	0.50	0.00	0.75	0.12	0.00	0.35
	E 3	1.00	0.00	1.41	0.00	0.00	0.00
	C	0.30	0.00	0.48	0.20	0.00	0.42
Single leg stance, Foam (SLS Foam)	E 1	5.71	6.00	1.11	4.00	4.00	1.00
	E 2	6.62	7.00	2.50	5.00	4.50	3.81
	E 3	6.42	6.00	1.98	3.57	3.00	1.61
	C	4.70	5.50	2.40	4.50	5.00	2.22

Table 4.5 continued

Table 4.5 continues

Stance	Group	Pre Training			Post Training		
		Mean	Median	SD	Mean	Median	SD
Tandem stance, Foam (TS Foam)	E 1	4.57	5.00	1.71	3.00	2.00	2.23
	E 2	5.50	4.00	4.03	1.75	2.00	1.66
	E 3	4.00	3.00	2.30	1.35	1.00	1.95
	C	3.20	3.00	1.31	3.60	3.50	0.96

4.2.1 Comparison between Pre and Post Training Phases

In order to reveal whether there is any statistical significance in the observed mean differences of number of errors, a pre-post comparison was done employing the Wilcoxon Signed Rank test separately for each participant group. Table 4.6 displays the Z values obtained. Statistically significant difference is seen in a number of conditions for the experimental groups but not for the control group.

Table 4.6: *Results of Wilcoxon Signed Rank test comparing the number of errors between pre and post training phases separately in the four groups of participants*

Test condition	Group 1	Group 2	Group 3	Group 4
SLS Firm	-2.37*	-2.02*	-2.04*	0.00
TS Firm	-2.03*	-2.06*	-1.34	-1.41
DLS Foam	-2.06*	-1.34	-1.63	-1.00
SLS Foam	-2.23*	-1.53	-2.38*	-0.81
TS Foam	-1.35	-2.37*	-2.21*	-1.63

*(Note: *p<0.05)*

4.2.2 Between-group Comparison in Pre and post Training Phases

The mean number of errors obtained from the three experimental groups were combined and compared with that of the control group using the Mann Whitney U test. This was done separately for the data of pre training and post training phases (Table 4.7). Significant difference was observed between the combined experimental group and control group in only one condition in the pre training phase (Tandem stance on firm surface). No significant difference was shown for the data in the post training phase.

Table 4.7: *Results of Mann Whitney U test showing comparison between the combined experimental group and control group in terms of their errors in the pre and post training phases*

Test Condition	Z	
	Z Pre training	Post training
DLS Firm	0.00	0.00
SLS Firm	-2.14*	-0.79
TS Firm	-2.55*	-0.18
DLS Foam	-1.40	-0.85
SLS Foam	-1.46	-0.62
TS Foam	-1.36	-0.02

*(Note: *p<0.05)*

4.2.3 Across-group Comparison of the Change Index

To investigate for the differential effect of the three types of training, difference in the number of errors between pre and post training phases was computed in the individual data. The three experimental groups were then computed on this difference values which is operationally termed as the change index. The change index in this test was calculated by subtracting the number of errors in the pre training phase from that of the post training phase. Therefore, if the number of errors were lesser in the post training phase compared to pre-training phase, the resultant change index was in the negative value and vice versa. The across-group comparison using Mann-Whitney test (Results in Table 4.8) showed that there was no statistically significant difference between any of the experimental groups.

Table 4.8: Results of Mann Whitney U test showing comparison across the three experimental groups in terms of their change index of error scores

Test condition	Group 1 – 2	Group 1 - 3	Group 2 - 3
DLS Firm	0.00	0.00	0.00
SLS Firm	-0.64	-1.57	-0.41
TS Firm	-0.72	-1.64	-1.20
DLS Foam	-1.71	-0.81	-0.89
SLS Foam	-0.28	-1.59	-1.08
TS Foam	-0.87	-0.19	-0.70

(Note: p values in all the above comparisons was more than 0.05)

4.2.4 Comparison of the Trend in Individual Data of Change Index

Scatterplots depicting the individual change index of the four groups is shown in Figure. 4.5. Each graph represents data of all the conditions within a group (Panel A-E1, Panel B-E2, Panel C-E3 and Panel 4-E4).It is evidently seen from the scatterplotsthat in more than 50% of the instances,participants of the experimental groups (Panel A, B and C) have made lesser number of errors in the post training phase compared to pre-training phase. However, no such trend was observed in the control group.

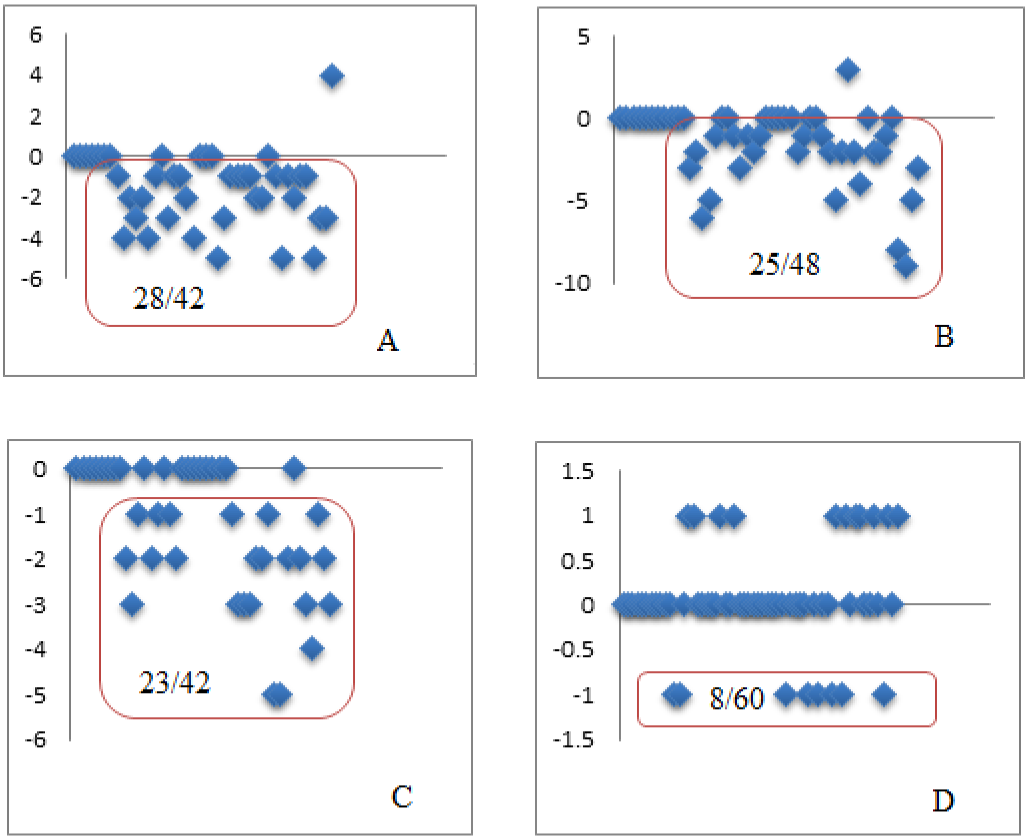


Figure 4.5: Scatterplot representing the individual change index of number of errors made in different test conditions in the 3 experimental groups (Panel A-Experimental group 1, Panel B-Experimental group 2 and Panel C-Experimental group 3) and control group (Panel D).

4.2.5 Correlation between Pre Training Performance and Change Index

Figure 4.6 is a scatterplot showing a relationship between pre training error scores and the respective change index in the experimental group (all the three experimental groups put together). It can be observed from the scatterplot that there was an inverse relation between the two variables. That is, when pre training error scores were more, change index was lesser, and vice-versa. This was further tested on Pearson's product moment correlation and the results showed a significant correlation ($p<0.01$) with a correlation coefficient of -0.689.

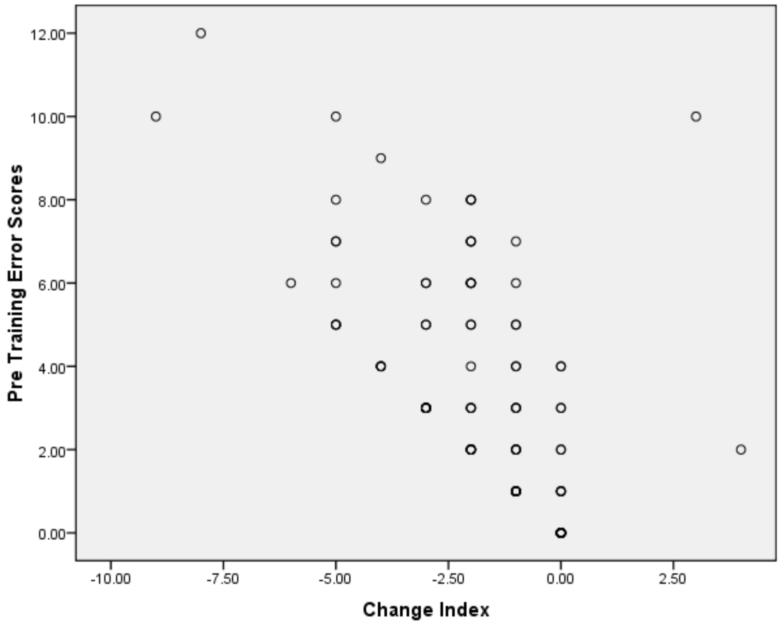


Figure 4.6: Scatterplot showing the relationship between pre training error scores and the respective change index in the experimental group.

4.3 Results of Foam and Dome Test

The foam and dome test looked at the ability of participants to maintain 4 postures on two proprioceptive and three visual conflicting conditions. The duration in seconds, for which they maintained the postures was recorded. The mean, median and standard deviation of the duration for which the participants maintained posture 3 and 4 in the test conditions (eyes open, eyes closed, wearing a dome, each on firm as well as foam surface) are presented in Table 4.9. All the participants could maintain postures 1 and 2 in the different proprioceptive and visual conflicting conditions for a duration of 30 seconds (which is the maximum duration of testing) in the pre as well as post training phases. Therefore, mean in these two postures was 30 seconds and the standard deviation was zero. These data were not presented in Table 4.9 in an attempt reduce the length of the table.

The following observations can be made from Table 4.9 on comparing the pre and post training phases. Groups 1 and 2 exhibited increase in the mean duration (in seconds) for which the participants could maintain the postures in all the test conditions. Mean duration of maintenance of posture in group 2 shows no change while maintaining Position 3 on a foam pad, wearing a dome, and it is reduced while maintaining position 3 on firm ground, wearing a dome. The mean duration of posture maintenance obtained from the control group either showed no difference or reduction in the values while maintaining position 3 (on foam) and position 4 (firm, eyes open and foam eyes open).

Table 4.9: *Mean, median and standard deviation of the duration of maintenance of postures (in seconds) in the pre and post training phases in the four groups of participants*

Posture	Group	Pre Training			Post Training		
		Mean (sec)	Median (sec)	SD	Mean (sec)	Median (sec)	SD
Posture 3 Eyes Open Firm	E 1	23.42	25.00	7.00	29.71	30.00	0.75
	E 2	22.00	30.00	11.35	24.87	30.00	9.50
	E 3	29.28	30.00	1.88	30.00	30.00	0.00
	C	28.90	30.00	1.91	29.40	30.00	1.34
Posture 3 Eyes Closed Firm	E 1	13.85	18.00	9.65	25.71	30.00	7.86
	E 2	9.12	8.00	9.14	16.60	12.50	11.59
	E 3	14.57	17.00	10.26	28.28	30.00	4.53
	C	20.00	19.50	9.24	23.10	30.00	9.74
Posture 3 Dome Firm	E 1	9.14	6.00	7.22	22.85	27.00	10.30
	E 2	15.87	11.50	12.08	14.50	10.50	10.95
	E 3	11.71	10.00	8.38	20.71	22.00	10.46
	C	17.70	18.00	6.70	20.30	19.00	8.43
Posture 3 Eyes Open Foam	E 1	15.00	9.00	11.61	22.28	30.00	9.74
	E 2	13.50	12.50	9.47	17.12	14.50	9.92
	E 3	17.57	25.00	12.60	23.57	30.00	10.35
	C	25.50	27.50	5.70	25.70	28.00	5.81
Posture 3 Eyes Closed Foam	E 1	2.71	2.00	1.70	5.85	6.00	1.34
	E 2	2.50	3.00	1.77	7.75	5.50	5.67
	E 3	2.42	1.00	2.57	7.85	8.00	4.45
	C	4.90	5.00	3.24	5.10	5.00	2.88
Posture 3 Dome Foam	E 1	2.71	2.00	2.36	7.00	7.00	1.73
	E 2	5.00	5.50	2.13	5.50	5.50	4.24
	E 3	2.00	2.00	1.29	7.71	6.00	4.46
	C	6.00	6.00	3.16	5.70	5.50	3.36

Table 4.9 continued

Table 4.9 continues

Posture	Group	Pre Training			Post Training		
		Mean (sec)	Median (sec)	SD	Mean (sec)	Median (sec)	SD
Posture 4 Eyes Open Firm	E 1	24.57	30.00	7.72	30.00	30.00	0.00
	E 2	21.37	30.00	11.95	26.00	30.00	7.48
	E 3	30.00	29.42	1.51	30.00	30.00	0.00
	C	29.50	30.00	1.08	29.50	30.00	1.58
Posture 4 Eyes Closed Firm	E 1	12.00	7.00	8.79	25.71	28.00	4.82
	E 2	13.62	11.50	12.60	16.25	13.50	11.41
	E 3	18.14	20.00	10.58	26.28	30.00	9.82
	C	23.50	21.00	4.94	25.00	26.50	5.14
Posture 4 Dome Firm	E 1	8.71	8.00	6.10	21.00	22.00	7.65
	E 2	14.87	15.00	10.78	16.00	14.00	10.21
	E 3	17.71	20.00	11.38	22.57	30.00	10.16
	C	18.00	19.00	5.92	19.30	18.50	8.95
Posture 4 Eyes Open Foam	E 1	15.28	12.00	9.94	27.42	30.00	6.80
	E 2	12.12	8.50	11.84	17.00	16.00	9.00
	E 3	18.57	27.00	12.60	24.57	30.00	9.89
	C	23.90	24.00	6.27	23.20	23.00	6.23
Posture 4 Eyes Closed Foam	E 1	2.14	2.00	1.46	7.28	7.00	4.53
	E 2	3.37	2.50	3.29	10.37	8.50	8.66
	E 3	4.00	5.00	2.16	10.00	9.00	9.48
	C	5.80	6.00	2.74	6.20	6.00	2.82
Posture 4 Dome Foam	E 1	2.00	2.00	1.00	8.42	6.00	4.64
	E 2	4.37	2.50	4.30	6.25	4.50	5.59
	E 3	3.00	2.00	2.88	10.42	5.00	9.93
	C	5.90	3.00	3.26	6.00	6.00	2.58

4.3.1 Comparison between Pre and Post Training Phases

The statistical significance of the differences in the mean observed between pre and post training phases was tested on Wilcoxon signed rank test. Table 4.10 shows the results of the test for postures 3 and 4. Postures 1 and 2 showed a Z value of 0.00 and thereby the two phases did not differ signficantly.

It is seen from Table 4.10 that significant difference in the mean duration in seconds was observed in all the three experimental groups (10 conditions in group 1, 4 conditions in group 2 and 8 conditions in group 3). No such observation is made for the control group.

Table 4.10: *Results of Wilcoxon Signed Rank test comparing the duration of maintenance of posture (in seconds) between pre and post training phases separately in the four groups of participants*

Posture	Base Surface	Visual condition	E 1	E 2	E 3	C
3	Firm	Eyes Open	-1.82	-1.06	-1.00	-1.63
		Eyes Closed	-2.37*	-2.37*	-2.20*	-1.70
		Dome	-2.36*	-0.27	-2.12*	-1.45
	Foam	Eyes Open	-2.02*	-1.43	-1.84	-0.55
		Eyes Closed	-2.37*	-2.38*	-2.37*	-0.57
		Dome	-2.21*	-0.21	-2.37*	-1.13
4	Firm	Eyes Open	-1.60	-1.60	-1.00	-0.00
		Eyes Closed	-2.37*	-1.89	-2.02*	-0.51
		Dome	-2.37*	-0.68	-2.03*	-0.28
	Foam	Eyes Open	-2.20*	-2.20*	-2.03*	-1.03
		Eyes Closed	-2.36*	-2.37*	-1.87	-0.93
		Dome	-2.37*	-1.35	-2.38*	-0.30

*(Note: *p<0.05)*

4.3.2 Between-group Comparison in Pre and Post Training Phases

Table 4.11: *Results of Mann Whitney U showing comparison between the combined experimental group and control group in terms of their duration of maintenance of postures in the pre and post training phases*

Posture	Base Surface	Visual condition	Z	
			Pre training	Post training
3	Firm	Eyes Open	-0.86	-0.35
		Eyes Closed	-1.83	-0.04
		Dome	-1.57	-0.16
	Foam	Eyes Open	-2.32*	-0.80
		Eyes Closed	-1.98*	-1.25
		Dome	-2.29*	-0.49
4	Firm	Eyes Open	-1.02	0.00
		Eyes Closed	-2.11*	-0.12
		Dome	-1.43	-0.20
	Foam	Eyes Open	-1.95	-0.38
		Eyes Closed	-2.43*	-1.10
		Dome	-2.74*	-0.34

*(Note: *p<0.05)*

In Table 4.11, one can observe that there is a difference in the mean duration for which the participants of experimental (group 1, 2 and 3) groups maintained a few of the postures compared to control group. This is true for the pre as well as post training phases. For this the data from the three experimental groups was combined and compared against the control group on Mann Whitney U Test. The results of the test are displayed in Table 4.11. It can be observed from the table that performance of the participants of the experimental group in the Foam and Dome test was significantly different from the control group in 6 conditions in the pre training phase, whereas it is not significantly different in any of the conditions in the post training phase.

4.3.3 Across-group Comparison of the Change Index

To investigate the group difference further, duration for which each participant maintained each of the test positions in the pre training phase was subtracted from the duration in the post training phase (arriving at the change index). Mann Whitney U test was administered on the resultant change index, comparing experimental group 1, 2 and 3 against each other. Significant difference in the duration was seen in only 1 condition between groups 1 and 3, in 2 conditions between groups 2 and 3, and in 5 conditions between groups 1 and 2 (Table 4.12). Conditions that showed significant difference were the ones in which either dome was used or eyes were closed to cut down the visual feedback.

Table 4.12: Results of Mann Whitney U test showing comparison across the three experimental groups in terms of their change index of duration of maintenance of postures

Condition	Group 1 – 2	Group 1 – 3	Group 2 - 3
Position 3 Firm Eyes Open	-1.19	-1.79	-0.14
Position 3 Firm Eyes Closed	-1.50	-0.58	-1.21
Position 3 Firm Dome	-2.78*	-0.77	-2.26*
Position 4 Firm Eyes Open	-0.26	-1.36	-1.18

Table 4.12 continued

Table 4.12 continues

Condition	Group 1 – 2	Group 1 – 3	Group 2 - 3
Position 4 Firm Eyes Closed	-2.90*	-1.28	-1.34
Position 4 Firm Dome	-2.91*	-2.05*	-1.53
Position 3 Foam Eyes Open	-0.69	-0.19	-0.58
Position 3 Foam Eyes Closed	-0.41	-1.42	-0.46
Position 3 Foam Dome	-1.97*	-0.19	-2.09*
Position 4 Foam Eyes Open	-1.28	-1.34	-0.17
Position 4 Foam Eyes Closed	-0.17	-0.19	-0.46
Position 4 Foam Dome	-2.10*	-0.19	-1.93

(Note: *p<0.05)

4.3.4 Comparison of the Trend in Individual Data of Change Index

Scatterplots depicting change index of the duration for which participants in different groups could maintain various postures are shown in Figure 4.7 (Panel A-Experimental group 1, Panel B-Experimental group 2 and Panel C-Experimental group 3 and Panel D-control group). If the duration for which participants maintained a particular posture was more in post-training than the pre-training, change index was in positive value and vice versa. The change index was calculated only for posture 3 and 4, but not for posture 1 and 2, as there was ceiling effect in these two postures. As can be observed from the scatterplot, most of the data in the experimental groups (depicted in panels A, B and C) fell more on the positive quadrant. This was not seen in the control group (panel D).

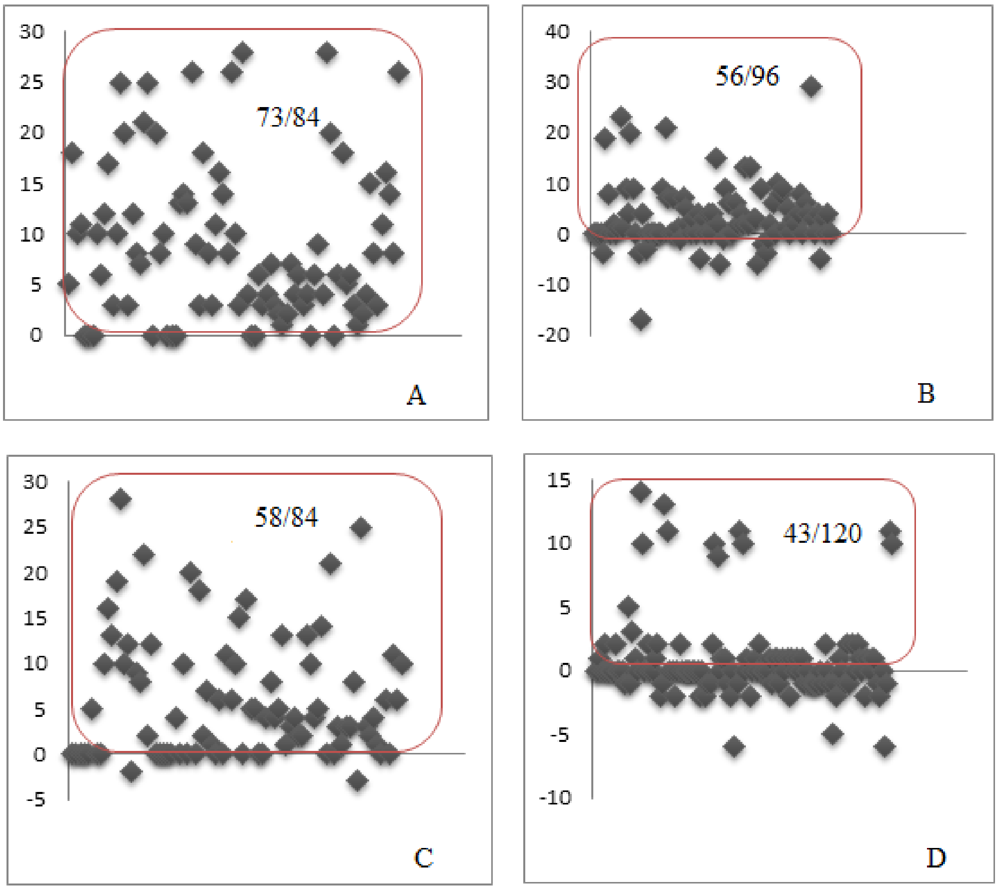


Figure 4.7: Scatterplot representing the individual change index of duration for which various postures could be maintained in different test conditions, in the 3 experimental groups (Panel A-Experimental group 1, Panel B-Experimental group 2 and Panel C-Experimental group 3) and control group (Panel D).

4.3.5 Correlation between Pre Training Performance and Change Index

Figure 4.8 is a scatterplot showing the relationship between pre training duration of maintenance of the test postures to the respective change index in the experimental groups. It can be seen from the scatterplot that there was an inverse relationship. That means, when the pre training value were lesser, the change index was more and vice versa. This was tested for statistical significance on Pearson's product moment correlation and the results showed a significant correlation ($p<0.01$) with a correlation coefficient of -0.331.

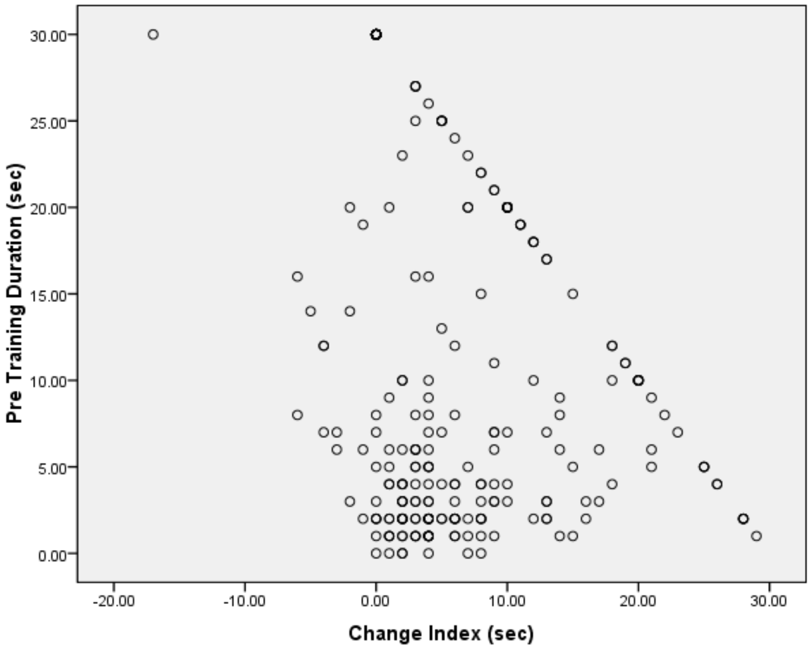


Figure 4.8: Scatterplot showing relationship between pre training duration of maintenance of the test postures to the respective change index in the experimental groups.

4.4 Results of Star Excursion Balance Test

In this test, leg excursion lengths of the participants in 8 directions with left legged stance and right legged stance were measured in the pre and post training phases. The mean, median and standard deviation of these excursions are shown in Tables 4.13 and 4.14.The data in Table 4.13 and 4.14 show higher mean leg excursion lengths in all the 8 directions in the post-training phase compared to pre-training phase, in the experimental groups. This was true for right as well as left legged stance. However no such trend was seen in control group.

Table 4.13: *Mean, median and standard deviation of the leg excursion lengths (in inches) obtained in 8 directions (in inches), with a* ***left legged stance*** *in the pre and post training phases, in the four groups of participants*

Direction	Group	Pre Training			Post Training		
		Mean (inches)	Median (inches)	SD	Mean (inches)	Median (inches)	SD
Anterior	E 1	28.61	27.50	4.10	32.35	34.80	3.54
	E 2	24.64	24.55	3.90	29.45	30.00	4.21
	E 3	24.48	23.50	2.44	27.38	28.7	2.65
	C	25.93	25.25	2.11	25.02	24.70	2.21
Antero-lateral	E 1	27.77	28.60	4.80	30.61	31.10	3.72
	E 2	24.18	24.40	3.18	29.51	29.85	3.22
	E 3	24.05	24.20	2.67	27.61	28.50	2.91
	C	24.57	23.35	3.54	24.20	23.00	3.36
Lateral	E 1	28.68	29.40	4.01	30.52	31.60	3.38
	E 2	24.64	25.85	3.77	28.27	27.70	2.94
	E 3	23.97	23.60	3.21	26.65	26.50	3.66
	C	24.55	24.35	3.33	24.71	24.30	2.98
Posterio-Lateral	E 1	29.02	29.90	4.57	31.20	31.50	4.83
	E 2	24.48	23.70	4.20	28.98	28.70	4.31
	E 3	25.10	25.20	3.75	26.67	26.40	2.85
	C	24.61	23.85	4.37	24.66	23.85	3.93
Posterior	E 1	28.61	25.80	6.23	31.77	31.80	3.95
	E 2	24.45	24.05	5.42	27.81	27.00	4.65
	E 3	23.82	24.00	4.03	25.77	26.60	3.40
	C	24.18	23.30	4.72	24.46	22.90	4.18
Posterio-medial	E 1	24.92	23.00	6.31	28.01	27.90	4.11
	E 2	24.30	24.95	4.74	28.32	26.75	4.64
	E 3	23.97	23.50	4.10	24.10	24.30	3.73
	C	23.58	23.55	3.58	23.37	22.75	3.63
Medial	E 1	23.55	22.50	24.2	25.22	25.20	2.80
	E 2	22.30	21.60	2.99	25.00	24.35	3.38
	E 3	19.58	19.00	4.37	22.62	22.40	2.21
	C	21.85	20.60	2.71	22.03	21.90	2.67
Antero-Medial	E 1	25.51	24.20	4.17	28.74	29.80	2.55
	E 2	24.48	25.05	2.74	28.37	28.65	3.65
	E 3	23.38	23.80	1.85	25.78	25.30	3.14
		24.82	24.60	2.81	24.29	23.30	3.29

Table 4.14: *Mean, median and standard deviation of the leg excursion lengths (in inches)obtained in 8 directions, with a* ***right legged stance*** *in the pre and post training phases in the four groups, 1, 2, 3 and 4*

Direction	Group	Pre Training			Post Training		
		Mean (inches)	Median (inches)	SD	Mean (inches)	Median (inches)	SD
Anterior	E1	26.80	26.90	5.55	31.58	34.10	3.76
	E2	24.28	24.35	3.73	28.36	29.35	4.52
	E3	23.50	23.00	4.44	28.14	29.90	3.97
	C	25.49	24.85	2.45	25.45	24.30	2.67
Antero-lateral	E1	27.95	31.00	5.25	30.08	32.00	4.03
	E2	26.13	26.85	3.54	29.22	30.85	4.03
	E3	23.21	22.50	2.11	28.20	28.90	4.47
	C	23.69	23.75	2.33	23.13	22.60	2.00
Lateral	E1	28.80	21.60	5.37	31.04	30.20	4.27
	E2	25.23	25.50	3.87	28.82	29.35	3.53
	E3	23.24	23.00	2.48	27.62	28.80	4.58
	C	24.13	24.25	3.98	24.73	24.45	2.85
Posterio-Lateral	E1	26.67	27.50	5.90	30.92	32.00	5.70
	E2	25.81	25.60	3.46	29.18	29.05	3.65
	E3	24.35	23.60	2.78	27.55	28.70	3.44
	C	23.34	23.45	2.30	23.71	23.45	1.66
Posterior	E1	26.67	27.50	5.90	30.92	32.00	5.70
	E2	25.81	25.60	3.46	29.18	29.05	3.65
	E3	24.35	23.60	2.78	27.55	28.70	3.44
	C	23.34	23.45	2.30	23.71	23.45	1.66
Posterio-medial	E1	26.58	26.70	4.69	28.84	30.70	3.43
	E2	25.77	25.20	3.04	27.70	27.10	4.14
	E3	22.38	23.10	2.74	26.15	27.20	2.88
	C	23.29	24.30	2.68	23.20	23.40	2.38
Medial	E1	24.20	22.60	4.79	26.54	27.20	3.20
	E2	21.92	21.15	4.54	24.27	23.35	5.18
	E3	19.24	20.00	2.92	22.57	21.90	2.54
	C	20.58	21.00	1.56	21.01	21.05	1.39
Antero-medial	E1	27.55	27.80	2.78	29.58	30.70	2.49
	E2	24.10	24.45	2.83	26.31	27.50	3.26
	E3	21.95	22.40	3.25	26.67	26.90	2.89
	C	24.00	23.80	2.92	23.87	23.55	2.57

4.4.1 Comparison between Pre and Post Training Phases

Statistical significance of the observed mean difference of the participants' performance in the pre and post training phases was verified using the Wilcoxon Signed rank test. The Z values are shown in Table 4.15. The following observation can be made from the table

a) Significant difference between pre and post training was observed only in the experimental groups but not in the control group.
b) Significant difference between pre and post training was observed in more number of directions in the right legged stance than the left legged stance. In the right legged stance, while group 2 and 3 showed significant difference in all the directions, group 1 did not show significant difference in medial, postero-medial, and lateral directions.
c) In the left legged stance, group 2 showed significant difference between pre and post training phases in all the directions. Whereas, group 1 and 3 showed significant difference only in few of the directions.

Table 4.15: *Results of Wilcoxon Signed Rank test comparing the leg excursion lengths (in inches) between pre and post training phases separately in the four groups of participants*

Stance	Direction	Group 1	Group 2	Group 3	Group 4
Left Legged	Anterior	-2.37*	-2.52*	-1.35	-1.78
	Anterolateral	-2.36*	-2.52*	-2.19*	-1.07
	Lateral	-1.69	-2.38*	-1.69	-0.45
	Postero Lateral	-2.19*	-2.52*	-1.52	-0.15
	Posterior	-1.35	-2.38*	-2.20*	-0.35
	Postromedial	-1.35	-2.51*	-0.33	-1.32
	Medial	-1.60	-2.52*	-1.97	-0.71
	Antero Medial	-2.37*	-2.52*	-1.86	-1.22
Right Legged	Anterior	-2.36*	-2.52*	-2.19*	-0.05
	Anterolateral	-2.37*	-2.38*	-2.36*	-1.12
	Lateral	-1.52	-2.52*	-2.20*	-0.15
	Postero Lateral	-2.19*	-2.19*	-2.36*	-0.56
	Posterior	-2.19*	-2.52*	-2.37*	-0.10
	Posteromedial	-1.42	-2.38*	-2.36*	-0.05
	Medial	-1.69	-2.52*	-2.19*	-1.48
	Antero Medial	-2.20*	-2.52*	-2.36*	-0.25

*(Note: *p<0.05)*

4.4.2 Between-group Comparison in Pre and Post Training Phases

Table 4.16 shows mean differences between experimental and control groups both in the pre and post training phases. To find out whether the experimental group differed significantly from the control group, the three experimental groups were combined and then compared against the control group. Results of Mann-Whitney test are given in Table 4.16. Results showed that the experimental group significantly differed from the control group in no conditions in the pre training phase and in 15 conditions in the post training phase.

Table 4.16*: Results of Mann Whitney U showing comparison between the combined experimental group and control group in terms of their leg excursion length, in the pre and post training phases*

Stance	Direction	Z	
		Pre training	Post training
Left Legged	Anterior	-1.38	-3.07*
	Anterolateral	-1.15	-3.17*
	Lateral	-1.38	-2.48*
	Postero Lateral	-1.96*	-2.46*
	Posterior	-1.21	-2.44*
	Postromedial	-0.11	-2.03*
	Medial	-0.86	-1.87
	Antero Medial	-0.34	-2.50*
Right Legged	Anterior	-0.92	-2.34*
	Anterolateral	-1.04	-3.43*
	Lateral	-1.62	-2.60*
	Postero Lateral	-0.34	-3.27*
	Posterior	-1.27	-2.76
	Postromedial	-0.34	-3.49*
	Medial	-1.04	-2.80*
	Antero Medial	-1.91	-2.86*

*(Note: *p<0.05)*

4.4.3 Across-group Comparison of the Change Index

To verify whether the type of dance movements had an influence on balance skills assessed in SEBT, the three experimental groups were compared with each other using the Mann Whitney U test (Table 4.17). Change index of excursion length was calculated for this purpose. To obtain the change index, leg excursion lengths of the participants in the pre training phase were subtracted from the leg excursion lengths in the post training phase. This was done on the individual data. Therefore, if an individual had higher excursion length in the post-training phase compared to pre-training phase, the resultant change index was in positive value and vice versa. Results of Mann Whitney U test showed significant differences between the following listed groups.

a) group 1 and 2 in the postero-lateral direction in the left legged stance
b) group 1 and 3 in the antero medial direction in the right legged stance
c) group 2and 3 in the poster-lateral and postero-medial directions in the left legged stance and, antero-medial in the right legged stance.

Table 4.17: *Results of Mann Whitney U test showing comparison across the three experimental groups in terms of their change index of leg excursion lengths*

Stance	Parameter	Group 1 – 2	Group 1 - 3	Group 2 - 3
Left legged	Anterior	-0.34	-0.64	-0.57
	Anterolateral	-1.56	-0.25	-0.92
	Lateral	-0.63	-0.57	-0.58
	Postero-lateral	-2.08*	-0.19	-2.54*
	Posterior	0.00	-0.95	-1.21
	Postero-medial	-0.34	-1.59	-2.25*
	Medial	-0.37	-0.64	-0.11
	Antero Medial	-0.52	-0.57	-1.33
Right Legged	Anterior	-0.57	-0.31	-0.81
	Anterolateral	-0.92	-1.85	-0.92
	Lateral	-0.75	-0.70	-0.05
	Postero Lateral	-0.92	-0.83	-0.46
	Posterior	-0.63	-0.12	-1.10
	Postromedial	-0.57	-0.70	-1.50
	Medial	-0.46	-0.25	-0.46
	Antero Medial	0.00	-2.11*	-1.96*

*(Note: *p<0.05)*

4.4.4 Comparison of the Trend in Individual Data of Change Index

Scatterplots of the change index for excursion lengths in the four groups of participants is shown in Figure 4.9 (Panel A-Experimental group 1, Panel B-

Experimental group 2 and Panel C-Experimental group 3, Panel D-control group). It can be seen from the figure that majority of the time, participants in the experimental group had higher excursion length in the post-training phase compared to pre-training phase. This was true for all the three experimental groups. On the other hand in the control group, almost equal numbers of data were distributed on either side of the zero.

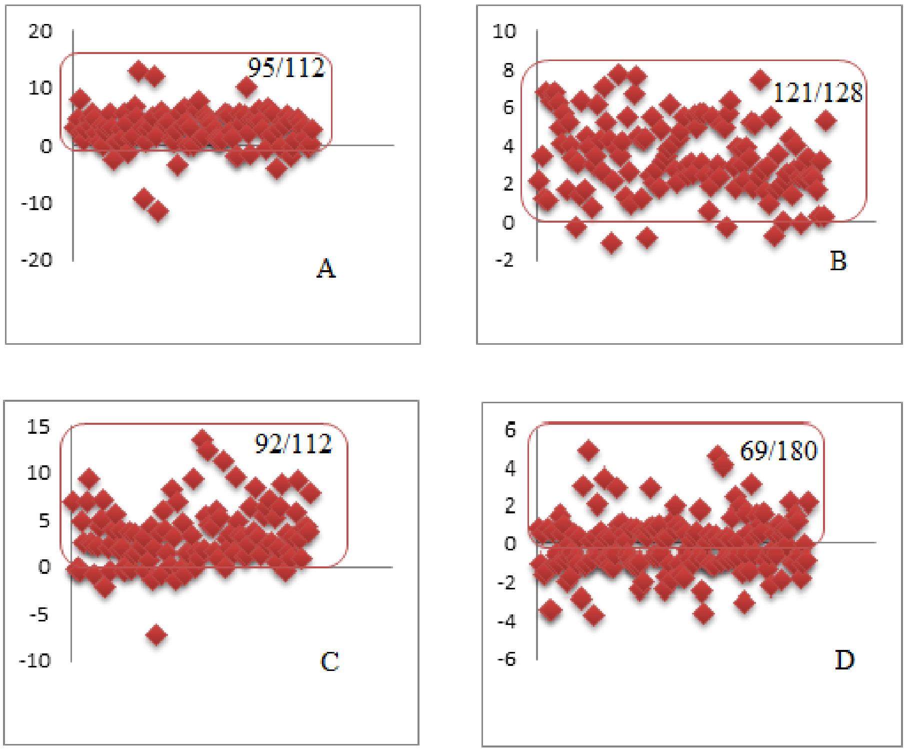


Figure 4.9: Scatterplot representing the individual change index of leg excursion lengths (right and left legged stances combined) in the 3 experimental groups (Panel A-Experimental group 1, Panel B-Experimental group 2 and Panel C-Experimental group 3) and control group (Panel D).

4.4.5 Correlation between Pre Training Performance and Change Index

Figure 4.10 is a scatterplot showing the relationship between pre training leg excursion lengths and the corresponding change index in the experimental groups. It can be seen from the scatterplot that when the pre training value was less, the change index was more and vice versa. This was tested on Pearson's correlation and the results showed a significant correlation ($p<0.01$) with a correlation coefficient of -0.288.

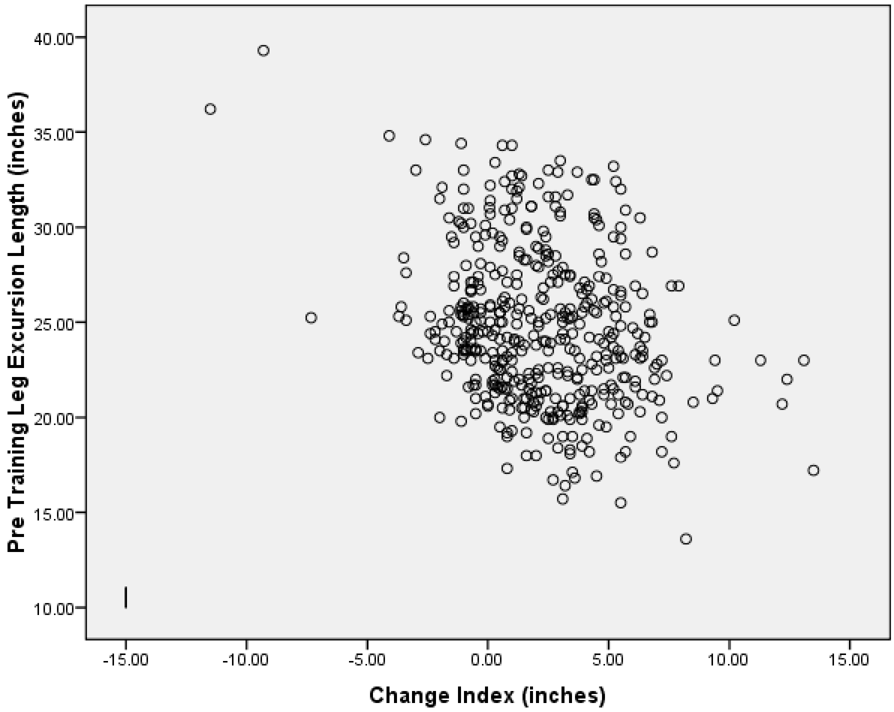


Figure 4.10: Scatterplot showing relationship between pre training leg excursion lengths and the corresponding change index in the experimental groups.

Chapter 5

DISCUSSIONS

Balancing the body - be it static or dynamic balance, is a complex task utilizing coordinated information from three sensory systems and overall controlled by the central nervous system. Both the peripheral as well as central pathologies/disorders involving physiological systems of balance mechanisms are known to result in balancing difficulties, which are deleterious for the other functional domains such as psychosocial, occupational and communicative domains. Therefore occurrence of balance difficulties calls for immediate repair which could be either medical, or rehabilitative in its approach. Most of the acute pathologies are medically treatable. While the chronic ones need secondary rehabilitation to improvise the body balance. One of the most common rehabilitative strategies is Vestibular Rehabilitation Therapy (VRT), wherein a series of exercises involving head and body are hierarchically practiced to train the balance mechanism. Although there are standardised charts which are given to the individuals with balance disorders by the professionals, these turn out to be less successful due to monotony involved in practicing.

As a modification to the conventional VRT, dance based therapies were introduced. These programs supposedly drive a greater interest and pursuance as the head and body movements that trigger the balance mechanism are learnt and practiced with a music. Most of the time such therapies are carried out in groups of individuals with similar difficulties. The basis for these programs are the research findings that have shown better balancing abilities in dancers compared to non-dancers (Crotts, Thompson, Nahom, Ryan, & Newton, 1996; Ambegaonkar, Caswell, Winchester, Shimokochi, Cortes, & Caswell, 2013)

In the present study, utility of basics of one of the Indian dance forms (Bharathanatya), based on Abhinayadarpana, in improving body balance of young and healthy adults was investigated. The movements involved in the present program were simple and systematic, to be used even for elderly individuals. A longitudinal approach was used to derive effect of Abhinayadarpana based dance training on body balance.

The training related changes were documented on 4 behavioural tests of balance function. These tests assessed static as well as dynamic balance and involved different sensory systems either in isolation or in combination with the other sensory systems.

The present study involved both experimental groups and control group. While the experimental groups underwent training in different types of dance movements, control group did not undergo any training. This was based on the assumption that if dance was to be the causative factor for improvement in the body balance, the improvements would be present only in the experimental groups, but not in the control group.

5.1 Effect of Training as Found on Pre- Post Comparison

The balancing abilities in the 4 tests were compared between pre and post training separately for the experimental group and control group. Results showed that there is a significant improvement in the angle of deviation on Fukuda test. That is, there was a reduction in the angle of deviation secondary to the dance training. In the Fukuda test, the input from visual system is cut down by asking the individual to close the eyes and the input from the proprioceptive system is cut down by asking him to step at the rate of 110 per second. Therefore the only system that provided input while performing the Fukuda task is the vestibular system. Angle of deviation would represent symmetry in the function of the two vestibular systems. The present finding of reduction in the angle of deviation in the post training phase would mean that the symmetry between the two vestibular systems improved after the Abhinayadarpana based dance training. Therefore, it can be inferred that dance training has positive influence on the vestibular system and the vestibular system is trainable.

In the present study, training was given in 21 sessions, each session being of half an hour. Therefore it can be inferred that even a short term training is sufficient to find noticeable changes in the symmetry of vestibular system. The results did not show difference in the distance of deviation between pre and post training phases. Although the exact reason for this is not clear, it is probably either due to less number of participants or due to not-enough duration of training.

Findings in the Balance Error Scoring Test (BEST) showed that there was significant effect due to reduction in the number of errors in the post training phase compared to the pre training phase. Such reductions were present in the experimental groups but not in the control group. This supports that the Abhinayadarpana based dance training has positive influence on the balance mechanism. BEST checks for static balance in various postures with eyes being closed. Therefore, it involves only the vestibular and proprioceptive systems while cutting the visual input. Improvement found in the BEST secondary to dance training would mean that either there is improvement in the individual sensory system or there is improvement in the coordinated input provided by these two systems to the central nervous system. In any case, such an improvement can be evidenced even with a short-term dance training of 21 days.

In their study involving 15 dancers and 18 non dancers, Ambegaonkar, et al. (2013), found lower error score on BEST by the dancers, as compared to non-dancers. This difference can be ascribed to the dance training and practice they were involved in.

Foam and dome test also evidenced a very clear trend of improvement in the post training phase compared to pre training phase. In this test, of the four postures used, posture 1 and posture 2 were maintained for the maximum duration (30 seconds) by all the participants of all the groups in the pre training phase itself. This resulted in a ceiling effect due to which no training related changes could be evidenced through comparing pre and post training phases. On the other hand, posture 3 and 4 evidenced training related improvements in several of the proprioceptive and visual conflicting conditions. Foam and Dome test hierarchically cuts down the inputs from visual and proprioceptive systems. While the eyes closed and with dome conditions cut down the visual input, the foam surface cuts down the proprioceptive input. The improvements observed in the foam and dome tests were either in the dome condition or in the eyes closed condition and it is seen both in firm and foam surfaces. The improvements were also observed in the eyes open condition but only on the foam surface. The vestibular system in the improvements observed in the eyes closed or dome condition, on foam surface can be used to support the findings in Fukuda test. In both these tests improvements in the vestibular physiology secondary to Abhinayadarpana based dance training are clearly evident. Foam and dome test, like in BEST tests for static balance. Therefore the findings suggest that the Abhinayadarpana based dance training can be used to improve static balance.

Balancing abilities of ballet dancers on a modified version of Foam and dome test was compared to that of non-dancers by Crotts, et al. (1996). They observed better performance by the dancers, wherein they maintained the test postures for longer durations. This lead the authors to suggest that the strategies used by dancers may be analysed and used for treating injured dancers as well as those individuals with balancing difficulties. Even one word though the participants of this study were dancers who had received training for a longer duration, this result can be compared with the results of the present study as in both better performance in the balance testis attributed to dance training.

Star excursion balance test (SEBT) also showed improvements in the post training test compared to pre training test. These improvements were observed in the experimental groups and not in the control group. Therefore the improvements can be attributed to the training that the experimental group underwent but for anything else. The improvements were seen for both right legged stance as well as left legged stance. But right legged stance showed improvements in most of the directions while the left legged stance evidenced improvements only in a few directions. SEBT checks for dynamic balance and involves the inputs from all three sensory systems. The resultant training related improvements observed in SEBT can be attributed to all the three systems, as it is difficult to attribute the improvements to an individual sensory system. Although the exact reason for right legged stance showing more improvement is not clear, one can presume that the left leg stance was easy for the participants, they being right leg dominant.

The study by Ambegaonkar, et al. (2013) tested for the performance of dancers versus non dancers in the SEBT as well. They found increased leg excursion length in dancers in two directions. Their finding supports the present findings of improved leg excursion length after the Abhinayadarpana based dance training. What the present study documents is a pre- post difference, and it was evident in more directions.

Overall, results of the present study support improvements in both static as well as dynamic balance secondary to Abhinayadarpana based dance training. Because the training was given for only 21 days, it can be concluded that the short-term training based on Abhinayadarpana would be sufficient to evidence the improvements. On analysing the findings of the four tests, it can be deduced that vestibular system shows improvement with dance training. However, improvements in the visual and proprioceptive sensory systems cannot be isolated.

5.2 Effect of Training as Found in Between-group Comparison

In the present study, the experimental and control group were compared separately in the pre and post training phases. If there was no difference between the experimental and control group in the pretraining phase it would support equivalency in the balancing abilities of the participants in the two groups. In such a case, if there was a difference between the two groups in post training phase, with experimental group performing better than the control group, it would support training related changes in the experimental groups. Most of the parameters studied in the four tests showed that the two groups were equivalent in the pre training phase. This supports a good sampling even when the number of subjects was less (10 in the control group and 22 in the experimental group).

In the Fukuda stepping test, there is a significant difference in the two groups in the post training phase with the mean performance of the experimental group being better than control group. This was seen in the absence of group difference in the pre training phase. This finding supports training related improvements in the dynamic balance.

In the BEST, significant difference was found between the control group and combined experimental group in two parameters in the pre training phase, whereas no differences were found in the post training phase. Although the reason for such a finding is unclear, one may infer that the comparison between experimental group and control group is not a reliable measure to find the effect of Abhinayadarpana based dance training on the experimental groups. The inherent variability in the data, and the small number of participants might be the contributing reasons for these findings.

In the Foam and Dome test again, the combined experimental group showed significant difference from the control group in 6 parameters in the pre training phase, whereas there are no differences shown in any of the parameters in the post training phase. The high standard deviation observed in the data implies higher variability. This, coupled with lesser number of subjects would have resulted in such findings. However, this finding suggests that the credibility of a between group comparison, in the post training phase is not reliable.

SEBT results showed significant difference between the experimental and control group in all, but one parameters in the post training phase, whereas, a significant difference was found only in one parameter in the pre training phase. Like the Fukuda test, SEBT tests for dynamic balance, and the results support relative improvements in dynamic balance.

Overall, in the comparison between experimental and control groups, one can find support for training related changes in the dynamic balance (based on Fukuda and SEBT). Whereas the improvements shown in the static balance cannot be strongly attributed to training as there were group differences in the pre training phase itself.

5.3 Effect of Type of Dance Movements on the Training Related Changes

There were three experimental groups used in the present study. Each of them were trained for different types of dance movements. Experimental group 1 was trained for static postures and gait movements, Experimental group 2 was trained for eye and head movements and experimental group 3 was trained in both. Therefore, any differences across the three groups could have been attributed to the type of dance movements for which they underwent dance training (or) number of domains in which they were trained. Change index was calculated for this purpose in each individual data by subtracting pre training performance from the post training performance. The value of change index would indicate whether there was improvement, decrement or no change with the dance training.

Results of Fukuda test showed there were no group differences in the change index, in both distance as well as degree of deviation. This would mean that whatever influence the three types of dance movements had on the three experimental groups, it was comparable. Therefore it can be inferred that the dynamic balance as assessed through distance and angle of deviation of Fukuda test did not depend on the type of dance movements. Considering that there were training related changes as evidenced on pre-post comparison and between group comparison, one can conclude improvements seem similar with eye and head movements and, body movements and gait. Through these findings, it can be inferred that it would be sufficient to train on either eye and head movements or body movements or gait to bring positive changes in the dynamic balance assessed by the Fukuda test.

Balance Error Scoring Test (BEST), again, did not reveal any group differences among the experimental groups in terms of their change index. Therefore it can be inferred that the static balance that is assessed on BEST would not differ between eye and head movements and, body movements and gait. Also, it doesn't depend on whether training is given in one domain (either eye and head movements or body movements and gait), or in both domains. Thus it is concluded that training in any one domain for a period of 21 days would be sufficient to bring in positive changes in the static balance.

In contrast to the previous 2 tests, Foam and Dome test and SEBT showed group differences in the change index. In Foam and Dome test, there were significant differences between the ones trained for eye and head movements, and the ones trained for body movements and gait. Also, there were differences between the group that underwent training in one domain (either eye and head movements or body movements and gait) and the group that underwent training in both the domains. Incidentally, these differences were seen in the conditions wherein visual input was cut either by asking them to close their eyes or by placing the dome. In these conditions the balance is primarily regulated by vestibular and proprioceptive systems. Analysis of the mean in the three groups in the conditions that had group difference showed that the group that underwent training in body movements and gait showed greater improvement compared to group that underwent training in eye and head movements. Also, the group that underwent training in both the domains had more improvements than the group that was trained only in one domain.

Therefore, it can be inferred that type of dance movement does have an influence on the static balance as assessed by Foam and Dome test. Because the group differences were seen only in the conditions where the visual input was cut, one can attribute the differential effects of dance movements to vestibular and proprioceptive systems.

In the SEBT, the significant differences were seen between group 1 and 2 in the posterolateral direction of left legged stance and, between group 1 and 3 in the anteromedial direction of right legged stance. Whereas group 2 and 3 differed in the posterolateral and posteromedial directions of left legged stance and anteromedial direction in the right legged stance. Analysis of the mean change index of three experimental groups in the left legged stance showed that group 2 showed better improvements successively followed by group 1 and group 3. This means that the ones who underwent training in eye and head movements showed more improvements in the dynamic balance assessed by SEBT. Overall the findings of SEBT again supports differential effects of different dance movements used in the present study.

The earlier studies (Crotts, Thompson, Nahom, Ryan & Newton, 1996; Ambegaonkar, Caswell, Winchester, Shimokochi, Cortes, & Caswell, 2013) have not explored the impact of differential training in the different balance tests. However, these studies support the finding of the present study, implying that dance training has a positive influence on the balancing abilities of the individuals.

5.4 Effect of Training as found from the Trend in Individual Data

In the present study, it was of interest to investigate whether training related improvements are seen in most of the participants. If the experimental group had shown improvements compared to control group, but only few of the participants had shown the improvements, implications of these findings would have been weaker. On the other hand, if most of the participants had shown the improvements, it would have served as an advantage while suggesting this short term Abhinayadarpana based dance training to improve body balance. Results of the present study showed that the improvements were observed in majority of the participants in the experimental groups. The changes were equivocal in the control group. This difference in the trend between experimental and control groups once again supports training as a causative factor for improvement in body balance.

The trend of improvement in most of the subjects is present in all the four tests and in all the three experimental groups. That is, both static balance and dynamic balance were improved in most of the subjects irrespective of the type of dance movements they were trained for. These improvements in most of the subjects had happened consequent to short-term training of 21 days.

5.5 Relationship between Pre-training Balancing Abilities and the Extent of Improvement

Correlation between the pre training performance and the change index revealed a significant relationship in all the four tests. This analysis was done only for the data from experimental group. The correlation coefficients suggest high correlation in Fukuda test and BEST but low correlation in Foam-Dome test and SEBT. From these findings it can be inferred that if the balancing abilities are poor, the training related improvements are more and vice-versa. This relationship is stronger for dynamic balance assessed in Fukuda test and static balance assessed in BEST.

This finding has important implications for the generalization of the present study to individuals with balancing difficulty. Considering individuals with balancing difficulties would perform poorly on all these tests, short-term Abhinayadarpana based dance training is likely to show more improvements in them than that in adults with normal balance function. However this remains only an inference and one needs to take up such a study in individuals with balance disorders before drawing a strong conclusion.

Overall, from the different types of data analysis carried out in the present study, it can be concluded that Abhinayadarpana based dance training is useful for improving body balance. This is true for both static as well as dynamic balancing abilities. Compared to exercises in the vestibular rehabilitation therapy, the present Abhinayadarpana based dance therapy is expected to be more joyous and therefore considering its usefulness the clinicians dealing with balancing disorders may advice this program. In the present study training was given for 21 days, each session being half an hour. The findings showed improvements even with this short term training. Considering that there is a negative relationship between pre training performance and the extent of improvement, clinicians could expect more improvements in the individuals with balancing disorders than what is recorded in the present study.

The improvements secondary to dance training did depend on the type of dance movement used and number of domains trained, although not to a great extent. The movements of Abhinayadarpana based dance are simple, easy to learn and require less time to perform. Therefore, clinicians could advice using eye and head movements as well as body movements and gait.

However, in spite of the clear evidences for positive influence of Abhinayadarpana based dance training on body balance in the present study, one is cautioned while generalizing the findings to the pathological population. Future research in the similar lines can be carried out in elderly population and in pathological population to support the implications drawn in the present study.

Chapter 6

SUMMARY AND CONCLUSIONS

Several rehabilitative exercises have been advised for improving balance in individuals with balance disorders. However, most of these have not been successful due to the monotony and in turn boredom involved in them. As an improvement, dance based therapies were initiated and have been proved to be successful. Most of these programs are based on the western dance forms and are difficult to adopt in the Indian context. Therefore, the present study aimed to investigate the influence of basic movements of Bharathanatya on balancing abilities. Bharathanatya is based on Abhinayadarpana which is an ancient text for most of the Indian forms of dance. The movements derived from Abhinayadarpana have the advantage of being simple and structured.

There were two objectives of the present study. One, to investigate the effect of short-term dance training utilizing movements cited in Abhinayadarpana (as used in Bharathanatyam) in improving balancing abilities of individuals. Second, in the event of an improvement being observable, to compare across the movements for differential effects, if any.

There were 32 participants in the present study. They were divided into three experimental groups (E1, E2 and E3) and one control group depending on whether they underwent dance training or not, and the type of dance movement learnt. The balancing abilities of the participants were documented on 4 behavioural tests, before and after the dance training. The dance training was given for a period of 21 days daily for a duration of half an hour. The data was analysed to compare the performance before and after the training and also between control and experimental groups. To verify the second objective the data within the three experimental groups were compared with each other.

Results of the present study showed that,

a) There was significant increase in the post-training phase compared to pre-training phase in the balancing abilities of experimental groups. This was true in all the 4 tests of balance function. Such changes were not seen in the control group.

b) Comparison between experimental and control groups, separately in the pre and post-training phases, did reveal differences in all the tests.
c) Comparison of the change index (pre-training scores subtracted from post-training scores) across the three experimental groups, showed that the type of dance movements influenced the training related changes in the Foam and Dome Test and the Star Excursion Balance Test.
d) Distribution of the individual data of change index showed that the training related improvement could be observed in majority of the participants in the experimental groups.
e) Correlation between the pre-training data and the individual change index showed high negative correlations, suggesting that individuals who had poorer scores in the pre-training improved more in the post-training and vice-versa.

Overall, findings of the present study support that dance training based on Abhinayadarpana is useful in training balance function. Because the training was only for a period of 21 days, it can be concluded that even short-term is beneficial in bringing noticeable improvement in the balance functions. The fact that all the tests evidenced improvements suggests that both static and dynamic balance improves with Abhinayadarpana based dance training. Incidentally, improvements secondary to dance training were present in most of the participants in the experimental groups.

Group differences in the change index indicate that the influence of dance training is dependent on which type of dance movements is used and also on the number of movement domains. The improvements observed also depended on the pre-training performance. If the pre-training performance was poor, such individuals were likely to get more benefit from the dance training.

However, in spite of clear evidences for positive influence of Abhinayadarpana based dance training on body balance in the present study, one is cautioned while generalizing the findings to the pathological population. Future research in the similar lines can be carried out in elderly population and in pathological population to support the implication drawn in the present study.

REFERENCES

Allum, J. H., & Pfaltz, C. R. (1985). Visual and vestibular contributions to pitch sway stabilisation in the ankle muscles of normals and patients with bilateral peripheral deficits. *Experimental Brain Research*, *58*, 82-94.

Ambegaonkar, J. P., Caswell, S. V., Winchester, J. B, Shimokochi, Y., Cortes, N., &Caswell, A. M. (2013). Balance comparisons between female dancers and active nondancers. *Research Quarterly for Exercise and Sport*, *84*(1), 24-9.

Bach, Y., Rita, P., Collins, C., & Hyde, J. (Eds.). (1971). *The control of eye movements*. New York: Academic Press.

Baloh, R. W., & Honrubia, V. (1990). *Clinical neurophysiology of the vestibular system*. Philadelphia: F.A. Davis Co.

Batson, G. (2010). Understanding balance: Applying science to dance training. *The IADMS Bulletin for Teachers*, *2*(1), 14-16.

Berencsi, A., Ishihara, M., & Imanaka, K. (2005). The functional role of central and peripheral vision in the control of posture. *Human Movement Science*, *24*(5/6), 689-790. doi:10.1016/j.humov.2005.10.014

Black, F. (1982). Normal subject postural sway during the Romberg test. *American Journal of Otolaryngology*, *3*(2), 309-318. doi:10.1016/S0196-0709(82)80002-1

Blakeslee, S., & Blakeslee, M. (2008). The Body Has a Mind of its Own. New York: Random House.

Blakeslee, S., & Blakeslee, M. (2008). *The body has a mind of its own: New discoveries about how the mind-body connection helps us master the world*. New York: Random House.

Blatt, P. J., Georgakakis, G. A., Herdman, S. J., Clendaniel, R. A., & Tusa, R. J. (2000). *The effect of the canalith repositioning maneuver on resolving postural instability in patients with benign paroxysmal positional vertigo. American Journal of Otolaryngology*, *21*, 356-363.

Byung In Han, Hyun Seok Song, Ji Soo Kim. (2011). Vestibular Rehabilitation Therapy: Review of Indications, Mechanisms, and Key Exercises. *Journal of Clinical Neurology*, *7*, 184-196.

Cannon, S. C., & Robinson, D. A. (1987). Loss of the neural integrator of the oculomotor system from brain stem lesions in monkey. *Journal of Neurophysiology*, *57*(5). doi:1383-1409

Cawthorne, T. (1946). Vestibular injuries. *Journal of the Royal Society of Medicine*, *39*, 270-273.

Colledge, N. R., Cantley, P., Peaston, I., Brash, H., Lewis, S., & Wilson, J. A. (1994). Ageing and balance: the measurement of spontaneous sway by posturography. *Gerontology*, *40*(5), 273- 278. .

Cooksey, F. S. (1946). Rehabilitation in vestibular injuries. *Journal of the Royal Society of Medicine*, *39*, 273-278.

Cooper, L., & Thomas, H. (2002). Growing old gracefully: social dance in the third age. *Ageing & Society*, *22*(6), 689-708. doi:10.1017/S0144686X02008929

Corbin, D. E. & Metal, C. J. (1983). Reach for It!! A Handbook of Exercise and Dance Activities for Older Adults. Eddie Bowers publishers. pp 232.

Crichton, S. (1997) 'Moving is the language I use - communication is my goal', *Journal of Dementia Care*, 5 (6), 16-17.

Crotts, D., Thompson, B., Nahom, M., Ryan, S., & Newton, R. A. (1996). Balance abilities of professional dancers on select balance tests. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(1), 12-7.

Diamantopoulos, I. I., Clifford, E., & Birchall, J. P. (2003). Short-term learning effects of practice during the performance of the tandem Romberg test. *Clinical Otolaryngology and Allied Sciences*, *28*(2), 308-313. doi:10.1046/j.1365-2273.2003.00710.x

Fay, B. H. (2007). Role of the Vestibular System in Postural Control. *Vestibular Rehabilitation*. 32-53.

Fukuda T. (1959). The stepping test. *ActaOto-Laryngologica*, *50*, 95–108.

Ghosh, M. (1957). Nandikesvara's Abhinayadarpanam: *A manual of gesture and posture used in Hindu dance and drama* (Nandikeśvara, Trans). Calcutta Oriental Press. (Original work published unknown)

Goebel, J. A. (2001). *Practical management of the dizzy patient*. Philadelphia: Lippincott Williams & Wilkins.

Gribble, H. (2004). Effect of lower-extremity fatigue on postural control. *Archives of Physical Medicine and Rehabilitation*, *85*, 589–592.

Gribble, P. A., & Hertel, J. (2003). Considerations for normalizing measures of the star excursion balance test. *Measurement in Physical Education and Exercise Science*, *7*(2), 89–100.

Gribble, P. A., &Hertel, J. (2004). Effect of lower-extremity muscle fatigue on postural control.*Archives of Physical Medicine and Rehabilitation*, *85*(4), 589-592.

Guerraz, M., & Bronstein, A. M. (2008). Ocular versus extraocular control of posture and equilibrium. *Neurophysiologie Clinique-clinical Neurophysiology*, *38*, 391-398. doi:10.1016/j.neucli.2008.09.007

Hackney, M. E., & Earhart, G. M. (2010). Effects of Dance on Gait and Balance in Parkinson's Disease: A Comparison of Partnered and Nonpartnered Dance Movement.*Neurorehabilitation and Neural Repair*, *32*(8), 679–684. doi:10.3109/09638280903247905

Hall, C. D., Heusel-Gillig , L., Tusa, R. J., & Herdman, S. J. (2010). Efficacy of gaze stability exercises in older adults with dizziness. *Journal of Neurologic Physical Therapy*, *34*, 64-69.

Halmagyi, G. M., Weber , K. P., & Curthoys , I. S. (2010). Vestibular function after acute vestibular neuritis. *Restorative Neurology and Neuroscience*, *28*, 37-46.

Han, B. I., Song, H. S., & Kim, J. S. (2011). Vestibular rehabilitation therapy: review of indications, mechanisms, and key exercises. *Journal of Clinical Neurology*, *7*, 184-196.

Herdman, S. J. (1997). *Advances in the treatment of vestibular disorders*. *Journal of Physical Therapy*, 602-618.

Hobeika, C. P. (1999). Equilibrium and balance in the elderly. *Ear Nose Throat*, *78*, 558-565.

Horak, F. B. (1987). Clinical measurement of postural control in adults. *Physical Therapy*, 67, 1881–5.

Johnson, B. G., Wright, A. D., Beazley, M. F., Harvey, T. C., Hillenbrand, P., & Imray, C. H. (2005). The Sharpened Romberg Test for Assessing Ataxia in Mild Acute Mountain Sickness. *Wilderness & Environmental Medicine*, *2*. doi:10.1580/PR02-04.1

Kapoula, Z. & Le, T. (2006). Effects of distance and gaze position on postural stability in young and old subjects. *Experimental Brain Research, 173*, 438-445. doi: 10.1007/s00221-006-0382-1

Kattenstroth, J. C., Kalisch, T., Holt, S., Tegenthoff, M., & Dinse, H. R. (2013). Six months of dance intervention enhances postural, sensorimotor, and cognitive performance in elderly without affecting cardio-respiratory functions. *Frontiers in Aging Neuroscience*, *5*, 5-32.

Krampe, J. (2010). Dance-based therapy to decrease fall risk in older persons. Ph. D. Thesis. University of Missouri-Columbia.

Krampe, J., Rantz, M., Dowell, L., Schamp, R., Skubic, M., & Abbott, C. (2010). Dance-based therapy in a program of all-inclusive care for the elderly: an integrative approach to decrease fall risk. *Nursing Administration Quarterly*, *34*(2), 156-161.

Laurel, J. T., Xiaoqing, G., Jing-jiang, L., Karen, L., & Laurence, R. H. (2009) The primal role of the vestibular system in determining musical rhythm. *Cortex*, *45*, 35–43.

Longridge, N. S., & Mallinson, A. I. (2010). Clinical Romberg Testing Does Not Detect Vestibular Disease. *Otology & Neurotology*, *31*(5), 803-806. doi:10.1097/MAO.0b013e3181e3deb2

Massion, J. (1998). Postural control systems in developmental perspective. *Neuroscience and Biobehaviour Review*, *22*, 465-72.

Merla, J. L., & Spaulding, S. J. (1997). The Balance System: Implications for Occupational therapy intervention. *Physical & Occupational Therapy in Geriatrics*, *15*(1), 21-33. doi:10.1080/J148v15n01_02

Coomaraswamy, K. A., & Duggirala, G. K. (1917). *The Mirror of Gesture - Being the Abhinaya Darpana of Nandikeśvara* (Nandikeśvara, Trans.). Harvard University Press. (Original work published unknown)

Nederlands Tijdschrift voor Geneeskunde | sneller bij kennis. (n.d.). Retrieved from http://www.ntvg.nl/publicatie/kwantificering-en-evaluatie-van-5-neurologische-evenwichtstests-bij-proefpersonen-en-pati/volledig/print

Pender, D. J. (1992). *Practical otology*. Philadelphia: J.B. Lippincott.

Riemann, B. L., & Lephart, S. M. (2002). The sensorimotor system, Part II: The role of proprioception in motor control and functional joint stability. *Journal of Athletic Training, 37*(1), 80–84.

Sathyanarayana, R., & Gorak, V. K. (1968). *Bharatanatya: A Critical study*. Mysore: Sri Varalakshmi Academy Publications.

Schafer, R. C. (1987). Clinical Biomechanics: Musculoskeletal Actions and Reactions. U.S.A: Lippincott Williams & Wilkins.

Schuknecht, H. F. (1993). *Pathology of the ear*. Philadelphia: Lea & Febiger.

Shepard, N., & Asher, A. (2000). Treatment of patients with nonvestibular dizziness and disequilibrium. In *Vestibular Rehabilitation* (4th ed., pp. 534-544). Philadelphia: Davis.

Shepard, N. T., & Telian, S. A. (1995). Programmatic vestibular rehabilitation. *Journal of Otolaryngology Head and Neck Surgery, 112*, 173-182.

Shepard, N. T., Telian, S. A., & Smith-Wheelock, M. (1990). Habituation and balance retraining therapy. A retrospective review. *Journal of Neurology Clinics, 8*, 459-475.

Shumway-Cook, A., & Horak, F. B. (1986). Assessing the influence of sensory interaction on balance. *Physiotherapy. 66* (10); 1548-50

Simmons, R.W. (2005). Neuromuscular responses of trained ballet dancers to postural perturbations. *International Journal of Neuroscience, 115*, 1193-1203.

Swathi, V. M., & Sinha, S. K. (2012). Effect of dance training on vestibular evoked myogenic potentials. Published in Student Research at AIISH, Mysore (Article based on Dissertation done at AIISH).

The Eyes (Human Anatomy): Diagram, Optic Nerve, Iris, Cornea, Pupil, & More. (n.d.). Retrieved from http://www.webmd.com/eye-health/picture-of-the-eyes

Walls, G. L. (1988). The evolutionary history of eye movements. In R. H. Carpenter (Ed.), *Movements of the eyes* (2nd ed., pp. 69-80). London: Pion.

Walls, A. (2010). Effectiveness of dance for improving balance in healthy elderly adults: an evidence-based review. PT, MS, DPTc PT 209-910.

Zee, D. S. (2007). Vestibular adaptation. In S. J. Herdman (Ed.), *Vestibular rehabilitation* (3rd ed., pp. 77-90). Philadelphia: F.A. Davis.

Appendix I

Movements from Abhinayadarpana Used for the Study

A1. Head Movements (*śirōbhēdāḥ*)

A1.1. *samaśiraḥ*

When the head is kept motionless without bending or raising up, it is named *sama*.

A1.2. *udvāhitaśiraḥ*

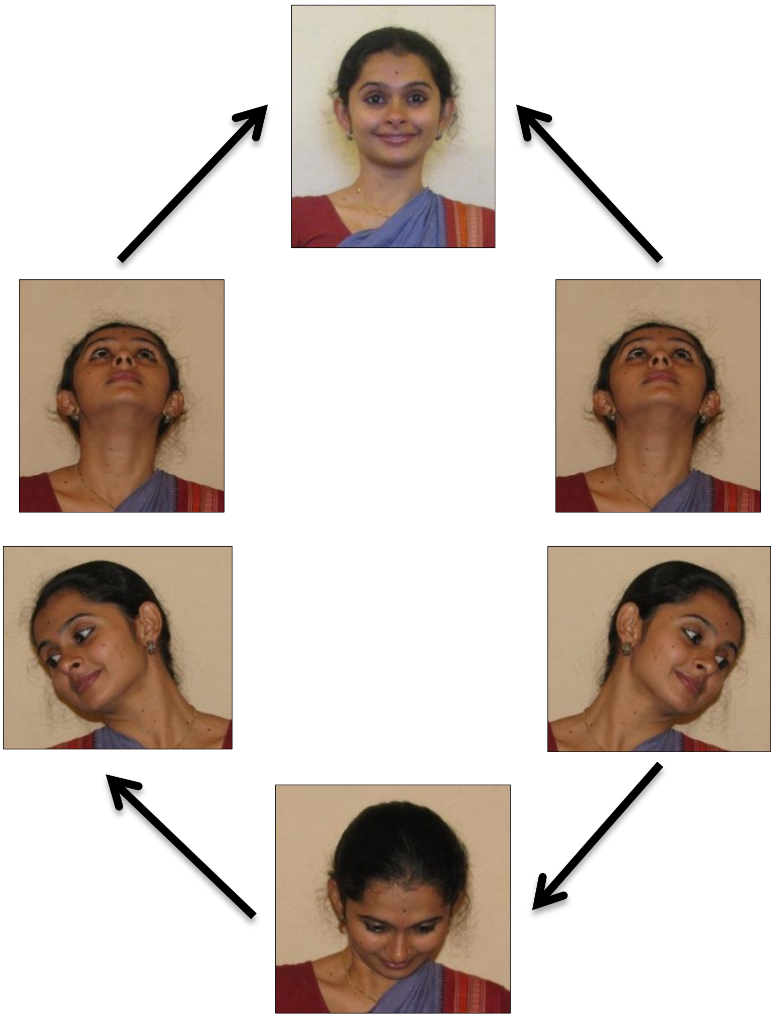
When the face is raised up, the head is named *udvāhita*.

A1.3. *adhomukhaśiraḥ*

When the face is cast down, the head is called *adhomukha*.

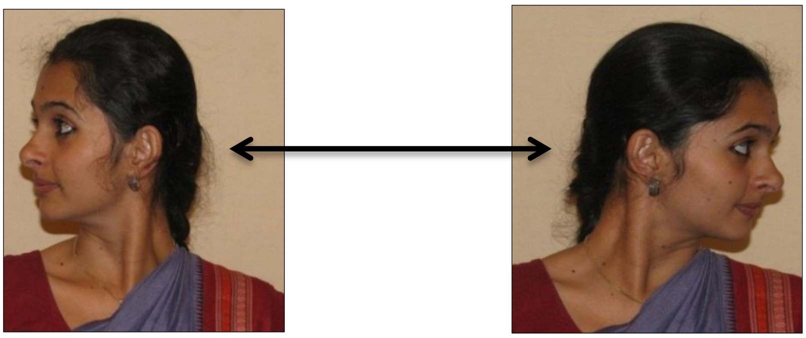
A1.4. *ālōlitaśiraḥ*

When the head is moved round it is called ālolita.



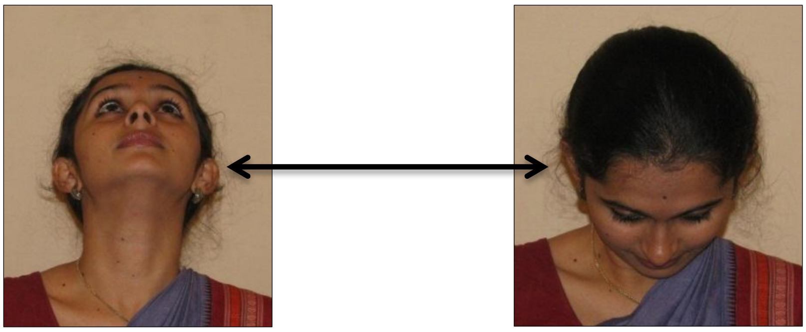
A1.5. *dhutaśiraḥ*

When the head is moved from the left side to the right one and vice-versa, the head is called *Dhuta*.



A1.6. *kampitamśiraḥ*

When the head is shaken up and down, it is called *Kampita*.



A1.7. *parāvṛttaśiraḥ*

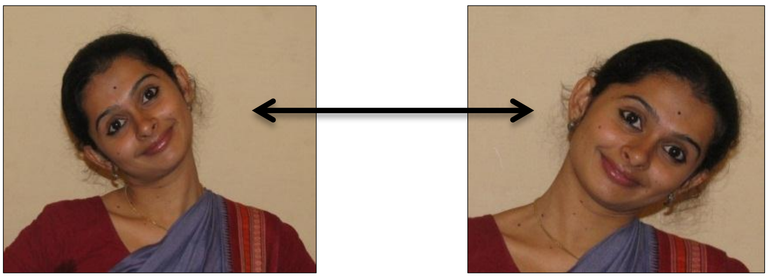
When the face is turned round the head is called *Parāvṛtta*.

A1.8. *utkṣiptaśiraḥ*

When the head is turned aside and then raised up, it is called *Utkṣipta*.

A1.9. *parivāhitaśiraḥ*

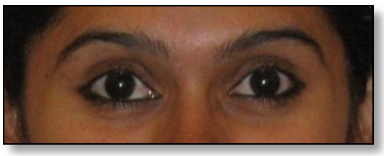
When the head is moved from side to side like a *cāmara*, the head is called *Parivāhita*



A2. Eye Movements (*dṛṣṭibhēdāḥ*)

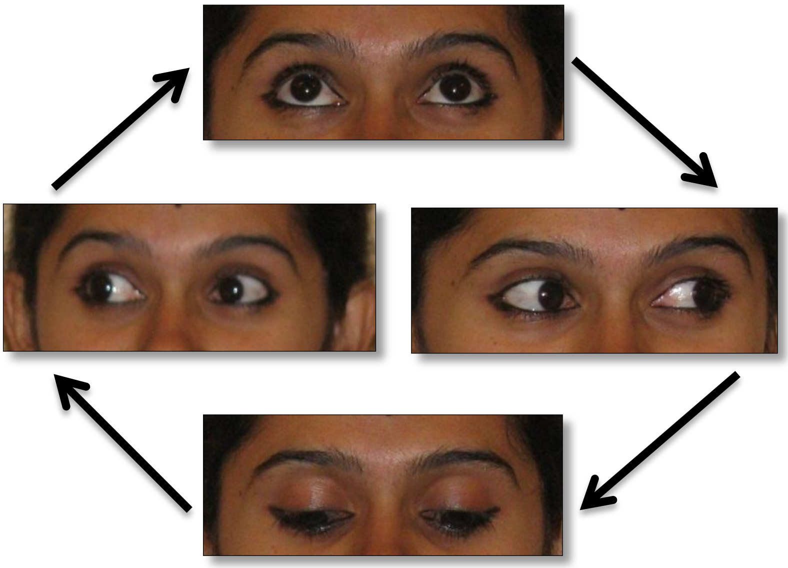
A2.1. *sama dṛṣṭiḥ*

The [straight] glance [without moving the eye-lashes], like that of a female divinity, is called *Sama.*



A2.2. *ālōkitadṛṣṭiḥ*

Gazing quickly around with open eyes is called *ālōkita.*

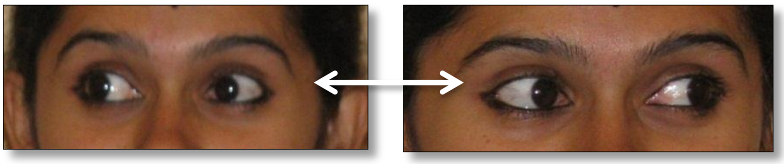


A2.3. *sācīdṛṣṭiḥ*

Looking out of the corner of the eyes is called *sāci.*

A2.4. *pralōkitadṛṣṭhiḥ*

Looking from side to side is called pralōkita.

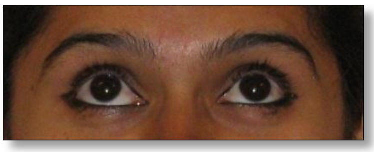


A2.5. *mīlita dṛṣṭhiḥ*

Half-closed eyes make the *nimīlita* glance.

A2.6. *ullōkitadṛṣṭhiḥ*

Looking upwards is called *ullokita*.



A2.7. *anuvṛttadṛṣhṭiḥ*

Glancing quickly up and down is called *anuvṛtta*.

A2.8. *avalōkitadṛṣhṭiḥ*

Looking downwards is called *avalōkita*.

A3. Leg movements *(pādabhedaḥ)*

A**3.1. Postures (*maṇḍalabhēdā*)**

A3.1.1. *stānakamaṇḍalam*

Standing with both feet in the same line and touching the hip with ardhacandra hands, will be *stānaka*

A3.1.2. *āyatamaṇdalam*

Standing with two feet half a cubit apart from each other in a caturaśra posture and at the same time bending knees a little apart and placing one of them upon the other, will give rise to the *āyata* posture.

A3.1.3. *alīḍamaṇdalam*

Place the left foot before the right one at a distance of one cubit and a half, make *śikhara* with the left hand and *katakāmukha* with the right one; this, according to Bharata and others, will give rise to the *ālīḍha* posture.

A3.1.4. *pratyālīḍhamaṇḍalam*

Putting one foot by the side of another heel and having *kūrma* hands, will give rise to the *preṅkhaṇa* posture.

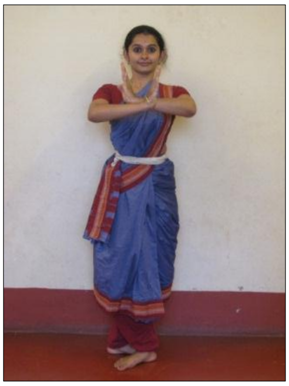
 

A3.1.5. *prēritamaṇḍalam*

Putting one foot violently [on the earth] at a distance of one cubit and a half from another and standing with knees bent and one of them put across another and holding the *śikhara* hand at chest level and showing the *patāka* hand stretched out, will give rise to the *prērita* posture.

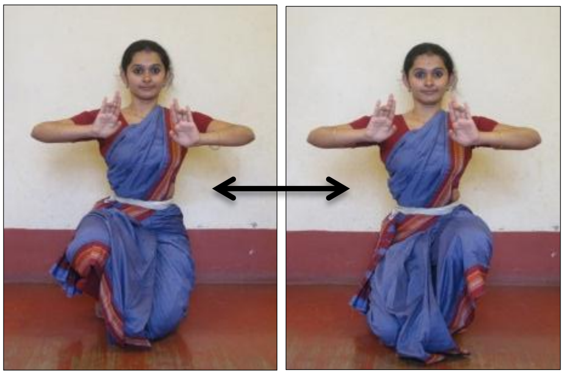
A3.1.6. *svastikamaṇḍalam*

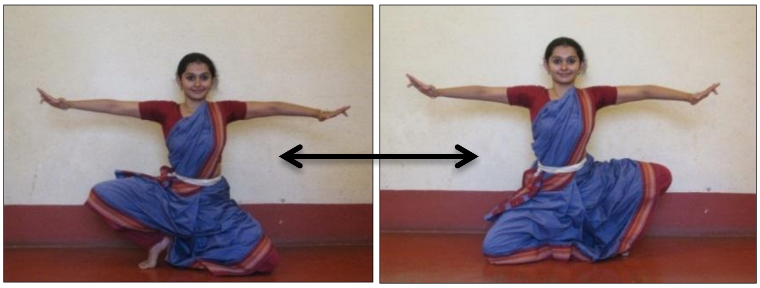
The right foot should be put across the left foot, and the right hand should be put across the left hand; thus will be the *svastika* posture.

A3.1.7. *mōṭhitamanḍalam*

Rest on the earth with the forepart (toes) of the feet and touch the earth with each knee alternately and make *tripatāka* with both the hands; this will give rise to the *mōṭhita* posture.





A3.1.8. *samasūcīmaṇḍalam*

A posture in which the earth is touched with toes and knees is called *samasūci*.

A3.1.9. *pārṡvaṡūcimaṇḍalam*

The posture in which the earth is touched with toes and by one knee on one side is called *pārśvasūci*.

A3.2. Types of Resting Postures (*sthānaka*)

sthānaka bhēdāḥ

A3.2.1. *samapādasthānam*

Standing with two feet alike is called *samapāda*.

A3.2.2. *ēkapādasthānam*

Standing with one foot and laying the other across the knee of that foot will give the *ēkapāda* position.

A3.2.3. *nāgabandhasthānam*

Standing like a serpent intertwining two feet and two hands together will give the *nāgabandha* posture.

A3.2.4. *aindrakasthānam*

Standing with one leg bent and the other leg and knee raised and hands hanging naturally, will give rise to *aindra* posture.

A3.2.5. *garuḍastnakam*

If in the *ālīḍha* posture one knee is put on the ground and the two hands jointly show the gesture it will be the Garuda posture.

A3.2.6. *brahmasthānam*

Sitting with one foot on one knee and another foot on another knee will give rise to Brahma posture. It is used to denote *japa* (repeated muttering of prayers) and similar matters.

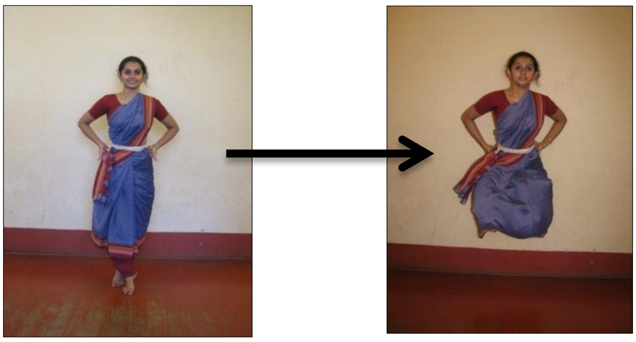
A3.3. Types of Leaps (*utplavanabhēdāḥ*)

A3.3.1. *alagōtplavanam*

Leaping with both the feet and placing *śikhara* hand on the hip, at the same time, will be *alaga*.

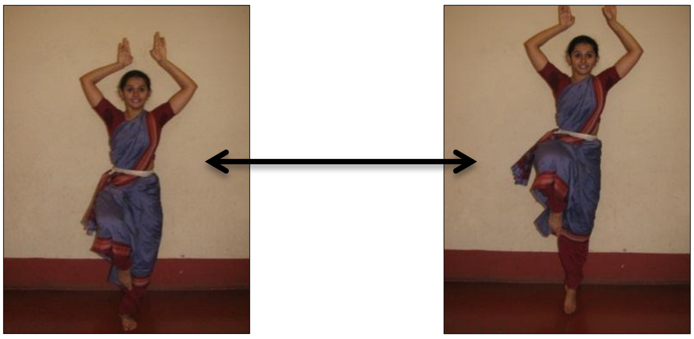
A3.3.2. *utplavanakartari*

Leaping on toes with *kartari*, and holding on one's waist a downward *śikhara* hand at the same time, will be *kartari* jump.



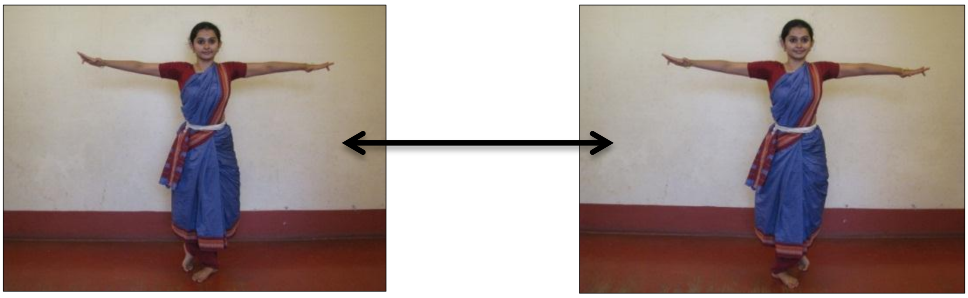
A3.3.3. *aśvotplavanam*

First, leap on two feet and then place them together, and make *tripatāka* with both the hands. This will be *aśva* jump.



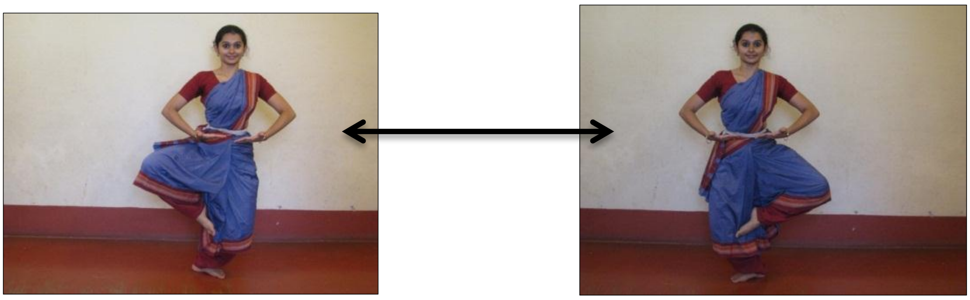
A3.3.4. *mōṭitōtplavanam*

Leaping on both sides alternately like a *kartarī*, will be *mōṭita* jump.



A3.3.5. *kṛpālagōtplavanam*

By heels of both the feet alternately touch the hip and keep *ardhacandra* hands between the two. This will make *kṛpālaga*.



A3.4 Types of Spins (*bhramarī*)

bhramarī lakṡaṇam

A3.4.1. *utplutabhramarī*

If a person moves round his entire body from a *samapāda* posture, he is said to perform the *utpluta bhramarī.*

A3.4.2. *cakrabhramarī*

If keeping feet on the earth and carrying *tripatāka* hands, one moves round rapidly one then performs *cakra bhramarī.*

A3.4.3. *garuḍabhramarī*

Stretch one foot across another and put the knee on the earth and then move about rapidly with outstretched arms. This will be the Garuda *bhramarī.*

A3.4.4. *ekapādabhramarī*

Moving round alternately on one foot will be the *ekapāda bhramarī*.

A3.4.5. *kuñcitabhramarī*

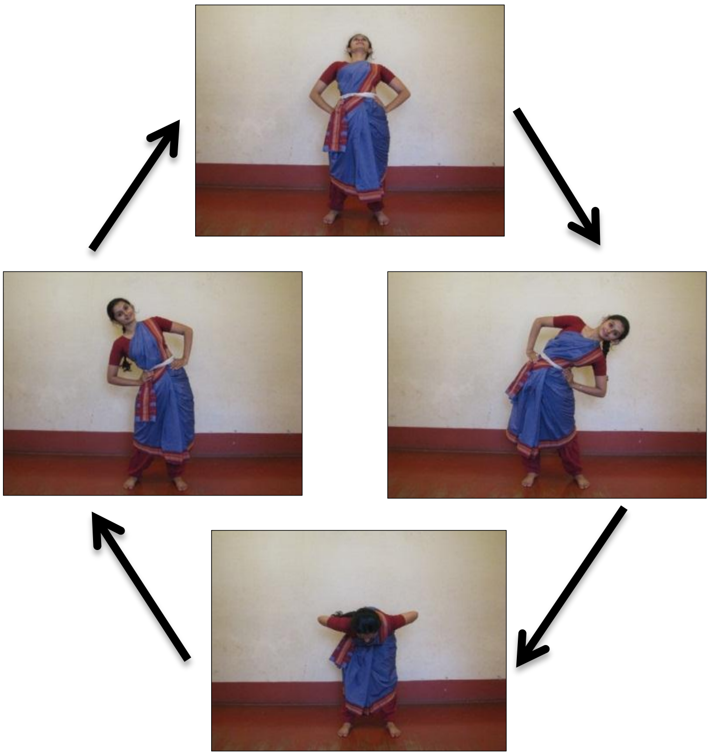
Moving round with knees bent will be the *Kuncita bhramarī*.

A3.4.6. *ākāśabhramarī*

If one moves round his entire body after making his fully stretched feet wide apart in a jump, he will make the *ākaśa bhramarī*.

A3.4.7. *aṅgabhramarī*

If one leaps with feet half a cubit apart and then stops, he performs the Aṅga bhramarī.



A3.5 Types of shifting positions (*cārībhēdāḥ*)

A3.5.1. *calanacāri*

Advancing a foot from its natural place will be *Calana* (walking).

A3.5.2. *Caṁkramaṇam*

Persons well-versed in *nātya* say that a gait made by two feet carefully raised up and thrown sideways alternately, is called *caṁkramaṇa* (making a leap).




A3.5.3. *saraṇam*

Moving like a leech that is covering ground, by joining one heel with another [at each step] and holding at the same time *Patāka* hands, is called *Saraṇa* (moving).



A3.5.4. *vēginī*

If a *naṭa* walks swiftly on his heels or toes or by his entire sole, and holds *alapadma* and *tripataka* hands alternately, he is said to go with *vegini* (running) gait.


A3.5.5. *kuṭṭaṇam*

The striking of the earth with the heel or the fore-part of a foot or the entire sole, is called *kuṭṭaṇa*.

A3.5.6. *luṭhitam*

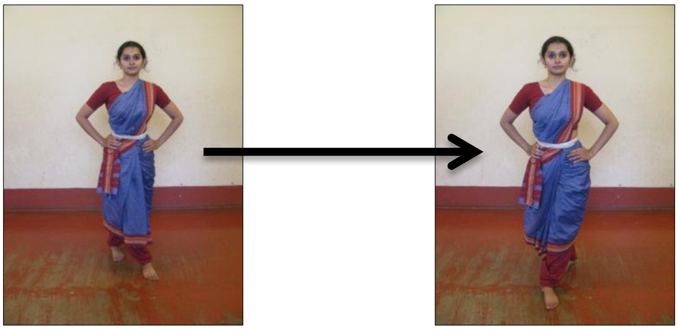
Performing *kuṭṭaṇa* from the *svastika* posture, is called *luṭhita* (rolling).

A3.5.7. *lōlitam*

Slowly moving a foot which has not touched the earth after performing *kuṭṭaṇa* as described before, is called *lolita* (trembling).

A3.5.8. *viśamasañcāraḥ*

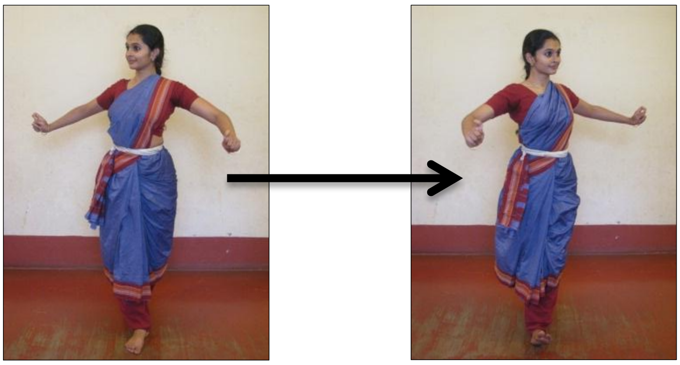
Setting the left foot to the right of the right one, and the right foot to the left of the left one alternately at the time of walking, is called *viśama* (rough) gait.



A3.6. Types of Gaits (*gati bhēdāḥ*)

A3.6.1. *hamsīgatiḥ*

Placing slowly one foot after another at a distance of half a cubit and bending on two sides alternately and carrying *kapittha* with both hands, will be stepping like a goose.



A3.6.2. *mayūrīgatiḥ*

To stand on toes and to carry *kapittha* in both the hands and to move both the knees alternately will be making Peacock-steps.

A3.6.3. *gajalīlāgatiḥ*

To walk slowly with *samapāda* feet with hands holding *patāka* on both sides is to have Elephant-step.

A3.6.4. *turaṅgiṇīgatiḥ*

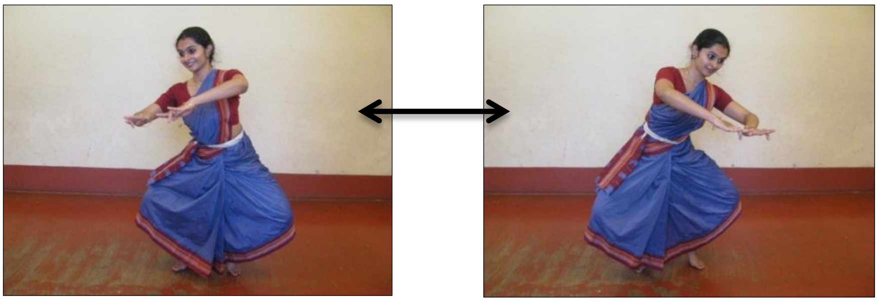
To raise the right foot and jump in quick succession and to hold *śikhara* with the left hand and *patāka* with the right [hand] will be the Horse-step.

A3.6.5. *simhīgatiḥ*

First stand on toes and then jump forward swiftly and proceed in this manner with *śikhara* held in both the hands. This will be the Lion-step.

A3.6.6. *bhujaṅgīgati*

If one holds *tripatāka* with both hands and on both sides and walks as before, he is said to move like a snake.



A3.6.7. *maṇḍūkīgatiḥ*

If one holds *śikhara* with both hands and steps almost like a lion, he is said to go with Frog-steps.

A3.6.8. *vīrāgatiḥ*

Coming from a distance holding *śikhara* with the left hand and *patāka* with the right one, will be called the Heroic step.

A3.6.9. *mānavīgatiḥ*

When one goes round in quick succession and puts the left hand on the waist, holds *kaṭakāmukha* with the right one, he is said to move with Humans