Training Related Enhancements in Anticipatory Postural Adjustments in Healthy Older Adults

By

SAILEE JAGDHANE

B.P.Th. Tilak Maharashtra University, India, 2011

THESIS

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Defense Committee:

Alexander S. Aruin, Chair and Advisor
Tanvi Bhatt, Physical Therapy
Gay Girolami, Physical Therapy

Dedicated to my husband Abhijit Ghawate, with whom I look forward to grow old and wise and 'Papa' - my father-in-law, Subhash Ghawate, whose love has left the memories that cannot be stolen for they are treasured forever.

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Last but not the least my humble salute to all the participants who participated in my study. It was not easy for them and I find myself at a loss of words to thank them for their time and effort.

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LIST OF ABBREVIATIONS

ABC – Activity Specific Balance Confidence Scale

ANOVA - Analysis of variance

APAs – Anticipatory Postural Adjustments

BBS – Berg Balance Scale

BM – Balance Master

BOS – Base of support

CG – Control Group

CNS – Central Nervous System

COG – Center of Gravity

COM - Center of Mass

EC- Eyes Closed

EG – Experimental group

EMG-Electromyography

EO – Eyes Open

FRT- Functional Reach Test

ICF - International Classification of Functioning Disability and Health

MCTSIB – Modified Clinical Test of Sensory Interaction on Balance

RBF – Right Biceps Femoris

REO- Right External Oblique

RES – Right Erector Spinae

RGM – Right Gluteus Medius

RGM – Right Medial Gastrocnemius

LIST OF ABBREVIATIONS (continued)

RRA – Right Rectus Abdominis

RRF – Right Rectus Femoris

RTA - Right Tibialis Anterior

TuG – Timed UP and Go

SUMMARY

This thesis primarily focuses on effects of training on the on enhancement of generation APA in elder adults. The study tries to answer these questions - Will there be an enhancement in APAs due to the 4 weeks training?, Will the enhancement in APA translate to better performance of functional tasks as measured in clinical assessment?, and Will clinical assessment show retention of enhancement in functional activity over a period of time?

The first chapter first begins by providing an understanding of falls, balance and human posture. It then introduces the concept of anticipatory postural adjustments (APAs) and further discusses factors affecting generation of APAs and how perturbations have been used in studies so far to study APAs. The chapter also introduces another concept called muscle synergies to present another aspect in understanding APAs. After providing a deep understanding of the theory of balance and APAs, the introduction chapter turns to tackle aging and effect of aging on human body and posture leading to decline in generation of APAs. It then describes possible strategies that could be used in rehabilitating elderly and restoration of APAs brining us back to the motivation behind this study.

The second chapter clearly states the aim of the study and thus provides a clear understanding of what the study has set out to achieve. The third chapter describes the methods of the study. It states how participants were chosen for the study and outlines experimental set. It also describes in detail the primary assessment method – Electromyography (EMG), the pendulum paradigm assessment setup used to record EMG activity as well as the application sites (muscles) used to record EMG activity. The secondary outcome measure - Clinical Tests – used by the study are then outlined and described briefly. Next it outlines the intervention method and then describes how data analysis was carried out.

Chapter five is devoted to reporting the results after statistical data analysis for assessments done during the study in the form of pre, post and retention results for the various tests described in

Summary (continued)

chapter three. Chapter five is dedicated to carry out a discussion on the results and the data analysis. It will call out the significant findings of the test and provide the authors view on the findings.

Chapter six outlines the limitations of the study and chapter seven finally provides a conclusion taking into account all the previous theory and results as well as discussions

1 INTRODUCTION

A succinct definition of a 'fall' is provided in a study on predicting falls in the elderly as - "an event which results in a person coming to rest inadvertently on the ground or other lower level and other than as a consequence of a violent blow, loss of consciousness or sudden onset of paralysis" (Lajoie and Gallagher 2004). Any individual performing daily activities or postural tasks, like walking, sitting, reaching, jumping etc., is putting himself in a situation that may potentially cause loss of balance leading to a fall. These postural challenges affect the equilibrium of the body by disturbing or perturbing it and thus causing a loss of balance. The main factor that decides if the disturbance to balance (perturbation) will cause a fall is if the body is able or unable to restore balance (Maki and McIlroy 2006). "The relationship between posture, balance and intentional movements is particularly important in the elderly population because a generalized decrease in balance control is accompanied by an increased frequency of movement related falls" (Rogers, Kukulka et al. 1992). Elderly individuals (age approximately 70-80 years) generally observe that they cannot move as swiftly as before while performing everyday tasks that may cause loss of balance (Woollacott and Manchester 1993). Several important issues need to be considered while studying postural control in the elderly. The following sections provide background related to these issues.

1.1 Understanding Postural Balance and Control

"Postural stability also referred to as balance which is the ability to control the center of mass (COM) relative to the base of support (BOS)" (Shumway-Cook and Woollacott 2012). "Normal balance requires control of both – gravitational forces to maintain posture and acceleration forces (internal and external) to maintain equilibrium" (Huxham, Goldie et al. 2001). Balance control relies upon the maintaining the COM within controllable limits of a 'static BOS' (as is observed while standing), or on track to a 'dynamic BOS' (as is observed while walking or running)(Huxham, Goldie et al. 2001). A study

(Latash, Krishnamoorthy et al. 2005) explains the complexity of maintaining human posture balance owing to human anatomy. The human body has a bipedal structure and can be likened to an inverted pendulum which is unstable. The center of mass is higher than ideal and it is resting on a small base of support. This task of maintaining posture is further complicated as there are several joints along the vertical axis of the body, frequent external disruptions of the body posture and voluntary motor actions by person standing on their own.

1.2 <u>Understanding Anticipatory Postural Adjustments</u>

Anticipatory Postural Adjustments (APAs) can be best described as a feed forward postural response mechanism of the body that maintains postural balance during and after movement. It is a preprogrammed postural adjustment that precedes the impending movement (Shumway Cook and Woollacott 2012).

In their seminal work scientists Belen’kii, Gurfinkel and Pal’tsev (Belen'kii, Gurfinkel et al. 1967) describe how postural muscles behave in response to command for movement. While asking a standing subject to perform fast elbow flexion movement, they observed that the postural muscle (biceps femoris) activation patterns are divided into two parts. The first is the ‘Preparatory Phase’ in which postural muscles were activated more than 50 ms in advance of the prime mover (anterior deltoid) muscles to compensate in advance for the destabilizing effects of the movement. The second is a ‘Compensatory Phase’ in which the postural muscles were again activated after the prime movers in a feedback manner to further stabilize the body.

Thus we can say APAs mark the initiation of muscle activity in anticipation of a movement. Before the voluntary movement there must be enough postural control preceding the desired action and so APAs occur before and during the movement. This study also illustrated that although the task of balance restoration taken in its entirety, performed by the Central Nervous System (CNS), is apparently complex, there is nevertheless an exact sequence in the activation of skeletal muscles(Belen'kii, Gurfinkel et al. 1967).

1.3 **Factors affecting Anticipatory Postural Adjustments**

The generation of APAs is impacted by certain key factors such as magnitude of perturbation, direction of the perturbation, magnitude of the motor action associated with the perturbation and the postural task (Aruin 2002).

1.3.1 **Magnitude of perturbation**

With an increase in the magnitude of the perturbation the generation of APAs activity increases while with a decrease in the magnitude, the generation of APAs activity is reduced. The study by Aruin and Latash (Aruin and Latash 1995) demonstrates this by showing APAs could be scaled with respect to the magnitude of a self-triggered perturbation.

1.3.2 **Direction of Perturbation**

The direction of the perturbation causes scaling of anticipatory postural activities. A study on directional specificity of postural muscles concluded that altering of the direction of voluntary movement lead to changes in the muscles used to generate APAs

1.3.3 **Magnitude of motor action associated with perturbation**

The motor action or the specific voluntary action associated with the perturbation has an effect on the magnitude of APAs generated. It was observed that the magnitude of the motor action that triggered the postural perturbation had a direct effect on the magnitude of the generated APAs (Aruin and Latash 1996).

1.3.4 Postural Task

By varying the stability level of the body, studies have tried to analyze the effects of the postural task on the magnitude of the APAs generated. Unstable posture leads to conditions in which no APAs generated (Nouillot, Bouisset et al. 1992). Likewise even a stable posture leads to absence of APAs (Nardone and Schieppati 1988). A study investigating the effects of unstable posture on APA generation demonstrated that in conditions of a standard perturbation and standard motor action two factors related to the postural task affected the magnitude of APAs generated – plane of postural stability and area of support (Aruin, Forrest et al. 1998).

1.4 Inducing Perturbations to study Anticipatory Postural Adjustments

Earlier studies have employed various methods to induce perturbations and observe APAs**.** These can be categorized based on the method used to elicit the perturbation; - self-induced or externally induced. Movements like forward arm flexion (Belen'kii, Gurfinkel et al. 1967), leg flexion (Mouchnino, Aurenty et al. 1992), trunk flexion (Oddsson and Thorstensson 1987) and releasing a load (Aruin and Latash 1995) are self-induced perturbations commonly used in studies. Very few studies have focused on studying APAs by inducing external perturbations like the pendulum impact paradigm (Santos, Kanekar et al. 2010, Kanekar and Aruin 2014). This is a novel approach adopted in more recent studies.

1.5 Muscle Synergies

Various studies have proposed the idea of “Synergies” to explain how various muscle groups, joints and actions are coordinated by the CNS and specifically the COM controller to bring about desired movements while maintaining the postural balance. Shumway-Cook defines synergy as the functional coupling of groups of muscles that are constrained to act together as a unit (Shumway-Cook and Woollacott 2012). Muscle synergies or muscle modes (M-modes) have been defined as “groups of muscles activated in synchrony or with fixed time delays for use by the CNS on a hierarchical scheme”

It can thus be inferred that maintaining postural balance is a complex activity for humans and in effect brings into play complex interactions between the musculoskeletal, neuromuscular, sensory and cognitive systems culminating in APAs. Thus one would expect any deterioration in these systems to have an impact on APA response.

1.6 **Aging**

Aging is generally associated with deterioration of various bodily functions and so it would be logical to conclude that it has an adverse effect on the body’s ability to maintain and control postural balance (Rogers, Kukulka et al. 1992). The process of aging occurs continually across the life span of humans. Although aging is definite and is generally thought of having a detrimental effect on the body and its various systems, the striking aspect is how different the aging process is from individual to individual. A surprising feature of most studies on aging is the great heterogeneity in the aging process, with older adults of the same chronological age showing physical function that ranges from the physically elite to the physically dependent and disabled (Shumway-Cook and Woollacott 2012). Due to the variability in the nature of aging, and also the variability of aging in the different systems within an individual, the studies related to aging are not all encompassing and there may be outliers who show different behavior compared to those in the same chronological age. Therefore, while it is useful to discuss the typical declines in functions, it is important to keep in mind that any one individual may show remarkable variability from his or her peers (Lewis and Bottomley 2007).

1.7 Effects of aging on Anticipatory Postural Adjustments

Some studies (Man'kovskii, Mints et al. 1980, Woollacott and Manchester 1993) show that the elderly perform better when the movement is slow. APAs of postural muscles occurs to maintain balance during a voluntary movement. The comparative study (Man'kovskii, Mints et al. 1980) between a young age group and an elderly group performing voluntary movement (knee flexion) showed that with increased age the latent period of APAs also increases. This leads to a decrease in the time between the onset of the APAs and the occurrence of the voluntary movement. Subsequently the performance of the motor task suffers and the probability of loss of balance increases in the elderly.

When this same task is performed at a slower speed, the onset of APAs precedes the voluntary movement by considerable amount among the older age group. This allows the whole postural control system to function more appropriately and thus the voluntary movement is achieved without less likelihood of loss of balance. The impression was that very complex motor task, are more advantageously performed slow, with increasing age, to optimize conditions for the maintenance of posture and balance the (Man'kovskii, Mints et al. 1980).

Aging is a continuous process that causes significant changes in skeletal muscles. This has a corresponding effect on the functional capacity of the muscles. With aging muscles become smaller and the reduction of muscle mass is greater in the lower extremities than in the upper extremities (Shumway-Cook and Woollacott 2012).The loss of muscle mass and strength that occurs with aging is called Sarcopenia which is a consequence of natural aging and is not associated with a disease (Lewis and Bottomley 2007). All studies so far agree that the elderly show a different response when compared to young individuals and that this difference is seen across varied movements, varied test conditions, different speeds of movement and when performing the task using different focal muscles. This suggests that there may be a common underlying factor related to aging that can cause this. Woollacott and Manchester (Woollacott and Manchester 1993) suggest that "age related physical deficits, strategy changes, and/or cognitive effects may be influencing the response of the older adults”. They also note that when the ‘healthy’ older subjects involved in their study were given a “neurological exam, specific subclinical signs of pathology were noted, and there was a strong correlation between the adults showing subclinical neural deficits and those with abnormal response characteristics”.

From our earlier understanding of the complexity of maintaining human postural balance, it can be concluded that a significant part of the CNS activity is brought into action to generate APAs and maintain balance. The brain mass or weight slowly decreases in the latter half of human life translating to cell loss. CNS cells are post mitotic and remaining cells continue to decline in numbers and efficiency; the conductive velocity of the CNS decreases with advancing age (Lewis and Bottomley 2007). The combination of decline in other brain functions and delay in the CNS results in the balance control problems in the elderly. They have diminished ability to judge loss of balance and also reduced ability to initiate APAs or corrective actions (Kanekar and Aruin 2014).

1.8 Balance Restoration Strategies

Bleuse and colleagues (Bleuse, Cassim et al. 2006) noted that the elderly adopted various muscle strategies to perform the same unilateral arm movement as the young with less stability. It was observed that in self-paced conditions of performance of the arm movements, elderly subjects used a hip strategy while young used ankle strategy. Various other studies also suggest that the elderly prefer hip strategy as opposed to the ankle strategy observed in the young, to regain balance after being perturbed. A possible cause could be explained by the fact that aging causes decrease in the number of active functional motor units and fiber types. Asaka and Wang (Asaka and Wang 2008) concluded that “greater hip dependence shown in the elderly could be due to greater motor unit loss in distal compared to proximal muscles” and because the somatosensory information input from the distal lower limb and foot is insufficient. Also it is observed that the maximum isometric force decreases in quadriceps and gastrocnemius muscles. This can also be the reason for the elderly using the hip strategy instead of ankle strategy.

1.9 Rehabilitation Strategies for Restoring Anticipatory Postural Adjustments in the elderly

We have so far discussed various problems and issues that present challenges for postural balance control system and a need to generate adequate APAs in the elderly. Predominant causes which we saw are increase in latent period of APAs (seen in postural muscles) and decrease in latent period of focal muscles. Older adults favor a, co-activation strategy over reciprocal strategy, adoption of Hip-Strategy as opposed to Ankle-Strategy due to greater loss of motor-unit in distal muscles, neuromuscular-degeneration and the adverse effects on CNS, Muscle Strength and Endurance and development of abnormal muscle synergies.

It is important that rehabilitation strategies must be devised taking into consideration all the issues discussed above. The most inevitable effect of aging are the changes to the neuromuscular system. This is the physical manifestation of aging that may not be entirely avoidable. Even so there may be ways in which changes in the neuromuscular system might be delayed or its intensity reduced. For example, sarcopenia, that is the loss of muscle mass and strength due to the process of aging, can be reversed with high intensity progressive resistive exercise which can also slow its development (Lewis and Bottomley 2007). In the process of aging, compared to loss of strength, the loss of endurance is lesser. This suggests that to deal with muscle weakness power training can have better results than strength training in elderly (Shumway-Cook and Woollacott 2012).

In a study of effects of physical activity in APAs in the elderly, Carvalho and colleagues (Carvalho, Vasconcelos et al. 2010) concluded that the practice of physical exercise seems to delay the decline associated to the natural aging process, demonstrating that the strategies adopted by the elderly (who performed physical exercise) approach those of the young adults. The present study simulates physical exercise in the form of a ball catching repeated over a period of time.

In 2010, the annual healthcare cost in US due to falls summed up to $30 billion while 2.4 million nonfatal fall injuries among older adults were treated in 2011. According to the National Institute of Aging, the estimated number of Americans aged 85 and older will be 19.4 million in 2050. An exercise protocol which could target the improvement in APAs response in the elderly might substantially reduce these high healthcare costs. The majority of the rehabilitation programs that use conventional treatment methods to address balance problems do not consider the enhancement of anticipatory postural adjustment as the goal of program.

Since the discovery of APAs many researchers have used rapid arm-raising/reaching tasks which induce internal perturbation, to produce postural perturbations in the anterior direction (Belen'kii, Gurfinkel et al. 1967), (Bouisset and Zattara 1987). We have cited in an earlier section several previous studies that used similar actions that induce internal perturbations. While performing such actions, the postural stability is threatened. The action causes an abrupt change of the body geometry, destabilizing it and requiring action from the CNS to restore balance. For example rapid arm raising leads to a forward acceleration of the center of mass (COM). A destabilizing reaction force on the supporting segments is produced as a result of internal forces of the raised arm and the forward acceleration. To act against this destabilizing force the CNS generates APAs, which takes place at the same time or just prior to the initiation of voluntary movement of raising the arm.

Internal perturbations usually are result of voluntary actions. One of the more recent studies raises an important question of whether aging directly affects the changes in APAs seen in the elderly or whether the aging process slow down voluntary movements which in turn affects APAs (Kanekar and Aruin 2014). Although the effects of internal perturbation have been studied for several decades, to study the effect of external perturbation on APAs using external perturbations, as noted earlier is still a novel approach. The study by Kanekar and Aruin suggests that by using predictable externally induced perturbations of constant magnitude we can investigate the direct effect of aging on APAs by eliminating the effect of age related changes in voluntary movements (Kanekar and Aruin 2014).

Catching a ball from a distance induces external perturbation. Postural disequilibrium is caused while catching an approaching object. As there is a demand to raise arm upwards and towards the object, the CNS scales the magnitude of APAs as per expected and actual mechanical impact of the forthcoming object on the hand. Catching the ball requires accurate spatiotemporal coordination between the hand and the ball at the specific time and place. “The function of APAs in catching is to predict the stability perturbing forces to be imposed by the object on the catcher and to produce preparatory muscular activity in order to stabilize the limb/body in advance of the catch” (Tijtgat, Vanrenterghem et al. 2013).

A previous study demonstrated that APAs in younger adults were improved with a single session training of catching the ball (Kanekar and Aruin 2015). Yet, little is known about the effects of short and long-term training in improving and maintaining the efficacy of APAs in balance control of older adults. Thus the aim of this study is to exactly do that.

2 AIM

The present study was focused on examining the effects of a 4 week long training protocol on the utilization and enhancements of the anticipatory postural adjustments (APAs) in the balance control of healthy older adults. The study was focused on answering the following specific questions:

a. Will there be an enhancement in APAs due to the 4 week training?

b. Will the enhancement in APA translate to better performance of functional tasks as measured by a clinical balance assessment?

c. Will the clinical assessment show retention of the enhanced functional activity 4 weeks following the end of the training

3 METHODS

3.1 Participants

Six older adults consented to participate in this study. The mean age was 73 ± 5 years. The participants were randomly divided into 2 groups – experimental group (2 females, 1 male) and control group (3 females). For the experimental group the average height was 165.94 ± 16.19 cm and average weight was 175.33 ± 21.92 kg respectively. For the control group the average height was 160.02 ± 2.54 cm and average weight was 129 ± 10.59 kg.

All participants were community dwelling healthy older adults who signed a written informed consent approved by the Institutional Review Board of University of Illinois, Chicago.

The inclusion criteria were - participant's age should be between 65- 89 years and the participant should be free from any neurological disorder such as Parkinson's disease or Stroke, musculoskeletal disorders or deformities, vestibular dysfunction, low back pain or any surgeries. It was crucial that participants were ambulatory and prospective subjects were excluded if they were unable to walk 10 meters without assistance.

As part of initial assessment, participants completed a brief questionnaire focused on basic demographics, medical history, power of glasses, hypertension and diabetes status and number of falls experienced in the past one year. Of the six participants, four experienced one fall in the past year, one experienced a near fall and one subject did not experience any falls.

3.2 Experimental Setup and Procedure

To study the effects of ball catching training, the participant pool was divided into two equal groups. Group A was the experimental group (EG) which underwent ball catching training while Group B was the control group (CG) and received no training.

Irrespective of group assignment each participant was assessed three times during the study. The assessment points were prior to the start of training (pre), after four weeks of training was completed (post) and one month after the end of training (retention) (Figure 1)

The assessment was divided in three sections:

1. Assessment of changes in the APAs using Electromyography (EMG)
2. Clinical Balance tests
3. Balance assessment using instrumented measurement (Balance Master)

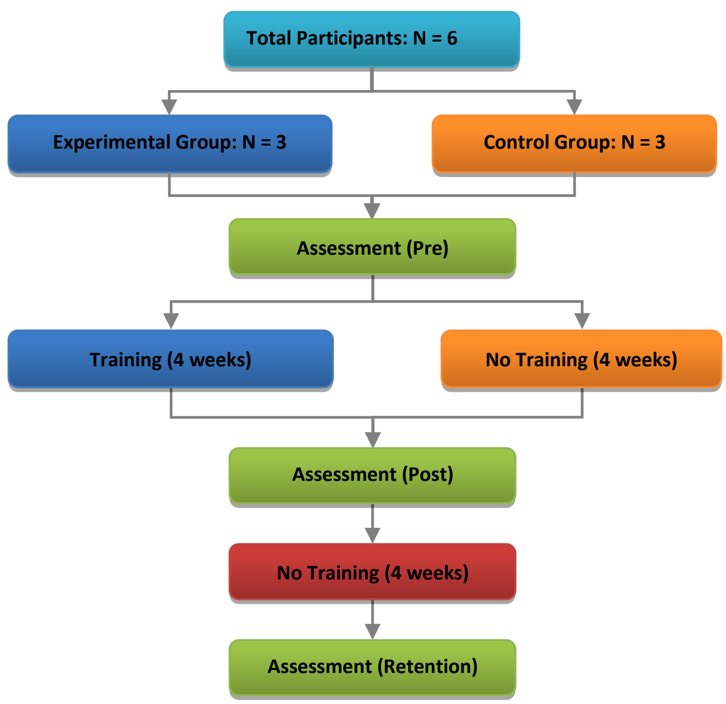

Figure 1. Study Design

3.2.1 Assessment of changes in the APAs using the Electromyography

To record the EMG activity associated with a perturbation, a pendulum paradigm was used. The pendulum paradigm or the pendulum test is used to apply external perturbations to the human body that may induce loss of balance. The test measures the body's response to this external perturbation in preparation for an upcoming perturbation and while recovering balance post perturbation.

3.2.1.1 Pendulum experimental setup:

To set up the test, the subject stood upright on a force platform while wearing a safety harness attached to the ceiling. EMG electrodes were attached to the subject's trunk and limb muscles bilaterally. A pendulum was hung from the ceiling in front of the subject (in sagittal plane). The length of the pendulum could be adjusted between 1.1m to 1.4m from the ceiling to accommodate the varying heights of the subjects.

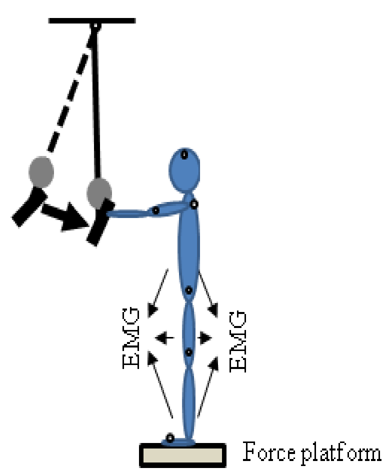

Figure 2. Pendulum assessment setup

The bottom end of the pendulum had a bar attached to it which formed an ‘inverted T’ in such a way that the bar lies parallel - lengthwise - to the subject’s palms when his shoulders were flexed at 90° with wrists extended at 90°. The pendulum could be loaded with varying weights (7% of subject’s body weight) using sand weights.

The pendulum was tethered in front of the subject to a hook on the opposite side with respect to the pendulum such that the distance between the subject and the pendulum bar was 0.8m. When unhooked the pendulum would swing towards the subject. Another rope was directly attached to the pendulum and was used to act as a brake to stop the pendulum from swinging further as required.

The participants received the swaying pendulum on the palms of their hands with their arms flexed at 90° and wrist extended at 90°. Maintenance of balance after the perturbation caused by the pendulum was required (Kanekar and Aruin 2014). An accelerometer (Model 208CO3, PCB Piezotronics Inc, USA) attached to the pendulum was used to record the moment of impact of the pendulum against the subjects palm (Santos and Aruin 2009).

3.2.1.2 Electromyography Data Collection

The EMG data was collected for the primary outcome measures of EMG muscle onset. Collection, filtering and amplification of EMG signals (10-500 Hz, gain 2000) was carried out by using an EMG system that was available commercially (Myopac, Run Technologies, USA). Sixteen muscles in the trunk and of both the legs were selected to record electromyography activity. The signals were recorded by means of disposable surface electrodes (Red Dot 3M, USA). The skin surface area was cleaned with alcohol preps. This was done to ensure good quality of EMG signal as any dirt particles are cleansed by the alcohol preps, reducing signal interference. To determine the muscle activation timing in milliseconds, muscle onset latency was used. Individual trials were examined on the computer screen. For every subject, data from the 5 best trials of the pendulum impact were collected. The first visible onset rise of the accelerometer signal in relation to its baseline referred to as moment of perturbation T_0 (impact of pendulum on subject's body) was measured. In relation to T_0, the muscle onset latency was detected in a time window from -450ms to +200ms.

3.2.1.3 EMG application site

The electrodes were attached bilaterally to the muscle bellies of the Tibialis Anterior (TA), Medial Gastrocnemius (MG), Rectus Femoris (RF), Biceps Femoris (BF), Gluteus Medius (GM), External Oblique (EO), Rectus Abdominis (RA) and Erector Spinae (ES). A ground electrode was attached to the anterior aspect of the leg over the tibia bone.

EMG, the technique of recording and evaluating the electrical activity produced by skeletal muscles, was used as an objective assessment tool. EMG records the myoelectric signals which are formed by physiological variations in the muscle fiber membranes (Konrad 2005). Researchers have shown from their study with sample of 20 young, healthy individuals that EMG is a highly reliable and valid technique to evaluate muscle activity (Marshall and Murphy 2003). A study assessing the between day and within day reliability of EMG application established excellent reliability ICC = 0.88 (Dankaerts, O'Sullivan et al. 2004). The intra-operator reliability of ICC >0.75 is established (Danneels, Cagnie et al. 2001).

3.2.2 Clinical Tests

It was also important to evaluate changes in the balance ability of the study participants during the duration of the study (Sibley, Howe et al. 2015). Balance impairments are difficult to quantify because of the variability in individuals. . The clinical measures that were administered and used as secondary outcome measures were: Timed Up and Go test, Activity –specific Balance Confidence Scale, Berg Balance Scale, and functional Reach Test.

3.2.2.1 Timed Up and Go Test

Timed Up and Go (TuG) test is a clinical measure at the 'activity' level of the International Classification of Functioning Disability and Health (ICF) domain. For TuG the patient sits in a chair which is about 46 cm high. The patient's back is against the chair and a marker is positioned at 3 meters distance in a straight line in front of the chair. The observer gives a voice command 'go' upon which the patient gets up from the chair and walks to the marker position, walks around the marker position to face the chair and then walks back to the chair and sits down. No assistive device such as a cane or a walker was used by the participants. The activity is timed starting from the command 'go' till the patient sits back in the chair and this is considered to be one trial. The average time in seconds of three such trials was used as the data point for this outcome measure. TuG is used to assess the participant's mobility and requires him to maintain both static and dynamic balance. The test- retest reliability for community dwelling elderly population is established to be excellent (ICC = 0.97) (Steffen, Hacker et al. 2002).

3.2.2.2 Activity-specific Balance Confidence Scale:

The Activity-specific Balance Confidence (ABC) scale is at activity level of the (ICF) domain. It is a subjective measure of confidence while performing ambulatory activities measured on a sixteen items questionnaire. Participants are asked to rate their balance confidence level while performing the tasks. The scoring ranges from 0 to 100, where 0 represents 'no confidence' while 100 is 'complete confidence'. The final score is the sum of the individual item scores, divided by the maximum total score possible. The test –retest reliability for the elderly population, examined at an interval of two weeks is reported to be excellent (r = 0.92, p < 0.001)(Powell and Myers 1995). The inter-rater and intra rater reliability has not yet been established.

3.2.2.3 Berg Balance Scale (BBS):

The Berg Balance Scale is an objective evaluation for elder population of risk of fall and static balance using a list 14 itemized tasks. According to the ICF domain BBS measures 'ACTIVITY' level performance. The test includes tasks ranging from sit to stand, reach forward, turn and look over the shoulder to standing on one leg, step and stand with narrow base of support. Each item is graded on a 5 point scale ranging from 0 (unable) to 4 (independent) with a, the maximum total score of 56 points (Berg, Wood-Dauphinee et al. 1995).The BBS shows excellent inter-rater reliability (ICC= 0.88)(Holbein-Jenny, Billek-Sawhney et al. 2005) and intra-rater reliability (ICC=0.97) (Berg, Wood-Dauphinee et al. 1992). For elderly population the test –retest reliability is established as ICC = 0.91 (Berg, Maki et al. 1992) . (Holbein-Jenny, Billek-Sawhney et al. 2005) estimated excellent test –retest reliability for institutionalized older adults to be as ICC = 0.77.

3.2.2.4 Functional Reach Test (FRT):

The Functional Reach test was developed by Duncan et al 1990, to provide a quick screen of balance problems in older adults - "It is the maximal distance one can reach forward beyond ones arm length while maintaining a fixed base of support in the standing position" and it has excellent test-retest reliability among community dwelling elderly with an ICC = 0.89 (Weiner, Duncan et al. 1992) and ICC = 0.92 (Duncan, Weiner et al. 1990). The test is conducted using a measuring tape stuck to the wall horizontally at the acromion level of the participant. Five conditions are recorded for the test. With the participants back perpendicular to the wall: bilateral arm reach, right arm reach, left arm reach was recorded. With the participants back against the wall, sideways reach for left arm and right arm were recorded. For all conditions the arms were flexed at 90 degrees with extended elbows and hand fisted. The tester asked the participant to extend his/her arms and a first measurement, at the position of the metacarpal, was noted. The participant was then asked to reach forward (for back perpendicular to the wall) or sideways (for back against the wall) as far as possible without losing balance or taking a step. A second measure was taken at each of these positions using the metacarpal for reference. The difference between the two measures was calculated as the measure for one trial. The average of two such trials for each condition was taken as the final measure.

3.2.2.5 Instrumented Balance Measurement

A Balance Master (BM) system from NeuroCom™ was used for instrumented balance measurements. The BM platform consists of two force plates with fixed dimensions of 45.72 cm * 152.4 cm. When participants perform a test on the platform their feet exert vertical force on the force plates. This vertical force is measured and recorded by the connected computer of the BM. For testing the participants stand on the force platform bare feet. The medial malleoli of each foot are aligned with the transverse force plate line. Each subject participated in the three tests described below.

3.2.2.6 Modified Clinical Test of Sensory Integration on Balance:

Measures postural sway velocity with the patient standing quietly on the force plate, first on firm surface with eyes open (Firm-EO) and with eyes closed (Firm-EC), then on a foam surface with eyes open (Foam-EO) and eyes closed (Foam-EC). The relative absence of sway is “stability”. The purpose of this assessment is to identify abnormalities in the sensory system contributions to postural control. The measured parameter was COG Sway Velocity “expressed as the ratio of the distance traveled by the COG in degrees to the time of the trial” (10 seconds) (Manual 2002).

3.2.2.7 Step Up Over:

Measures motor control characteristics. “The patient steps up onto a curb with one foot, lifting the body through an erect position over the curb, swings the other foot over the curb and then lowers the body to land the swing leg on the force plate” (Manual 2002). All tests are performed first the left leg as the leading leg and then the right leg as the leading leg.

The measured parameters are:

- **Lift-Up Index:** “The average maximum force exerted by the step-up leg, expressed as a percent of body weight”.
- **Movement Time:** “The average amount of time to complete the step over, expressed in second”.
- **Impact Index:** “The average maximum force transmitted through the lagging leg as it lands on the surface, expressed as a percent of body weight”.

3.2.2.8 Unilateral Stance:

Measures postural sway velocity with the patient standing quietly on one foot on the force plate, with eyes open or closed. The relative absence of sway is “stability”. For this assessment only eyes open stance was considered and the length of each trial was 10 seconds) (Manual 2002). The measured parameter was COG Sway Velocity expressed as “the ratio of the distance traveled by the COG in degrees to the time of the trial” (10 seconds) (Manual 2002).

3.3 Intervention

The experimental group participated in the 4 week training protocol (the intervention involved ball catching exercise) while the control group maintained their daily routine. The training protocol for the experimental group consisted of catching the ball multiple times in standing under four challenging base of support conditions:

1. Feet shoulder width apart (normal base of support)
2. Feet close together (narrow stance)
3. Right foot placed on a step (15 cm high) and
4. Left foot placed on a step (15 cm high)

2 lbs. and 4 lbs. medicine balls were alternated across the training sessions to induce different magnitudes of perturbation. To increase the intensity of training the number of repetitions was also increased over every week ranging from 100 in first week to 220 in the fourth week in order

3.4 **Data Analysis**

The data were analyzed using SPSS software version 22. To indicate the general trend of the group over the period of study descriptive statistics were used to obtain mean values for the two groups Further Mixed Design ANOVA or Split plot ANOVA analysis was carried out on the data. This analysis incorporates both a repeated measures effect as well as a between groups effect. The data from the two groups thus was analyzed based on two factors: the effect of time (within group repeated measure) and the effect of training/lack of training (between groups).

4 RESULTS

4.1 Assessment of changes in the APAs using the Electromyography

To report the APA-related changes in the EMG activity, timing of muscle onset latencies was used. Three muscles showed an onset of anticipatory postural adjustments in the EG (the group participating in the APA-focused training) after training earlier than the CG. APA activity in control group occurred close to the moment of perturbation and in some cases few milliseconds after the perturbation (Figure 2).

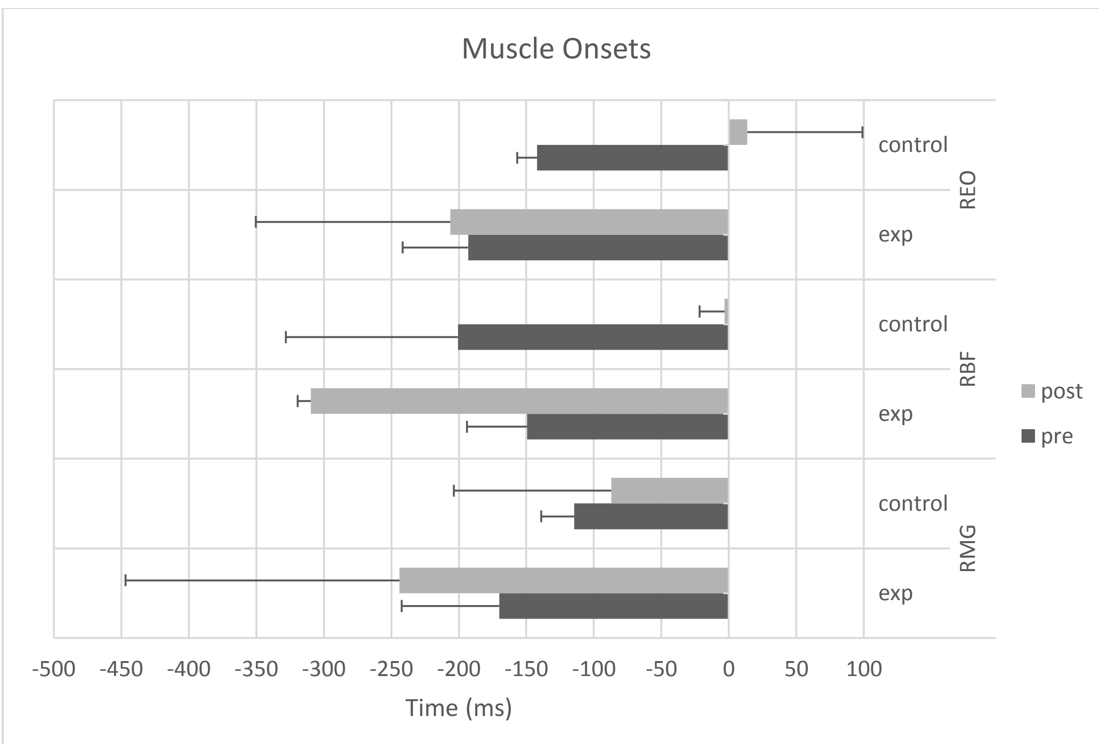

Figure 3. EMG Muscle Onsets for Experimental Group and Control Group

The onset of APA activity for the two groups was as follows:

Right MG: for EG, pre was (-145.4 ± 82.5 ms) and post was (-244 ± 202.93 ms); for CG, pre was (-114.5 ± 24.39) ms and post was (-25.12 ± 64.87 ms); $F(1, 4) = 3.147$, $p = 0.21$.

Right BF: for EG, pre was (-149.50 ± 44.5 ms) and post was (-200.62 ± 127.4 ms); for CG, pre was (-309.5 ± 9.8 ms) and post was (-3.16 ± 18.61 ms); $F(1, 4) = 8.40$, $p = 0.10$.

Right EO: for EG, pre was (-192.9 ± 48.61 ms) and post was (-206.33 ± 144.13 ms); CG, pre was (-142.12 ± 14.67 ms), post was (-26.5 ± 70.0 ms); $F(1, 5) = 1.08$, $p = 0.37$).

Although the above muscles and results showed a definite pattern of improvement in the EG (early activation of muscles) when compared to the CG, no statistical significance was found.

4.2 **Clinical Tests**

4.2.1 **Timed-Up and Go test**

The mean and standard deviations values obtained from the descriptive statistical analysis of the TuG for the experimental group and the control group at three different assessments: pre, post and retention are presented in Figure 3.

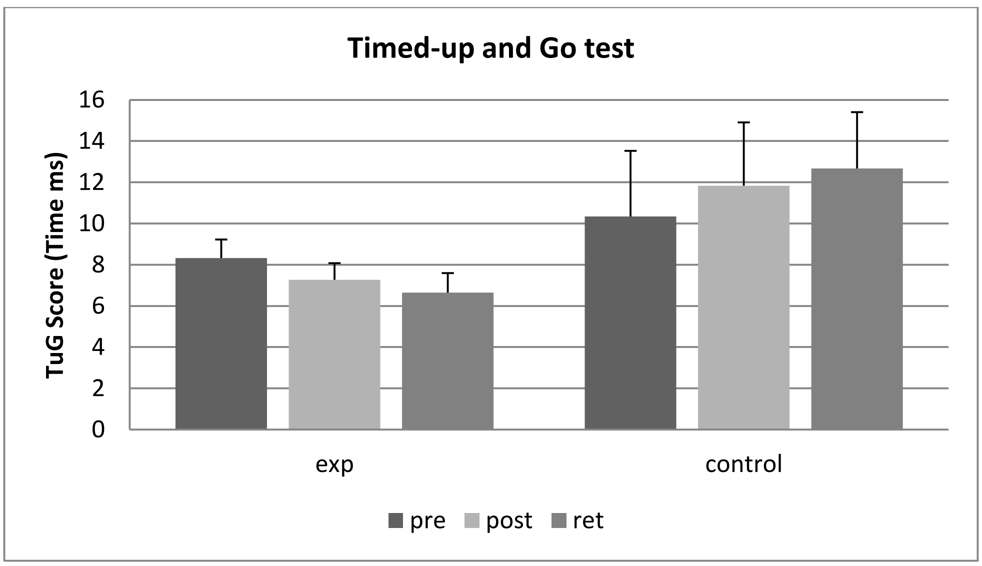

Figure 4. Mean Scores on TuG for pre, post and retention assessment - Experimental group demonstrates improvement with decreasing scores over time.

For the experimental group the analysis showed a mean pre score of 8.2 sec and a mean post score of 7.27 sec while the mean retention score was 6.64 seconds. For the control group the mean pre score was 10.34 sec, mean post score was 11.83 sec while the mean retention score was 12.67.

The analysis of the TuG scores shows marked improvement in the time taken by subjects in the EG to perform the test. The mixed ANOVA analysis also showed significant results ($F(2, 6) = 31.73$, $P < 0.001$). This indicates that training in experimental group led to decrease in time to perform the test as contrasted with the control group who required a longer time period to complete the TuG test.

4.2.2 Activity-specific Balance Confidence Scale

The mean and standard deviations values obtained from the descriptive statistical analysis on the ABC scale for the experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure. 4

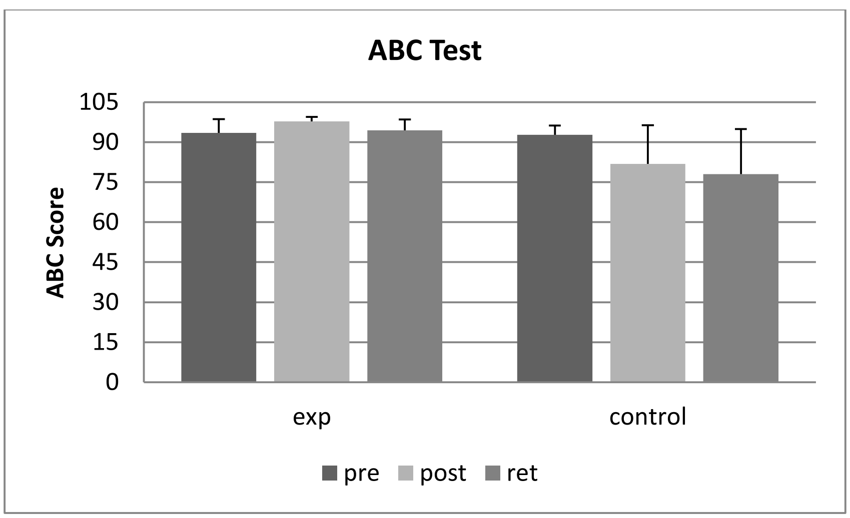

Figure 5. Mean Score on Activity-specific Confidence Scale for the Experimental and Control Groups

For the experimental group the analysis showed an increase in the mean score from pre to post testing with scores of 93.43 and 97.72 respectively. The retention score of 94.45 also indicates improvement over the pre score indicating the effects were sustained over time. For the control group there was a decrease in the pre score of 92.07 to a post score of 89.79. The retention score further decreased to 78.0.

These results seem to indicate an empirical improvement in the ABC Scale score in the experimental group while the control group shows further deterioration of balance in the absence of training. Although the mean score analysis seemingly upholds the hypothesis, the lack of significance in the statistical analysis ($F(2, 6) = 2.3$, $p = 0.162$) might indicate the training was not long enough to impact scores on this test or does not contribute to change in the items on this test.

4.2.3 Berg Balance Scale

The mean and standard deviations values obtained from the descriptive statistical analysis on the BBS scale for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 5.

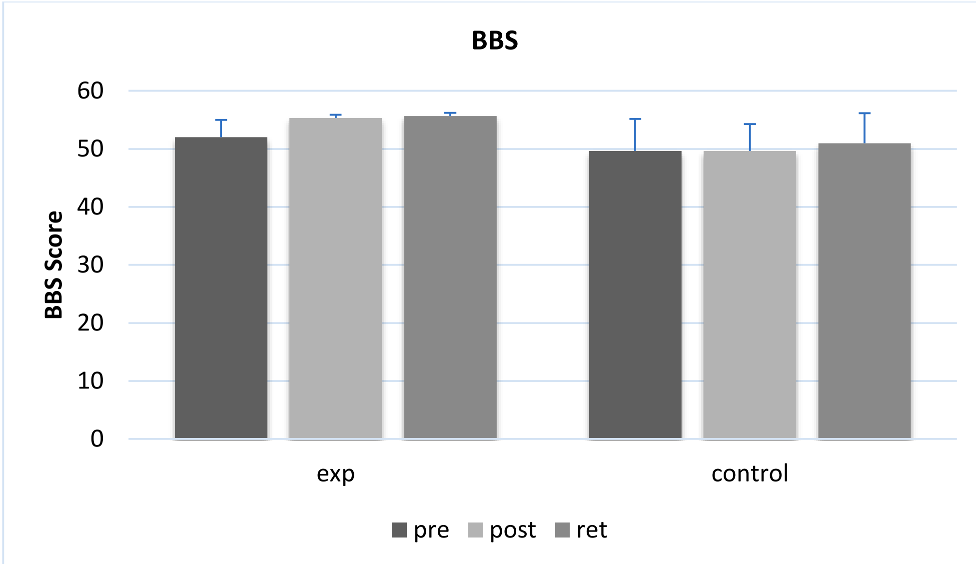

Figure 6. Mean scores on Berg Balance Scale for the Experimental and Control Group.

For the experimental group the analysis showed an increase in the mean score from pre to post with scores of 52.0 and 55.33 respectively. Since the minimal detectable change on the Berg Balance scale is 6.5 points an increase in 3 points do not have any significance(Romero, Bishop et al. 2011). The retention score 55.66 also indicates improvement over the pre score showing that the effects were sustained over time. For the control group the pre score and post scores were both 49.66 showing no improvement. The retention score was found to be 51.0 which is a non-significant improvement over the pre and post scores.

These results seem to indicate an empirical improvement in the BBS Scale score in the experimental group that underwent the training while the control group that did not undergo training shows same state in post assessment and insignificant improvement during retention. Although the mean score analysis seemingly upholds the hypothesis, there is lack of significance in the statistical analysis ($F(2, 6) = 0.71$, $p = 0.52$).

4.2.4 Functional Reach Test

The mean and standard deviations values obtained from the descriptive statistical analysis on the FRT scores (for each of the five conditions) for experimental group and the control group at three different assessments: pre, post and retention are as follows.

- **Bilateral Reach**: For the experimental group for bilateral reach the analysis showed a mean pre score of 25.50 cm and a mean post score of 25.66 cm while the mean retention score was 25.5 cm. For the control group the mean pre score was 25.833 cm, mean post scores was 24.83 cm while the mean retention score was 25.33 cm There was no statistical significance between the tests (F (2, 6) = 0.108, p = 0.89).

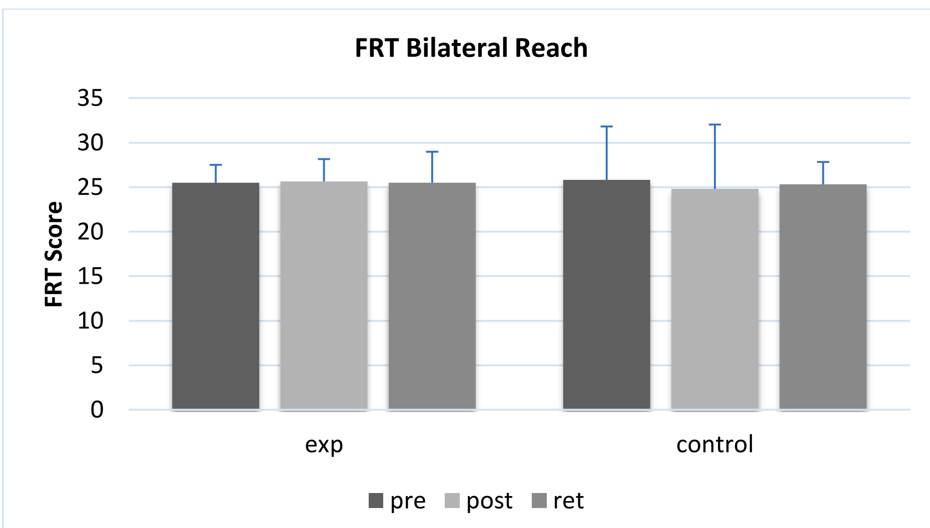

Figure 7. Mean scores for bilateral functional reach for the Experimental and Control groups

- **Front Right**: For the experimental group the analysis showed a mean pre score of 24.0 cm and a mean post score of 23.66 cm while the mean retention score was 26.83 cm. For the control group the mean pre score was 24.0, mean post scores was 19.5 while the mean retention score was 26.33. No statistical significance was reached (F (2, 6) = 0.44, p = 0.65).

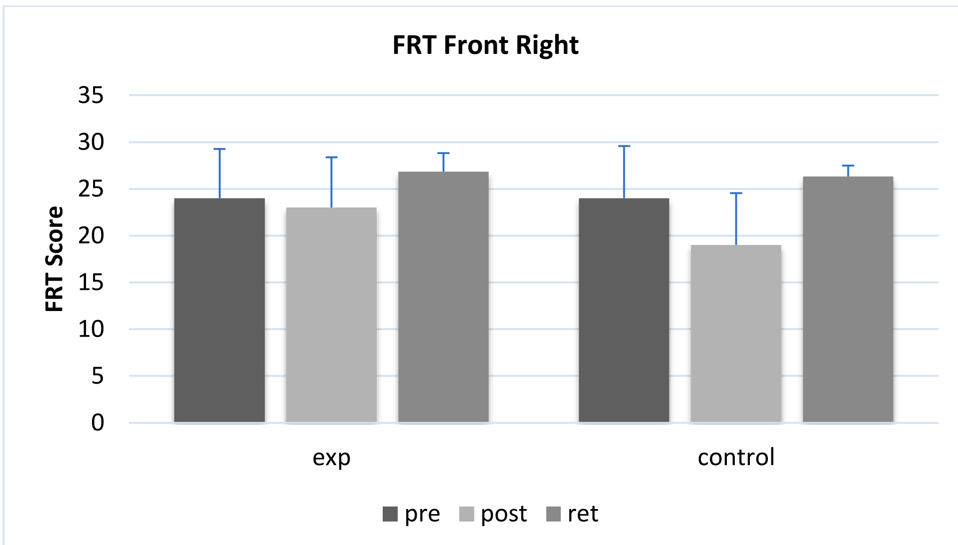

Figure 8. Mean Score for Functional Reach Test in the front right direction for the Experimental group and the Control group

- **Front Left**: For the experimental group the analysis showed a mean pre score of 24.16 cm and a mean post score of 23.0 cm while the mean retention score was 26.33 cm. For the control group the mean pre score was 25.33, mean post scores was 27.0 while the mean retention score was 23.66. There was no statistical significance (F (2, 6) = 1.71, p = 0.24).

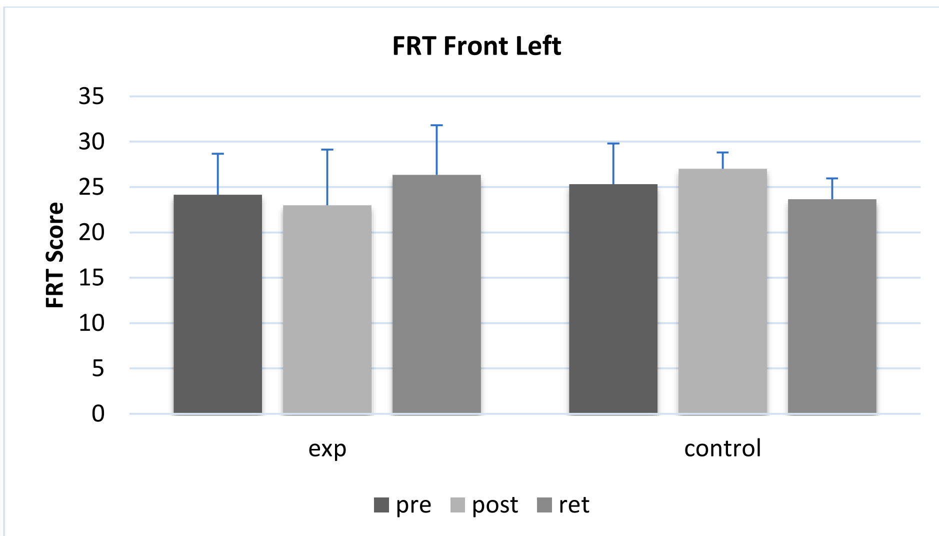

Figure 9. Mean scores on functional reach test in the front left direction for the Experimental group and Control group

- **Sideways Left**: For the experimental group the analysis showed a mean pre score of 13.5 cm and a mean post score of 14.66 cm while the mean retention score was 18.66 cm. For the control group the mean pre score was 12.83, mean post scores was 12.83 while the mean retention score was 12.83 (F (2, 6) = 1.01, p =0.40).

Here the sideways left conditions seems to show promising results as the reach out in the experimental group increased while in the control group remain same. The other FRT conditions tested do not show any pattern of improvement. The results do not seem to point toward any fixed pattern.

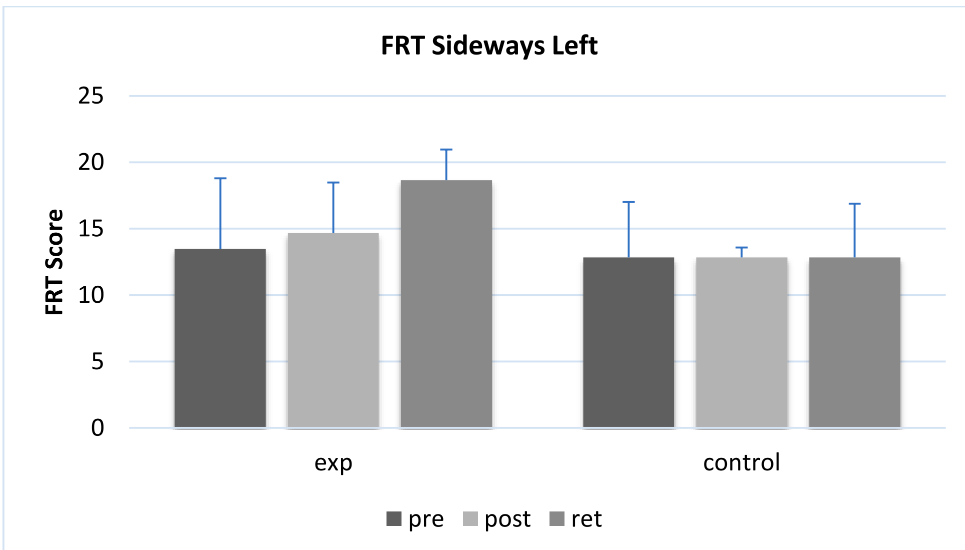

Figure 10. Mean scores for Functional reach test in the sideways left direction for the Experimental and Control groups.

- **Sideways Right**: For the experimental group the analysis showed a mean pre score of 19.0 cm and a mean post score of 17.33 cm while the mean retention score was 21.66 cm. For the control group the mean pre score was 18.66, mean post scores was 16.16 while the mean retention score was 15.0. ($F (2, 6) = 1.43$, $p = 0.294$).

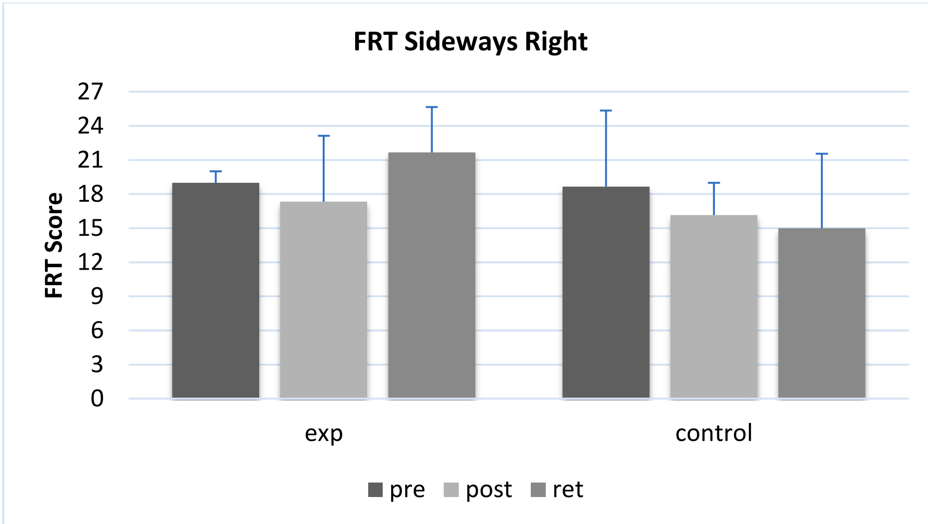

Figure 11. Mean scores for functional reach test in the sideways right direction for the Experimental and Control groups

4.3 Instrumented Balance Master Results

4.3.1 MCTSIB

- **Firm-EO:** The mean and standard deviations values obtained from the descriptive statistical analysis on the MCTSIB Firm EO condition for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 12. For the experimental group mean values of 0.26, 0.40, and 0.30 were obtained for pre, post and retention assessment respectively. For the control group mean values of 0.26, 0.30, and 0.33 were obtained for pre, post and retention assessment respectively (F (2, 6) = 0.55, p =0.59).

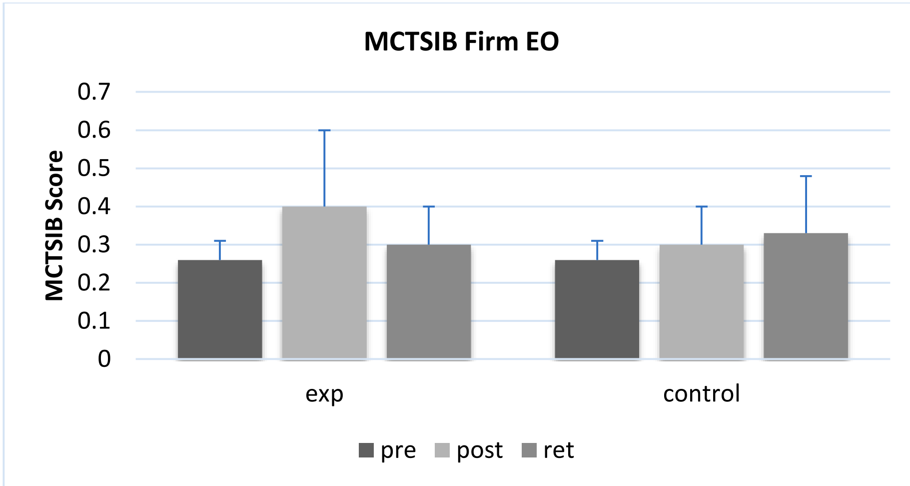

Figure 12. . Mean scores for the MCTSIB Firm Eyes Open for the Experimental and Control groups.

- **Firm-EC:** The mean and standard deviations values obtained from the descriptive statistical analysis on the MCTSIB Firm EC condition for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 13. For the experimental group mean values of 0.40, 0.33, and 0.43 were obtained for pre, post and retention assessment respectively. For the control group mean values of 0.93, 0.36, and 0.33 were obtained for pre, post and retention assessment respectively (F (2, 6) = 0.864, p =0.45).

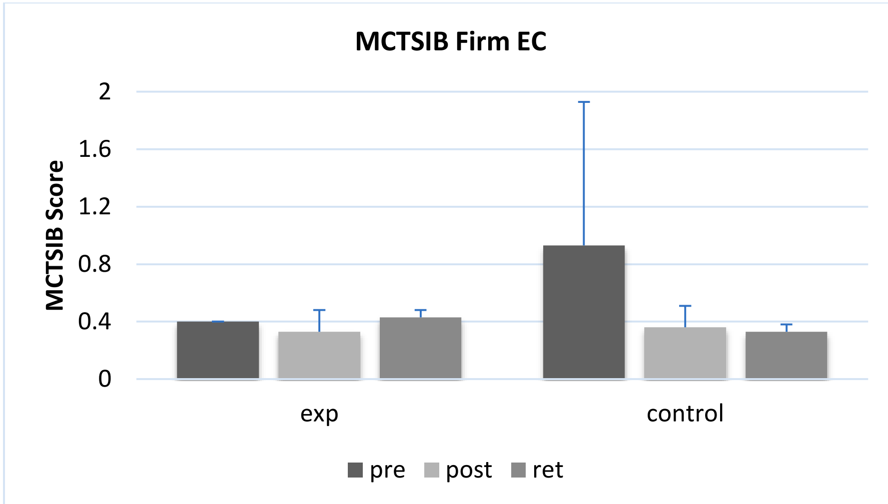

Figure 13. . Mean scores for the Firm Eyes Closed for the Experimental and Control groups.

- **Foam-EO:** The mean and standard deviations values obtained from the descriptive statistical analysis on the MCTSIB Foam Eyes Open condition for experimental group and the control group for the pre, post and retention assessments are presented in the Figure 14. For the experimental group mean values of 1.26, 0.90, and 0.93 were obtained for pre, post and retention assessment respectively. For the control group mean values of 1.0, 0.86, and 0.90 were obtained for pre, post and retention assessment respectively ($F(2, 6) = 0.328$, $p = 0.73$).

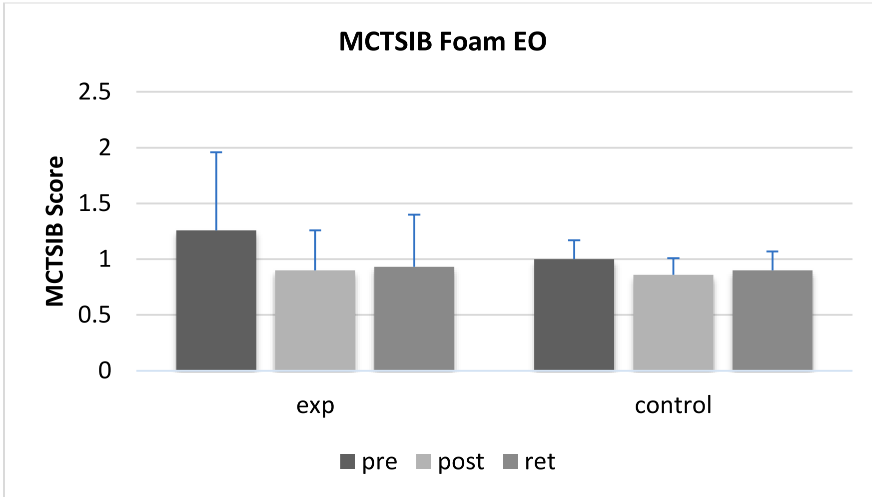

Figure 14. Mean scores for the MCTSIB Foam Eyes Open condition. Data for the Experimental and Control groups are shown.

- **Foam-EC:** The mean and standard deviations values obtained from the descriptive statistical analysis on the MCTSIB Foam Eyes Closed condition for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 15. For the experimental group mean values of 2.50, 2.10, and 1.60 were obtained for pre, post and retention assessment respectively. For the control group mean values of 1.60, 1.86, and 1.73 were obtained for pre, post and retention assessment respectively ($F(2, 6) = 7.37$, $p = 0.1$)

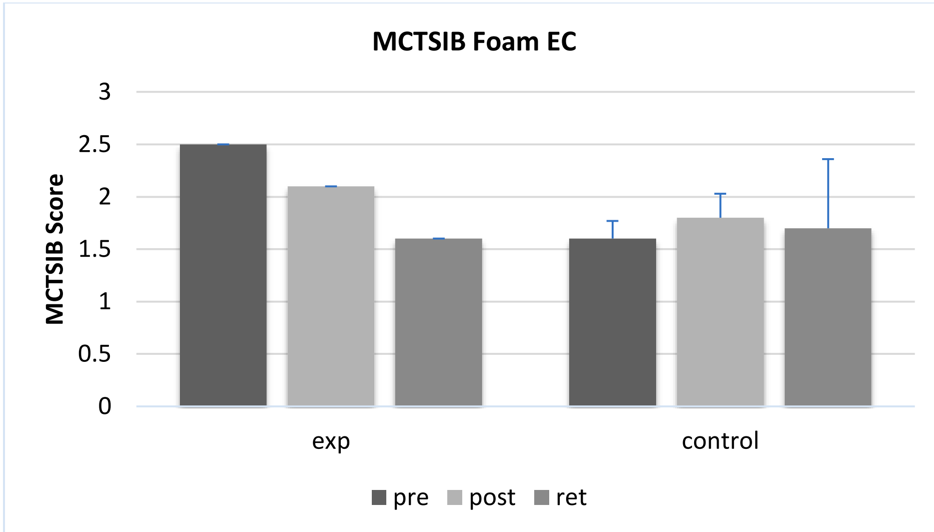

Figure 15. Mean scores for the MCTSIB Foam Eyes closed condition in the Experimental and Control groups.

- **Composite:** See Figure 17 for the mean and standard deviations values obtained from the descriptive statistical analysis on the MCTSIB composite scores for experimental group and the control group for the pre, post and retention assessments. For the experimental group mean values of 1.23, 0.90, and 0.90 were obtained for pre, post and retention assessment respectively. For the control group mean values of 0.96, 0.86, and 0.86 were obtained for pre, post and retention assessment respectively (F (2, 6) = 0.513, p =0.61).

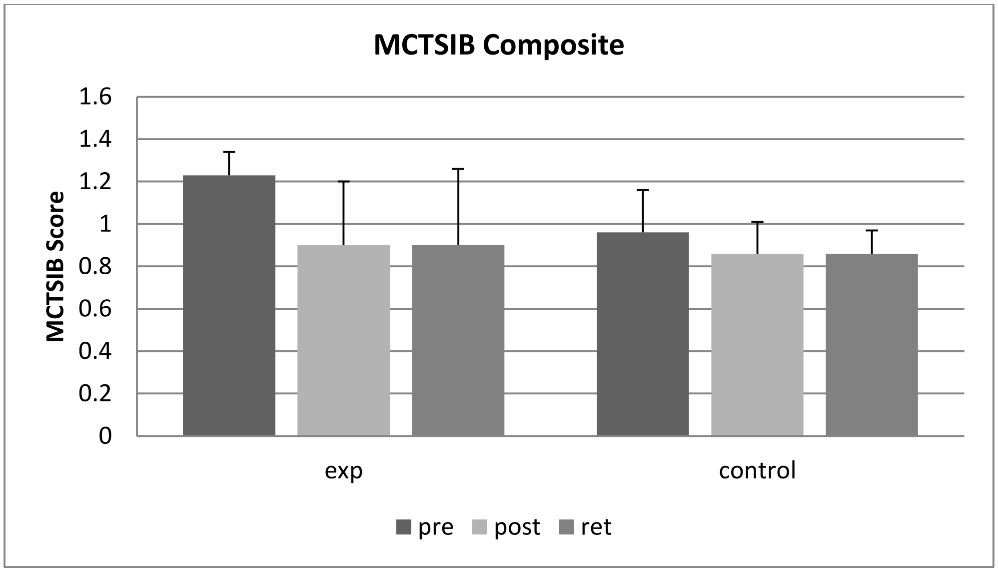

Figure 16. Mean scores for the MCTSIB Composite condition in the Experimental and Control groups

4.3.2 Step-up and Over

- **Lift-up index - %Body Weight - Left:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Lift-up index – (%Body Weight) - Left for the experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 18. For the experimental group mean values of 30.66, 26.33 and 30.0 were obtained for the pre, post and retention assessment respectively. For the control group mean values of 23.33, 20.0 and 15.66 were obtained for pre, post and retention assessment respectively (F (2, 6) = 1.28, p = 0.32).

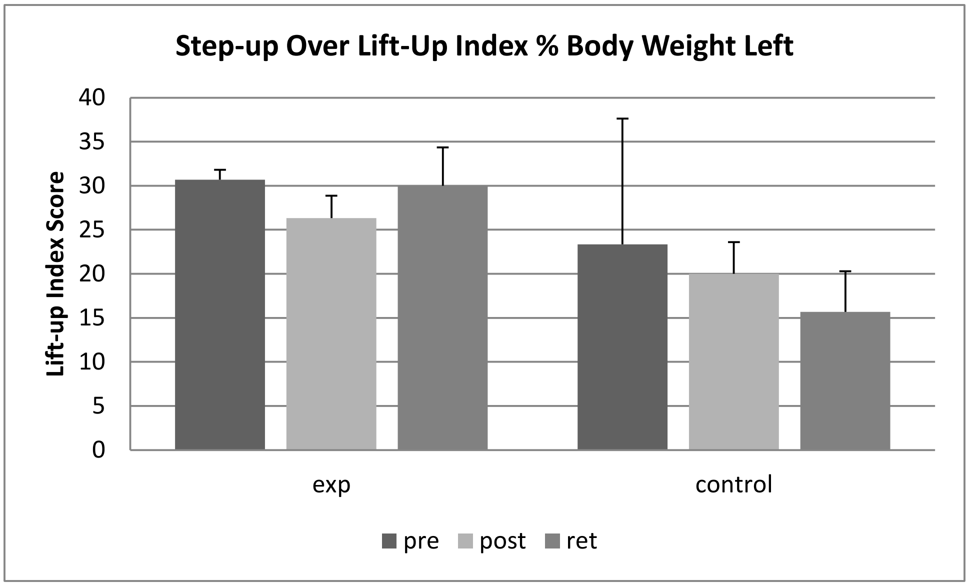

Figure 17. Mean scores for the Step-up Over, Lift-up Index for %Body weight with left leg in the Experimental and Control groups.

- **Lift-up index - %Body Weight - Right:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Lift-up index (%Body Weight) - Right for the experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 19. For the experimental group mean values of 35.0, 39.33 and 40.66 were obtained for pre, post and retention assessment respectively. For the control group mean values of 26.0, 24.60 and 27.30 were obtained for pre, post and retention assessment respectively. There was no statistical significance between the groups ($F (2, 6) = 0.42$, $p = 0.66$).

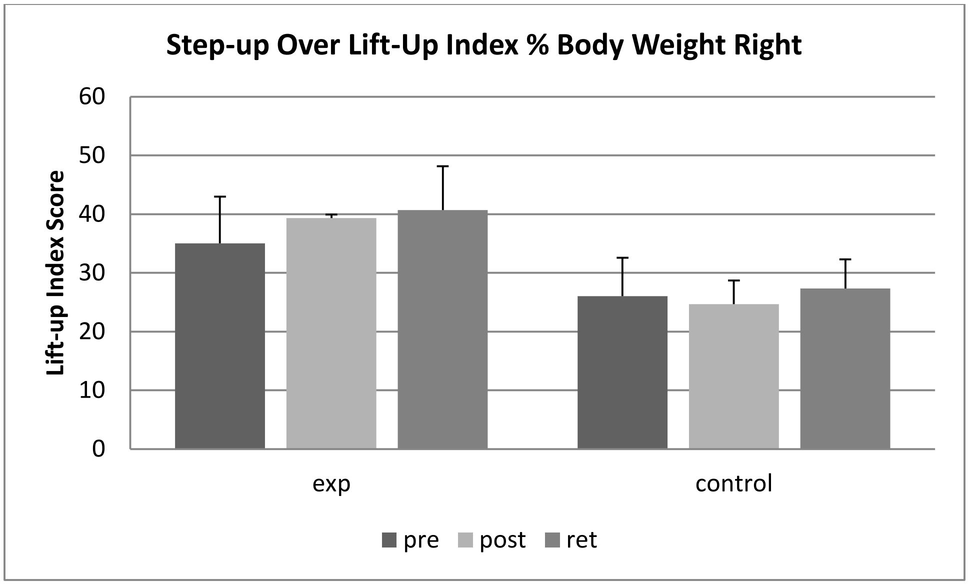

Figure 18. Mean scores for the Step-up Over, Lift-up Index for %Body weight with right leg in the Experimental and Control groups.

- **Lift-up index - % Difference:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Lift-up index - %Difference for experimental group and the control group at three different assessments: pre, post and retention are presented in the Fig. 20. For the experimental group mean values of 9.00, 20.00 and 14.60 were obtained for pre, post and retention assessment respectively. For the control group mean values of 15.6, 15.33 and 27.33 were obtained for pre, post and retention assessment respectively. The results of statistical analysis revealed that there was no difference between the groups ($F(2, 6) = 1.01$, $p = 0.40$).

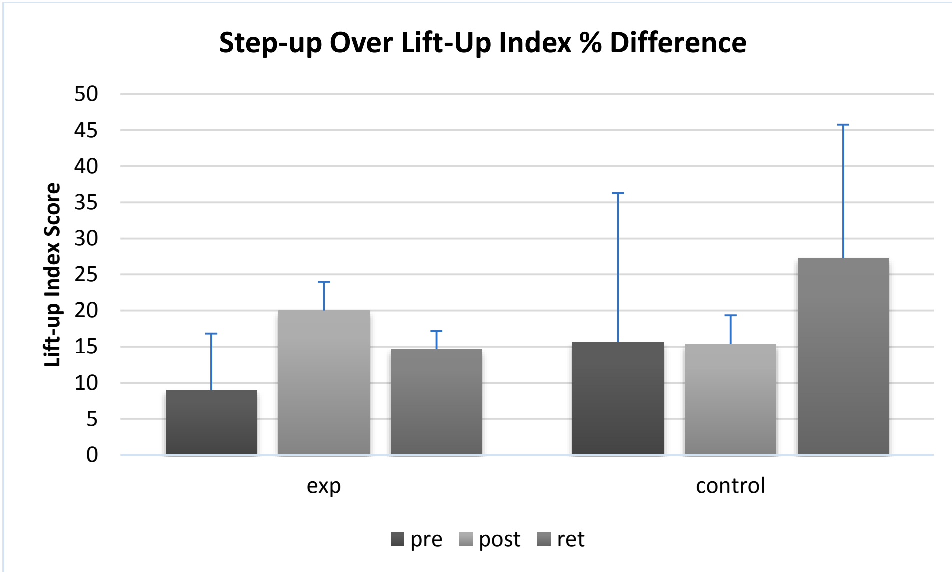

Figure 19. Mean scores for the %Difference in the Step-up over Lift-up Index in the Experimental and Control groups

- **Movement Time - Left:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Movement Time - Left for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 21. For the experimental group mean values of 0.93, 0.86 and 0.59 were obtained for pre, post and retention assessment respectively. For the control group mean values of 1.77, 2.06 and 2.09 were obtained for pre, post and retention assessment respectively. The differences were not statistically significant (F (2, 6) = 0.25, p = 0.77).

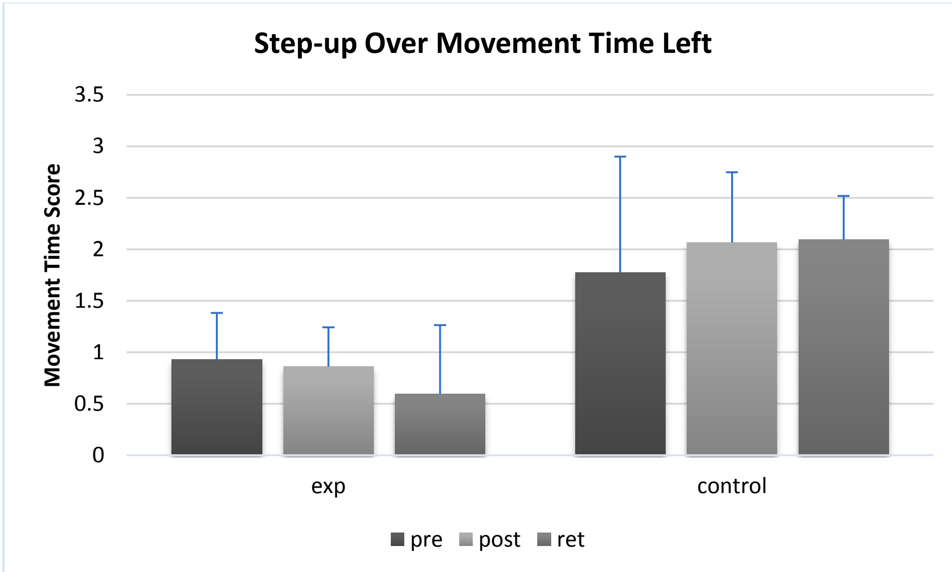

Figure 20. Mean scores for the Step-up Over, Movement time with left leg in the Experimental and Control groups.

- **Movement Time - Right:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Movement Time - Right for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 22. For the experimental group mean values of 0.95, 0.74 and 0.60 were obtained for pre, post and retention assessment respectively. For the control group mean values of 1.04, 1.27 and 0.80 were obtained for pre, post and retention assessment respectively. The results of statistical analysis revealed that there was no difference between the groups ($F(2, 6) = 3.098$, $p = 0.10$).

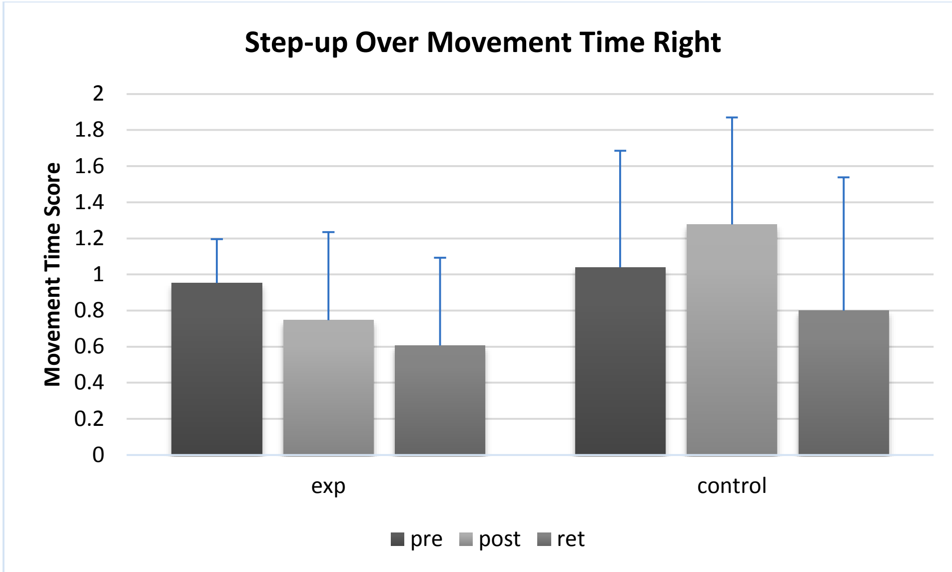

Figure 21. Mean scores for the Step-up Over, Movement time with right leg in the Experimental and control groups.

- **Movement Time - % Difference:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Movement Time - % Difference for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 23. For the experimental group mean values of 18.33, 15.0 and 60.00 were obtained for pre, post and retention assessment respectively. For the control group mean values of 26.33, 32.33 and 48.33 were obtained for pre, post and retention assessment respectively. The differences were not statistically significant ($F(2, 6) = 0.315$, $p = 0.73$).

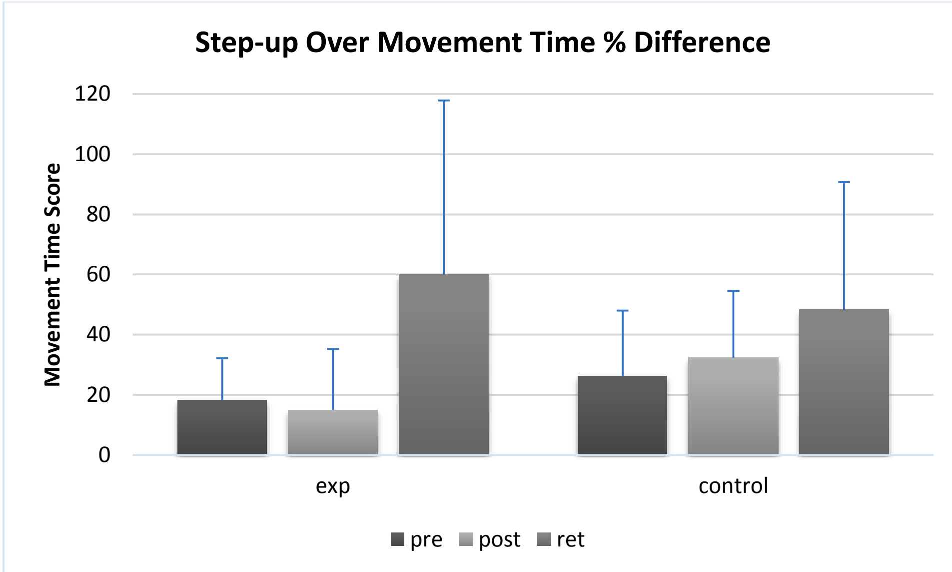

Figure 22. Mean scores for the %Difference for Step-up Over, Movement time in the Experimental and Control groups.

- **Impact Index - Left:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Impact Index - Left for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 24. For the experimental group mean values of 38.33, 42.00 and 34.00 were obtained for pre, post and retention assessment respectively. For the control group mean values of 33.33, 24.66 and 21.66 were obtained for pre, post and retention assessment respectively. The differences were not statistically significant ($F (2, 6) = 0.58$, $p = 0.57$).

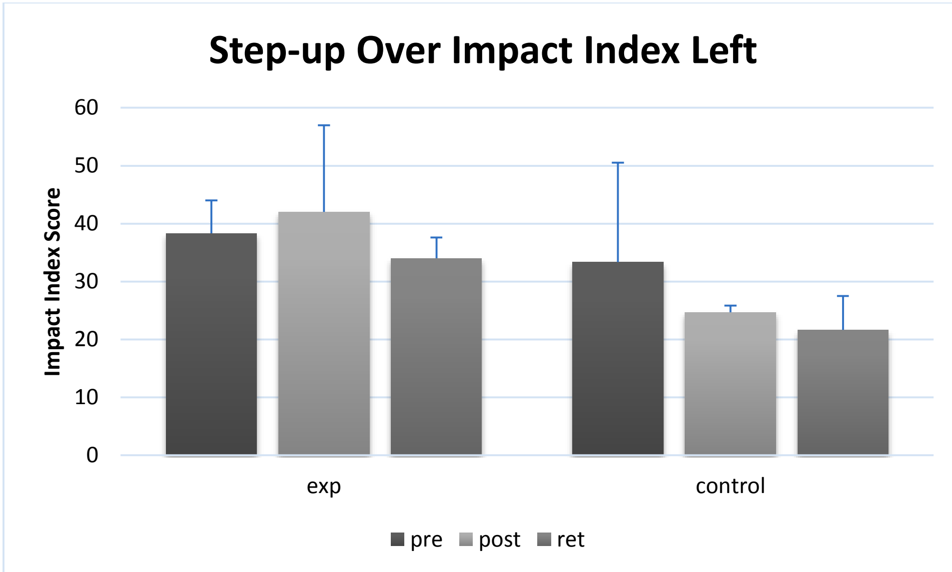

Figure 23. Mean scores for the Step-up over Impact Index for Left leg for the Experimental and Control groups.

- **Impact Index - Right:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Impact Index - Right for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 25. For the experimental group mean values of 42.66, 45.00 and 48.66 were obtained for pre, post and retention assessment respectively. For the control group mean values of 40.00, 29.33 and 31.00 were obtained for pre, post and retention assessment respectively. The differences were not statistically significant (F (2, 6) = 1.10, p = 0.37).

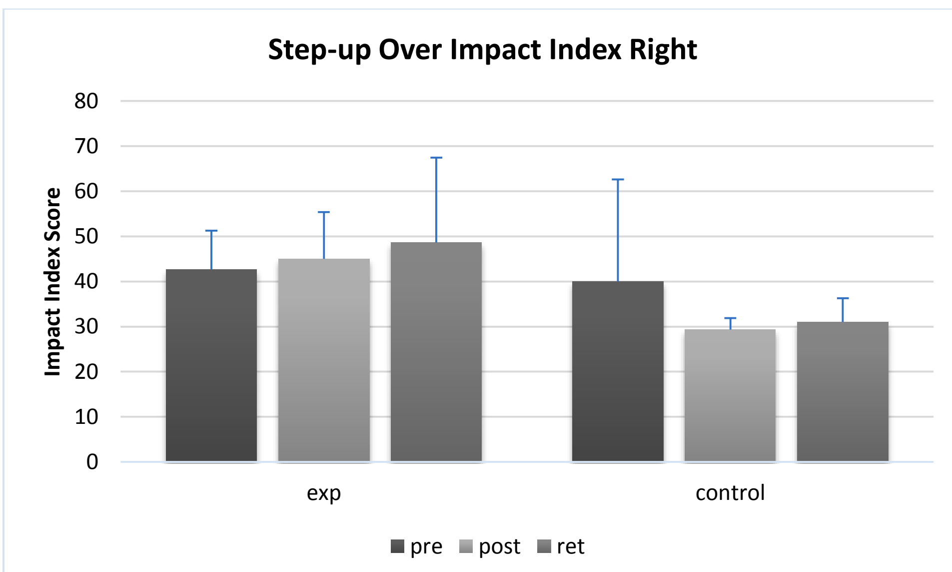

Figure 24. Mean score for the Step-up over Impact Index for right leg for the Experimental and Control groups.

- **Impact Index - % Difference:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Impact Index - % Difference for experimental group and the control group at three different assessments:pre, post and retention are presented in the Figure 26. For the experimental group mean values of 6.33, 7.33 and 15.33 were obtained for pre, post and retention assessment respectively. For the control group mean values of 9.66, 8.33 and 19.33 were obtained for pre, post and retention assessment respectively. The results of statistical analysis revealed that there was no difference between the groups (F (2, 6) = 0.037, p = 0.96).

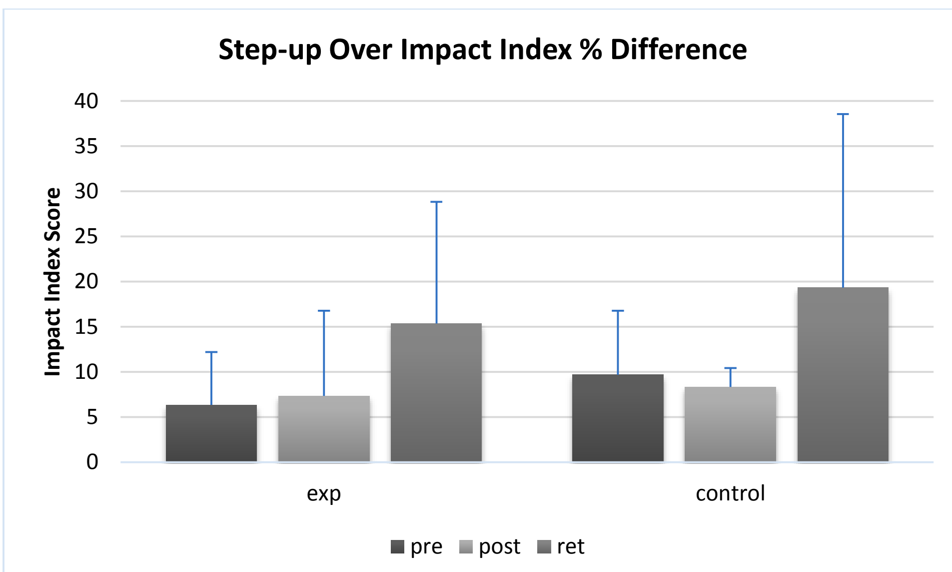

Figure 25. Mean score for the %Difference for Step-up over Impact Index for the Experimental and Control groups.

4.3.3 Unilateral Stance

- **Mean COG Sway Velocity Left:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Mean COG Sway Velocity Left for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 27. For the experimental group mean values of 3.10, 1.36 and 2.23 were obtained for pre, post and retention assessment respectively. For the control group mean values of 5.43, 6.73 and 5.16 were obtained for pre, post and retention assessment respectively. The results of statistical analysis revealed that there was no difference between the groups (F (2, 6) = 0.302, p = 0.74).

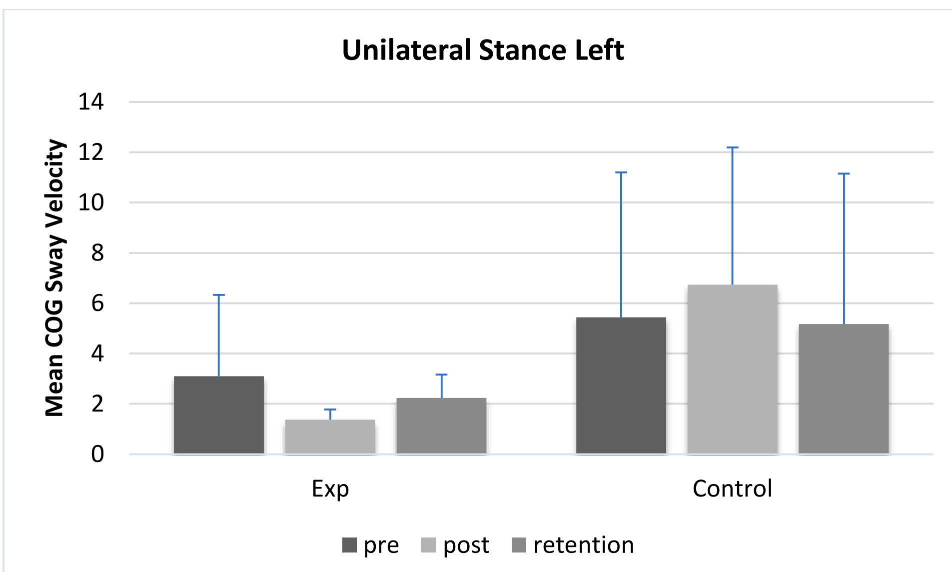

Figure 26. Mean COG sway velocity for the Unilateral Stance for the Left leg in the Experimental and Control groups.

- **Mean COG Sway Velocity Right:** The mean and standard deviations values obtained from the descriptive statistical analysis on the Mean COG Sway Velocity Right for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 28. For the experimental group mean values of 3.33, 1.13 and 1.83 were obtained for pre, post and retention assessment respectively. For the control group mean values of 3.96, 2.96 and 1.53 were obtained for pre, post and retention assessment respectively. The results of statistical analysis revealed that there was no difference between the groups (F (2, 6) = 0.39, p = 0.68).

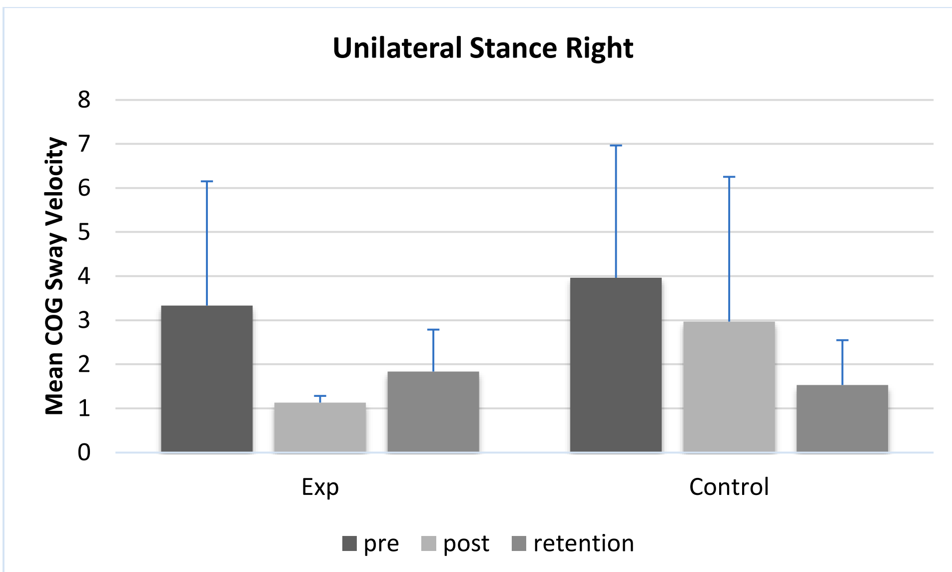

Figure 27. Mean COG sway velocity for Unilateral Stance for the Left leg for the Experimental and Control groups.

- **Mean COG Sway Velocity % Difference**: The mean and standard deviations values obtained from the descriptive statistical analysis on the Mean COG Sway Velocity % Difference for experimental group and the control group at three different assessments: pre, post and retention are presented in the Figure 29. For the experimental group mean values of 56.00, 11.00 and 14.00 were obtained for pre, post and retention assessment respectively. For the control group mean values of 18.33, 26.33 and 29.00 were obtained for pre, post and retention assessment respectively. The difference was not statistically significant (F (2, 6) = 2.20, p = 0.17).

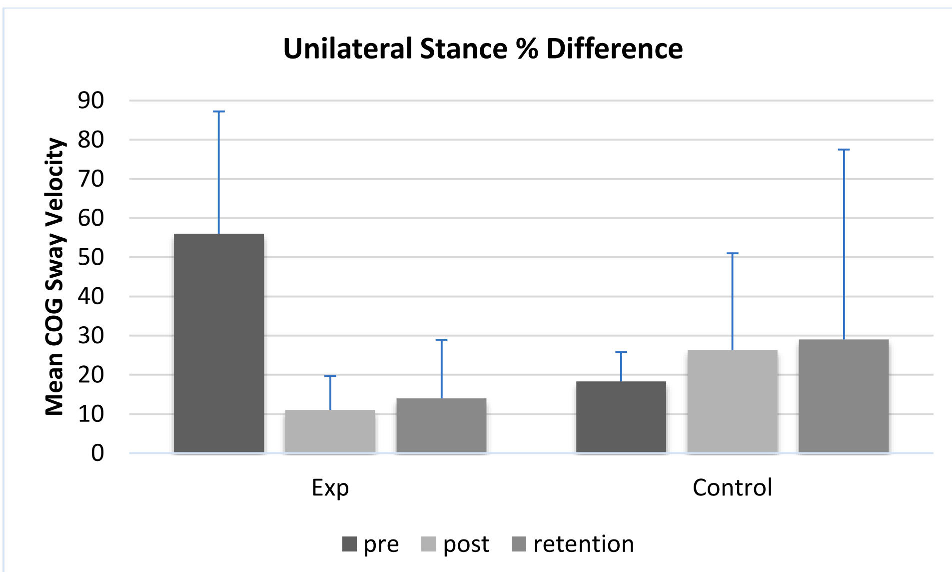

Figure 28. Mean COG sway velocity for Unilateral Stance for the %Difference in the Experimental and Control groups.

5 DISCUSSION

The aim of the study was to investigate the effects of training on anticipatory postural adjustments in healthy older adults. The main focus of the study was to answer the following questions a) whether training leads to enhanced APAs, b) if these enhancements translate into better performance of functional activity and c) if the enhanced performance of the functional activity is retained over time. Overall the results indicate an affirmative answer to the question posed by the study. The general pattern shows that APAs were enhanced in a few muscles in the EG seen as earlier EMG onsets when compared to the CG although the group interaction failed to show significance. A more interesting result was the improvement observed in the clinical outcome measure TuG. The group interaction statistical analysis was significant demonstrating improved functional performance by the EG. There was also an improvement pattern in all other clinical outcome measures for the EG, but statistical significance was not achieved. Thus, the main finding of the study from all observed results and specifically of TuG suggests that underlying enhancements in motor-control translated to improvement in functional performance.

Previous studies have focused on the study of APAs using internally induced perturbations or voluntary movements. In their study Man'kovskii and colleagues (Man'kovskii, Mints et al. 1980), had young and elderly subjects, raise their outstretched hand, raise the distal part of the foot and flex the lower limb at the knee in different series of experiments in response to instructions. They concluded that if the task is performed sufficiently slower in the older adults, the preparatory period of the complex motor act can be regulated. They also suggest that, the slowness of the movements in the older adults must be regarded as a compensatory mechanism aimed at adaptation to regulatory changes developing in the motor system (Man'kovskii, Mints et al. 1980). Another study used displacement of a rod (push and pull) and LED lights indicators to study and compare the APAs in simple reaction and choice reaction time between young adults and elderly adults (Stelmach, Populin et al. 1990). This study shows that the elderly were slightly slower than the young under simple reaction situations while considerably slower in choice reaction situations in which they were made to select between two or more responses. Predominantly earlier studies have involved voluntary movements or internally induced perturbations as a mode of studying APAs.

As noted earlier in the Rehabilitation Strategies section, studying APAs in the elderly would require us to isolate any effects that aging might have on the performance of a task leading to changes in APAs and study the direct effect of aging on generation of APAs. The present study uses ball catching exercise to induce external perturbations. This paradigm presents distinct advantages over using voluntary movements because: a) we are able to study postural preparation in isolation of the characteristics of voluntary movement if any, b) it is predictable and externally induced causing the body to generate stronger APAs that can be studied, and c) it mimics everyday functional activities like opening a door, retrieving an object from a shelf or embracing a child running toward you to name a few.

Earlier studies have indicated that regular generalized physical exercise (Carvalho, Vasconcelos et al. 2010) and isolated muscle training (Tsao and Hodges 2007) may have led to improvements in generation of APAs. Very few studies focus on elderly adults and fewer on extended training. In their 2008 study Tsao and Hodges (Tsao and Hodges 2008) showed improved APAs in the test subjects after 4 weeks of training with subjects with lower back pain. Two studies demonstrated that training in a single session of ball catching (Kanekar and Aruin 2015) or a single session of ball throwing (Aruin, Kanekar et al. 2015) was enough to observe enhancement in generation of APAs in young and older adults respectively. The present study aims were designed to build on these findings by assessing the effects of four weeks of training (ball catching) in the elderly and the enhancement, if any, in generation APAs.

As stated earlier the known factors affecting generation of APAs are a) magnitude of perturbation, b) direction of perturbation, c) voluntary action associated with the perturbation and d) the postural task. In the current study, voluntary action and a postural task were not altered. Instead externally induced perturbations were used to perturb balancer requiring the subject to generate APAs to regain equilibrium. The other factors, magnitude and direction, were controlled and kept constant for each subject. It can thus be said that by nullifying the potential effect of these factors, the observed change in generation of APAs was a result of the training related enhancements.

Specifically for the EG, 3 muscles showed enhancements in the form of earlier onsets. At the same time for the CG, these 3 muscles either showed worsening or no improvement. We observed that for the experimental group, for clinical outcome measure TuG, the post assessment showed a mean score of 7.27 +/- 0.8 sec which is an improvement over its pre assessment mean score of 8.32 +/- 0.9 sec. Furthermore the retention assessment showed a mean score of 6.6 +/- 0.9 sec indicating that the enhancement was retained over the period between post and retention assessment. The control group shows gradual deterioration in the form of increased time to perform the same task (pre=10.34 +/- 3.1sec, post=11.8 +/-3.0 sec and retention 12.6 +/-2.7 sec). TuG is an excellent simulation of everyday functional task as it involves various daily activities like sit-to-stand, walk, turn around, approach and sit in a chair. This necessitates the maintenance of static as well as dynamic equilibrium. Any improvements in the TuG score can be extrapolated into the functioning of most routine activities for the elderly.

6 LIMITATIONS

The study was carried out on a small sample set from a population of elderly adults (between 65 years and 85 years of age). The study thus assumed the effect of aging as a factor on the APAs generation. We have earlier pointed out that the process of aging is highly variable and there exists a great heterogeneity in this process within the sample population set by nature. This mandates a greater size sample to reduce standard error and deviation. It also results in high variability of the scores making it extremely difficult to obtain significance in any of the statistical analyses. It also makes it difficult to draw firm conclusions as to the effect of the training, but is a pilot that warrants further study.

7 CONCLUSION

The study shows a definite enhanced pattern of generation of APAs in older adults participating in the specialized training. Summarizing from the EMG and clinical outcome measure TuG results, we can conclude that training resulted in enhancements in generation of APAs which resulted in improvement of performance of functional performance. These enhancements are a direct result of the four week long training protocol as everything else remained constant for pre, post and retention assessments. While the absence of significance for some of the tests can be attributed to the small sample size and general heterogeneity of the aging process, it nevertheless provides enough impetus for any future study that wishes to build on these results. The information gained from this study may be useful to design future studies and provide help in designing appropriate assessment and training strategies. More such studies will provide valuable data and input in designing a rehabilitation protocol for elderly adults.

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VITA

NAME

Sailee Jagdhane

EDUCATION

- MS Candidate in Rehabilitation Sciences Program,

  Department of Physical Therapy, Applied Health Sciences
  University Of Illinois at Chicago (UIC)
  2013 -2015 (expected)

- Bachelor of Physiotherapy (B.P.Th.)

  Tilak Maharashtra Vidyapeeth,
  India (2005-2010)

PROJECTS

- Final year BPTh project: To study the circadian rhythm of human grip of strength

CLINICAL EXPERIENCE

- Owner of Physiotherapy clinic – AGASHE clinic, Pune, India (2010 – 2012)

  Mainly treated population with orthopedic conditions like
  Cerebral Palsy
  Stoke
  Conducted pre –natal care classes

- Visiting Physiotherapist at:

  Ranka Hospital, Pune, India
  Dhanvantari Hospital,Pune,India
  Shraddha Hospital, Pune,India
  Hardikar Hospital, Pune, India

- Internship: Sahayadri Hospital, Pune, India (August 2009 – January 2010)

  Rotational clinical postings in Intensive Care Unit, Cardiac Care Unit, Neurology, Pediatrics, Orthopedic and Outpatient Departments

PRESENTATIONS / SEMINARS

- UIC Forum 2015: Training Related Enhancements in Anticipatory Postural Adjustments in Healthy Older Adults
- UIC Forum 2014: Training Related Enhancements in Anticipatory Postural Adjustments in Older Adults, Case- control study
- Psychometrics of Outcome Measure – Balance Evaluation Systems Test (2014)
- Statistical Analysis System: Do Hispanics Immigrants require access to care (ATC) for depression if acculturation to American Culture is not achieved? (2014)
- Psychosomatic pain and paralysis (2009)
- Fractures of spine – Classification, Complications and Management (2008)
- Muscle types and functions (2007)

WORKSHOPS and CONFERENCE -

- Participation in Workshop: Current Practice in Critical Care Unit - Role of Physiotherapist (November 2010) Total credit hours - 16
- Participation in 49 th Annual Conference Of Indian Association Of Physical Therapy (January 2011)

MEMBERSHIPS

- Member of Indian Association of Physiotherapy – (IAP) (Since 2011)
- Student member of Indian Association of Charted Physiotherapist (2006-2011)

VOLUNTEER WORK

- Bone marrow density camp – AGASHE clinic (2011)
- Lions club social activity – Pilgrim medical checkup (2008)
- Chicago Dance Marathon (2013)

PRESS

- "Playing catch could prevent falls in older adults"- UIC News. January 28, 2015, p.6 http://news.uic.edu/playing-catch-could-prevent-falls-in-older-adults