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Research Article

THE EFFECT OF STRENGTHENING THE ANKLE MUSCULATURE ON BALANCE IN ELDERLY USING EMG BIOFEEDBACK VERSUS CONVENTIONAL METHOD

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ABSTRACT

A review of the literature revealed a paucity of studies that have explicitly examined the effects of EMG biofeedback training in improving muscle strength and balance in the elderly population. This study focuses to evaluate the differential effects of two types of strengthening techniques, EMG biofeedback versus a training Conventional technique on the strength of the ankle musculature and balance in the elderly. A two group, pre-test post-test (mixed – group x repeated measures) experimental study design, where a total of 40 community dwelling elderly participants with age 60 years and above, were randomly assigned to a conventional (Theraband training) and experimental group (EMG Biofeedback + Theraband). The patients were treated for 30 minutes per day thrice a week, for 6 weeks. They were assessed on Functional Reach Test, Berg Balance Scale, and Strength using strain gauge, pre and post intervention. There is a significant improvement in strength of the ankle musculature following exercises. However, balance as measured by the berg balance scale was significantly better following EMG biofeedback training compared to conventional exercise training. EMG Biofeedback training in addition to strengthening exercises has significant beneficial effects on balance of community living elderly.

INTRODUCTION

The world's population is ageing due to increasing life spans and decreasing birth rates. It is estimated that there will be an increase in elderly population from 6.7% in 1991 to 10% in 2021. India has acquired the label of an aging nation with 7.7% of its population being older than 60 years [1, 2]. As the elderly age there is decline in physical activity [3-6], a decrease in muscle strength, and endurance [4,6,7], and an increase in postural sway [8-12]. Advancing age in addition to significant sensorimotor changes, was accompanied with a generalized reduction of the vision and vestibular function and consequently balance leading to falls. In elderly there was significant decrease in their ability to recover effectively and quickly from a perturbation, due to several factors, including decreased muscle strength, decreased reaction time, lack of flexibility, decreased range of motion, etc., which may result in fall [4,2,13].

The motor control system, depending on the magnitude of the destabilizing force to recover from a perturbation, namely an ankle, hip and stepping strategy. The ankle strategy was commonly used when the disturbances are small and involves shifting the COM forward and back by moving the body as a relatively fixed pendulum about the ankle joint within the limits of stability (LOS). Ankle dorsi-flexor and plantar-flexor strength have been reported to be independent predictors of balance and mobility loss in the elderly [5,14, 15, 16]. Both muscles are key regulators and play an important role in supporting body weight, providing stability at ankle and feet during standing and during gait. With aging, there is a significant decrement in the strength of the ankle musculature, which consequently increases the degree of anterior-posterior (AP) sway [6,17,18]. Muscle strengthening traditionally has been achieved using resistance training with the help of weights and/or resistance bands. In recent times biofeedback has been increasing, used as a muscle strengthening technique [3]. It was reported that EMG technique has an essential role in increasing the maximum torque produced by muscle [3,18]. A major benefit of the EMG system was that it leads to greater adherence to the exercise regime, and better improvements in strength and balance of the elderly [3,9]. According to a study EMG biofeedback was a key factor in improving effectiveness of exercise therapy as it enhances performance of weakened or paralyzed muscle by facilitating motor learning through use of bio-signals provided by real time biofeedback [10,11].

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Aims

To evaluate the effects of EMG Biofeedback in strengthening of ankle Plantar-flexor and Dorsi-flexor muscles and balance, compared to a conventional technique.

Objectives

To study the relative effectiveness of EMG Biofeedback versus conventional muscle training for strengthening of the ankle plantar-flexors and dorsi-flexors on balance.

Inclusion Criteria

- Community living elderly individual aged 60 years or more.
- Ambulatory individual with or without assistive device.
- Male and female both population with or without history of falls
- Elderly with MMSE score ≥24

Exclusion Criteria

- Uncontrolled hypertension/ diabetes.
- Active inflammatory disease.
- Individual with progressive neurological disorder.
- Uncorrected visual disparity.
- Inner / middle ear disorders.
- Severe joint pain, fracture.
- Terminal illness
- Severe cardiopulmonary diseases

MATERIALS & METHOD

A mixed group repeated measures experimental study design. Approval was taken from Amar Jyoti Institutional Review Board- Ethical Committee. Forty community dwelling elderly participants were recruited as volunteers from Amar Jyoti Hospital & resident welfare societies according to the inclusion & exclusion criteria. The purpose and the benefits of the research were explained to the patients. After meeting the inclusion and exclusion criteria through an assessment performa, volunteers were asked to sign an approved informed consent and then subjects were allocated to the two groups: Conventional group and the Experimental group. Participants were measured on their strength using strain gauge & balance using berg balance scale and functional reach test. Following this, all participants underwent an initial baseline assessment. Both groups received conventional exercises. The experimental group in addition received EMG Biofeedback training. The intervention period was 6 weeks in duration, 3 days/week.

Subjects underwent dependent exercise program for 40 minutes that included 5 minutes warm up and 5 minutes cool down, plus 30 minutes strength training. Conventional exercises consisted of Thera band training using yellow and red bands as follows:

Thera band training

Patient were seated in a comfortable chair with their back supported and heels touching the ground, while their feet were free to move up and down. One end of elastic band attached to a table in front or chair behind, while the other end was attached to the foot. Instruction were given as per the training protocol.

The training program to both groups comprised of warm-up exercise session for five minutes, and a strengthening exercise program for 30 minutes depending on the interventional group, followed by a cool-down exercise session for five minutes.

The subjects performed static stretching exercises of the ankle musculature for 15 minutes prior to the intervention. Subject should be in sitting with back supported, heels should touch the ground. Resistance training consisted of first using the yellow color Thera bands (resistance power of 1.0 kg when extended by 40 cm) and progressing to a red color Thera bands (resistance power of 1.6 kg when extended by 40cm) 30 minutes per day. The exercise intensity was set with rating scale of perceived exertion at 13 to 14 [15]. The exercises were performed slowly, so that the concentric and eccentric contractions occurred effectively [6,19].

For training the dorsi flexors, each subject sat on chair with one end of elastic band attached to a table in front and the other end attached to the foot. Subjects remained firmly seated in the chair with the heel touching the ground. They were then instructed to pull their foot against the resistance of the offered by the elastic band, towards their leg without bending their knee such that movement occurs only at the use the ankle joint [20]. For training the plantarflexor, the Thera band was attached behind the subject and the foot is moved forward and downward away from the leg. Each exercise was performed ten (10) times in sets of three (3). There was a 30 second rest period between each set and a 3 to 5 minute rest period between each exercise.

EMG Biofeedback training

Experimental group - EMG Biofeedback training along with therabands was given to the second group. Patient was positioned in a sitting position with their back supported. The EMG electrodes were attached on the muscle belly of the tibialis anterior (dorsi-flexor) and medial head of the gastrocnemius (plantar-flexor) to record muscle activity that was the used to provide a visual training target to the EMG biofeedback training group. The electrodes for tibialis anterior, the dorsiflexor (Fig 1), were attached in the upper part of the lower leg, laterally 2 cm from the anterior line of tibia.

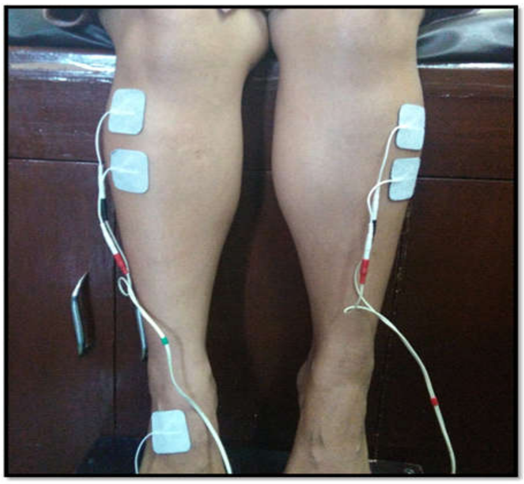

Figure 1 Showing electrode placement for Dorsiflexors

While the electrodes for calf muscle, the plantar flexor (Fig 2), were attached on the medial head of the gastrocnemius muscle, medially, 2 cm away from the popliteal part center line.

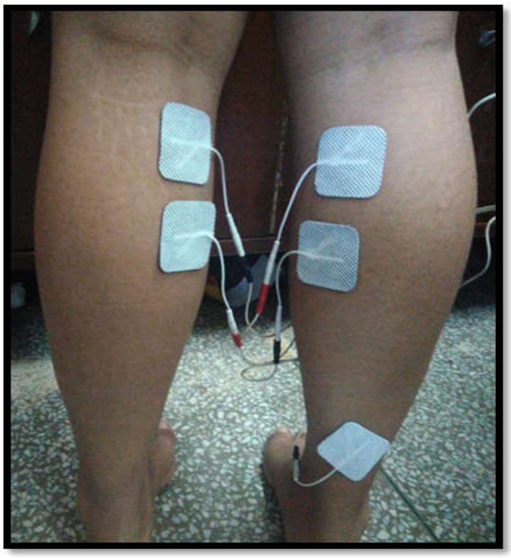

Figure 2 Showing electrode placement for medial gastrocnemius muscle

Patients in the EMG biofeedback group trained using the EMG signal received during the simultaneous activation of the muscles. They were asked to use a predetermined target threshold to activate the muscles. After completion of 6 weeks treatment all participants received follow up assessment. Participants were assessed on outcome measures for balance and strength using strain gauge (Strength, BBS and FRT).

Figure 3 Showing plantar flexors strengthening using red color Thera bands along with EMG Biofeedback.

Statistical Analysis

The data was analyzed using SPSS v 16.0. The statistical values were expressed as mean ±SD. Repeated Measure ANOVA was used to analyze the effect of EMG Biofeedback* (NeuroTrac Software) on community dwelling elderly. Statistical significance was fixed at 0.05. Tukey's HSD post hoc were carried out at a significance level of p<0.05 for all multiple comparisons.

RESULTS

The demographic detail of the elderly who participated in the study were in table 1. A total of 40 subjects participated in study in which 11 were males and 29 were females.

Table 1 Demographic Data

	Age (Mean ±SD)	MMSE (Mean ±SD)
Conventional group	62.5±2.39	25.75 ±1.37
Experimental group	65.5±5.5	25.6 ±1.53

Strength of right dorsiflexors

The analysis revealed non-significant main effect for group, $F_{(1, 38)}$ =1.29, p > 0.05, a significant main effect of time, $F_{(1, 38)}$ = 44.01, p < 0.05, and a non-significant group X time interaction, $F_{(1, 38)}$ = 1.58, p>0.05.

Strength of left dorsiflexors

The analysis revealed non-significant main effect for group, $F_{(1, 38)}$ =2.13, p > 0.05, a significant main effect of time, $F_{(1, 38)}$ = 78.39, p < 0.05, and a non- group X time interaction, $F_{(1, 38)}$ = 0.87, p>0.05.

Strength of right plantarflexors

The analysis revealed non-significant main effect for group, $F_{(1, 38)}$ =0.67, p > 0.05, a significant main effect of time, $F_{(1, 38)}$ = 79.58, p < 0.05, and a non-significant group X time interaction, $F_{(1, 38)}$ = 1.79, p>0.05.

Strength of left plantarflexors

The analysis revealed non-significant main effect for group, $F_{(1, 38)}$ =0.068, p > 0.05, a significant main effect of time, $F_{(1, 38)}$ = 79.43, p < 0.05, and a non-significant group X time interaction, $F_{(1, 38)}$ = 0.25, p>0.05.

Functional Reach Test

The analysis revealed non-significant main effect for group, $F_{(1, 38)}$ =0.31, p > 0.05, a significant main effect of time, $F_{(1, 38)}$ = 13.71, p < 0.05, and non-significant group X time interaction, $F_{(1, 38)}$ = 0.43, p>0.05.

Berg Balance Scale

The analysis revealed statistically significant effect for group, $F_{(1, 38)}$ =0.24, p > 0.05. However, there was a significant main effect of time, $F_{(1, 38)}$ = 127.31, p < 0.05. There was significant improvement in BBS over a period of 6 weeks irrespective of the group. However it was supported by an interference pattern with $F_{(1, 38)}$ =18.83 and p=.00 which statistically significant. Tukey's Post Hoc performed based on MSD=0.476 there was a significant difference between pre and post intervention value of Conventional and Experimental. As seen in figure 3 the mean difference in BBS of conventional group is 1.2 ± 0.87 and the mean difference value of experimental group is 2.56 ±1.19.

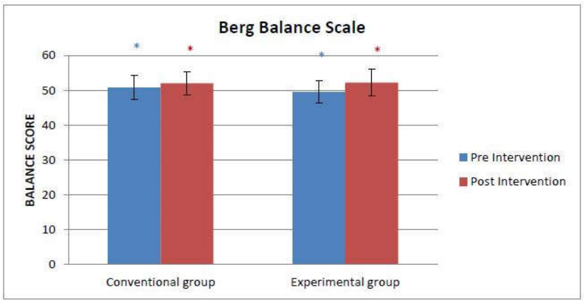

Figure 3 Means (+ SD) of BBS for pre, post intervention for the Conventional and EMG Biofeedback groups.

*Main effect for time, p<0.05, *Main effect for group, p<0.05, **Interaction group x time, p<0.05

There was an overall improvement in static and dynamic balance following strengthening of the ankle dorsi-flexors and plantar-flexors. This suggests that improvements in strength of the ankle musculature in the elderly leads to an improvement in the synergistic coordination of the ankle dorsi-flexors and plantar-flexors and thus, the ankle strategy that controls balance. It was important to note that both types of strength training facilitated an improvement in static as well as dynamic balance. These benefits were reflected in greater functional reach (FRT) and berg balances scores (BBS) following six weeks (6) of strength training. It was also observed more specifically and importantly, that there were greater improvements in dynamic balance (BBS) following EMG biofeedback training compared to the conventional training. It appears that biofeedback back training probably leads to better coordinated control and adaptations of the ankle muscles [6, 19].

DISCUSSION

This study was designed to test the proposals that EMG biofeedback strength training combined with a conventional exercise program would result in significant benefits in strength and balance in community living healthy elderly compared to a conventional exercise program. Overall, the results supported this proposal and it was observed that there were significant increases in the strength of the ankle musculature post a strength training program as well on all balance measures. Importantly, it was found that there were relatively greater improvements in dynamic balance, as measured by the Berg Balance Scale, following EMG biofeedback combined with conventional exercises than just exercises.

The demographic data of the sample was a good representation of community living healthy elderly in Delhi, with an age range between 60 – 70 years, however the gender representation within the groups was skewed such that there were more females than males in the conventional exercise group compared to the experimental group, in which there were equal males and females. It needs to be pointed out it was a sample of convenience, however the assignment to groups was random.

Both exercise groups showed significant improvements in muscle strength post intervention, regardless of the type of exercises. This suggests that strengthening with Thera-bands was equally effective, and there was no additional benefit gained from EMG biofeedback in strengthening the ankle plantar flexors and dorsi-flexors over a six (6) week period for a total of 18 sessions. It was conceivable that strength specific changes in learning require a longer interventional time period (6 – 10 weeks) or a greater number of sessions (30 sessions), and/or greater exercise intensity (higher feedback thresholds). Thera bands used in this study were of low resistance (yellow resistance power 1.0 kg when extended 40 cm and Red resistance power 1.6 kg when extended 40 cm), as prescribed for elderly population according to Borg rating scale of perceived exertion, which probably was sufficient to improve the strength of Plantar flexors and Dorsi flexors to a sufficient level in both groups within the six (6) weeks of the intervention period [15]. A study suggests that a short-term training program with a varied protocol to improve neural activity, motor unit synchronization and an increase in agonist muscle activation to improve muscle strength. The lack of significant change in muscle mass and strength in study particularly because of short period of intervention as compared to previous studies associates with strength training [19,23]. However, in this study, the addition of EMG biofeedback did not enhance significantly the strength of the ankle muscles, over and above the conventional program.

There was an overall improvement in static and dynamic balance following strengthening of the ankle dorsi-flexors and plantar-flexors. This suggests that improvements in strength of the ankle musculature in the elderly leads to an improvement in the synergistic coordination of the ankle dorsi-flexors and plantar-flexors and thus, the ankle strategy that controls balance. It is important to note that both types of strength training facilitated an improvement in static as well as dynamic balance. These benefits were reflected in greater functional reach (FRT) and berg balances scores (BBS) following six weeks (6) of strength training. It was also observed more specifically and importantly, that there were greater improvements in dynamic balance (BBS) following EMG biofeedback training compared to the conventional training. It appears that biofeedback back training probably leads to better coordinated control and adaptations of the ankle muscles [15].

A similar study conducted on 27 stroke patients using ankle biofeedback training and conventional strength training, it was observed that there was an overall improvement in dynamic balance, presumably based on the effects of training the reflex control of muscle activity induced by exercising in a closed kinematic chain with known proprioceptive effects. The significant improvement in balance was explained due to improved muscular coordination and more efficient joint stabilization. Some studies have reported the reinforcement of electrophysiological traces during the performance of certain movements and thus, learning [6,10,15].

CONCLUSION

All community living elderly that participated in this study improved strength in the ankle musculature, and concurrently balance, while reaching in the standing position and moving around following a limited exercise training program. Additionally, it was found that EMG biofeedback training improved dynamic stability in the elderly to a greater extent than conventional strengthening exercise with Thera bands. These results have significant clinical implications in the management of fall prevention in healthy community living elderly.

Limitations

The main limitation of this study was the small sample size and the use of a sample of convenience. A small sample size reduces statistical power, and thus, the application of the results were generalized to a greater population with caution, there was limited external validity. The study population consist of community-living elderly in the age group between 60 – 70 years, mostly from East Delhi, again limiting generalizability of the results. A significant limitation of this study is probably the short interventional period, the reduced resistance intensity and/or number of exercise sessions. Another limitation in this study was that only ankle muscles were targeted. As balance strategies involve multiple muscles across multiple joints, several other lower extremity muscles should be targeted in future studies.

Future Research

Future research needs to include a larger sample size in order increase internal validity and improve the generalizability of the findings to a greater population. It is important that males and females be recruited in equitable numbers and the age range needs to be expanded. The interventional period and/or the number of exercise sessions in future studies should be increased and extended to include multiple lower extremity muscles, so that resistance intensity can be progressed in a step-wise manner and improvements in coordination between muscles can be comprehensively evaluated.

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