Effectiveness of Backward Walking With and Without Electromyography (EMG) Biofeedback to Improve the Gait And Balance In Stroke Patients- A Comparative Study

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Abstract

Background
Stroke, the fourth leading cause of death and fifth leading cause of disability, results from interrupted blood supply to the brain, leading to cell death. Prevalence rates vary between urban (45-487/100000) and rural (55-388.4/100000) areas. Balance and gait impairment post-stroke are significant concerns, causing loss of balance, reduced independence, and falls.
Methodology
This comparative study investigates the effects of backward walking with and without EMG biofeedback on improving gait and balance in stroke patients. Forty stroke patients were recruited and divided into Group A (with EMG) and Group B (without EMG). FAC and MMSE were assessed pre-recruitment. Both groups underwent a 6-week protocol, with Group A receiving conventional therapy along with backward walking and EMG biofeedback, while Group B received conventional therapy with backward walking only. Pre and post-intervention assessments utilized BBS, DGI, and 3MBWT.
Results
The intervention of backward walking with and without EMG biofeedback showed significant improvement in post-test Berg Balance Scale (Z value= 1.791, P= 0.073) and 3Meter Backward Test (t value= 1.837, P= 0.074) for both groups compared to the Dynamic Gait Index, where results were not statistically significant (Z value= 0.533, P= 0.594).
Conclusion
Backward walking with or without EMG biofeedback significantly improves balance and walking speed compared to gait alone in stroke patients. This intervention leads to better gait correction, timing, and functional independence. Given limited research on EMG biofeedback for lower limbs, this study provides valuable insights into a potential non-pharmacological approach for managing balance and gait impairments in stroke patients.

Keywords:
Stroke, balance, gait, electromyography (EMG) biofeedback, backward walking, Berg balance scale, dynamic gait index, 3 meter backward test.

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Introduction

Stroke is now the fourth leading cause of death and the fifth leading cause of disability. (1) According to the WHO "stroke is a rapidly developed clinical sign of focal disturbance of cerebral function, lasting more than 24 hours or leading to death with no apparent cause other than vascular origin. (2) Among stroke survivors, disability is a common sequela.(3) They are often accompanied by , balance impairment(4), gait alteration(5), coordination deterioration(6) and high risk of falling(7).Worldwide one in six people will have stroke in their lifetime and more than 13.7 million people have stroke each year. (1) The prevalence rate of stroke for total urban and rural populations, varied from 44.54 to 150/100000 where the urban population prevalence rate was 45 to 487/100000 and the rural population was 55 to 388.4/100000.(8)

Stroke, a formidable cerebrovascular affliction, ranks among the most significant public health challenges of our time. This medical emergency occurs when the blood supply to a specific area of the brain is disrupted or reduced, leading to the rapid death of brain cells. Therefore, stroke can manifest in a range of neurological impairments, including paralysis, speech difficulties, and cognitive deficits. The impact of stroke extends far beyond individual patients, burdening families, healthcare systems, and societies. (21)

Various domains are affected after stroke such as physical functions, satisfaction with social roles, and executive functions. (9)The most common signs and symptoms of stroke are contralateral hemiparesis, speech impairment, ataxia, facial paralysis, and nystagmus (10)

Walking is a basic requirement for participating in various daily living activities. There are walking impairments that occur in patients suffering from stroke. There are some studies show presentations of gait asymmetry in patients with stroke (11) Stroke causes motor impairment, which can be described as loss, or limitation of muscle control functions or movements (12)

There are various interventions used for stroke patients to improve flexibility and joint integrity, unilateral neglect, strength, and movement control. There are walking impairments that occur in patients suffering from stroke. Some studies show that there are gait asymmetry presentations in stroke patients. Stroke reduces the weight-bearing capacity of the lower limb and has decreased stance phase and prolonged swing phase on the paretic side. (11)

Balance impairments often result from damage to brain regions responsible for coordinating motor control, sensory integration, and spatial awareness. These impairments contribute to an increased risk of falls, decreased mobility, and reduced quality of life in stroke patients. Post-stroke balance impairments are multifactorial and can arise from various underlying mechanisms. Hemiparesis, altered muscle tone, sensory deficits, and cognitive impairments. In addition, disruptions in proprioceptive, vestibular, and visual systems further complicate balance control. (30)

Gait-related impairments need combinations of therapeutic interventions where the conventional therapy treatment has a common set of interventions such as heat therapy, joint mobilization, stretching, and strengthening exercises for pain reduction and to improve particular muscle activity. (15)

Backward walking (BW) has been recently introduced as a means of balance improvement. As an individual has to rely more on the senses other than the visual system during backward walking, BW is observed to have additional biomechanical benefits over forward walking and increase the forward gait speed. (14) Backward walking, also known as retro-walking or reverse walking is a gait pattern where an individual walks backward instead of forward. This unique way of walking requires greater attention, coordination, and activation of different muscle groups as compared to forward walking. Research also suggests that backward walking may offer distinct advantages for stroke patients due to its ability to engage different neural pathways stimulate sensorimotor integration and challenge the motor control systems.

Recent evidence from clinical studies has shown results regarding the benefits of backward walking in stroke rehabilitation. These studies have explored various aspects of backward walking, such as its effects on gait parameters, balance, functional capacity, and overall quality of life for stroke survivors. By examining the findings from the clinical studies, and neurophysiological research the aim is to shed light on the efficacy and safety of incorporating backward walking exercises into stroke rehabilitation protocol.

One of the most important strategies to improve motor learning is feedback. Surface EMG biofeedback can be used to give augmented feedback. (10)EMG biofeedback has been used to improve motor functions in patients with stroke.

EMG biofeedback is a non-invasive and therapeutic technique that utilizes real-time measurements of muscle activity. This technique has gained popularity in various fields of rehabilitation and performance enhancement due to its potential to facilitate motor learning and improve functional outcomes. Recent research has provided valuable insights into the efficacy and applications of EMG biofeedback in different populations, ranging from patients with neurological disorders to athletes seeking performance optimization.

The technique allows altering motor unit activity based on augmented audio and visual feedback. Electrodes placed on the skin overlying target muscles, and detect electrical signals generated during muscle contraction, and this information is translated into real-time feedback. By observing these signals, individuals can learn to modulate their muscle activity, which can lead to better motor control, reduced muscle imbalances, and enhanced overall performance. The training can focus on voluntary inhibition of spastic muscles. Patients with more than 6 months post-stroke have shown positive results to EMG biofeedback. It improves ROM, voluntary control, and function. (10)

The application of EMG biofeedback encourages stroke patients to actively engage in rehabilitation exercises, facilitating the recruitment of appropriate muscle groups and reinforcing proper movement patterns. By providing patients with direct feedback on their muscle activity, EMG biofeedback enables them to develop a heightened sense of proprioception, which is crucial for regaining motor control and coordination. (33)

Recent evidence from clinical studies has also explored various ranges of applications of EMG biofeedback, including its use in upper limb rehabilitation to enhance hand dexterity and grasp strength, as well as in lower limb to promote walking and balance recovery.

Objectives

Primary Objective

- To assess and compare the effectiveness of backward walking programme with and without EMG biofeedback to improve the gait and balance in stroke patients.

Secondary Objective

- To assess the gait and balance in post-stroke patients
- To study the effectiveness of backward walking with EMG biofeedback to improve the gait and balance in post-stroke patients.
- To study the effectiveness of the backward walking program
- Improve the gait and balance in post-stroke patients without EMG biofeedback.

Need of the study

Backward walking is shown to be the most effective treatment to improve balance and gait in patients suffering from stroke and on the other hand, EMG biofeedback has been used in patients with various conditions in order to improve various aspects in patients suffering from stroke and other conditions (14).

As patients with stroke have a high chance of having gait impairments, there are no studies showing the effectiveness of backward walking and EMG biofeedback in patients suffering from stroke. The protocol is set in a kind where backward walking with the EMG biofeedback can create an impact on the gait pattern and balance of patients with stroke. Studies also suggest that backward walking significantly improves the gait and it helps in taking this study further by using surface EMG biofeedback in the lower limb to improve the gait.

Therefore, the study aims to find the effectiveness of backward walking with and without EMG biofeedback in post-stroke patients.

Research Question:

Is backward walking with EMG biofeedback more effective than backward walking without EMG biofeedback in improving the gait and balance in stroke patients?

Hypothesis

Null hypothesis:

There may not be any significant difference between backward walking with EMG biofeedback and Without EMG biofeedback to improve the gait and balance in stroke patients.

Alternate hypothesis:

There may be a significant difference between the backward walking Programme with EMG biofeedback and Without EMG biofeedback to improve the gait and balance in stroke patients.

REVIEW OF LITERATURE

A study conducted by Louis DeMark et. al in the year of 2019 in USA to investigate the application of backward walking training to improve walking functions, balance, and fall risk in acute stroke. Eight patients with first time stroke with at least 2 weeks duration participated in this study. The patients participated for 10 sessions that included 20 minutes of over ground backward walking training for each sessions. The results of this study showed that all eight patients showed improvements in all outcome with a clinically meaningful increase in forward walking.(15)

A systemic review and meta-analysis performed by Chen ZH et. al in the year 2020 to investigate the effectiveness of backward walking for people affected by stroke. A total of ten studies were included according to inclusion and exclusion criteria, all studies described some positive influences of backward walking on stroke, relative to the control group (forward walking or conventional therapy) compared to control group, there is statistically significant improvement for backward walking group in gait velocity (mean difference [MD]= 6.87, 95% Cl). The study concludes that for patients with stroke backward walking training, as an adjunct to conventional treatment can improve Berg balance score (moderate evidence).(16)

A randomized control trial was carried out by Chang-Yong Kim et. al to compare the effects of lateral and backward walking training on walking functions in patients with post stroke hemiplegia. Fifty-one subjects with hemiplegic stroke were randomly allocated to 3 groups, each containing 17 subjects: the control group, the backward walking training group and the lateral walking training group. The walking abilities of each group were assessed using 10m walk test and GAITRite system for spatiotemporal gait. The results show that there were significantly greater post test increase in gait velocity (F=-12.09, P= 0.02) and stride length (F=-11.50, P=0.02), decreases in value of 10m walk test (F=-7.10, P= 0.03) and improves in gait asymmetry (F=13.88, P=0.002). These findings demonstrate that asymmetric gait patterns in post stroke patients could be improved by receiving additional lateral walking training therapy rather than backward walking therapy.(17)

A pilot randomized control trial was implemented by Dorian K. Rose et. al in Florida to study effectiveness of backward walking training program to improve balance and mobility in acute stroke. 18 individuals 1 week post stroke were randomized to 8, 30 minutes session of backward walking training or standing balance training was scheduled. 5m walk test, 3m backward walk test, Berg balance scale, function independence measure were accessed pre and post intervention. Results showed that exercise with backward walking training not only improves faster backward walking speed but also prevents fall, forward gait speed and increases balance self-efficacy.(18)

A systemic review and meta-analysis was conducted by Jungie Wang et.al to study effectiveness of backward walking training on balance performance. 11 studies that met the eligibility criteria were included in the review where all the studies reported beneficial effects of backward walking on balance performance. The study concluded that backward walking training could serve as potentially useful tool to improve balance performance among those with high risk of fall.(19)

A study was carried out in Taiwan by Peih- Ling Tsaih et. al to investigate the effects of practice variability with task oriented Electromyographic biofeedback(EMGBFB) on strength and balance in people with chronic stroke. Thirty three participants were randomly assigned into constant force electromyographic biofeedback on Tibialis anterior (TA) exercise (constant) group, the variable force EMGBFB tibialis anterior exercise (variable) group, or the upper extremity exercise without EMGBFB (control) group. Subjects in each group received 6 weekly sessions of exercise training (18 sessions, 40 minutes each). Motor outcomes were TA strength, balance walking speed, Timed Up and Go test (TUGT), and six-minute walk test (6MWT). This concluded that Task-oriented EMGBFB-assisted TA exercise training improved muscle strength in people with chronic stroke.(20)

A pilot study employing randomized controlled methods was executed by Yiyeop Moon et. al to examine the impacts of observational training involving backward walking on the ability to walk (gait) in individuals dealing with chronic stroke. A total of 14 patients who were in the chronic stages of stroke were deliberately divided into two groups: an experimental group (n=7) and a control group (n=7). Both groups engaged in conventional therapy sessions five times per week, and additionally, the experimental group participated in backward walking with observational training three times a week. The outcomes displayed that the experimental group, which underwent backward walking along with observational therapy, exhibited notable advancements in comparison to the control group. This leads to the conclusion that incorporating observational therapy into backward walking is an effective approach for enhancing gait ability in individuals with chronic stroke.(31)

An analysis of a case series was studied by Louis DeMark et. al to highlight the practical application of backward walking training as a means to enhance walking ability, balance, and mitigate fall risks among individuals in the acute stages of stroke. Eight patients who had experienced their first stroke participated in a sequence of ten consecutive sessions. These sessions encompassed 20-minute periods of over-ground backward walking training. The study encompassed several outcome measures, including the 10-Meter Walk Test (10MWT), 3-Minute Walk Test (3MBWT), Timed Up and Go (TUG) test, and the Berg Balance Scale (BBS). The findings revealed noticeable enhancements in all measured outcomes, particularly a significant improvement in the 10MWT, signifying clinical relevance. This suggests that despite substantial walking impairments, considerable progress was observed in terms of balance and walking function. Consequently, this program exhibits potential for enhancing outcomes in patients with characteristics commonly encountered in inpatient rehabilitation settings.(30)

A study was performed by Jeollabuk-do et. al where objective of this study was to assess the impact of EMG biofeedback training on the upper extremity functions of stroke patients. The study enrolled 30 participants with hemiplegia, each having a disease duration of over six months. These participants were randomly allocated into two distinct groups. The first group, designated as the control group, underwent conventional rehabilitation therapy. Meanwhile, the second group, the experimental group, engaged in traditional rehabilitation techniques along with the incorporation of EMG biofeedback, all spanning a duration of four weeks. Upon comparing the outcomes of the study, it was evident that individuals within the experimental group exhibited notably greater enhancements in upper extremity functions across all administered tests compared to those in the control group. The findings led to the conclusion that stroke patients who underwent intensive EMG biofeedback as part of their rehabilitation exhibited more substantial recovery in upper extremity function compared to those who solely underwent traditional rehabilitation therapy.(32)

An investigation was conducted by Gülseren Dost Sürücü et. al to assess the effectiveness of EMG biofeedback therapy for treating ankle dorsiflexion issues in hemiplegic patients. The study included 40 patients within a randomized control design, where participants were divided into two groups through random assignment. In the first group of 20 patients, EMG biofeedback therapy targeting the tibialis anterior muscle—an ankle extensor—was administered five days a week for three weeks, in conjunction with conventional therapy. The remaining 20 patients constituted the control group, receiving only conventional therapy. Comprehensive evaluations, including spasticity assessments, ankle range of motion measurements, modified motor assessment scale scores, and Brunnstrom's neurophysiological assessment, were conducted both before and after the treatment phase. The results showcased significant enhancements in both groups, with the experimental group demonstrating greater significance. Overall, the study underscores the potential of EMG biofeedback therapy to enhance clinical and functional parameters related to lower extremity issues in hemiplegic patients dealing with ankle dorsiflexion challenges.(33)
Top of Form

A study by Peih-Ling Tsaih et. al aimed to assess the impact of combining practice variability with task-oriented electromyographic biofeedback (EMGBFB) on strength and balance in individuals with chronic stroke. Thirty-three participants were randomly assigned to the constant force EMGBFB tibialis anterior (TA) exercise group, variable force EMGBFB TA exercise group, or upper extremity exercise without EMGBFB control group. Each group underwent six weekly exercise training sessions (totaling 18 sessions, 40 minutes each). Outcome measures included TA strength, balance (measured by anteroposterior sway amplitude in dynamic posturography), walking speed, Timed Up and Go test (TUGT), and six-minute walk test (6MWT), evaluated at baseline, 1 day, 2 weeks, and 6 weeks post-training. Both constant and variable groups exhibited significant increases in TA strength, while balance improved notably only in the variable group. All participants showed enhancements in walking speed, TUGT, and 6MWT. The study underscores the benefits of task-oriented EMGBFB-assisted TA exercise for enhancing muscle strength in chronic stroke patients. Notably, practicing variable force levels during EMGBFB-assisted exercises improved anteroposterior sway ability during standing, emphasizing the importance of incorporating motor learning principles and task-oriented approaches when utilizing EMGBFB as supplementary therapy in stroke rehabilitation.(34)

A systematic review featuring meta-analysis of randomized trials by Rosalyn Stanton et. al was implemented using a PEDro score exceeding 4 aimed to evaluate the impact of biofeedback interventions concurrent with practice of various activities (sitting, standing up, standing, or walking) in individuals post-stroke, in comparison to equivalent practice without biofeedback. A total of 18 trials encompassing 429 participants met the criteria, showcasing moderately high trial quality with an average PEDro score of 6.2 out of 10. Employing a standardized mean difference (SMD) due to diverse outcome measures, the pooled effect size demonstrated that biofeedback led to superior improvements in activity performance when contrasted with standard therapy (SMD 0.50, 95% CI 0.30 to 0.70). In conclusion, this review underscores the efficacy of biofeedback interventions over conventional therapy in enhancing activity performance among post-stroke individuals.(35)

Methodology

Source of data
R.V. College of Physiotherapy- OPD, Brains hospital, Newro rehab centre-Bengaluru
Study design
Non randomized comparative study
Study subjects
Subjects diagnosed with stroke who fulfill the inclusion and exclusion criteria
Study duration
6 months
Sampling technique
Purposive sampling
Inclusion criteria

- Subjects who are willing to participate as volunteers and sign the informed written consent.
- Subjects diagnosed with one-time stroke.
- Able to maintain an upright standing posture with moderate assistance
- Age group 35-65 years
- Subjects with supra tentorial stroke
- Subjects who are medically stable
- Subjects with MMSE scores of more than 24
- Subjects with FAC score 4-5

Exclusion criteria

- Any other neurological or rheumatic disorders
- Significant orthopaedics or pain condition in the upper extremity
- Any spinal or limb deformities
- Uncontrolled hypertension
- Skin rashes or allergy
- Lower extremity joint or weight-bearing pain
- Inability to follow commands
- Cardiopulmonary conditions

Materials required

- Consent form
- Screening form (FAC, MMSE)
- Stopwatch
- Standard chair without armrest or wheels
- Measured distance of 3 meters (10 feet)

- EMG biofeedback machine(Myoplus) with surface electrode

Screening tools

- Functional ambulatory category (FAC)
- Mini-mental scale examination (MMSE)

Outcome measuring tools

- Dynamic gait index (DGI)
- Berg-balance scale (BBS)
- 3-meter backward test

Procedure

After obtaining approval from the Institutional Ethics Committee (IEC) of R.V. College of Physiotherapy®, Bengaluru. Subjects were selected according to the inclusion and exclusion criteria of the study. Subjects who fulfilled the inclusion and exclusion criteria were included in the study. Informed consent was taken from the subjects, the study procedure was explained to them, and a detailed neurological examination was conducted.

Pre-test

Subjects were screened using functional ambulatory category (FAC) and mini-mental scale examination (MMSE) was performed.the investigator performed a pre-assessment of outcome measures (DGI, BBS, 3-meter backward test). Subjects were allotted according to purposive sampling. Subjects were divided into two groups where group Ahad conventional therapy and backward walking with emg biofeedback and group B had conventional therapy and backward walking without emg biofeedback

Post-test

At the end of 6 weeks, the researcher re-evaluated the outcome measures (dGI, BBS, 3-meter backward test)

The conventional therapy that was given to both groups included:

1. Stretching
2. Strengthening techniques such as:

Sr. No.	Techniques	Dosage
1.	Weight-bearingin standing(knee extended)	2-3 minutes
2.	Weight-bearing in standing on an inclined wedge	2-3 minutes
3.	Knee flexion control in the prone position	10 repetitions
4.	Active assistive movements using activities using a balance board, static cycle for hip(flexion), knee(flexion-extension), ankle(dorsiflexion–plantarflexion)	10 repetitions each

The program was conducted for three days a week for six weeks for both groups where the subject was not allowed to use any assistive device or foot orthosis. In group A along with the conventional therapy, the patient was given backward walking with emg biofeedback where the subject was walking backward for 10 minutes in the set of two with emg biofeedback. The electrodes for emg were placed on muscles such as gluteus maximus, quadriceps, hamstrings, and tibialis anterior. In group B along with the conventional therapy, the patient was given backward walking without emg biofeedback where the patient was walking backward for 10 minutes in the set of two. The work/rest method of emg biofeedback was used with a work time of 98 seconds and a rest time of 2 seconds. After the completion of 6 weeks, the subjects were reassessed in person using the outcome measures. The pre and post-results were compared for the analysis for further comparison.

Statistical Analysis

Sample size calculation of n=20 was determined by the calculation based on the prevalence of Stroke subjects in Bengaluru using the formula:

n=$(Z\alpha/2 + Z\beta)^2$p.q÷ d^2

Where,
$Z\alpha/2$ = 1.96, for α=0.05, 95% CI
Zβ = 1.282, for β=0.01, 90% power
p =487/100000 = 0.0048
q =1-p = 1-0.0048=0.9952
d =0.05%
n= $(1.96+1.282)^2$ * 0.0048 * 0.9952 ÷ $(0.05)^2$
n= 20
Total sample size =40(Group A=20 & Group B=20)

Statistical Software Jamovi 2.3.16 was used for analysis. Microsoft Excel and Word were used to generate tables and graphs.
Descriptive statistics:
The categorical variables will be presented on the form of tables along with percentage. The quantitative variables will be described by computing mean and standard deviation along with 95% confidence interval for mean, median, and interquartile range depending on normality assumption verification. The results will also be presented graphically wherever necessary.
Inferential statistics:
The comparison between the groups will be tested by using student unpaired t-test Mann-Whitney test subject to normal assumption verification. The effectiveness within the groups will be tested by using a student-paired t-test/ Wilcoxon signed Rank sum test subject to normality assumption verification. Results will be considered significant whenever P≤0.05.
Strategy for analysis

- The descriptive data and the data for outcome was derived from Jamovi.
- Normality was calculated by Kolmogorov- Smirnov normality test
- Pre-test for DGI, BBS, 3MBWT and Post-test for DGI, BBS, 3MBWT values were taken for analysis

Results

Table 1. Age distribution among Group A

AGE (YEARS)	FREQUENCY	PERCENTAGE
20-30	2	10%
30-40	3	15%
40-50	8	40%
50-60	3	15%
60-70	4	20%
TOTAL	20	100%

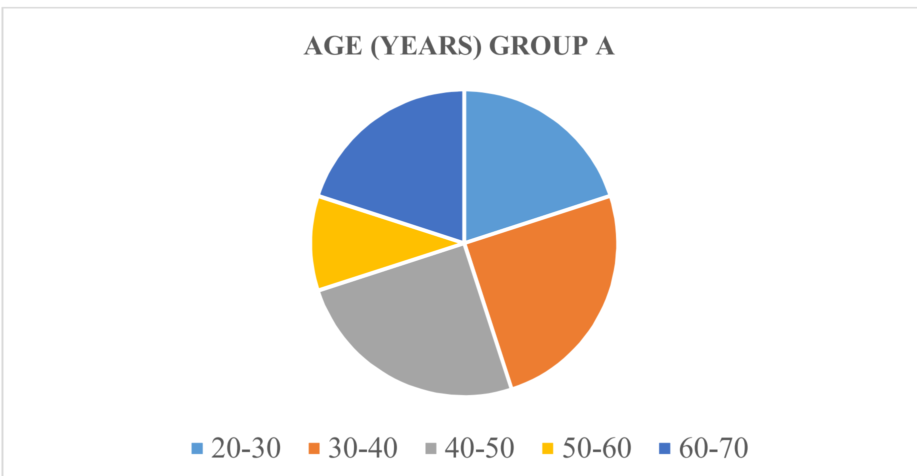

Figure 1: Pie diagram showing age distribution percentage among Group A.

In the present study of the 20 subjects treated in Group A, 10% were between 20-30 years of age, 15% were between 30-40 years of age, 40% were between 40-50 years of age, 15% were between 50-60 years of age, and 20% were between 60-70 years of age respectively.

Table 2. Age distribution among Group B

AGE (YEARS)	FREQUENCY	PERCENTAGE
20-30	4	20%
30-40	5	25%
40-50	5	25%
50-60	2	10%
60-70	4	20%
TOTAL	20	100%

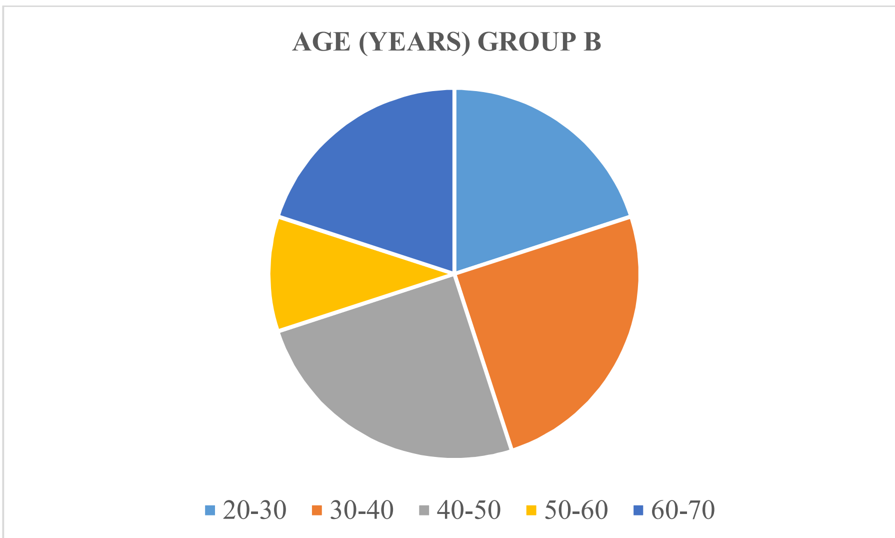

Figure 2: Pie diagram showing age distribution percentage among Group B.

Among another 20 treated in Group B, 20% were between 20-30 years of age, 25% were between 30-40 years of age, 25% were between 40-50 years of age, 10% were between 50-60 years of age, and 15% were between 60-70 years of age respectively.

Table 3. Gender distribution between group A and Group B

GENDER	GROUP A	GROUP B
MALE	11	11
FEMALE	9	9
TOTAL	20	20

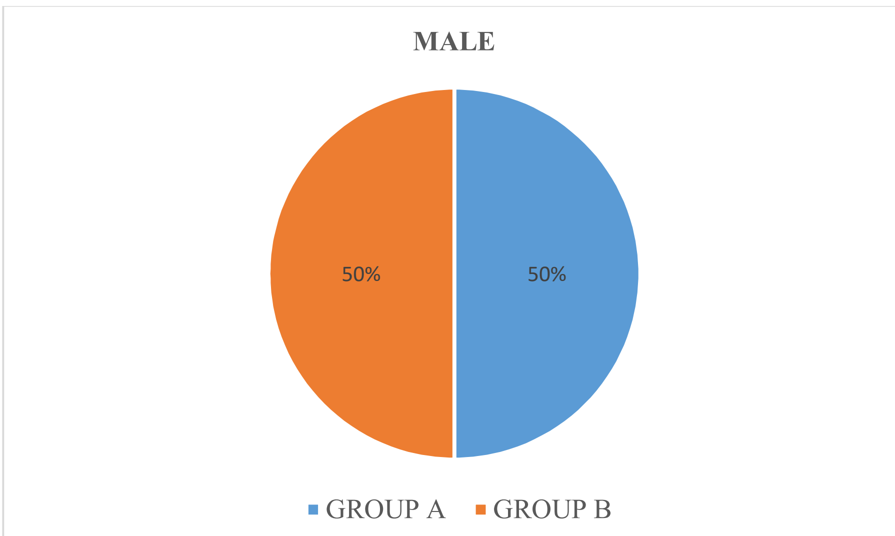

Figure 3: Pie diagram showing gender distribution percentage among both groups in Males.

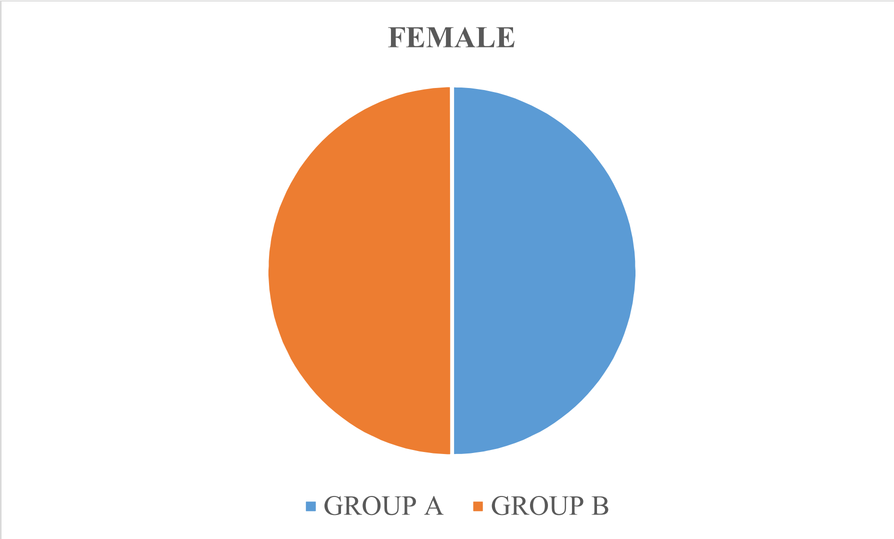

Figure 4: Pie diagram showing gender distribution percentage among both groups in Females.

In the above table, there are equal distribution of Males and Females between Group A and Group B

Table 4. BMI distribution among Group A

BMI	FREQUENCY	PERCENTAGE
UNDERWEIGHT	1	5%
NORMAL WEIGHT	7	35%
OVERWEIGHT	6	30%
OBESE	6	30%
TOTAL	20	100%

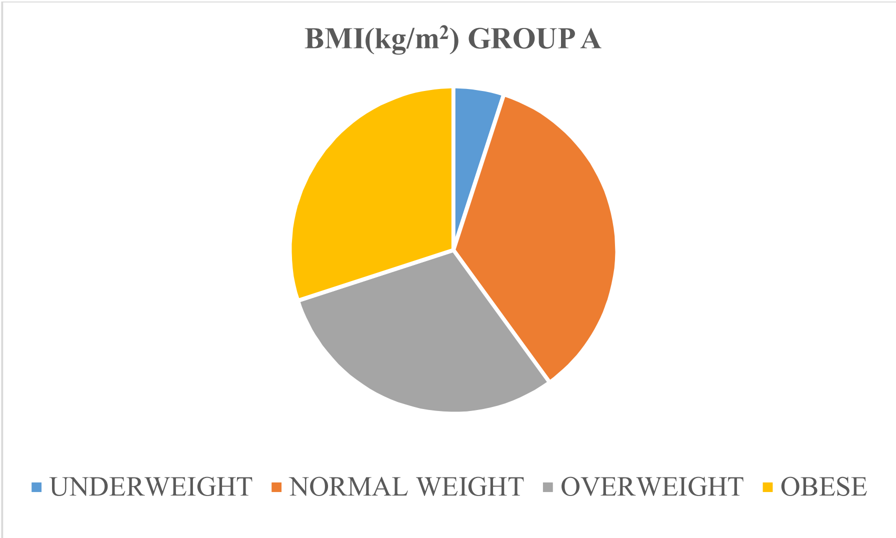

Figure 5: Pie diagram showing BMI distribution percentage among Group A

In the above table of the 20 subjects treated in Group A, 5% were Underweight, 35% were of normal weight, and the remaining 30% were overweight and obese respectively.

Table 5. BMI distribution among Group B

BMI	FREQUENCY	PERCENTAGE
UNDERWEIGHT	1	5%
NORMAL WEIGHT	7	35%
OVERWEIGHT	6	30%
OBESE	6	30%
TOTAL	20	100%

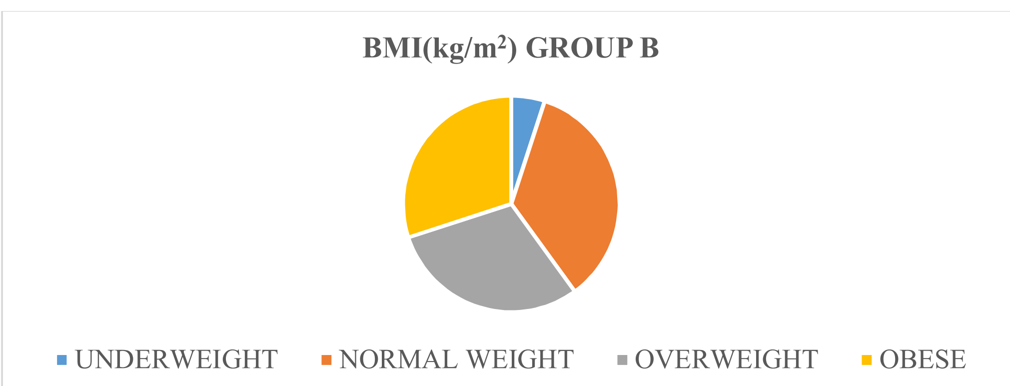

Figure 6: Pie diagram showing BMI distribution percentage among Group B.

In the above table of the 20 subjects treated in Group A, 5% were Underweight, 10% were of normal weight, 65% were overweight and the remaining 20% were obese respectively.

Table 6. Test of normality

	Study group	Statistic	df	P-value
BMI (kg/m2)	Group A	0.088	20	0.200*
	Group B	0.268	20	0.001
FAC	Group A	0.387	20	0
	Group B	0.413	20	0
MMSE	Group A	0.157	20	0.200*
	Group B	0.187	20	0.066
Pre- test DGI	Group A	0.122	20	0.200*
	Group B	0.134	20	0.200*
Post- test DGI	Group A	0.287	20	< 0.001
	Group B	0.164	20	0.161
Pre- test BBS	Group A	0.2	20	0.034
	Group B	0.16	20	0.195
Post-test BBS	Group A	0.191	20	0.054
	Group B	0.188	20	0.062
Pre- test 3MBWT	Group A	0.155	20	0.200*
	Group B	0.115	20	0.200*
Post-test 3MBWT	Group A	0.129	20	0.200*
	Group B	0.138	20	0.200*

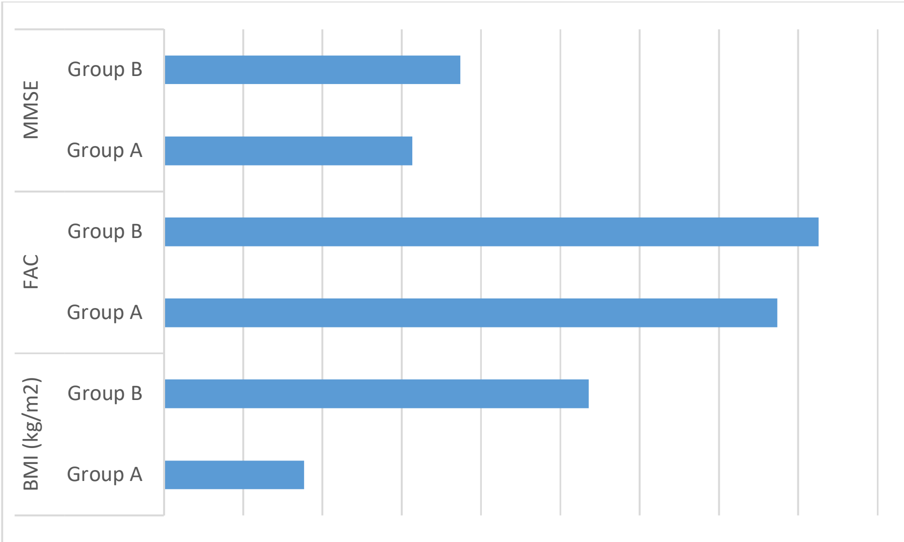

Figure 7: Graphical representation for Test of normality for BMI, FAC, MMSE.

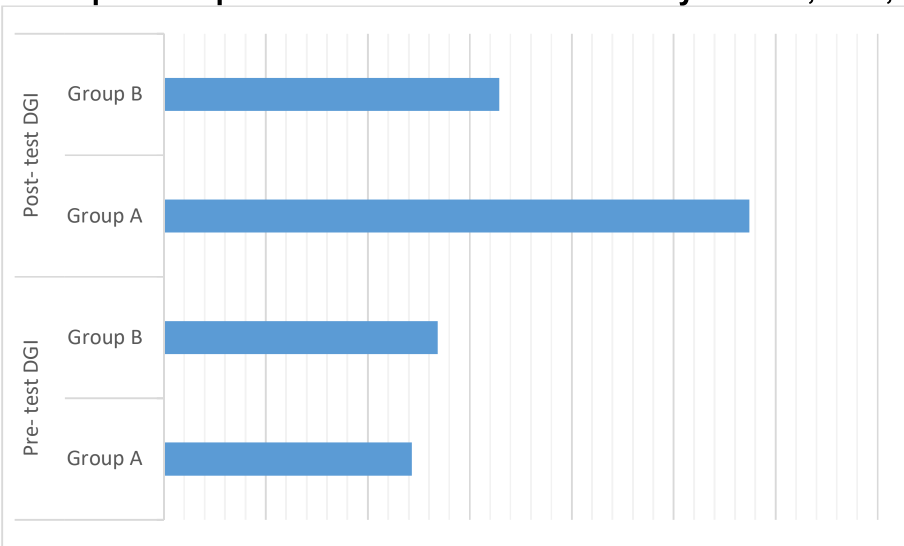

Figure 8: Graphical representation for Test of normality for DGI.

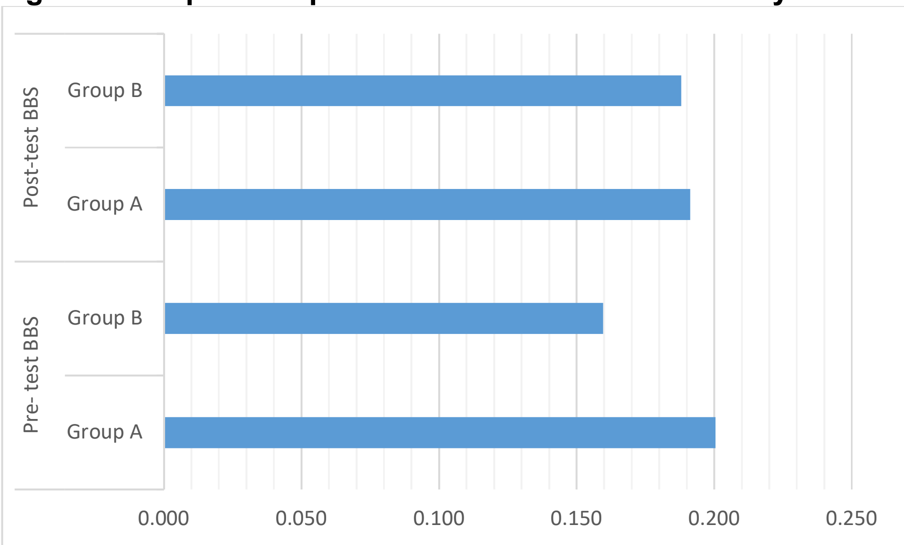

Figure 9: Graphical representation for Test of normality fr BBS.

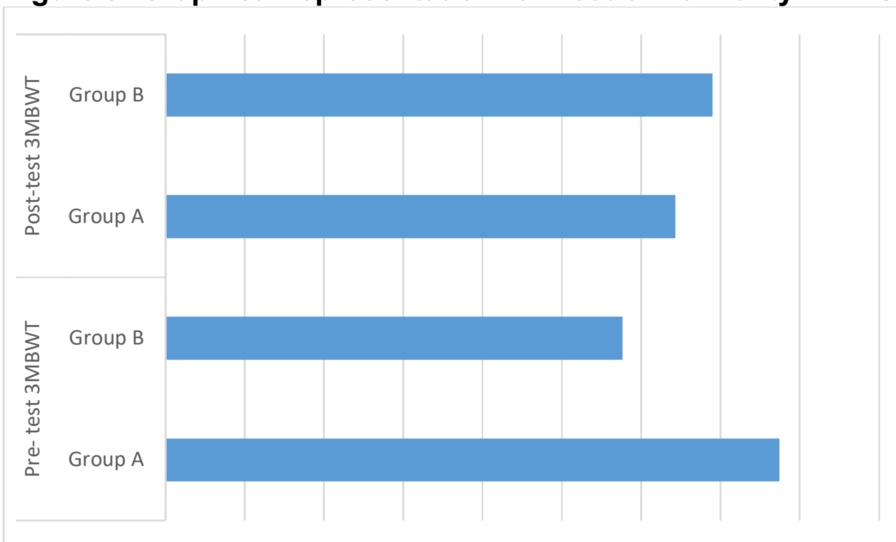

Figure 10: Graphical representation for Test of normality for 3MBWT.

The data obtained from the above table among the different parameters of MMSE, Pre-test DGI, Post-test BBS, Pre, and Post-test 3MBWT were found to be normally distributed and hence are analyzed unpaired and paired T-test. BMI, FAC, Post-test DGI, and Pre-test BBS are found to be non-normally distributed and hence analyzed using Mann Whitney U-test and Wilcoxon Signed Ranked test.

Table 7: Wilcoxon Signed Ranks Test for Group A

	Mean	SD	z-value	P-value
Pre-test DGI	14.35	4.91	3.855	< 0.001
Post- test DGI	16.7	4.71		
Pre-test BBS	40.35	8.36	4.027	< 0.001
Post- test BBS	42.65	8.26		

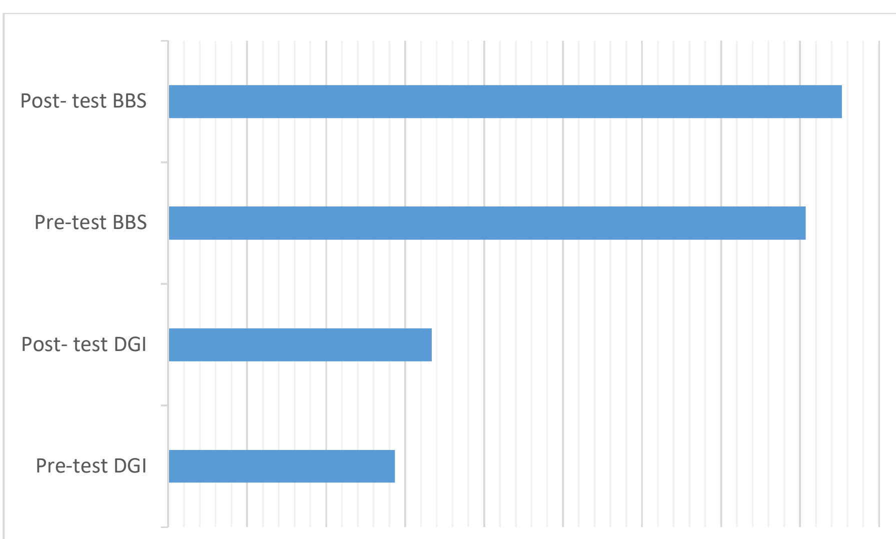

Figure 11: Graphical representation of Wilcoxon Signed Ranks Test for Group A

The mean ± SD of the Pre-test DGI was 14.35 ± 4.91 for the post-test 16.7 ± 4.71. The Z value is 3.855 with P< 0.001 which clearly shows that there is an increase of the scores of DGI from the pre-test to the post-test. The mean ± SD of the Pre-test BBS was 40.35 ± 8.36 for the post-test 42.65 ± 8.26. The Z value= is 4.027 with P< 0.001 which clearly shows that there is a clear increase in the scores of BBS from the pre-test to the post-test.

Table 8. Paired Samples t-test for Group A

	Mean	SD	t-value	P-value
Pre- test 3MBWT	22.5965	4.30638	7.217	< 0.001
Post-test 3MBWT	21.3785	4.69718		

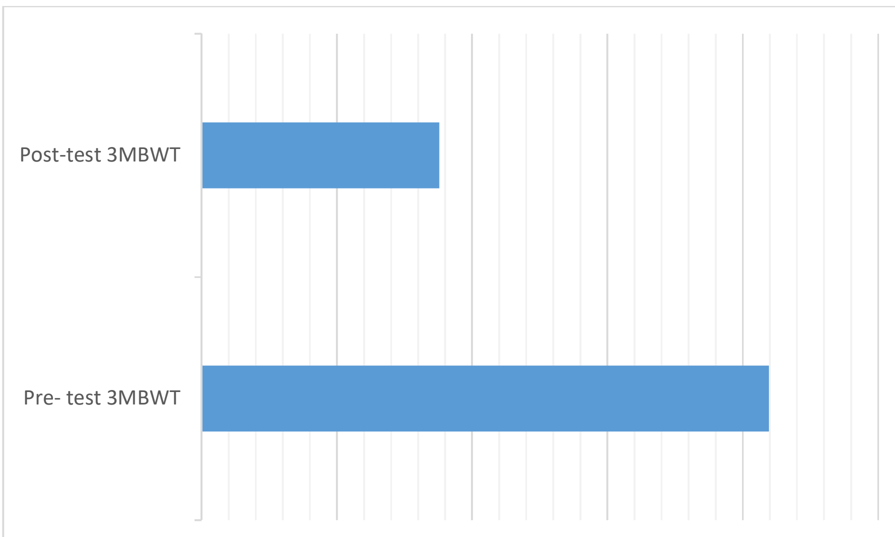

Figure 12: Graphical representation of Paired Samples t-test for Group A

The mean ± SD of Pre-test 3MBWT was 22.60 ±4.31 and for post-test 21.38 ±4.70. the t-value= 7.217 with P< 0.001 which clearly shows that there is a clear reduction of the scores of 3MBWT from the pre-test to the post-test.

Table 9: Wilcoxon Signed Ranks Test for Group B

	Mean	SD	Z-value	P-value
Pre- test BBS	37.2	9.704	3.758	< 0.001
Post-test BBS	34.4	8.899		

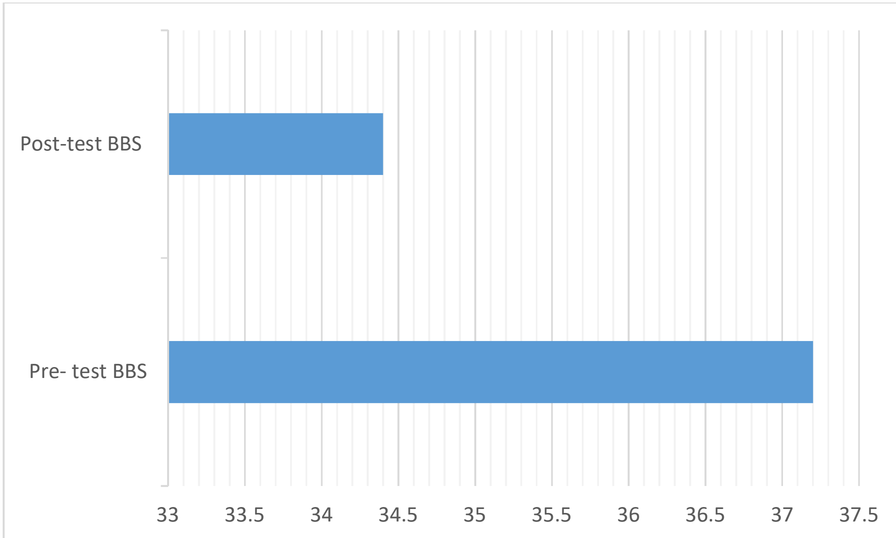

Figure 13: Graphical representation of Wilcoxon Signed Ranks Test for Group B

The mean ± SD of Pre-test BBS was 37.2± 9.704 and for post-test 34.4± 8.899. The Z-value= 3.758 with P< 0.001 which clearly shows that there is a clear increase of the scores of BBS from the pre-test to the post-test.

Table 10. Paired Samples t-test for Group B

	Mean	SD	t-value	P-value
Pre-test DGI	15.50	3.50	11.139	< 0001
Post- test DGI	17.80	3.58		
Pre- test 3MBWT	19.47	7.26	9.287	< 0.001
Post-test 3MBWT	17.76	7.44		

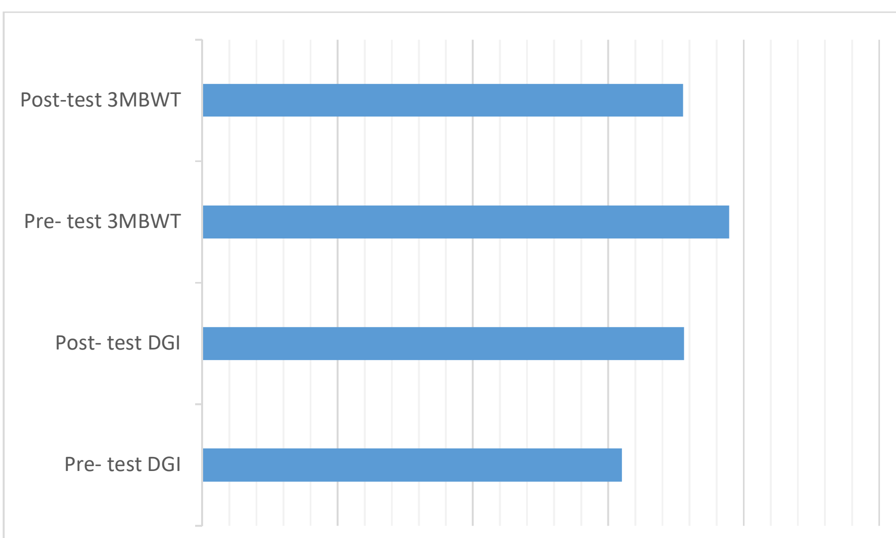

Figure 14: Graphical representation of Paired Samples t-test for Group B

The mean ± SD of the Pre-test DGI was 15.50± 3.50 for the post-test 17.80± 3.58. The t value is 11.139 with P< 0.001 which clearly shows that there is an increase of the scores of DGI from the pre-test to the post-test. The mean ± SD of the Pre-test 3MBWT was 19.47± 7.26for the post-test 17.76± 7.44 The t value= is 9.287with P< 0.001 which clearly shows that there is a clear reduction of the scores of 3MBWT from pre-test to post-test.

Table 11: Unpaired t-test among Group A and Group B

Unpaired t-test	Study group	Mean	SD	t-value	P-value
Pre- test DGI	Group A	14.35	4.913	0.852	0.399
	Group B	15.50	3.502		
Pre- test 3MBWT	Group A	22.5965	4.30638	1.658	0.106
	Group B	19.4670	7.25970		
Post-test 3MBWT	Group A	21.3785	4.69718	1.837	0.074
	Group B	17.7625	7.44410		

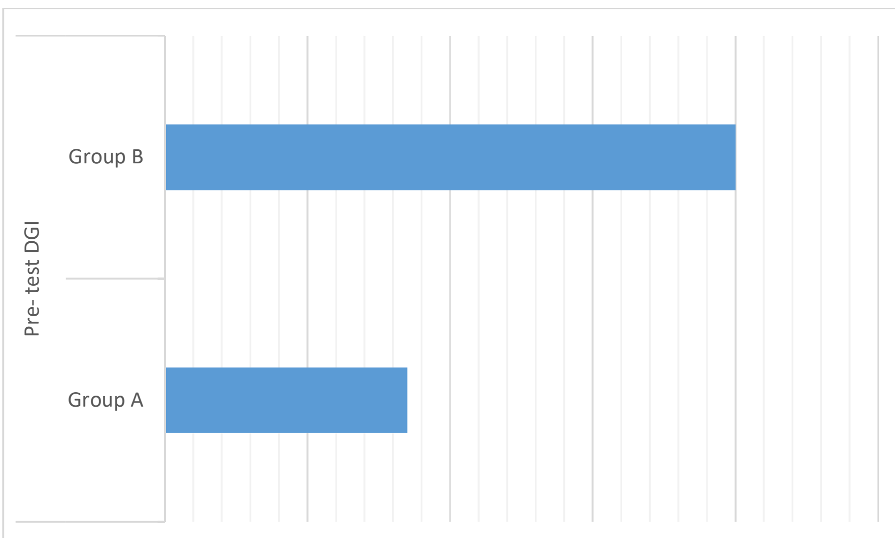

Figure 15: Graphical representation of Unpaired t-test among Group A and Group B for pre- test DGI

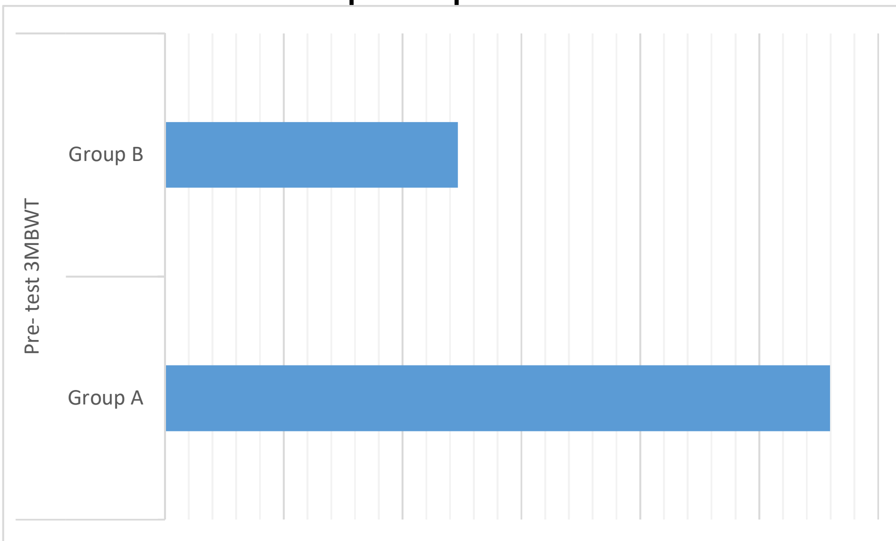

Figure 16: Graphical representation of Unpaired t-test among Group A and Group B for pre-test 3MBWT

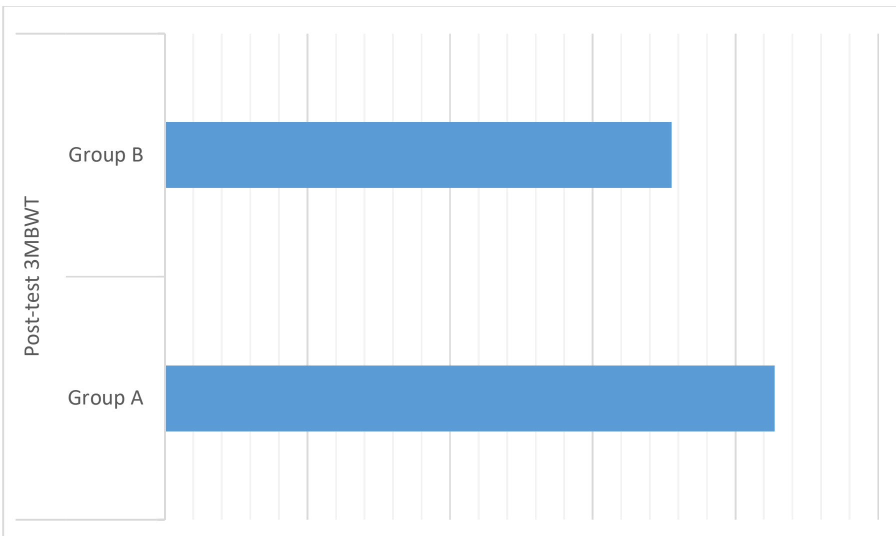

Figure 17: Graphical representation of Unpaired t-test among Group A and Group B for post-test 3MBWT

The mean ±SD of pre- test DGI for Group A was 14.35 ± 4.913 and for Group B was 15.50 ±3.502. the t-value= 0.852 with p value of 0.399 which clearly shows that it is statistically not significant. The mean ±SD of pre- test 3MBWT for Group A was 22.59 ± 4.30 and for Group B was 19.46 ±7.25. the t-value= 1.658 with p value of 0.106 which clearly shows that it is statistically not significant. The mean ±SD of post- test 3MBWT for Group A was 21.37 ± 4.69 and for Group B was 17.76 ±7.44. the t-value= 1.837 with p value of 0.074 which clearly shows that it is statistically significant.

Table 12: Mann-Whitney U-test among Group A and Group B

Mann-Whitney U-test	Study	Mean	SD	Z-value	P-value
Post-test DGI	Group A	16.7	4.714	0.533	0.594
	Group B	17.8	3.578		
Post-test BBS	Group A	42.65	8.267	1.791	0.073
	Group B	37.2	9.704		
Pre-test BBS	Group A	21.37	4.697	2.282	0.022
	Group B	17.76	7.444		

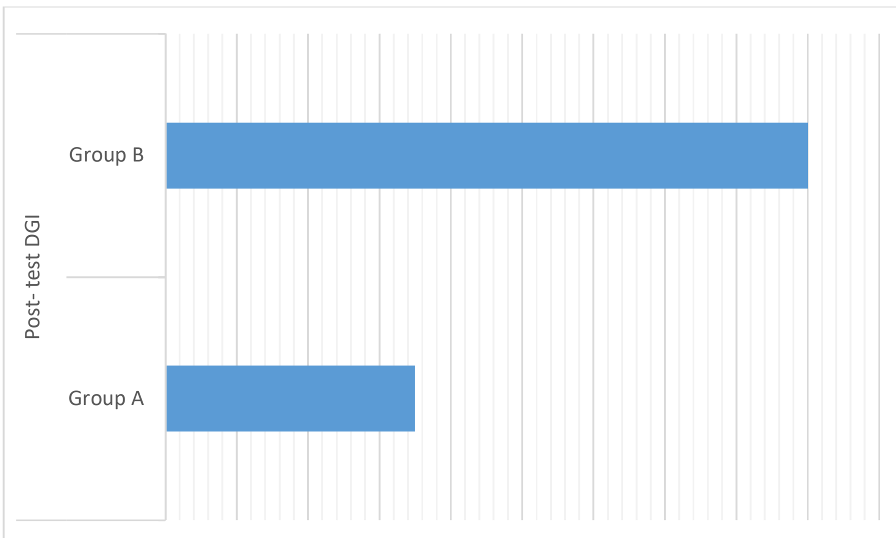

Figure 18: Graphical representation of Mann-Whitney U-test among Group A and Group B for post-test DGI.

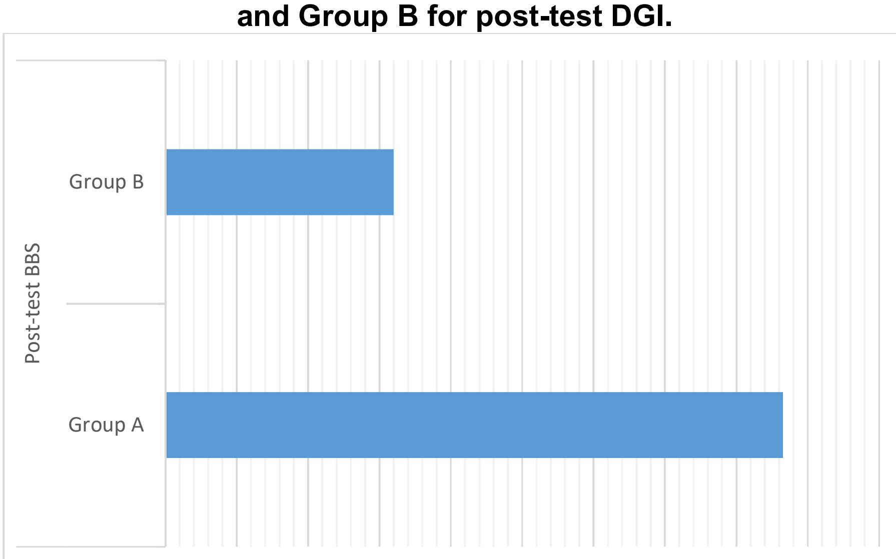

Figure 19: Graphical representation of Mann-Whitney U-test among Group A and Group B for post-test BBS.

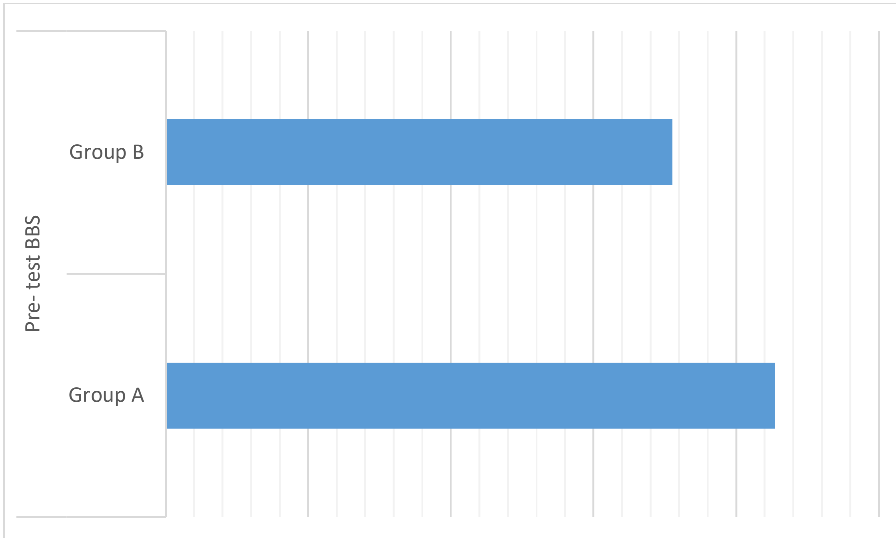

Figure 20: Graphical representation of Mann-Whitney U-test among Group A and Group B for pre-test BBS.

The mean ±SD of post- test DGI for Group A was 16.7 ± 4.714 and for Group B was 17.8 ±3.578. the Z-value= 0.533 with p value of 0.594 which clearly shows that it is statistically not significant. The mean ±SD of post-test BBS for Group A was 42.65 ± 8.267 and for Group B was 37.2 ±9.704. the Z-value=1.791 with p value of 0.073 which clearly shows that it is statistically significant. The mean ±SD of pre- test BBS for Group A was 21.37 ± 4.697 and for Group B was 17.76 ±7.44. the Z-value= 2.282 with p value of 0.022 which clearly shows that it is statistically significant.

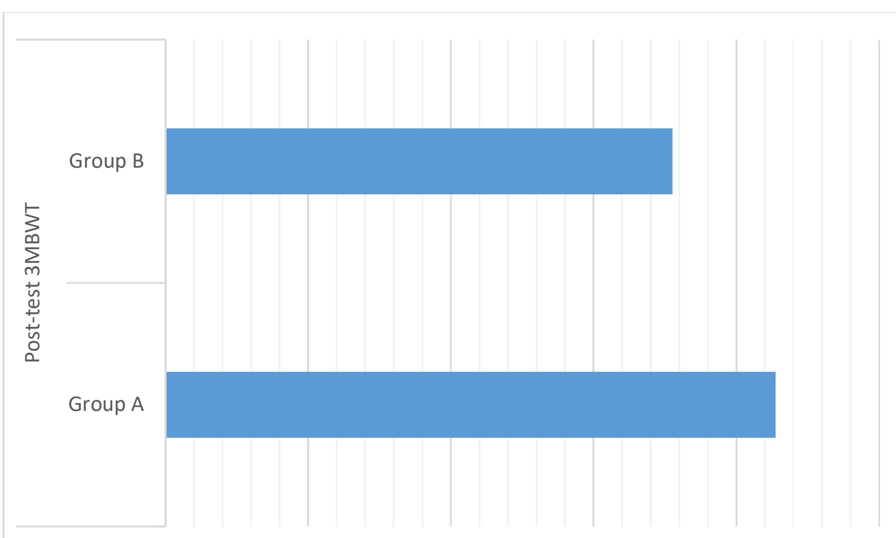

Figure 17: Graphical representation of Unpaired t-test among Group A and Group B for post-test 3MBWT

The mean ±SD of pre- test DGI for Group A was 14.35 ± 4.913 and for Group B was 15.50 ±3.502. the t-value= 0.852 with p value of 0.399 which clearly shows that it is statistically not significant. The mean ±SD of pre- test 3MBWT for Group A was 22.59 ± 4.30 and for Group B was 19.46 ±7.25. the t-value= 1.658 with p value of 0.106 which clearly shows that it is statistically not significant. The mean ±SD of post- test 3MBWT for Group A was 21.37 ± 4.69 and for Group B was 17.76 ±7.44. the t-value= 1.837 with p value of 0.074 which clearly shows that it is statistically significant.

Table 12: Mann-Whitney U-test among Group A and Group B

Mann-Whitney U-test	Study	Mean	SD	Z-value	P-value
Post-test DGI	Group A	16.7	4.714	0.533	0.594
	Group B	17.8	3.578		
Post-test BBS	Group A	42.65	8.267	1.791	0.073
	Group B	37.2	9.704		
Pre-test BBS	Group A	21.37	4.697	2.282	0.022
	Group B	17.76	7.444		

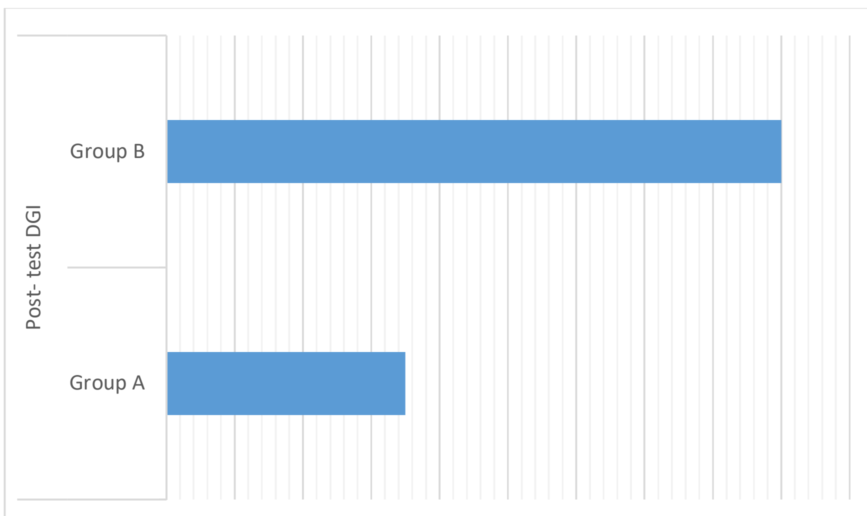

Figure 18: Graphical representation of Mann-Whitney U-test among Group A and Group B for post-test DGI.

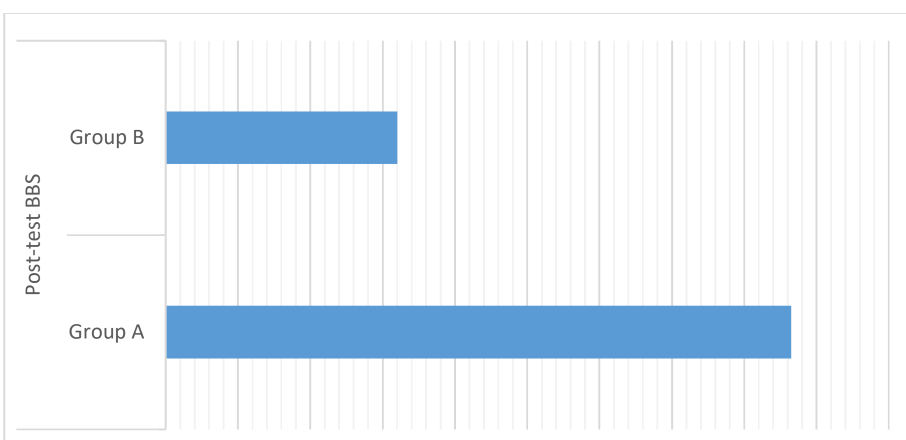

Figure 19: Graphical representation of Mann-Whitney U-test among Group A and Group B for post-test BBS.

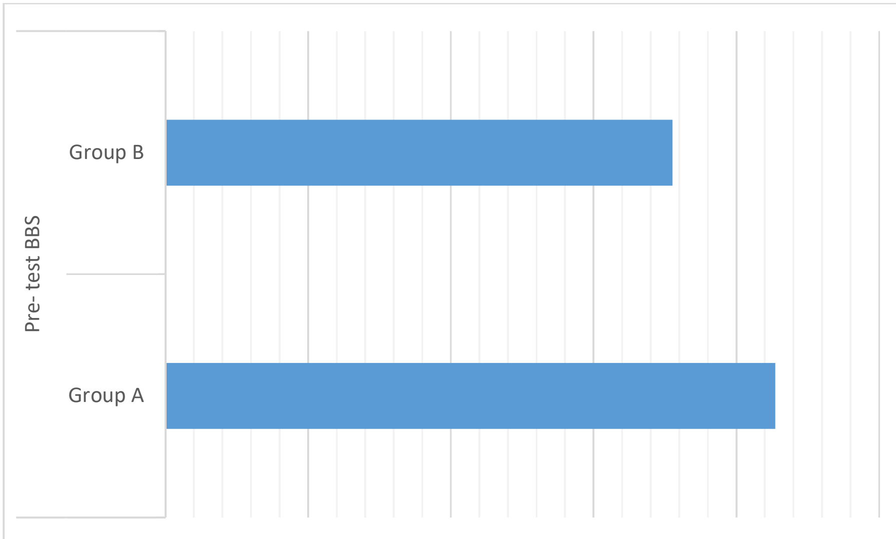

Figure 20: Graphical representation of Mann-Whitney U-test among Group A and Group B for pre-test BBS.

The mean ±SD of post- test DGI for Group A was 16.7 ± 4.714 and for Group B was 17.8 ±3.578. the Z-value= 0.533 with p value of 0.594 which clearly shows that it is statistically not significant. The mean ±SD of post-test BBS for Group A was 42.65 ± 8.267 and for Group B was 37.2 ±9.704. the Z-value=1.791 with p value of 0.073 which clearly shows that it is statistically significant. The mean ±SD of pre- test BBS for Group A was 21.37 ± 4.697 and for Group B was 17.76 ±7.44. the Z-value= 2.282 with p value of 0.022 which clearly shows that it is statistically significant.

Discussion

The present study focuses on the effectiveness of backward walking with and without Electromyography (EMG) Biofeedback to improve the gait and balance in stroke patients.

Gait and balance are essential components of human mobility and overall well-being. Impairments in these areas can lead to increased fall risk and reduced quality of life. Backward walking, also known as retro walking, has gained attention as a potential intervention to enhance gait and balance. Additionally incorporating electromyography (EMG) biofeedback into backward walking intervention could give real-time muscle activation information, potentially optimizing the training effects.

Backward walking involves walking in the reverse direction, which requires a greater degree of concentration and balance control compared to forward walking. The biomechanical differences between the two forms of walking engage different muscle groups and sensory feedback mechanisms. Backward walking challenges the proprioceptive systems, enhancing spatial awareness and balance control. It requires more recruitment of hip extensor muscles, which are crucial for maintaining an upright posture and preventing falls.

EMG biofeedback involves real-time monitoring and display of muscle activation levels using electromyography. It provides individuals with immediate information about their muscle activity, enabling them to make conscious adjustments to optimize movement patterns. When applied to backward walking, EMG biofeedback can assist participants in fine-tuning muscle recruitment, leading to more efficient gait and improved balance control. Enhanced sensory feedback, Muscle activation, Gait correction mechanisms that work along with backward walking which benefits patients suffering from stroke.

Various studies showed that there can be an improvement in forward walking speed. Backward walking not only challenges motor rehabilitation but also engages cognitive processes, capitalizing on the task's novelty to boost attention and cognitive involvement, thereby stimulating neuroplasticity. These brain changes, crucial for stroke recovery, encompass recruiting alternative neural pathways to enhance functional improvement. Integrating backward walking into rehabilitation protocols has the potential to harness the brain's adaptability after a stroke. In a study by Oliveira et al. (2018), incorporating backward walking resulted in improvements in spanning motor function, cognitive capabilities, and spatial awareness. These outcomes underscore the holistic potential of backward walking as an inclusive rehabilitation approach for stroke survivors.

Gilmore G, Gouelle et. al [36] mention that there is an improvement in walking pattern Parkinson's disease patients compared to younger adults when walking backward. Backward walking is a difficult task and is expected to demand higher coordination. An eight-week forward, backward, and sideways gait and step intervention have been reported to have improved gait speed. However, our findings partially agree with the study done by Whitely et al, which reported to have improved gait speed.

Gülseren Dost Sürücü et al [36] reported in the study the effect of EMG biofeedback on lower extremity function in hemiplegic patients Results showed that the improvements in ROM, muscle strength, muscle tone, and functions were much higher in the hemiplegic patients who were rehabilitated with lower extremity EMG BF combined with conventional physiotherapy compared to those who were only treated with conventional physiotherapy. So compared with this the present study had a group engaged in supervised backward walking sessions, while another group combined backward walking with EMG biofeedback. Both groups exhibited significant improvements in balance, gait parameters, and walking speed whereas backward walking with EMG biofeedback showed minimal improvement more than backward walking without EMG biofeedback.

Backward walking challenges patients to engage muscles in novel ways, particularly those responsible for stability and postural control. The continuous feedback from EMG sensors enables patients to better understand and optimize their muscle engagement. Over time the targeted muscles improve core strength, proprioception, and overall balance, reducing the risk of falls.

Neuroplasticity plays an important role in motor skill acquisition and refinement. Both backward walking and EMG biofeedback likely engage neural adaptation processes, enhancing neuromuscular coordination and control. The improvements in backward walking with and without EMG biofeedback could potentially translate into enhanced performance during other daily activities, contributing to a higher level of functional independence.

The effectiveness of backward walking interventions, regardless of the presence of EMG biofeedback, may depend on individual preferences, initial impairment, and overall rehabilitation goals. Some individuals might benefit more from the immediate feedback provided by EMG biofeedback, while others may adapt well to the inherent challenges of backward walking alone. Long-term benefits of improved gait and balance could include reduced fall risk, enhanced confidence, and increased participation in physical activities.

Limitations

The restricted sample size of 20 individuals per group hinders the generalizability of the findings. A larger sample size would have produced more sturdy conclusions. Furthermore, the relatively brief 6-week duration of the study could have influenced the magnitude of the observed improvements. A randomized controlled study could not be conducted, as the study would have shown better conclusions between a controlled group and the experimental group.

Future implications

Conducting additional research employing a larger sample size, an extended intervention duration, and subsequent follow-up assessments could offer a more holistic understanding of the enduring impacts of backward walking, with or without EMG biofeedback, on individuals who have experienced strokes. Prolonging the intervention timeframe might lead to more prominent and persistent outcomes. Furthermore, investigating the effects of backward walking on stroke survivors over a period exceeding 6 weeks would provide valuable insights into its longer-term implications.

Conclusion

The effectiveness of backward walking, both with and without EMG biofeedback, in enhancing balance and gait among stroke patients is a promising finding. This rehabilitation approach taps into the brain's remarkable neuroplasticity, allowing it to adapt and relearn motor skills. Backward walking challenges patients' motor control systems in unique ways, engaging various muscle groups and stimulating proprioceptive pathways. The incorporation of EMG biofeedback further augments this process by providing real-time information, aiding patients in refining their movements and muscle activation patterns.

The study shows the importance of adding backward walking with or without EMG biofeedback in order to improve balance and gait. By harnessing the brain's inherent capacity to rewire itself, healthcare professionals can continue to optimize stroke patients' recovery journeys, ultimately enhancing their overall quality of life and functional independence.

Summary

This comparative study aimed to investigate the effectiveness of backward walking with and without Electromyography (EMG) biofeedback to improve balance and gait in stroke patients. The study enrolled A sample of 40 patients with Stroke which was further divided into two groups that is Group A(with EMG) and Group B (without EMG) respectively. FAC and MMSE were checked before the recruitment to check their ambulation and cognitive abilities. A 6-week protocol was given for both the groups where Group A was given conventional therapy along with backward walking and EMG biofeedback whereas Group B was given only conventional therapy with backward walking. Pre and Post-intervention assessments were conducted using BBS, DGI, 3MBWT.

Results demonstrated an improvement in balance and gait along with the walking speed as indicated by the DGI, BBS and 3MBWT. The intervention of backward walking with and without EMG biofeedback indicated high significance in the post-test Berg Balance Scale (Z value= 1.791, P= 0.073) and 3Meter Backward Test (t value= 1.837, P= 0.074) in both the groups as compared to Dynamic Gait Index where the results where not statistically significant (Z value= 0.533, P= 0.594). these findings suggest that backward walking with and without EMG biofeedback is effective in improving gait and balance in patients with stroke.

The evidence suggests that incorporating backward walking, both with and without EMG biofeedback, can be a beneficial intervention for improving balance and gait in patients who have experienced a stroke. This variation in movement patterns appears to enhance proprioception, coordination, and overall stability. This feedback-driven approach enables them to make targeted adjustments, further improving their motor control and enhancing their ability to perform both backward and forward walking.

This study also suggests incorporating backward walking with or without EMG Biofeedback in the protocols of patients with stroke in order to improve the gait and balance of the patient. Other studies suggest that backward walking is effective also in increasing the walking speed of the patient. It also creates awareness of the patients surrounding making it easier for them to prevent falls.

The restricted sample size of 20 individuals per group hinders the generalizability of the findings. A larger sample size would have produced more sturdy conclusions. Furthermore, the relatively brief 6-week duration of the study could have influenced the magnitude of the observed improvements.

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