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Original Article

Physiotherapy Section

Effect of Open versus Closed Kinetic Chain Exercise Program on Balance and Fall in Diabetic Neuropathy Patients: An Experimental Study

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ABSTRACT

Introduction: Diabetic Neuropathy (DN) is a diverse group of clinical or subclinical symptoms affecting Peripheral Nervous System (PNS) resulting from diabetic mellitus. A very common ailment that significantly impairs patients' Quality of Life (QoL) causes pain, and increases falls is DN.

Aim: To analyse the effect of four weeks of Open Kinetic Chain (OKC) and Closed Kinetic Chain (CKC) exercise program on balance and falls in DN.

Materials and Methods: The present experimental study was conducted on 30 patients at Royal Global University, Guwahati, Assam, India for six months from December 2023 to May 2024. The subjects were selected as per the inclusion (Clinically diagnosed controlled DN, Both male and females aged 35 to 70 years, Berg Balance Scale (BBS) score between 35-45, Timed Up and Go (TUG) score- not below 15 seconds) and exclusion. OKC and CKC exercise program was done for four weeks and the duration is six month from December 2023 to May 2024 to improve balance by utilising BBS and TUG. Every session lasts roughly thirty minutes, with ten minutes of walking for a warm-up and a quadriceps and hamstring stretch for a cool-down. The Statistical analysis has been done utilising paired t-test with p-value of <0.001 to compare pre- and post-intervention values.

Results: In terms of BBS, the pre-intervention score for OKC was 39.2 and the post-intervention score was 48.87 (SD±2.72) and for CKC was 38.53 and post-intervention was 51.73 (SD±2.02) with the p-value of <0.001. In terms of TUG test, the pre-intervention score for OKC was 16.33 and the post-intervention was 13.6 (SD±0.83) and for CKC the pre intervention was 15.93 and post was 11.8 (SD±0.86) with the p-value of <0.001.

Conclusion: The study showed statistically larger improvement of CKC in TUG as well as BBS in functional mobility, alongside balance, compared to the OKC group. Hence, CKC Exercise programs could be utilised in day-to-day clinical practice as well as a home exercise program to enhance strength along with balance, which eventually results in prevention of falls in DN.

Keywords: Berg balance scale, Diabetes mellitus, Time up and go test

INTRODUCTION

The DN is a diverse group of clinical or subclinical symptoms affecting PNS resulting from Diabetes Mellitus (DM) [1]. A very common ailment that significantly impairs patients' QoL, causes pain, and increases falls is DN [2]. Pain and significant morbidity are symptoms of a loss of sensory function that starts distally in the lower extremities (It is a painful condition with significant morbidity that affects the sensory function of the lower extremities in a distal direction). DN is a prevalent disease that significantly affects patients by causing discomfort, increasing falls, and decreasing QOL. Incidence of neuropathy is higher in individuals with Type 2 Diabetes Mellitus (T2DM) than in those with Type 1 Diabetes Mellitus (T1DM). There is a higher prevalence of DN in India compared with the West. Probably, Asian Indians are more prone to insulin resistance [3]. The International Diabetes Federation's most recent statistics show that 8.3% of people globally have diabetes. There are currently 387 million diabetics globally, and it is predicted that another 205 million will receive a diabetes diagnosis by 2035 [4]. Diabetes peripheral neuropathy is somewhat more common in those with type 2 diabetes, and it is more common in older adults and those who have had type 1 or type 2 diabetes for a long-time [5]. The age range of 40 to 59 years accounts for the largest number of DM cases. With 668,468,800 DM patients and a countrywide DM prevalence of 8.6%, India is second only to China in terms of DM burden [6].

Numbness, tingling, discomfort, and weakness that start in the feet and spread proximally in a length-dependent manner are common symptoms in patients with DN [7]. The most common cause of impaired balance, hence, elevated risk for falls in older persons with type 2 diabetes is DPN. Balance is an advanced ability that demands a combination of several sensorimotor along with cognitive processes, alongside functional decline in sensorimotor and cognitive.

Three somatosensory, visual as well as vestibular systems provide sensory information which requires balance control. Somatosensory system contributes information about position as well as movement of body's parts relative to one another, along with support surface, by utilising proprioceptive as well as cutaneous observations. The ocular system distributes information about environment along with body orientation. Information regarding head position and spatial orientation is dispersed by the vestibular system. When one or more sensory systems deteriorate, the central nervous system has less perceptual overlap, which can impair balance and raise the risk of falling.

Long-term hyperglycaemia could cause DPN and a progressive degradation of the somatosensory system's sensory nerve fibres. In DPN, cutaneous mechanoreceptors, 1a afferents from muscle spindles, and 1b afferents from Golgi tendon organs are the largest as well as fastest conducting sensory fibres that are impacted. Golgi tendons identify changes in muscle tension alongside muscle spindles quickly report changes in muscle length. Pressure information, along with vibration sensations, is provided by cutaneous mechanoreceptors. Due to the decrease in lower limb function, DPN

has long been thought to be the primary mediator between diabetes and falls. Capacity for recognising variations in balance as well as making the necessary corrections to prevent a fall is diminished by somatosensation. Additionally, it alters the cerebrum's architecture, which results in modifications to the projection tracts. It impacts the vermis and portions of the lobes in the cerebellum that receive impulses from the spinal cord and regulate the proximal muscles, which are essential for gait coordination [8].

One of the main causes of falls is impaired balance. Balance has been evaluated in the clinical and research domains using a range of techniques, including both subjective and objective methods. Balance in patients has been evaluated clinically using a variety of outcome indicators. Patients' balance is frequently evaluated using the clinician-administered TUG test and BBS [9].

One of the most used instruments for evaluating balance is BBS. The scale's psychometric qualities have been thoroughly evaluated, and it has proven to be a viable and trustworthy indicator of balance. The test takes around 10 to 15 minutes to complete and needs a few inexpensive pieces of equipment. With an estimated intra-rater reliability of 0.98 (95% CI 0.97 to 0.99) along with an inter-rater reliability of 0.97 (95% CI 0.96 to 0.98), BBS has a high degree of relative dependability. With a 95% confidence level that ranges from 2.8/56 to 6.6/56, BBS's absolute reliability varies along the scale. The absolute reliability decreases near the middle of the scale and increases toward the high end [10].

The body's movement is referred to as "kinetic chain," with the limbs operating in either an OKC or a CKC condition. When proximal portion of limb remains fixed but distal portion is allowed to move, this is known as an OKC exercise [11]. Exercises involving the OKC are vital for focusing on specific muscle groups. It is often employed in conjunction with concentric muscle contraction, alongside tends to provide greater rotational forces along with distraction. A CKC workout is one in which distal portion of the movement is fixed, such as when foot sole touches the floor or exercise equipment.

Both CKC and OKC exercise has positive effect on improving balance and falls. Resistance training is thus concurrently applied to the proximal and distal regions [11].

It has been demonstrated that the falls efficacy scale has a strong correlation with gait and balance measurements. Future reductions in functional capacity and falls can both be predicted by the FES. It has been demonstrated to be responsive to shifts in anxiety after a fall-specific intervention [12].

A reliable, cost-effective, safe as well as time-efficient method of measuring general functional mobility is TUG test. For longer distances, such as a 10-meter walk, TUG shows a strong correlation with other validated tests that gauge pure gait speed. TUG test requires participants to get out of a typical armchair, walk 3m to a marker, turn around, walk back, alongside then sit down once again [13]. People who take more than 30 seconds to finish a test typically cannot manage steps and require physical help with transfers. People who finish the test in less than 20 seconds are probably mobile on their own, and the majority of them can walk outside and manage steps [14].

However, no study has specifically examined the CKC and OKC exercise programs in patients with DN. So, this study proposes to examine efficiency of CKC as well as OKC exercise programs on balance and falls in DN patients.

The primary objective of the study was to appraise the effectiveness of open and close chain kinetic exercise program on balance and falls in DN patients. And the secondary objective was to determine the effectiveness of OKC and CKC exercises on balance and fall in DN patients within the group.

Null hypothesis stated that there would be no significant difference in improving balance and risk of fall following open and close kinetic chain exercise program in DN. And alternate hypothesis stated that a statistically significant difference would be observed.

MATERIALS AND METHODS

The present experimental study was followed by parallel design structure done at the Royal Global University, Guwahati, Assam, India. The duration of the study is six months from December 2023 to May 2024. The Study has been conducted after getting approval from institutional ethical committee board (RGU/IECHR/BPT/2024/01) on 20/05/2024 at Royal School of Medical and Applied Sciences.

Sample size calculation: The sample size for the present study was determined based on the standard deviation and expected mean difference reported in a previous study involving a similar population and outcome measure Kwon YJ et al., 2013 [11].

Let, N: Total sample size (to be divided equally among two groups).

$z_{(1-\alpha/2)}$: Standard normal deviates at a significance level of α (typically 0.05, corresponding to a z-value of 1.96)

$z_{(1-\beta)}$: Standard normal deviate at the desired power level $(1-\beta)$

δ: Expected difference in means between the two groups

s^2: Population variance

Sample size:

$$N=2 (z1-\alpha/2+z1-\beta)^2 \times s^2 \div \delta$$

Here,

$\alpha = 0.05$

$\beta = 0.2$

$\delta = 4$

$s = 6$

Therefore, N = 30

Hence, 15 per group were taken for the study.

Inclusion criteria: Clinically, diagnosed DN patients (controlled diabetic patients);

- Both male and females aged 35 to 70 years;
- BBS score between 35-45;
- TUG score- not below 15 seconds.

Exclusion criteria: Vestibular or vision impairments;

- Planter ulcer;
- Older adults with communication problems (hearing impairments);
- Elderly having previous hip replacement surgery.

Study Procedure

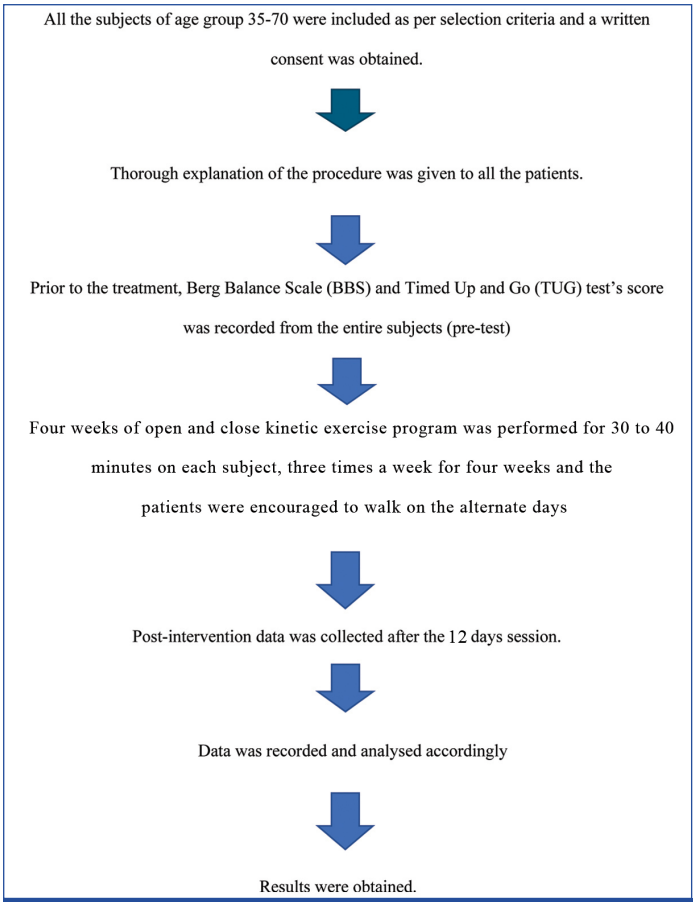
Subjects had been divided into two groups. Group A & B. Each subject was thoroughly informed about the procedure, and informed consent was obtained. The subjects were selected as per the inclusion and exclusion criteria. Pre-intervention data were collected using the BBS and TUG. Group A received CKC exercise program, as well as Group B received OKC exercise program [Table/Fig-1].

Participants in the CKC and OKC exercise groups underwent a four-week customised at-home workout routine consisting of at least three sessions per week. Every session lasts roughly thirty minutes, with a ten-minute walk serving as the warm-up and a quadriceps as well as hamstring stretch serving as the cool-down.

Group A (CKC exercise program)

For close kinetic chain exercise group, participants will perform following exercises for one set, 10 repetitions and three times a week:

1. Forward step-up and down [Table/Fig-2];



[Table/Fig-1]: Study protocol.

[Table/Fig-2]: Step-up (Forward).

2. Side step up and down. Hip abduction in lying position [Table/Fig-3];
3. Wall slide (semi squat) Hip abduction in lying position [Table/Fig-4].

Group B (OKC exercise program)

For OKC exercise group, participants will perform following exercises for one set, 10 repetitions and three times a week.

1. Hip abduction in lying position [Table/Fig-5]
2. Straight leg raising in lying position [Table/Fig-6]
3. Knee extension in sitting position [Table/Fig-7]

Post-intervention data were collected after the final session of fourth week using BBS and TUGT. BBS which is used to measure balance in elderly, it is now commonly used to measure balance in people with varying conditions and disabilities. It has a high relative reliability with inter rater reliability estimated at 0.97 and intra-rater reliability estimated at 0.98 [10]. TUGT is a reliable, cost-effective, safe and

[Table/Fig-3]: Step-up (side).

[Table/Fig-4]: Wall side exercise.

[Table/Fig-5]: Hip abduction.

[Table/Fig-6]: Straight leg raise.

[Table/Fig-7]: Knee extension.

time efficient way to evaluate overall functional mobility. It has a high correlation with over proven tests that measures pure gait speed for longer lengths such as 10 m walk [13].

Open Kinetic Chain (OKC) exercises:

STATISTICAL ANALYSIS

The statistical analysis for this study was conducted using Statistical Package for Social Sciences (SPSS) software. Descriptive analysis was used to summarise the central tendency and variability of the data for each group after intervention. A paired sample t-test has been conducted to check whether average scores before and after is significantly different. This study employs an experimental study design and followed by parallel design structure.

RESULTS

In OKC exercise, [Table/Fig-8], the pre-intervention mean score for BBS was 39.2 and the post-intervention score was 48.87 (SD±2.72) and for TUG pre intervention was 16.33 and post-intervention was 13.6 (SD±0.83) with the p-value of <0.001 indicating that the observed changes in BBS and TUG test scores after intervention were statistically significant and unlikely to be due to chance. Thus, statistically significant p-values support that the changes are not only numerical but represent meaningful improvements in balance and mobility that are relevant to daily activities.

Open Kinetic Chain (OKC)	Pre mean±SD	Post mean±SD	Mean difference	t-value	p-value
BBS	39.2±3.88	48.87±2.72	9.67	-9.55	<0.001
TUG	16.33±1.11	13.6±0.83	2.73	11.98	<0.001

[Table/Fig-8]: The comparisons of mean, standard deviation and mean difference of BBS and TUG for Open Kinetic Chain (OKC) exercise.

Whereas in terms of CKC exercise, [Table/Fig-9], the pre-intervention mean score for BBS was 38.53 and the post-intervention was 51.73 (SD±2.02) and for TUG the pre intervention was 15.93 and post was 11.8 (SD±0.86) with the p-value of <0.001 indicating that the observed changes in BBS and TUG test scores after intervention were statistically significant and unlikely to be due to chance. Thus, statistically significant p-values support that the changes are not only numerical but represent meaningful improvements in balance and mobility that are relevant to daily activities.

From the table it shows that there was a significant increase in BBS score after the intervention and decreased in TUG score [Table/Fig-9].

Since standard score of the sample before the treatment in both cases was less than the standard score of the sample after the treatment that is T value negative in BBS and T value is positive in

Closed Kinetic Chain (CKC)	Pre-mean±SD	Post-mean±SD	Mean difference	t-value	p-value
BBS	38.53±3.7	51.73±2.02	13.20	-16.14	<0.001
TUG	15.93±1.03	11.8±0.86	4.13	16.52	<0.001

[Table/Fig-9]: The comparisons of mean, standard deviation and mean difference of BBS and TUG for Closed Kinetic Chain (CKC) exercise.

TUGT, so it can be said that the patient health is improving after the treatment. The negative t values in both open and CKC groups indicate that the mean difference was negative. This shows that post-intervention BBS scores were higher than pre-intervention scores and higher BBS score reflect better balance, both exercise programs resulted in improved balance.

In both the exercise groups, the p-values were <0.001, indicating that the observed changes in BBS and TUG test scores after intervention were statistically significant and unlikely to be due to chance. Thus, statistically significant p-values support that the changes are not only numerical but represent meaningful improvements in balance and mobility that are relevant to daily activities.

The CKC score increased in BBS and signifies that the patient health has improved on balance and falls after the treatment, also the patients has taken less time in CKC, [Table/Fig-8], which signifies that the patient health has improved on balance and falls after the treatment.

The CKC group demonstrated greater improvement compared to the OKC group, as evidenced by a higher mean difference in BBS scores (13.20 vs 9.67) and a greater reduction in TUG time (4.13 vs 2.73 seconds). Although both interventions showed statistically significant improvement (p<0.001), CKC exercises produced superior outcomes in balance and functional mobility.

Finally, the result shows that the CKC group have a larger overall improvement in BBS and TUGT in the functional mobility and balance compared to the OKC group.

DISCUSSION

Balance is regarded as essential for many everyday actions, including easy ones like standing quietly to more difficult ones like walking while conversing or changing directions [15]. The comparative analysis indicates that both OKC and CKC interventions led to improvements in balance and functional mobility. The intervention protocol [Table/Fig-1] used in the present study were designed to address balance and mobility associated with DN patients.

However, the CKC group demonstrated a greater positive change. In terms of BBS, the OKC group improved from 39.2 to 48.87, [Table/Fig-8]); whereas the CKC group showed a significant improvement from 38.53 to 51.73 [Table/Fig-9], with a statistically significant p-value of <0.001. This suggests that CKC exercise were more effective in enhancing balance and reducing fall risk. In [Table/Fig-9], the larger mean change observed in CKC group demonstrates a greater treatment suggesting superior effectiveness in improving balance and reducing fall risk. The difference in post-intervention scores further supports the enhanced impact of CKC exercises on functional balance outcomes. This greater improvement indicates that CKC exercises were more effective in enhancing postural stability compared to OKC exercises within the study duration.

Similarly, the TUG results showed that although both groups improved, the CKC group again outperformed the OKC group. The OKC participants improved from 16.33 seconds to 13.6 seconds, while the CKC group improved from 15.93 seconds to 11.8 seconds, also with a significant p-value of <0.001. These findings collectively indicate that CKC exercises provide a greater overall benefit in improving balance and functional mobility compared to OKC exercise. The larger mean change observed in CKC group demonstrates a greater treatment suggesting superior effectiveness in improving balance and reducing fall risk. The difference in post-

intervention scores further supports the enhanced impact of CKC exercises on functional balance outcomes.

Diabetes patients with peripheral neuropathy are more likely to fall, and quantitative tests of balance have shown that their bodies swing more than those of their contemporaries without the condition [16]. In order to ascertain whether peripheral neuropathy or inner ear dysfunction is more likely to impair balance, the investigators examined individuals with diabetes who complained of dizziness [17].

Age distribution: In this study, mean age of patients varied from 35 years to 70 years. Early-stage DM is accompanied by neuropathy, which gradually worsens over years and damages the entire body. According to one study, a person with a 25-year history of diabetes has a 49% probability of developing neuropathy, and the severity of the condition increases with the length of DM and poor glycemic management. According to some research, neuropathy is most common among people over 55 [18].

According to a 2017 study by Pop-Busui R et al., 90.6% of the 4097 individuals had type 2 diabetes. Of those 90.6%, 19.4% had difficulties from DN, 17.5% from other DM issues such as erectile dysfunction, and 16.8% from diabetic retinopathy [19].

Gender distribution: Gender analysis of the participants revealed that the number of females and males is equal. Previous studies stated that males are more affected than females. Studies conducted at the individual level have confirmed this epidemiological conclusion, showing that men have a lower BMI and greater resistance than women. Their general inclination for hepatic and visceral deposition of lipid is the main cause of this [20].

According to a 2013 study by Deli G et al., peripheral neuropathy can affect reflex loss and muscular weakness, particularly at the ankles. This condition causes alterations in the walk and shape of the legs, including hammertoes. Patients with peripheral DN may develop ulcers on their legs due to suppression or damage to numb areas; if this is not treated appropriately, an infection may develop that spreads to the bone, necessitating its amputation [21]. Open as well as CKC exercises are two categories of exercises that describe nature of movement and the parts of the body involved in a workout. They are distinguished by whether the distal segment (the part farthest from the body's centre) is fixed or free to move.

Open Kinetic Chain (OKC) workouts: The distal section is allowed to move freely in space during these workouts. These exercises typically involve movements where the hand or foot is not in a fixed position and can move freely. OKC exercises tend to isolate specific muscle groups and joints, making them useful for targeting particular muscles.

Close Kinetic Chain Exercises (CKC): The distal section is stationary during CKC activities. Body moves to fixed segment, and multiple joints alongside muscle groups are typically engaged simultaneously. These exercises often mimic functional movements and can improve overall stability and coordination.

This study was an experimental approach to find efficiency of open vs closed kinetic exercise programs on improving balance, along with reducing fall-risk in DN patients. All the subjects were divided into two groups and received closed and open kinetic exercise program. Participants in the CKC and OKC exercise groups engaged in personalised home exercise for four weeks, completing at least three sessions each week. Each session lasts roughly thirty minutes, with a ten-minute walk serving as the warm-up and a quadriceps as well as hamstring stretch serving as the cool-down. A pre-treatment score was obtained just before the first day of therapy, and a post-treatment score was obtained on the last day.

In this trial, both CKC and OKC groups appear to have improved their BBS scores after the exercise program. All participants in both groups showed higher scores after the intervention. The CKC group seems to have a larger overall improvement in BBS scores compared to the OKC group. The TUG test is a measure of mobility and functional ability. Similar to BBS scores, both groups improved their TUG times following the intervention. All participants had lower TUG times after the exercise program. The CKC group seems to have a larger improvement in TUG times compared to the OKC group.

Limitation(s)

The limitations of this study were that there was a lack of control group and duration of DN was not considered. The recommendation of this study was that research can be conducted on other neurological conditions which affect balance and increase risk of falls. And further, RCT studies can be performed with control group.

CONCLUSION(S)

According to the findings of the study, it was concluded that the patients with DN demonstrated enhanced functional mobility as well as balance function. The study revealed statistically larger improvement of CKC in TUG as well as BBS in functional mobility, alongside balance, compared to the OKC group. Hence, CKC exercise programs could be utilised in day-to-day clinical practice, alongside as well as a home exercise program, to enhance strength as well as balance, which eventually results in prevention of falls in DN.

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