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Research Article

Effect of Lower Extremity Training in Diabetic Peripheral Neuropathy

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Abstract

Background: Diabetic peripheral neuropathy is a symmetrical length-dependent sensorimotor polyneuropathy due to chronic hyperglycemia. The World Health Organization (WHO) identified diabetes as a major global health concern. Diabetic neuropathy is characterized by motor dysfunctions (weakness and atrophy) especially at the distal muscles of lower limbs, and impaired dynamic muscular control in type 2 diabetes patients. Symptoms start in a distal-to proximal pattern in the feet, and ankle and proximally in the hip and knee for both flexors and extensors. Proximal muscle weakness affects postural stability. Dorsiflexor weakness causes increased hip, knee flexion and metatarsophalangeal extension in the initial swing whereas weakness in plantar flexors causes a greater amount of hip and knee flexion during the stance phase.

Methodology: 34 subjects with Diabetic Peripheral Neuropathy who fulfilled all the inclusion criteria were recruited for the study. Ethical standards have been maintained and informed consent was taken. Subjects were randomly assigned by lottery method into two groups, intervention, and control with 17 in each. Since it is a single blinded study subjects were blinded about the interventions provided. Pre and post-test scores were taken before and after 4 weeks using Surface Electromyography (sEMG), Kinovea Software, Functional Gait Assessment (FGA) and Short Form -36 (SF-36).

Results: The pre and post-score values of the kinematics of gait, Functional Gait Assessment, and Short Form - 36 were analyzed using a Paired t-test and Wilcoxon Signed Rank test within the group analysis, Mann- Whitney U test and Independent t-test for between the group analysis. Both groups displayed notable variations, whereas the intervention group exhibited more significant differences ($p < 0.05$). Thus, it can be inferred that lower extremity training significantly improves gait kinematics and quality of life in diabetic neuropathy.

Conclusion: Lower extremity training is effective in improving the kinematics of gait and quality of life in diabetic neuropathy.

Introduction

Diabetes is the most frequent condition associated with neuropathy, which affects the peripheral nervous tissues leading to peripheral neuropathy. The most common subtype of Diabetic Peripheral Neuropathy (DPN) is Distal Symmetric Polyneuropathy [1]. It is a long-term complication associated with nerve dysfunction and uncontrolled hyperglycemia characterised by sensory-motor dysfunction (pain, weakness, atrophy especially at the distal muscles of lower limbs), postural instability, and gait imbalance leading to impaired dynamic muscular control and high fall incidence [2,3].

The metabolic and microvascular impairments damage the endoneural capillaries (supply blood to peripheral nerves) and lead to sensory-motor dysfunctions. In addition, muscle weakness results from an accelerated loss of motor axons, which in turn results in the loss of motor units. These losses have a negative impact on functional capacity, gait, fall risk, and Quality of Life (QOL) [4,5].

The WHO identified diabetes as a major global health concern and India has become the "Diabetes capital of the world" [6]. In India, more than 74.2 million people are affected which will increase to 124.9 million by 2045 [7]. The overall prevalence of DPN in type 2 Diabetes is 45.8% and type 1 Diabetes is 37.5% [8,9]. According to the Diabetes Research Institute Foundation (2022), the incidence rate is greater in people over 45 years than in adults [10].

DPN is a factor that reduces lower extremity muscle strength in a distal-to-proximal pattern [11]. Strength declines distally in the feet (29%) and ankle (dorsiflexors- 57% and plantar flexors- 61%) and proximally in the hip and knee for both flexors and extensors [4]. The knee shows a 17% decline in flexors and a 16% decline in extensors [12]. Proximal muscle weakness affects postural stability [13]. Weakness in dorsiflexors causes increased metatarsophalangeal extension (MTP), and hip and knee flexion in the initial swing, and weakness in plantar flexors causes a greater amount of hip and knee flexion during the stance phase [14].

According to Adrienne D. Henderson, et al. hip flexion was increased in DPN throughout most of the stance and increased knee flexion throughout the early stance. Increased hip and knee flexion in early stance and increased hip extensor moment in mid stance show similarities with mild crouch gait [15]. Uazman Alam, et al. 2017 state that patients with DPN have a reduced Range of Motion (ROM) at the ankle in dorsiflexion and plantar flexion and at the knee in both flexion and extension. ROM at joints is altered in diabetes which occurs in relation to plantar pressure changes [16].

Gomes, et al. found an increase in flexion at the hip in patients with DPN, which they believed was due to a compensatory effect for the loss of motion at distal joints. There is an increased hip flexion throughout the stance phase and reduced knee flexion at the heel-off phase [17]. No available research shows the impact of lower extremity training on the kinematics of the hip, knee, and ankle during the gait cycle in DPN. The purpose of this study is to determine how lower extremity training affects the kinematics of the hip, knee, and ankle in DPN.

Methodology

study design

The study design was a single-blind randomized controlled trial used to identify the characteristic features of DPN in type 2 diabetes.

Sample population

This study is being conducted to assess the effect of lower extremity training on muscle activity, kinematics of gait, and QOL in DPN. A study conducted by Albina Jamal, et al. shows that the standard deviation of QOL in DPN was 52.39 ± 29. Based on this result the minimum sample size for the present study was calculated by using the equation:

$$n = \frac{2\sigma^2 (z_1 - \frac{\alpha}{2} + z_1 - \beta)^2}{\mu_d{}^2}$$

Were, σ = Pooled standard deviation μ_d = Clinical significance difference $Z_1 - \frac{\alpha}{2}$ and $Z_1 - \beta$ = Statistical table value Therefore, the minimum sample size required for this study was 17 in each group.`

Data collection

34 subjects with DPN who fulfilled all the inclusion criteria were recruited for the study. Ethical standards have been maintained (EC/17/2020 - Little Flower Hospital and Research Centre, Angamaly, Kerala, India) and informed consent was taken. They were randomly assigned by lottery method into intervention and control with 17 in each. Since it is a single blinded study subjects were blinded about the interventions provided. The intervention group received lower extremity strength training such as standing wall slides, lunges, bridging, etc. for the hip; Short arc terminal extension/quads, Multiple ankle isometrics – flexion or extension, etc. for knee; Heel walk, toe walk, heel raise etc. for ankle, towel scrunches, toe pickup activities etc. for foot; gait training (high march walking, tandem walk, ramp walking etc.), Transcutaneous Electrical Nerve Stimulation (TENS) and foot care education. Whereas, the control group received conventional treatment such as ankle, and foot strengthening exercises, gait training, TENS, and foot care education. For the first two weeks, 2 sets of 10 repetitions and for the third and fourth weeks, 3 sets of 10 repetitions were given with a duration of 45 minutes (2 minutes rest after every 10 minutes or rest shall be given as per the need of the patient). Pre and post-scores were taken before and after 4 weeks using Surface EMG of the knee (quadriceps, hamstrings) and ankle (tibialis anterior and gastrosoleus) for maximum voluntary isometric contraction, Kinovea Software for quantitative gait analysis, FGA for gait function and postural stability and SF-36 for quality of life assessment.

Statistical analysis

The IBM Statistical Package for Social Science (SPSS 20.00) version was used to conduct the analysis. All quantitative variables were presented as mean and standard deviation and qualitative variables as frequency and percentages. The Inferential statistics include the Paired t-test and Wilcoxon Signed Rank test for within the group analysis, Mann- Whitney U test and Independent t-test for between the group analysis.

Results

The present study aimed to find the effect of lower extremity training on gait and QOL in DPN patients. Significant differences were seen in both groups (Table 1), and group A showed a more statistically significant effect compared to group B ($p < 0.05$).

Discussion

This study aims to find the effect of lower extremity training on muscle activity, kinematics of gait, and QOL in DPN. 34 diagnosed cases (2 were excluded) who met the inclusion criteria were divided into two groups of 16 each, the intervention group and the control group. The intervention group received lower extremity training for flexors and extensors (hip, knee, ankle) whereas the control group received lower extremity training for the distal muscles (ankle and foot). The total duration of the intervention was 4 weeks. The outcome measures were Surface EMG, Kinovea software, FGA, and SF – 36. Pre and post-assessments were taken. Before follow-up, 1 from each group left. The results showed significant improvement in gait and QOL, especially in the intervention group. It indicates that lower extremity training along with conventional physiotherapy is effective in improving gait and QOL in DPN.

Table 1: Significant values of the intervention group.

Group A (Intervention group)		calculated table value Z = 2.14							
Age and Gender distribution	Mean ± SD	58.27 ± 5.53							
Joints (ROM)	Calculated z value	IC	FF	MS	HO	TO	IS	MS	TS
Hip	Left	-8.03	-3.58	15.20	5.60	-2.672	_	-13.30	-11.76
	Right	-5.43	-5.62	12.19	4.88	_	-6.57	-14.81	-15.05
Knee	Left	2.64	3.50	2.25	2.44	3.50	3.05	4	3.50
	Right	5.01	-13.45	12.55	6.49	-11.77	-7.52	-62.86	13.66
Ankle	Left	-7.86	-3.73	-19.17	-13.42	13.91	10.92	-2.98	-8.27
	Right	-8.47	-6.11	-6.54	-9.89	17.02	27.07	-2.42	-7.22
FGA		-16							
SF-36		-10.27							

Abbreviations: IC: Initial Contact; FF: Foot Flat; MS: Mid Stance; HO: Heel Off; TO: Toe Off; IS: Initial Swing; MS: Mid Swing; TS: Terminal Swing

DPN shows a centripetal pattern of progression first at the tip of the toes and feet, later more severe in distal regions, and finally to further proximal levels [12]. In mild DPN due to weakness of distal muscles, they walk more slowly to reduce the demands on major lower limb muscles [18]. Weakness in the dorsiflexors causes increased MTP extension, and hip and knee flexion in initial swing. Plantar flexor weakness causes an increase in hip and knee flexion during the stance phase [14]. Distal muscle weakness results in a shift in joint workload from distal to proximal [12]. Diabetic subjects showed weakness in proximal muscles such as the hip, knee flexors, and extensors. Thigh muscle weakness and changes in the angle of maximum torque production may alter the functional abilities of lower limbs [19].

Exercise increases the uptake of glucose by up to 50-fold through three key steps: delivery, transport across the muscle membrane, and intracellular flux through metabolic processes (glycolysis and glucose oxidation) [20]. Physical activities such as resistance/strength training (exercises with free weights, weight machines, bodyweight, or elastic resistance bands) enhance glycemic control that helps to improve muscle mass and number of insulin receptors in muscle cells, which elevates total insulin-mediated glucose uptake [21]. Janhavi Jagdish Atre, et al. in 2020, stated that strength training prevents muscle loss, and improves intermuscular and intramuscular synchronization through neural control [22]. The resistance exercise increases glucose transporter 4 expression, an effect that improves insulin action, glucose clearance, and enhanced glycogen storage. In this study body weight was used as resistance which may have led to improvement in symptoms of neuropathy [23]. The proximally observed alterations during the stance phase may have been enhanced by the distal muscle exercises. Hence the proximal muscle exercises may have helped to improve kinematics, functional gait, and quality of life by increasing strength and modifying the angle of torque production. Thus, it can be understood that the lower extremity training given to hip, knee and ankle muscles helped in improving the strength there by the gait and QOL.

Conclusion

The study primarily tried to analyze the effect of lower extremity training on improving the kinematics of gait and QOL in DPN. Statistical analysis of the data concluded that lower extremity training along with conventional physiotherapy is effective in improving kinematics of gait and QOL in DPN.

Limitations and suggestions

- Due to COVID 19 restraints both sample size and sEMG couldn't be used as planned.
- Future research could concentrate mostly on muscle activity, gait kinetics, and everyday living activities where long-term benefits can be assessed with a large sample size and proper follow-up.

(Supplementary file)

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