Comparisons of Neuromuscular Training Versus Quadriceps Training on Gait and WOMAC Index in Patients With Knee Osteoarthritis and Varus Malalignment

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ABSTRACT

Objective: The purpose of this study was to compare the effects of neuromuscular training (NMT) and quadriceps training (QT) on the altered gait patterns and Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index in patients with knee osteoarthritis (OA) and varus malalignment.

Methods: Sixty-six patients with knee pain ≥ 2 on 100-mm visual analog scale, radiographic knee OA changes ≥ 2 on Kellgren-Lawrence grading scale, and genu varum were allocated randomly into either the neuromuscular training group or quadriceps training group. Twelve weeks of supervised exercise protocol was given to the participants of both groups, which included 3 sessions per week. Primary outcomes were gait variables and self-reported physical function (WOMAC index).

Results: Of 66 knee OA patients, only 31 (94%) in the NMT group and 28 (84.8%) in the QT group completed the exercise protocol and were included in the analysis. There was a significant improvement in gait velocity ($P = .022$), stride length ($P = .009$), and global WOMAC index ($P = .011$) in the NMT group compared to the QT group. However, the scores of cadence ($P = .226$), gait cycle ($P = .332$), and double limb support ($P = .054$) were not found significant in the NMT group compared with the QT group.

Conclusion: The NMT group showed improvement in some of the gait parameters as well as improvement in pain, stiffness, and functional limitation compared with conventional QT. No additional improvement was found in cadence, gait cycle, and double limb support in patients who received NMT. (J Chiropr Med 2019;18:1-8)

Key Indexing Terms: *Osteoarthritis; Genu Varum*

INTRODUCTION

Knee osteoarthritis (OA) is a common degenerative condition that affects a larger proportion of the population.¹ Based on the Framingham Osteoarthritis Study, the prevalence of knee OA was 19.2% among individuals over 45 years of age.² On the contrary, its prevalence in India is considerably

higher at 22% to 39%.³ The degenerative changes are seen more commonly within the medial compartment than the lateral compartment of the knee joint.⁴ The susceptibility of the medial compartment to degenerative OA presumably is associated with the greater load (60%-80% of the entire load) passing through the medial tibiofemoral compartment compared with the lateral tibiofemoral compartment throughout gait even in healthy knees.⁵ Disproportionate loading of the medial compartment is believed to be the main cause of developing medial knee OA⁵; this may lead to or predispose one to varus malalignment.

Patients with medial knee OA have shown altered gait patterns in kinetic and kinematic studies. Gait parameters that tend to decrease in knee OA include walking velocity, stride length, and cadence; concurrently, double limb support time and stride time tend to increase.⁶ Reduction in velocity, cadence, and stride length have a direct relationship with disability related to knee OA.^{7,8}

A wider class of neuromuscular exercise programs is known by several names, such as proprioceptive training,

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agility training, perturbation training, or functional exercises. Neuromuscular training for the lower limb involves multiple joints and muscles that are carried in functional weight-bearing positions. Its emphasis is not only on the efficiency and quality of the movement, but also the trunk and lower limb alignment.⁹ In a population other than individuals experiencing knee OA, neuromuscular training has been shown to alter the biomechanics and muscle recruitment patterns around the knee joint, and in addition, improve functional performance. These exercises also have been beneficial in prevention and rehabilitation of knee injuries in the athletic population.¹⁰ However, there is a paucity of research that has revealed the benefits of neuromuscular exercise in knee OA.¹¹

One of the common findings in knee OA is weakness of quadriceps muscles,¹² and therefore one important component of the exercise program prescribed as part of conservative management is quadriceps strengthening. However, quadriceps strengthening alone is not sufficient in reducing pain and knee adduction movement in patients with knee OA, particularly in patients with varus malalignment.¹³ Quadriceps training primarily improves the strength of muscles (muscle output), rather than aiming at the biomechanical factors contributing to the medial compartment knee loading.¹⁴ Hence, an alternate treatment option in the form of exercises aimed at improving the symptoms in knee OA with varus malalignment becomes imperative.

The purpose this study was to evaluate an exercise protocol for knee OA with varus malalignment and to compare the efficacy of neuromuscular training (NMT) with the traditionally used quadriceps training (QT) in alleviating symptoms of pain and stiffness and improving physical function and altered gait patterns.

METHODS

Study Design and Participants

This interventional study was carried out at the Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia, New Delhi, India. Ethical approval was obtained from the Jamia Millia Islamia human research ethics committee. All patients were informed about the study, and written informed consent was obtained. Both male and female patients aged ≥ 45 years with a history of medial knee OA and varus malalignment were recruited from Ansari Health Centre and the adjoining hospitals. Prospective participants were informed about the study through notification on the university website, posters in the adjoining areas, word of mouth, and physician referral.

Eligibility criteria included knee pain over the past week ≥ 25 on 100-mm visual analog scale, visual varus alignment (intercondylar > intermalleolar distance), pain and tenderness over the medial joint line of the knee, and OA changes on radiographs. The specific radiological changes for

inclusion included Kellgren-Lawrence grade ≥ 2 , joint space of medial compartment < lateral compartment, and medial tibiofemoral osteophyte grade $\geq$ lateral tibiofemoral osteophyte grade.

Exclusion criteria were use of intra-articular or oral corticosteroid within the past 6 months or 4 weeks, respectively; postsurgical knee; systemic arthritis; knee or hip joint replacement surgery; tibial osteotomy; any other condition having an effect on lower limb function; participation in any form of exercise therapy within the past 6 months; current or past (6 months) nonpharmacological treatment including physiotherapy or massage or acupuncture; uncontrolled hypertension; history of cardiovascular disease, pregnancy, or cognitive impairments; or inability to ambulate without a gait aid. Patients on nonsteroidal anti-inflammatory drugs, chondroitin, or glucosamine drugs were allowed to participate in the study. Patients were requested not to seek any other treatment option for knee pain during the trial.

Sample size was determined using G power software (3.1.9.2) detecting a difference in the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index stiffness from 3.66 ± 2.64 to 2.10 ± 2.26 ¹⁵ in which effect of exercise was examined in patients with knee OA. Twenty-nine patients in each group were necessary based on the effect size of 0.631, α level of 0.05, and power of 0.95. The total sample size generated including a 12% dropout was 66. Of 66 participants, only 59 adhered to the treatment protocols, that is, 31 in NMT group and 28 in QT group.

All eligible participants were allocated randomly into either the NMT group or the QT group by simple random sampling. A lottery method was used to assign the participants into the 2 groups. Sixty-six small chits were placed in a box, and participants were allowed to take out the chits. The numbers were written in chits, and the odd-number chits were assigned to NMT group and even-number chits were assigned to QT group. The participants were distributed equally into the 2 groups, that is, 33 in the NMT group and 33 in the QT group, as shown in Fig 1.

For evaluation purposes, only 1 knee was taken into consideration because it reduced inconvenience to the participants during the laboratory testing time. The most symptomatic knee was considered if a participant presented with symptoms on both sides; if the symptoms were similar on both the sides, the right knee was nominated.

Procedure

The Stride Analyzer (B&L Engineering, Model SA-VI, software version 6.2, Santa Ana, California) was used to study the gait of participants before and after the intervention. Footswitches that were worn as insoles in the patients' shoes were connected to a transmitter by a thin cable. The adjustable leg belts were used to fasten the transmitters around the participants' legs. The receiver was

Fig 1. Flowchart for the screening and randomization of study patients.

connected to a computer, and the data were analyzed using software. The participants were asked to walk 6 m long distance at a self-selected pace.

A good agreement was found between the following Stride Analyzer and Vicon for temporospatial gait parameters: velocity, stride length, cadence, and gait cycle. However, low intraclass correlation coefficient values (<0.689) have been reported for the rest of the gait parameters.¹⁶

The WOMAC was used to measure pain, stiffness, and physical functioning of the patient with knee OA. It comprises 24 questions, 5 for pain, 2 for stiffness, and 17 for physical functions.¹⁷ Various studies have been conducted over time to establish aspects of validity such as content,¹⁸ factorial,^{19,20} criterion,²¹ and construct.²² It has shown fairly good results for all the parameters.

For training purposes, 1 repetition maximum (1 RM) of the quadriceps muscle was determined for the participants in the QT group. The 1 RM from reps to fatigue as proposed by Brzycki was calculated as follows:

$$\text{predicted 1 RM} = W / (1.0278 - 0.0278 \times X)$$

where W indicated weight lifted and X indicates the number of reps performed.²³ Quadriceps muscle strengthening was performed at an intensity of 40% to 60% of 1 RM.

Protocol

Participants in both the groups received intervention under the supervision of the expert physiotherapist (S.A.R.) who had a postgraduate degree in orthopedic physiotherapy and also had more than 10 years of clinical expertise in treating patients with knee OA. Each session lasted for 30 to 40 minutes in each group, with 3 sessions per week and a total of 36 sessions in 12 weeks. Before the beginning of subsequent training sessions, a brief assessment was carried out to find out any adverse effects of training and to make a decision about the progression of the exercise based on quality and performance.

In the QT group, the main focus was on quadriceps strengthening using quadriceps table and weight plates or weight cuffs. Other exercises included quadriceps isometrics and resistance band exercises, ankle dorsiflexion, ankle plantar flexion, knee flexion, knee extension, hip abduction, hip adduction, hip external rotation, and hip internal rotation. The list of NMT exercises are described in Table 1.

Data Analysis

Data were analyzed using IBM SPSS software version 20 (IBM Corp, Armonk, New York). The distributions of data were evaluated using the Shapiro-Wilk test and frequency histograms. Between-group comparisons of baseline data were

Table 1. Neuromuscular Training Exercises

Knee over toe position	In sliding and stepping lunge on even or uneven surface, with or without support
Wedding march	Take a step forward and slightly to one side with the main foot, unite the trailing foot with driving foot; interchange driving foot
Backward wedding march	As above, stepping backward
Side stepping	Walk sideways with the leading foot stepping sideways and trailing foot following to leading foot, then repeat the same in opposite direction
High knees march	March forward while bending hip around 90°
Semi-tandem walk	Heel of one foot lands just in front of but slightly medial to great toe of opposite foot
Tandem walk	Heel of one foot lands just in front of opposite foot and walk in straight line.
Modified grapevine	One foot stepping sideways, the trailing foot lands behind the driving foot, again leading foot stepping sideways and the trailing foot lands in front of the driving foot; repeat the cycle; interchange the driving foot and repeat in opposite direction
Cross-over walk	March forward with each foot crossing midline of body
Toe walking	Advancing forward on toes
Heel walking	Advancing forward on heels
Stability training	TheraBand stability trainer foam pads (green, blue, black, or silver)

undertaken using either an independent *t* test or Mann-Whitney *U* test. The gait parameters were compared using an independent sample *t* test between the NMT and QT group. The WOMAC scores were compared using the nonparametric test (Mann-Whitney *U* test) between the groups. However, within-group analysis was performed by using the paired *t* test or Wilcoxon signed-rank test for parametric and nonparametric data. A *P* value < 0.05 was considered significant.

RESULTS

Of 66 patients with knee OA, only 59 completed the exercise intervention, that is, 31 in the NMT group and 28 in the QT group, and were included in the analysis. Baseline characteristics are provided in Table 2. No significant between-group differences were noted in any of the baseline characteristics or outcomes.

Between-group analyses of gait parameters demonstrated a significant difference in the mean scores of velocity (65.59 ± 7.27 v 61.04 ± 7.49 , $P = .022$; Table 3, Fig 2) and stride length (1.28 ± 0.12 v 1.20 ± 0.10 , $P = .009$; Table 3, Fig 3) after intervention. However, the mean scores of cadence ($P = .226$), gait cycle ($P = .332$), and double limb support ($P = .054$) were not found significant (Table 3). Compared with changes observed in the QT group, the magnitude of improvement in the NMT group was greater for the WOMAC median score (median 15.62 [interquartile range 14.06] v 9.37 [interquartile range 3.12], $P = .011$; Table 3, Fig 4).

DISCUSSION

Varus malalignment in knee OA has a higher impact on the progression of medial tibiofemoral degeneration as more load is transferred through the medial compartment of the knee, which may lead to further reduction in physical functioning.²⁴ To our knowledge, this is probably the first study to evaluate the effects of NMT in patients with knee OA and varus malalignment. The purpose of the present study was to investigate the effects of 12 weeks' supervised NMT and QT in patients with knee OA and varus malalignment. Our findings indicate that the NMT significantly improved measures of gait and self-reported pain, stiffness, and physical function compared with QT. In the NMT group, 33 participants were enrolled in the study and 31 patients successfully completed the intervention (94%); only 2 patients were lost in follow-up because of medical reasons (Fig 1). Hence, the thrice-weekly NMT program was feasible for and well tolerated by patients with minimal to moderate knee OA.

Participants in the NMT group showed significant improvement in velocity and stride length compared to those in the QT group, reflecting that the patients were moving faster with an improved stride length. The results revealed that there was a positive effect on walking efficiency. Cadence and double limb support also improved in both the groups, but NMT failed to show its supremacy over QT. Decline in walking speed and stride length is a component of the adaptive mechanism to minimize pain by decreasing the knee movements. Reduced velocity, stride

Table 2. Descriptive and Baseline Characteristics of the Participants Between Groups

Variables	NMT	QT	P
Age (y)	57 ± 6.8	54.6 ± 9.3	.272
BMI	27.5 ± 3.8	28.6 ± 2.6	.233
VAS (0-10 cm)	5.2 ± 1.01	4.9 ± 0.8	.388
Sex, n (%)			
Male	22 (71)	11 (39.3)	-
Female	9 (29)	17 (60.7)	-
KL grades, n (%)			
2	10 (32.3)	15 (53.6)	-
3	21 (67.7)	13 (46.4)	-
4	-	-	-
VL (m/min)	51.47 ± 7.142	52.63 ± 7.103	.538
Cad (steps/min)	93.74 ± 6.510	95.70 ± 5.974	.235
SL (m)	1.12 ± 0.113	1.08 ± 0.116	.241
GC (s)	1.29 ± 0.089	1.26 ± 0.087	.255
DLS	29.74 ± 3.23	30.23 ± 3.85	.592
WOMAC, median (IQR)	32.29 (13.8)	33.85 (14.4)	.676

BMI, body mass index; Cad, cadence; DLS, double limb support; GC, gait cycle; IQR, interquartile range; KL, Kellgren-Lawrence scale; NMT, neuromuscular training group; QT, quadriceps training group; SL, stride length; VAS, visual analog scale; VL, velocity; WOMAC, Western Ontario and McMaster Universities Index.

Values are in mean and standard deviation unless otherwise stated.

Table 3. Post-treatment Results of Gait Parameters and WOMAC Index

Variables	NMT	QT	Mean Diff.	95% CI	P
VL (m/min)	65.59 ± 7.277	61.04 ± 7.490	4.54	0.69-8.39	.022 ^a
Cad (steps/min)	103.23 ± 5.621	101.39 ± 5.898	0.63	-2.7 to 4.04	.226
SL (m)	1.28 ± 0.122	1.20 ± 0.109	0.081	0.02-0.14	.009 ^a
GC (sec)	1.16 ± 0.072	1.18 ± 0.074	-0.007	0.04-0.03	.322
DLS %	27.35 ± 2.56	28.81 ± 3.15	0.005	0.98-0.99	.054
WOMAC, median (IQR)	9.37 (3.12)	15.62 (14.06)			.011 ^a

Cad, cadence; DLS, double limb support; GC, gait cycle; NMT, neuromuscular training group; QT, quadriceps training group; SL, stride length; VL, velocity; WOMAC, Western Ontario and McMaster Universities Index.

Values are in mean and standard deviation unless otherwise stated.

^a Significant at $P < .05$.

Fig 2. Plot depicting comparative changes in the scores of velocity (m/s) in neuromuscular training and quadriceps training before and after the intervention.

length, and cadence values are related to disability.^{7,25} There is a hindrance in early loading response, push off, and reduction of walking velocity that is considered a factor of this prolongation as part of the adaptive mechanism.^{6,26}

Improvements in gait parameters revealed in this study were similar to earlier findings by a study done by Bennell et al²⁷ that showed significant increase in walking pace after 12 weeks of NMT protocol in patients with knee OA. Chang et al²⁸ also found similar results in gait after 6 weeks of exercise intervention in patients with knee OA. However, our gait results are in contradiction to the study done by Eitzen et al,²⁹ who reported that the walking speed remained unchanged after 12 weeks of exercise therapy program in mild to moderate OA, owing to inadequate compliance.

Twelve weeks of NMT resulted in significant changes in the global score WOMAC questionnaire. The improvement in patient-reported outcomes (WOMAC) indicates that NMT may be the preferable exercise protocol for relief of pain and stiffness and improving physical functions in patients with genu varum.³⁰ The strength of the quadriceps muscles has a close relationship with symptoms of knee

OA. Quadriceps weakness in knee OA results in reduced shock absorption capacity and joint instability and further alters neuromuscular control of the joint.³¹ However, this study reveals that besides quadriceps strength, other areas like joint instability and functional performance and sensory motor deficiencies also should be focused.

The NMT program was aimed to produce controlled movements through coordinated muscle activity and dynamic stability. Earlier research has reported sensory motor deficiencies and reduced functional performance in patients with knee OA.³² Functional instability in knee OA limits functional tasks.³³ The data from our study suggest that there was an improvement in performance of knee joint during dynamic activities like walking and in performing activities of daily living.

Within-group analyses suggest that QT is also an effective treatment option for knee OA patients with genu varum because it also improved gait, pain, soreness, and physical function significantly compared to the baseline measurements, suggesting that muscle weakness is one of the major factors that also should be focused on knee OA

Fig 3. Plot showing comparative changes in the scores of stride length (m) in neuromuscular training and quadriceps training before and after the intervention.

Fig 4. Plot portraying comparative changes in the scores of self-reported physical function WOMAC in neuromuscular training and quadriceps training before and after the intervention. WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

patients with genu varum. Although there was no control group for comparison, our study confirms these findings from randomized controlled trials can be transferred into real-life clinical practice.

Limitations

This study lacked a control or placebo group for proper understanding of the progression of the disease. In this study, we used consecutive sampling because true random sampling was not feasible in the clinical setup. Therefore, the generalizability of results derived from this study should be used with caution. Genu varum was not measured as per gold-standard bilateral full-leg standing radiographs; rather, conventional method (Intercondylar/Intermalleolar distance) was used in this study, therefore, this study was not able to properly categorize the patients into severe, moderate, and mild genu varum. The treatment effects in different categories of genu varum need to be investigated. Further research should be conducted on different NMT exercise protocols in conjunction with quadriceps strengthening to find a better treatment option for knee OA patients with varus malalignment.

CONCLUSION

The NMT group showed improvement in some of the gait parameters (velocity and cadence) as well as improvement in pain, stiffness, and functional limitation (WOMAC index) compared with conventional QT in knee OA patients with varus malalignment. However, no additional improvement was found in cadence, gait cycle, and double limb support in patients who received NMT.

FUNDING SOURCES AND CONFLICTS OF INTEREST

No funding sources or conflicts of interest were reported for this study.

CONTRIBUTORSHIP INFORMATION

Concept development (provided idea for the research): S.A.R., M.E.H.

Design (planned the methods to generate the results): S.A.R., M.E.H.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): M.E.H.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): S.A.R.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): S.A.R., J.A.M.

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Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): S.A.R., S.S., M.S.R., S.M.R., M.E.H.

Practical Applications

- Neuromuscular training may act as adjunct treatment to the existing conventional rehabilitation of knee OA with varus malalignment.
- Present NMT protocol may be a feasible exercise form to improve gait, pain, stiffness, and physical functioning in patients with knee OA with varus malalignment.
- The present study has the potential to inform guidelines for prescription of exercise in osteoarthritis knee with varus malalignment.

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