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Effect of Neuromuscular Exercises versus Toe-in Squats on Intercondylar Distance in College Students with Genu Varum: A Comparative Experimental Study

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Abstract

Background: Genu varum is a frontal-plane lower-limb deformity characterised by an increased intercondylar distance (ICD), resulting in altered lower-limb biomechanics and increased medial compartment loading of the knee. Exercise-based interventions have been proposed to improve lower-limb alignment; however, evidence comparing different exercise approaches remains limited.

Objective: To compare the effectiveness of neuromuscular exercises and toe-in squats in reducing intercondylar distance among college students with genu varum.

Methods: A comparative experimental study was conducted among 30 college students aged 18–25 years with an intercondylar distance (ICD) >5 cm. Participants were divided into two groups (n=15 each). Group A performed neuromuscular exercises, while Group B performed toe-in squats, three times weekly for four weeks. ICD was assessed pre- and post-intervention. Within and between group differences were analysed using paired and independent t-tests, respectively, at $p<0.05$.

Results: Both groups demonstrated statistically significant reductions in intercondylar distance following the intervention. The mean ICD decreased from 5.64 ± 0.277 cm to 5.50 ± 0.313 cm in the neuromuscular exercise group ($t = 3.14$, $p = 0.001$) and from 6.06 ± 0.725 cm to 5.07 ± 0.532 cm in the toe-in squat group ($t = 9.12$, $p = 0.001$). The between-group comparison showed no statistically significant difference at baseline ($t = -2.09$, $p = 0.051$), while a statistically significant difference was observed in the post-intervention comparison ($t = 2.67$, $p = 0.001$).

Conclusion: Both neuromuscular exercises and toe-in squats demonstrated statistically significant reductions in intercondylar distance among college students with genu varum. The post-intervention intercondylar distance was lower in the toe-in squat group than in the neuromuscular exercise group.

Keywords: Genu varum; Intercondylar distance; Neuromuscular exercise; Toe-in squat; Lower-limb alignment.

Introduction

The knee joint is one of the largest, most complex, and most vulnerable joints of the human body. It plays a fundamental role in weight bearing, shock absorption, and locomotion during both static and dynamic activities. The joint is formed by the articulation of the femur, tibia, and patella, while the surrounding muscles, ligaments, and other soft tissues contribute to joint stability and efficient load

transmission.[6,12,14,15] Structural deformities affecting the lower limb include genu varum, genu valgum, and genu recurvatum.[7] Among these, genu varum, commonly referred to as bow-leggedness, is characterised by an increased distance between the knees when the medial malleoli are in contact during standing.[1] This deformity shifts the mechanical axis of the lower limb towards the medial compartment of the knee, increasing compressive loading and predisposing individuals to degenerative joint changes, impaired postural stability, and altered movement patterns.[7,9]

Genu varum may be classified as physiological or pathological. Physiological genu varum is considered part of normal skeletal development during early childhood and generally resolves spontaneously with growth, progressing through a transient phase of genu valgum.[10,12,13] In contrast, pathological genu varum may result from conditions such as Blount's disease, nutritional rickets, skeletal dysplasia, trauma, infection, or neoplastic disorders.[1] Risk factors associated with the development of genu varum include nutritional deficiencies, family history, and participation in soccer during adolescence.[1]

Previous studies have reported a higher prevalence of genu varum among males, underweight individuals, and those residing in rural areas.[2,12] In addition to cosmetic concerns, genu varum alters lower-limb biomechanics by increasing subtalar pronation moments and modifying weight distribution across the knee joint, which may adversely affect postural stability and functional performance.[9] Clinical manifestations include visible bowing of the lower limbs, lateral foot pain, swelling, tenderness, and gait alterations. Diagnosis is primarily based on clinical examination and confirmed using weight-bearing radiographic assessment.[22]

The severity of genu varum is commonly evaluated using the intercondylar distance (ICD), defined as the distance between the medial femoral condyles when the medial malleoli are approximated in the standing position. An ICD of less than 3 cm is generally considered normal, whereas an ICD greater than 5 cm is indicative of genu varum.[13]

Exercise-based interventions have been widely recommended for the conservative management of genu varum. Neuromuscular exercises aim to improve lower-limb muscle strength, proprioception, movement quality, and dynamic alignment during functional activities, whereas toe-in squat exercises have been reported to reduce intercondylar distance by promoting favourable lower-limb alignment during weight-bearing tasks.[5,8] However, limited evidence is available directly comparing the effectiveness of these two interventions in young adults with genu varum. Therefore, the present study aimed to compare the effectiveness of neuromuscular exercises and toe-in squat exercises in reducing intercondylar distance among college students with genu varum.

Methods

Ethical Approval

The study was approved by the Institutional Ethics Committee of Revathi Institute of Physiotherapy and Research (Approval No. RIPR/DT/21/4529). Written informed consent was obtained from all participants before enrolment in the study.

Study design and participants

A comparative experimental study was conducted at the Exercise Therapy Laboratory, Revathi Institute of Physiotherapy, over a period of eight months. Thirty participants aged 18–25 years with an intercondylar distance (ICD) greater than 5 cm were recruited using convenience sampling based on predefined inclusion and exclusion criteria.

Inclusion and exclusion criteria

Participants aged 18 to 25 years with genu varum and an intercondylar distance greater than 5 cm were included in the study. Subjects were required to be capable of performing physical exercises without restriction and willing to provide informed consent and participate throughout the 4-week study period. Individuals were excluded if they had a history of lower limb fracture or surgery, presence of other lower limb deformities, cardiovascular or systemic conditions that contraindicated exercise, ankle sprain within the previous six months, or any congenital bone or neuromuscular disorders.

Intervention

After obtaining informed consent, participants were allocated into two groups of 15 each. Group A received a neuromuscular exercise program of forward–backward stepping, sideways stepping, functional hip and knee strengthening, step-ups and downs, and balance board exercises. Group B performed toe-in

squats with the hips positioned in approximately 20° of adduction. Both groups completed 3 sets of 10 repetitions, three times per week for four weeks. Participants were informed of their right to withdraw from the study at any time if discomfort occurred.

Outcome measure

Intercondylar distance was measured using a tape measure before and after the intervention period to evaluate treatment effectiveness.

Statistical Analysis

The collected data were entered and analysed using the Statistical Package for the Social Sciences (SPSS), version 24.0. Statistical significance was set at $p < 0.05$, with a 95% confidence interval. The Shapiro–Wilk test was used to assess the normality of the data. As the data were normally distributed ($p > 0.05$), parametric tests were used. Paired-samples t-tests were performed to compare pre-test and post-test intercondylar distance within each group, while independent-samples t-tests were used to compare intercondylar distance between Group A and Group B.

Results

Thirty participants with genu varum were included in the study and divided equally into two groups, with 15 participants in each group. Group A received neuromuscular exercises, while Group B performed toe-in squats. Intercondylar distance was measured before and after the four-week intervention.

Between-group comparison

The comparison of pre-test intercondylar distance between Group A and Group B showed no statistically significant difference ($t = -2.09$, $df = 28$, $p = 0.051$). The mean pre-test intercondylar distance was 5.64 ± 0.277 cm in Group A and 6.06 ± 0.725 cm in Group B.

The comparison of post-test intercondylar distance showed a statistically significant difference between the groups ($t = 2.67$, $df = 28$, $p = 0.001$). The post-test mean intercondylar distance was 5.50 ± 0.313 cm in Group A and 5.07 ± 0.532 cm in Group B.

Within-group comparison

Group A demonstrated a statistically significant reduction in intercondylar distance between pre-test and post-test ($t = 3.14$, $p = 0.001$). The mean intercondylar distance decreased from 5.64 ± 0.277 cm to 5.50 ± 0.313 cm.

Group B also demonstrated a statistically significant reduction in intercondylar distance between pre-test and post-test ($t = 9.12$, $p = 0.001$). The mean intercondylar distance decreased from 6.06 ± 0.725 cm to 5.07 ± 0.532 cm.

Table 1: Comparison of intercondylar distance within Group A and Group B between pre-test and post-test

Group	Pre-test (Mean±SD)	Post-test (Mean±SD)	t-value	p-value
Group A	5.64 ± 0.227	5.50 ± 0.313	3.14	0.001*
Group B	6.06 ± 0.725	5.07 ± 0.532	9.12	0.001*

($p \leq 0.05$ indicates statistical significance.)

Table 2: Comparison of intercondylar distance between Group A and Group B at pre-test and post-test

Tests	Group A (Mean±SD)	Group B (Mean±SD)	t-value	df	p-value
Pre-test	5.64 ± 0.227	6.06 ± 0.725	-2.09	28	0.051
Post-test	5.50 ± 0.313	5.07 ± 0.532	2.67	28	0.001*

($p \leq 0.05$ indicates statistical significance.)

Discussion

The present study compared the effects of neuromuscular exercises and toe-in squats on intercondylar distance among college students with genu varum. Both groups demonstrated statistically significant reductions in intercondylar distance following the four-week intervention. Group A showed a reduction from 5.64 ± 0.277 cm to 5.50 ± 0.313 cm, representing a 2.48% reduction. Group B showed a reduction from 6.06 ± 0.725 cm to 5.07 ± 0.532 cm, representing a 16.34% reduction. The observed reduction was greater in Group B than in Group A. However, the findings should be interpreted in relation to the measured intercondylar distance, as radiological assessment of structural alignment was not performed.

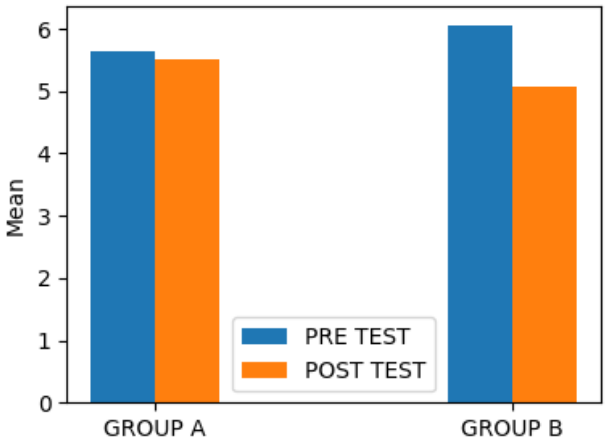


Fig 1. Comparison of Intercondylar Distance within Group–A and Group–B Between Pre Test and Post Test

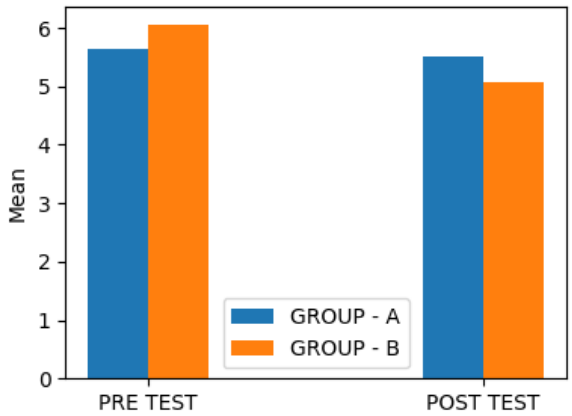


Fig 2. Comparison of Intercondylar Distance Between Group–A and Group–B at Pre and Post Test

These findings are consistent with previous research by Lee S-J, which reported greater improvement in genu varum alignment and reduction in knee separation following toe-in squats compared with conventional squats. The enhanced effectiveness of toe-in squats may be attributed to improved vastus medialis activation and correction of abnormal lower-limb mechanics, leading to better medial knee stability and alignment.

The results also support findings from Moon H-H, who observed improvements in lower-extremity alignment following exercise-based interventions. Although previous studies such as Bennell K L reported limited effects of neuromuscular exercise on varus alignment, the current study demonstrated a modest improvement, possibly due to the younger age and less severe deformity of the participants.

Several limitations should be considered, including the small sample size, short intervention period, restricted age range, and absence of radiological assessment. Future studies should include larger samples, longer follow-up periods, and imaging-based evaluations to confirm structural changes. Overall, both interventions were effective in reducing intercondylar distance, with toe-in squats showing superior improvement and potential as a conservative management strategy for genu varum.

Conclusion

Both neuromuscular exercises and toe-in squats demonstrated statistically significant reductions in intercondylar distance among college students with genu varum following a four-week intervention. The toe-in squat group demonstrated a greater reduction in measured intercondylar distance than the neuromuscular exercise group. Further studies with larger sample sizes, longer intervention periods, and radiological assessment are recommended to evaluate the effects on structural lower-limb alignment.

Limitations

The present study had several limitations. The study included only participants aged 18–25 years, limiting the generalizability of the findings to other age groups. The intervention period was relatively short (4 weeks), which restricted the evaluation of long-term effects. Additionally, the sample size was small, reducing the statistical power of the study. Radiological assessments were not performed to confirm structural or bony alignment changes, and no follow-up assessment was conducted to determine the persistence of treatment outcomes over time.

Recommendations

Future studies should include participants from a wider range of age groups to improve the generalizability of the findings. Research with a longer intervention period and larger sample size is recommended to enhance the reliability and statistical power of the results. The inclusion of radiological assessments may provide a more accurate evaluation of alignment changes and structural improvements. Additionally, long-term follow-up studies are suggested to determine the sustainability of treatment effects and the long-term effectiveness of the interventions.

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Author Contributions

Rahul P: Conceptualization, Methodology, Participant recruitment, Data collection, Formal analysis, Manuscript drafting.

Dr. Nithya V: Supervision, Methodology validation, Critical revision of the manuscript, Final approval of the manuscript.

Dr. P. Bright Alwin Victor: Research guidance, Manuscript review, Administrative support, Final approval of the manuscript.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

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