Efecto del ejercicio en cinta de correr cuesta arriba sobre la terapia estándar para la rigidez de los isquiotibiales en pacientes con osteoartritis de rodilla en el Hospital General Dr. Soetomo de Surabaya

Effect of Uphill Treadmill Exercise on Standard Therapy to Hamstrings Tightness in Patients with Knee Osteoarthritis at Dr. Soetomo General Hospital Surabaya

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Abstract

Introduction: Knee osteoarthritis causes excessive muscle contraction during walking, increased muscle tension in patients accompanied by changes in muscle stiffness related to hamstring tightness. Straight Leg Raise (SLR) is a measurement used to assess hamstring tightness using a gravity inclinometer.
Objective: To evaluate the effect of uphill treadmill exercise as an addition to standard therapy on hamstrings tightness in patients with grade II-III knee osteoarthritis at Dr. Soetomo General Hospital Surabaya.
Methodology: The control group received standard therapy (TENS and Q-bench) while the treatment group received standard therapy plus uphill treadmill exercise (8-degree inclination, speed 1.1 m/s, 30 minutes, 2x/week, for 5 weeks). Hamstring tightness was evaluated using SLR with a gravity inclinometer at three points: pre-intervention, post-intervention, and 20 days after the final exercise.
Results: The treatment group's value compared to the control group in early-late right ΔHT ($p=0.029$; Cohen's D=0.78) and early-late left P ΔHT ($p=0.02$; Cohen's D=1.12).
Discussion: Uphill treadmill exercise added to standard therapy significantly improved hamstring tightness in both legs with moderate to large effect sizes. The eccentric contractions during inclined walking likely contributed to reduced muscle tension and improved flexibility.
Conclusions: Additional uphill treadmill exercise produced meaningful changes in hamstring tightness in both legs for patients with grade II-III knee OA compared to standard therapy alone.

Keywords

Hamstring tightness; Osteoarthritis; Knee; Treadmill; Activity.

Resumen

Introducción: La osteoartritis de rodilla causa contracción muscular excesiva durante la marcha, aumento de la tensión muscular y cambios en la rigidez muscular relacionados con la tensión de los isquiotibiales. La Elevación Recta de Pierna (SLR) se utiliza para evaluar la tensión de los isquiotibiales usando un inclinómetro de gravedad.
Objetivo: Evaluar el efecto del ejercicio en cinta rodante inclinada añadido a la terapia estándar sobre la tensión de los isquiotibiales en pacientes con osteoartritis de rodilla grado II-III.
Metodología: El grupo control recibió terapia estándar (TENS y banco Q), mientras que el grupo de tratamiento recibió terapia estándar más ejercicio en cinta rodante inclinada. El entrenamiento se realizó 2 veces/semana durante 5 semanas. El ejercicio en cinta rodante inclinada se proporcionó con una inclinación de 8 grados, velocidad de 1.1 m/s, durante 30 minutos. Las mediciones SLR mediante inclinómetro de gravedad (valor < 80° indica tensión isquiotibial) se tomaron al inicio del estudio, inmediatamente después del último ejercicio y 20 días después de la finalización.
Resultados: El grupo de tratamiento mostró mejoras significativas en comparación con el grupo control en ΔHT derecho inicial-final ($p=0.029$; D de Cohen=0.78) y ΔHT izquierdo inicial-final ($p=0.02$; D de Cohen=1.12).
Discusión: El ejercicio en cinta rodante inclinada añadido a la terapia estándar demostró mejoras significativas en la tensión de los isquiotibiales bilateralmente con efectos de moderados a grandes. La marcha en pendiente probablemente activó los músculos isquiotibiales mediante contracciones excéntricas, contribuyendo a reducir la tensión muscular y mejorar la flexibilidad.
Conclusiones: El ejercicio adicional en cinta rodante inclinada produjo cambios significativos en la tensión de los isquiotibiales en ambas piernas para pacientes con osteoartritis de rodilla grado II-III en comparación con la terapia estándar sola.

Palabras clave

Tensión en los isquiotibiales; Osteoartritis; Rodilla; Cinta de correr; Actividad.

Introduction

In clinical practice, it has been observed that some patients with knee osteoarthritis experience stiffness in the posterior knee region, pain during traction, limited flexion and extension, even leading to abnormal gait. According to hypotheses, patients with knee osteoarthritis exhibit excessive muscle contraction during walking, which may help strengthen and stabilise the knee whilst walking through increased compressive forces and joint loading (Sharma, 2021). Skeletal muscles undergo structural changes with abnormal prolonged muscle contractions that can alter their biomechanical properties. Histologically, changes in biomechanical properties are associated with alterations in muscle composition including myosteatosis, myofibrosis and dysfunction of extracellular elastic fibres (Henin et al., 2024; Wang et al., 2024). These changes can alter biomechanical properties resulting in increased muscle stiffness, limited movement, and muscle pain due to traction. A substantial body of research indicates that increased muscle tension in patients is accompanied by changes in muscle stiffness; these symptoms are related to hamstring tightness (Li et al., 2022).

The parameter used to assess hamstring tightness is the Straight Leg Raise (SLR). For accurate measurement of hamstring flexibility, the gravity inclinometer represents the gold standard assessment tool due to its superior reliability and precision compared to traditional goniometric methods. Previous research using a gravity inclinometer reported validity of research results using the SLR test of 0.97 (14.22), demonstrating excellent inter-rater and intra-rater reliability. The inclinometer's ability to eliminate measurement errors associated with visual estimation and provide objective digital readings makes it particularly advantageous over conventional protractor-based measurements, which are subject to parallax errors and examiner bias. Furthermore, the inclinometer's portability and ease of use in clinical settings enhance its practical application for routine assessment. An SLR of 80° has been proposed as the primary score to indicate hamstring tightness (Pesonen et al., 2021).

Patients with knee osteoarthritis demonstrate impaired walking ability; therefore, accurate measurement of gait parameters is necessary in clinical examination. Quantitative analysis of gait patterns using a treadmill can be performed at self-selected or pre-determined speeds and also at pre-determined degrees of inclination. Thus, evaluation of gait parameters using a treadmill at various speeds or inclines may reveal undetected changes in normal gait patterns (Pacifico et al., 2020).

Among various therapeutic exercise modalities, uphill treadmill walking offers distinct biomechanical advantages over conventional flat-surface exercises and other incline training methods. Unlike stair climbing or outdoor hill walking, which present variable and uncontrolled conditions, treadmill incline training provides a standardized, progressively adjustable environment that allows for precise monitoring and gradual intensity modification. Compared to static stretching protocols or manual therapy techniques commonly used for hamstring tightness, uphill walking uniquely combines dynamic muscle lengthening with functional movement patterns that mirror activities of daily living. According to previous research, uphill walking provides functional exercise that increases muscle activation around the affected joint, achieves appropriate range of motion, and provides a controlled environment that minimises the possibility of further damage. The uphill position can reduce pronation and internal tibial rotation. This may lead to decreased external tibial rotation and the need for eccentric control by the medial hamstrings during the propulsive phase of walking. Increased hip flexion and ankle dorsiflexion at heel strike with uphill walking may contribute to knee joint stabilisation. Moreover, the gravitational assistance provided by incline walking facilitates hamstring elongation through a natural stretching mechanism that occurs during the swing phase, making it more tolerable and sustainable than aggressive manual stretching techniques (Jiang et al., 2024).

Transcutaneous Electrical Nerve Stimulation (TENS) is widely used in the management of knee osteoarthritis to relieve pain and facilitate the performance of therapeutic activities to maintain or improve physical function. Systematic review guidelines for the management of knee osteoarthritis state that 8 out of 10 guidelines recommend the use of TENS. Based on the Gate-Control Theory, the use of TENS inhibits pain perception. This theory suggests that afferent stimuli such as electrical stimulation, concurrent with pain stimuli at the spinal cord level, will attenuate pain perception in the central nervous system. Another mechanism involves stimulation of β-endorphin production. Therefore, the use of TENS is suggested to improve clinical complaints of knee osteoarthritis, with fewer side effects compared to medical therapy (Reichenbach et al., 2022).

Sufferers of knee osteoarthritis have muscle weakness around the joint that can lead to increased joint pressure. Weakness of the knee supporting muscle, the quadriceps femoris, is one of the main factors in functional impairment. Additionally, there is a correlation between quadriceps femoris muscle weakness and knee pain and function. Therefore, most exercise programmes are primarily focused on muscle strengthening, particularly the quadriceps muscle, which is a rehabilitation target in patients with knee osteoarthritis (Kus & Yeldan, 2019).

Given the high prevalence of hamstring tightness in knee osteoarthritis patients and its impact on gait mechanics and functional limitations, there is a compelling need for targeted interventions that address this specific clinical feature. While conventional conservative therapies focus primarily on quadriceps strengthening and pain management, they may not adequately address the biomechanical alterations caused by hamstring tightness. The integration of uphill treadmill exercise, with its demonstrated effects on lower limb biomechanics and muscle activation patterns, presents a promising yet insufficiently explored therapeutic approach that offers advantages over traditional exercise modalities through its controlled, progressive, and functionally relevant characteristics. Therefore, this research aims to determine the effect of adding uphill treadmill exercise to conventional conservative therapy on reducing hamstring tightness in knee osteoarthritis patients. This investigation could establish evidence-based protocols that more comprehensively address the musculoskeletal adaptations associated with knee osteoarthritis, potentially improving functional outcomes and quality of life for these patients.

Method

This study employed a true experimental design with a randomised pre-test and post-test control group design to investigate the effects of adding uphill treadmill exercise to conservative therapy on hamstring tightness in knee osteoarthritis patients. The study received ethical approval from the Ethics Commission for Basic/Clinical Science Research at Dr Soetomo General Hospital, Surabaya (No. 0751/KEPK/VIII/2023). Written informed consent was obtained from all participants prior to enrolment.

Participants

Thirty-six patients with grade II and III knee osteoarthritis (based on Kellgren-Lawrence scale) aged 50-60 years with BMI < 30 kg/m^2 and pain levels of 30-60mm on the Visual Analogue Scale were recruited and randomly allocated to either the control group (n=18) or intervention group (n=18) using simple random sampling. Sample size was calculated using Lwanga and Lemeshow's formula, with an additional 20% to account for potential dropouts. Exclusion criteria included history of knee injuries, recent knee injections, discopathy, acute inflammation, uncontrolled comorbidities, and sensory disturbances.

Intervention Protocol

The detailed intervention protocol is summarized in Table 1. The control group received conventional therapy comprising Transcutaneous Electrical Nerve Stimulation (TENS) for 20 minutes at 100 Hz frequency and 50 ms pulse duration, plus quadriceps strengthening exercises using a Q-bench machine (4-5 sets of 15 repetitions, at 20-30% of one-repetition maximum). The intervention group received the same conventional therapy preceded by 30 minutes of uphill treadmill walking at 8° inclination and 1.1 m/s speed. All interventions were administered twice weekly for a total of 10 sessions over 5 weeks.

Table 1. Characteristics of Research Participants

Component	Control Group	Intervention Group
Uphill Treadmill	-	30 minutes at 8° inclination, 1.1 m/s speed
TENS Therapy	- 20 minutes - Frequency: 100 Hz - Pulse duration: 50 ms	20 minutes - Frequency: 100 Hz - Pulse duration: 50 ms
Quadriceps Strengthening	- Q-bench machine - 4-5 sets of 15 repetitions - Intensity: 20-30% of 1RM	- Q-bench machine - 4-5 sets of 15 repetitions - Intensity: 20-30% of 1RM

Session Frequency	2 times per week	2 times per week
Total Sessions	10 sessions over 5 weeks	10 sessions over 5 weeks
Total Duration per Session	~45 minutes	~75 minutes

Measurement

Hamstring tightness was measured using the Straight Leg Raise (SLR) test at baseline, immediately after completing the 10 treatment sessions, and at 20-day follow-up. For the SLR test, patients were positioned supine with both lower extremities extended; the examiner passively raised the ipsilateral lower extremity by flexing the hip joint while maintaining the knee in full extension and ankle in slight plantarflexion and measured the hip joint angle using a gravity inclinometer.

To minimize measurement bias and ensure objectivity, a single trained physiotherapist who was blinded to group allocation performed all SLR measurements throughout the study. The blinded evaluator was not involved in the intervention delivery and had no knowledge of which treatment protocol each participant received. This blinding procedure was maintained by having different personnel conduct the interventions and measurements, with the measurement sessions scheduled separately from treatment sessions. Additionally, participants were instructed not to discuss their treatment details with the evaluator during measurement sessions.

Statistical Analysis

Statistical analysis was performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess data normality. For normally distributed data, paired t-test was used to compare pre- and post-intervention results within groups, and independent t-test was used to compare differences between groups. For non-normally distributed data, Wilcoxon Signed Rank test was applied for within-group comparisons, and Wilcoxon-Mann Whitney test was used for between-group comparisons. Statistical significance was set at $p < 0.05$ for all analyses.

Results

The study initially enrolled 36 participants (18 per group). One participant from the intervention group met the drop-out criteria, and one participant from the control group withdrew. Final analysis included 17 participants in each group. Baseline characteristics of study participants are presented in Table 2. The mean age of participants was 54.59 ± 2.98 years (range 50-59) in the control group and 55.35 ± 2.96 years (range 50-59) in the intervention group. Age distribution was homogeneous between groups (p=0.92).

Table 2. Characteristics of Research Participants

Characteristics	Control Group (n=17)	Treatment Group (n=17)	*p-value*
Age (years)	54.59 ± 2.98	55.35 ± 2.96	0.92
Sex			
Male	3 (17.6%)	2 (11.7%)	-
Female	14 (82.4%)	15 (88.3%)	-
OA Severity			
Grade II	13 (76.5%)	14 (82.4%)	-
Grade III	4 (23.5%)	3 (17.6%)	-
OA Presentation			
Unilateral	9 (52.9%)	8 (47.1%)	-
Bilateral	8 (47.1%)	9 (52.9%)	-
Weight (kg)	66.82 ± 11.34	64.18 ± 9.41	0.30
Height (cm)	160.35 ± 9.17	156.94 ± 6.65	0.20
BMI (kg/m^2)	25.87 ± 2.80	25.94 ± 2.47	0.40
Right HT P1 (°)	77.47 ± 8.65	76.18 ± 9.66	0.52
Left HT P1 (°)	76.82 ± 10.33	76.59 ± 8.99	0.89

Note: Data for age, height, weight, BMI, right HT P1 (baseline measurement) and left HT P1 (baseline measurement) are presented as mean ± standard deviation; percentages are shown for sex and OA severity. P-values represent homogeneity testing; significance defined as p<0.05. HT = Hamstring tightness.

Regarding sex distribution, the control group comprised 3 males (17.6%) and 14 females (82.4%), whilst the intervention group comprised 2 males (11.7%) and 15 females (88.3%). OA severity in the control group included 13 patients with grade II OA (76.5%) and 4 patients with grade III OA (23.5%), whilst the intervention group included 14 patients with grade II OA (82.4%) and 3 patients with grade III OA (17.6%). Unilateral OA was present in 9 participants (52.9%) in the control group and 8 participants (47.1%) in the intervention group, whilst bilateral OA was observed in 8 participants (47.1%) in the control group and 9 participants (52.9%) in the intervention group.

Mean weight was 66.82 ± 11.34 kg (range 52-89) in the control group and 64.18 ± 9.41 kg (range 48-78) in the intervention group, with no significant difference between groups (p=0.30). Mean height was 160.35 ± 9.17 cm (range 145-177) in the control group and 156.94 ± 6.65 cm (range 145-169) in the intervention group, with no significant difference between groups (p=0.20). Mean BMI was 25.87 ± 2.80 kg/m^2 (range 20.57-29.64) in the control group and 25.94 ± 2.47 kg/m^2 (range 21.23-29.55) in the intervention group, with no significant difference between groups (p=0.40).

Baseline mean right HT was 77.47° ± 8.65° (range 59°-90°) in the control group and 76.18° ± 9.66° (range 59°-89°) in the intervention group, with no significant difference between groups (p=0.52). Baseline mean left HT was 76.82° ± 10.33° (range 50°-96°) in the control group and 76.59° ± 8.99° (range 60°-94°) in the intervention group, with no significant difference between groups (p=0.89).

Table 3 shows hamstring tightness measurements in the control group. The Shapiro-Wilk test confirmed normal data distribution; thus, paired t-tests were employed. No significant differences in hamstring tightness were observed in either right or left limbs across all measurement timepoints.

Table 3. Hamstring Tightness Measurements in the Control Group

Limb	P1	P2	P3	p-value P1-P2	p-value P1-P3	p-value P2-P3
Right (°)	77.47 ± 8.65	78.24 ± 9.09	76.83 ± 11.39	0.33	0.65	0.40
Left (°)	76.83 ± 10.33	78.35 ± 10.87	77.24 ± 11.01	0.17	0.77	0.50

Note: Data presented as mean ± standard deviation; p-value significant at p<0.05. P1 (baseline measurement), P2 (measurement after 5 weeks of intervention), P3 (follow-up measurement at 20 days)

Table 4 shows hamstring tightness measurements in the intervention group. The Shapiro-Wilk test confirmed normal data distribution; thus, paired t-tests were employed. For the right limb, significant improvement in hamstring tightness was observed between baseline and post-intervention measurements (p=0.01), whilst no significant differences were found between baseline and follow-up, or between post-intervention and follow-up. For the left limb, significant improvements were observed between baseline and post-intervention measurements (p<0.01) and between baseline and follow-up measurements (p=0.02), whilst no significant difference was found between post-intervention and follow-up.

Table 4. Hamstring Tightness Measurements in the Intervention Group

Limb	P1	P2	P3	p-value P1-P2	p-value P1-P3	p-value P2-P3
Right (°)	76.18 ± 9.66	81.29 ± 8.82	78.64 ± 9.16	0.01*	0.10	0.08
Left (°)	76.59 ± 8.90	83.47 ± 8.81	80.59 ± 8.97	<0.01*	0.02*	0.06

Note: Data presented as mean ± standard deviation; p-value significant at p<0.05. P1 (baseline measurement), P2 (measurement after 5 weeks of intervention), P3 (follow-up measurement at 20 days). * indicates statistical significance

The longitudinal progression of hamstring tightness improvements in both groups is illustrated in Figure 1. This graphical representation clearly demonstrates the distinct trajectories between the control and intervention groups, with the intervention group showing marked improvement from baseline to post-intervention measurements, particularly evident in the left limb where sustained improvements were maintained at follow-up.

Figure 1. Longitudinal Changes in Hamstring Tightness Over Time

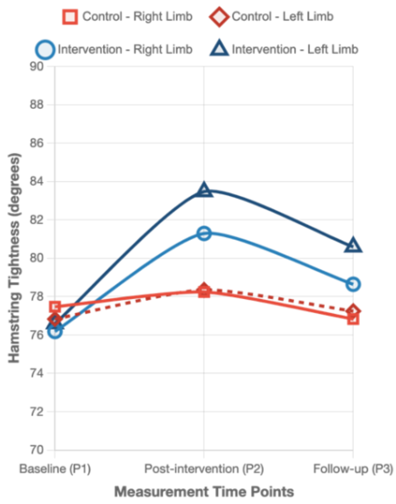

Table 5 compares changes in hamstring tightness between groups. The Shapiro-Wilk test confirmed normal data distribution; thus, independent t-tests were employed. Statistical analysis revealed significant effects of uphill treadmill exercise in the intervention group compared to the control group for right HT change from baseline to post-intervention (p=0.029; Cohen's D=0.78) and left HT change from baseline to post-intervention (p=0.002; Cohen's D=1.12).

Table 5. Comparison of Hamstring Tightness Changes Between Groups

Characteristic	Control Group (n=17)	Intervention Group (n=17)	p-value	Cohen's D
Δ Right HT P1-P2	0.76 ± 3.15	5.1 ± 7.19	0.029*	0.78
Δ Right HT P1-P3	-0.65 ± 5.79	2.47 ± 5.81	0.127	0.54
Δ Right HT P2-P3	-1.41 ± 6.79	-2.64 ± 5.86	0.574	0.20
Δ Left HT P1-P2	1.53 ± 4.43	6.88 ± 5.04	0.002*	1.12
Δ Left HT P1-P3	0.41 ± 5.71	4.00 ± 6.60	0.100	0.58
Δ Left HT P2-P3	-1.12 ± 6.59	-2.88 ± 6.03	0.422	0.28

Note: HT = Hamstring tightness. P1 (baseline measurement), P2 (measurement after 5 weeks of intervention), P3 (follow-up measurement at 20 days). P-values represent t-test results; significance defined as p<0.05. * indicates statistical significance.

The magnitude of treatment effects is visualized in Figure 2, which presents the mean changes in hamstring tightness with 95% confidence intervals. This graphical representation emphasizes the clinically meaningful improvements achieved by the intervention group, particularly highlighting the large effect sizes (Cohen's D > 0.8) observed for both limbs during the immediate post-intervention period.

Figure 2. Mean Changes in Hamstring Tightness Between Groups

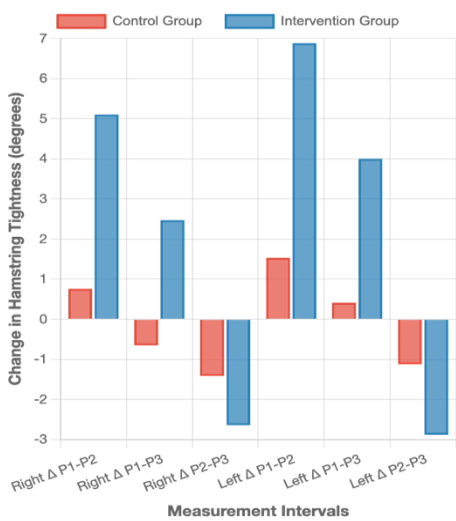

Table 6 compares absolute hamstring tightness values between groups. The Shapiro-Wilk test confirmed normal data distribution; thus, independent t-tests were employed. No significant differences in absolute hamstring tightness values were found between the intervention and control groups at any timepoint.

Table 6. Comparison of Hamstring Tightness Between Control and Intervention Groups

Characteristic	Control Group (n=17)	Intervention Group (n=17)	p-value	Cohen's D
Right HT P1 (°)	77.47 ± 8.65	76.18 ± 9.66	0.684	0.141
Right HT P2 (°)	78.23 ± 9.09	81.29 ± 8.82	0.327	0.34
Right HT P3 (°)	76.82 ± 11.39	78.65 ± 9.16	0.611	0.18
Left HT P1 (°)	76.82 ± 10.33	76.59 ± 8.99	0.944	0.024
Left HT P2 (°)	78.35 ± 10.87	83.47 ± 8.81	0.141	0.52
Left HT P3 (°)	77.23 ± 11.01	80.59 ± 8.97	0.337	0.33

Note: HT = Hamstring tightness. P1 (baseline measurement), P2 (measurement after 5 weeks of intervention), P3 (follow-up measurement at 20 days). P-values represent t-test results; significance defined as $p<0.05$.

Regarding adverse events, one subject in the control group (5.8%) reported back pain after seven training sessions and subsequently withdrew from the study. The subject had sought treatment at the neurology clinic and received Gabapentin, Sodium Diclofenac, and Diazepam. Lumbosacral X-ray results (reported approximately three days after withdrawal) revealed lumbar spondylosis. Follow-up approximately one week later (after medication completion) showed improvement in back pain, with Wong-Baker Scale decreasing from 6-7 initially to 2-3. The subject was provided with education and guidance regarding exercises for this condition. No adverse events were reported in the intervention group. The adverse event was reported in ethics attachment 40.

Discussion

The research compared two interventions for knee osteoarthritis (OA) patients: a control group receiving standard therapy alone and an intervention group receiving standard therapy plus uphill treadmill exercise. Standard therapy consisted of quadriceps strengthening exercises using Q-bench and TENS twice weekly for five weeks. The uphill treadmill exercise protocol involved a 30-minute session at an 8-degree inclination angle and 1.1 m/s speed, twice weekly for five weeks, totalling ten sessions. Minor exercise-related side effects were reported in the control group. Statistical analysis was performed on 17 subjects in each group.

The mean age of subjects was 59.6 ± 7.43 years in the control group and 53.8 ± 7.43 years in the intervention group. These ages align with epidemiological data showing rapidly increasing knee OA prevalence in the 55-64 age range. Radiographic changes, particularly osteophytes, frequently occur in elderly populations. Age-related musculoskeletal changes increase OA susceptibility, although affected joints and disease severity correlate closely with other risk factors such as joint injury, obesity, genetics, and anatomical factors affecting joint mechanics (Mi et al., 2024). Both groups fell within the 55-59 age range, where knee OA damage typically remains in early stages and medical rehabilitation interventions remain optimally effective (Tuna et al., 2022).

Female participants predominated in both study groups. Female gender represents the strongest risk factor for knee OA, followed by obesity and ageing. Women typically require more healthcare, experience different pain perception, inflammation levels, decreased cartilage volume, greater physical difficulties, and have smaller joints compared to men, contributing to increased knee OA prevalence in females (Tschon et al., 2021).

Regarding OA severity, most participants in both groups had grade II OA, with the remainder presenting grade III OA. Tuna et al. (2022) found a relationship between physical therapy and exercise effectiveness relative to radiological OA grade. Their research demonstrated that physical therapy and exercise were effective across all OA grades, though optimal results occurred in grade I OA.

Both research groups demonstrated homogeneous mean weight, height, and BMI measurements. BMI ranged from 20.57-29.64 kg/m^2 across groups, with grade 2 obesity serving as an exclusion criterion. Obesity represents a primary risk factor for knee OA alongside age and gender. Obesity causes excessive joint loading, altered biomechanical patterns, and hormonal and cytokine dysregulation. Obesity correlates with OA incidence and progression, response to rehabilitation interventions, joint replacement rates, and surgical complications. Weight reduction can produce clinically significant pain improvement and delay structural joint damage progression (Shumnalieva et al., 2023). Research has associated obesity with sedentary lifestyle (Chen et al., 2020), which correlates with hamstring tightness. Individuals with higher physical activity levels tend to demonstrate better hamstring flexibility compared to those with reduced physical activity (Liyanage et al., 2020).

Both study groups exhibited mean SLR test values below 80 degrees in both right and left legs, indicating hamstring tightness (Miyamoto et al., 2018). Knee joint movement occurs through two primary muscle groups—quadriceps and hamstrings—which facilitate smooth and precise knee joint motion (Alshami & Alhassany, 2020; Joshi & Singh Yadav, 2019; Lopes et al., 2024). The relationship between hamstring tightness and knee OA is significant because tight hamstrings can exert additional pressure on the knee joint, reduce range of motion, and cause compensatory movements that exacerbate the condition (Li et al., 2022; Miyamoto et al., 2018). Reduced hamstring flexibility has been consistently observed in knee OA patients (Raghava Neelapala et al., 2020). This decreased flexibility can increase compressive pressure on the patellofemoral joint and contribute to patellofemoral syndrome, which often contributes to osteoarthritis and can cause pain and physical function limitations (Alshami & Alhassany, 2020; Anjum et al., 2023; Joshi & Singh Yadav, 2019; Mahant & Shukla, 2021; Sherazi et al., 2022).

Our findings indicate that standard therapy in the control group (quadriceps strengthening exercises using Q-bench and TENS twice weekly for five weeks) did not significantly improve hamstring tightness. Conversely, the intervention group receiving standard therapy plus uphill treadmill exercise (8-degree inclination, 1.1 m/s speed, 30 minutes, twice weekly for five weeks) demonstrated significant hamstring tightness improvement. At the 20-day follow-up assessment, this improvement was maintained in left leg hamstring tightness measurements in the intervention group.

The hamstring muscles function as hip extensors and knee flexors. During the gait cycle's swing phase, these muscles engage in the final 25% when hip extension begins. Their activity persists through 50% of the swing phase, where they actively contribute to hip extension and resist knee extension. Notably, achieving full hip flexion is only possible when the knee joint is simultaneously flexed, a limitation attributable to the relatively short hamstring muscle length. Tight hamstrings are associated with dysfunction in the lumbar spine, pelvis, lower limbs, and abnormal gait. Beyond causing reduced range of motion, hamstring tightness can contribute to various conditions including knee OA, plantar fasciitis, and lower back pain. Muscle tightness affects the hamstrings' ability to maintain constant length-tension relationships and absorb loads. This decreased flexibility creates a cycle of limited range of motion and increased postural abnormalities (Anjum et al., 2023; Gulrandhe et al., 2023; Joshi & Singh Yadav, 2019).

These results align with previous research by Sedaghatnezhad et al. (2021), who found improved knee joint range of motion over time in knee OA patients receiving either standard therapy alone or standard therapy plus uphill treadmill exercise for two weeks. This improvement persisted at 20-day follow-up only in the intervention group receiving additional uphill treadmill exercise.

Uphill walking represents a functional stretching method for posterior knee joint muscles that improves shortened flexor muscles and restores the knee joint's pressure centre anteriorly. This technique also reduces quadriceps muscle activity and patellofemoral joint compression forces, thereby reducing knee pain. Additional benefits of uphill walking include increased ankle dorsiflexion, reduced subtalar joint pronation, decreased tibial and femoral internal rotation, and ultimately reduced knee joint degeneration (Sedaghatnezhad et al., 2021; Vincent et al., 2022). According to Vincent et al. (2022), treadmill inclines exceeding 12% (7 degrees) may benefit knee rehabilitation.

The intervention group received posterior muscle stretching whilst walking on an inclined treadmill. Research demonstrates that joint range of motion increases through stretching due to increased stretch tolerance, sarcomere numbers, and pain thresholds. Stretching can stimulate Golgi tendon organs and inhibit motor units in stretched muscles, causing muscle relaxation and increased joint range of motion. Therefore, increasing gastrocnemius, soleus, and hamstring muscle length through uphill treadmill walking reduces passive resistance caused by these shortened muscles and improves hamstring tightness (Kalkhoven et al., 2023; Kellis & Blazevich, 2022; Yoshida et al., 2024).

Additionally, combining dynamic stretching exercises with strengthening exercises provides benefits in muscle activation timing and clinical outcomes compared to static hamstring stretching with strengthening exercises or static stretching alone (Lee et al., 2021). Other research reveals that combining stretching and strengthening exercises produces greater short-term effects on pain intensity compared to minimal or no intervention (Mata Diz et al., 2017).

In Sedaghatnezhad et al. (2021), knee joint range of motion improvement occurred in both treatment groups, whereas our study found no improvement in the control group. This difference may stem from variations in physical modalities and exercises provided. In previous research, standard therapy included hot pack, TENS, and ultrasound, whereas our study provided only TENS. Strengthening exercises in previous research encompassed quadriceps, hip abductors, and gastrocnemius strengthening, whereas our study included only quadriceps strengthening. Ultrasound application to the knee joint has been proven to increase soft tissue extensibility around the knee, improve knee joint range of motion, and ameliorate hamstring tightness.

Physical activity and exercise performed by research subjects outside the study may have influenced measurement results. Liyanage et al demonstrated that sedentary lifestyle correlates with hamstring tightness incidence. Individuals with higher physical activity levels tend to exhibit better hamstring flexibility compared to those with reduced physical activity. Additionally, certain exercises such as gymnastics can provide improved hip and knee joint flexibility (Lima et al., 2019; Liyanage et al., 2020).

In our study, nine control group participants had unilateral OA (52.9%) and eight had bilateral OA (47.1%). In the intervention group, eight participants had unilateral OA (47.1%) and nine had bilateral OA (52.9%). Skeletal muscles undergo structural changes with prolonged and abnormal muscle contractions that can alter their biomechanical properties. Histologically, biomechanical property changes are associated with altered muscle composition including myosteatosis, myofibrosis, and extracellular elastic fibre dysfunction (Cai et al., 2023; Henin et al., 2024). These changes can modify biomechanical properties resulting in altered muscle stiffness, limited movement, and muscle strain pain (Li et al., 2022).

Research by Sailor et al. (2020) demonstrated that hamstring flexibility in individuals with knee osteoarthritis was lower compared to healthy controls. This implies that knee osteoarthritis affects hamstring muscle group flexibility. This research also found that hamstring flexibility significantly correlates with participant age. Progressive flexibility decline with advancing age results from elasticity changes and decreased physical activity levels. Knee OA typically affects older populations due to increased cartilage degeneration with age. Ozcan et al reported that hamstring tightness significantly correlates with arthritis severity in the proximal tibio-fibular joint of the knee (Lopes et al., 2024; Sailor et al., 2020).

Our results show superior hamstring tightness improvement in the intervention group. These superior outcomes were observed in both right and left leg hamstring tightness changes between initial and final measurements. These findings align with previous research by Sedaghatnezhad et al. (2021), who found intervention group effects over time on pain perception, knee joint range of motion, step length, walking speed, and quality in knee OA patients receiving combined standard therapy and uphill treadmill exercise. The superior results in the group with additional uphill treadmill exercise may stem from functional stretching of posterior muscles during uphill treadmill walking.

Flexibility represents the muscle's ability to elongate and permit joint movement. Quadriceps and hamstring muscle flexibility levels contribute to smooth and precise movement patterns in the knee joint. Inadequate flexibility predisposes individuals to injury and musculoskeletal dysfunction, potentially severely limiting mobility. The hamstring muscle group tends to shorten, and tightening produces increased patellofemoral compressive forces, potentially causing patellofemoral syndrome frequently associated with osteoarthritis (Mahant & Shukla, 2021).

Evidence indicates that stretching and strengthening exercises reduce pain and improve muscle strength, functional ability, and psychological wellbeing in knee OA patients. Stretching exercises increase muscle endurance, enhance proprioceptive acuity, and reduce arthrogenic muscle inhibition in quadriceps muscles (Christina et al., 2023). A meta-analysis by Luan et al. (2022) concluded that stretching exercises can benefit pain management in individuals with knee OA. We suggest that hamstring stretching exercises should be incorporated into knee OA treatment protocols, particularly to improve hamstring tightness.

Our research shows similar improvements in hamstring tightness measurements between control and intervention groups at final measurement and 20-day follow-up assessment. These results may stem from differing baseline values between control and intervention groups and mechanical limitations of hamstrings during SLR measurement (Erol & Bulut, 2024).

The findings of this study have several important implications for physiotherapists, rehabilitation specialists, and other healthcare professionals working with knee osteoarthritis patients in clinical practice. The demonstrated effectiveness of uphill treadmill exercise as an adjunct to conventional therapy provides clinicians with an evidence-based intervention that can be readily integrated into existing treatment protocols.

From a practical implementation perspective, the 8-degree inclination and 1.1 m/s speed protocol used in this study represents parameters that are easily achievable on standard clinical treadmills found in most rehabilitation facilities. The twice-weekly frequency over five weeks creates a treatment schedule that is both manageable for patients and feasible within typical healthcare delivery constraints. Importantly, the 30-minute session duration aligns well with standard physiotherapy appointment lengths, facilitating seamless integration into current practice patterns.

The sustained improvements observed in hamstring flexibility, particularly in the left limb at 20-day follow-up, suggest that this intervention may provide lasting benefits that extend beyond the active treatment period. This has significant implications for treatment planning and patient counseling, as clinicians can inform patients that improvements may persist after completing the structured program. The large effect sizes observed (Cohen's d = 0.78 for right limb, 1.12 for left limb) indicate clinically meaningful changes that would be noticeable to both patients and clinicians during routine assessments.

For busy clinical practices, the safety profile demonstrated in this study is particularly reassuring. The absence of adverse events in the intervention group, contrasted with minor complications in the control group, suggests that uphill treadmill exercise may actually be safer than conventional therapy alone. This finding should inform clinical decision-making, particularly for elderly patients or those with multiple comorbidities where treatment safety is paramount.

The specificity of the hamstring tightness improvements also provides clinicians with targeted treatment options. Rather than employing generalized exercise programs, healthcare professionals can now utilize uphill treadmill exercise specifically for patients presenting with hamstring tightness as a primary clinical feature. This targeted approach may improve treatment efficiency and resource allocation in clinical settings.

Furthermore, the functional nature of uphill walking as an intervention offers advantages for patient acceptance and adherence. Unlike static stretching protocols that patients may find boring or uncomfortable, uphill walking represents a familiar, functional activity that patients can easily understand and potentially continue independently after formal treatment concludes. This may improve long-term outcomes and patient self-management capabilities.

This represents the first study at Dr. Soetomo General Hospital Surabaya comparing standard therapy with additional uphill treadmill exercise over five weeks to improve hamstring tightness in knee osteoarthritis patients. Our findings demonstrate that adding uphill treadmill exercise to standard training for five weeks can positively impact hamstring tightness improvement in knee osteoarthritis patients, with benefits maintained through 20-day follow-up. During the five-week training period, minor adverse events including lower back pain occurred in the control group, whilst no adverse events were reported in the intervention group. Hamstring stretching exercises should be incorporated into knee OA management protocols, particularly to address hamstring tightness. Our findings may serve as a reference for subsequent research.

This study has several limitations. We did not assess other factors potentially influencing hamstring tightness, such as thigh muscle strength ratio, physical activity, and injury history. We did not conduct researcher blinding or third-party measurements to reduce research bias. Interventions occurred within relatively short training duration and follow-up periods, preventing examination of long-term exercise effects on gait speed assessment.

The single-center design limits the generalizability of findings to other healthcare settings and patient populations. Future multicenter studies should validate these results across diverse demographic groups and healthcare systems to establish broader clinical applicability. Additionally, the relatively small sample size, while adequate for detecting the observed effect sizes, may limit the ability to identify subgroups of patients who respond optimally to this intervention.

Conclusions

The conclusion of this study was that there was a change in hamstring tightness of the right leg and left leg in grade II-III knee OA patients who received additional uphill treadmill compared to standard.

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