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Original Article

Effects of Isotonic Strength Training with and Without Electrical Muscle Stimulation in Patients with Knee Osteoarthritis

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ABSTRACT

Background: Knee osteoarthritis is a common degenerative joint disorder associated with pain, quadriceps weakness, and functional limitation, and exercise-based rehabilitation remains a principal component of conservative management. Electrical muscle stimulation is frequently used as an adjunct to improve muscle activation, but its short-term additive value when combined with isotonic strengthening remains uncertain. Objective: To compare the short-term effectiveness of isotonic quadriceps strength training with and without electrical muscle stimulation in patients with knee osteoarthritis. Methods: This experimental pretest-posttest randomized clinical study was conducted in a physiotherapy outpatient department and included 35 patients aged 40 to 65 years with unilateral knee osteoarthritis. Group A (n=18) received isotonic quadriceps strengthening alone, while Group B (n=17) received electrical muscle stimulation followed by the same strengthening protocol. Treatment was delivered three times per week on alternate days for one week. Pain was assessed using the Visual Analogue Scale, and functional status was evaluated using the Western Ontario and McMaster Universities Osteoarthritis Index. Independent and paired t-tests were applied using SPSS version 20. Results: Both groups improved after intervention, but not statistically significant between-group difference was found for WOMAC (p=0.887) or VAS (p=0.109). Conclusion: Isotonic quadriceps strengthening with and without electrical muscle stimulation demonstrated comparable short-term effectiveness in reducing pain and improving function in patients with knee osteoarthritis, and the addition of electrical muscle stimulation did not show superior benefit over exercise alone during the study period. Keywords: knee osteoarthritis, isotonic exercise, quadriceps strengthening, electrical muscle stimulation, WOMAC, VAS.

INTRODUCTION

Knee osteoarthritis is one of the most prevalent musculoskeletal disorders and a major cause of chronic pain, reduced mobility, and physical disability worldwide. Among peripheral joint conditions, it is one of the most frequently reported disorders and has long been recognized as a major contributor to functional decline, particularly in middle-aged and older adults (1,2). It is currently regarded as one of the most common rheumatologic and degenerative joint disorders, with epidemiological estimates varying considerably across populations. Reported prevalence has reached 28.7% in India, while Asian population-based studies have shown rates ranging from 2% in Pakistan to 39% in suburban Beijing, reflecting differences in age structure, lifestyle, occupational loading, obesity, and sociocultural determinants of health (3-5). Beyond its frequency, knee osteoarthritis imposes a substantial individual

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and societal burden because it affects a major weight-bearing joint essential for walking, stair negotiation, transfers, and other basic daily functions (4).

Knee osteoarthritis is no longer understood as a simple consequence of aging or mechanical wear alone. Rather, it is a multifactorial disorder involving progressive degeneration of articular cartilage, remodeling of subchondral bone, osteophyte formation, synovial irritation, and altered joint biomechanics (6-8). Although advancing age remains an important risk factor, the onset and progression of disease are also influenced by obesity, heredity, trauma, occupational kneeling or repetitive loading, sex-related differences, and metabolic and inflammatory factors (4,7-9). At the tissue level, normal cartilage homeostasis depends on balanced chondrocyte activity; in osteoarthritis, excessive mechanical and biochemical stress disturbs this equilibrium, promoting inflammatory mediator release, altered matrix turnover, apoptosis, and catabolic degradation of cartilage structure (10-13). These pathological changes ultimately reduce the load-bearing efficiency of the joint and contribute to pain, stiffness, and activity limitation.

Clinically, pain is the dominant presenting complaint and often progresses from activity-related discomfort to persistent pain at rest in more advanced stages. Morning stiffness, crepitus, swelling, restricted range of motion, and impaired gait are also frequently observed (3,14). Symptoms arise not only from intra-articular degeneration but also from surrounding soft-tissue and neuromuscular dysfunction, particularly quadriceps weakness, which has a central role in reduced dynamic stabilization and increased mechanical stress across the knee (6,20). Diagnosis is commonly established using established clinical and radiographic criteria, including the American College of Rheumatology classification framework and the Kellgren-Lawrence grading system, both of which support disease characterization and staging in clinical and research settings (15,16).

Management of knee osteoarthritis includes both surgical and non-surgical strategies, with conservative treatment recommended for most patients in the early and moderate phases of disease. Surgical procedures such as osteotomy, arthroplasty, and arthrodesis are generally reserved for advanced cases or for individuals who do not respond adequately to non-operative care (17). Conservative management integrates pharmacological therapy, education, weight control, and physiotherapy, with exercise-based rehabilitation considered a cornerstone because of its potential to reduce pain, improve physical function, and preserve independence (18,19). Among physiotherapeutic approaches, quadriceps strengthening is particularly important because weakness of this muscle group is strongly associated with pain severity, altered joint loading, instability, and progression of disability in knee osteoarthritis (20).

Isotonic strengthening exercises are commonly used in rehabilitation because they involve dynamic muscle contraction through a range of motion against a constant external load, thereby supporting functional muscle performance relevant to daily activities (21,22). Electrical muscle stimulation is frequently used as an adjunct modality to facilitate muscle contraction and enhance motor unit recruitment, especially in patients with inhibition, weakness, or reduced voluntary activation (23). Prior studies have shown that both strengthening interventions and electrotherapeutic modalities may improve pain and function in individuals with knee osteoarthritis (24-26). However, the available evidence is more robust for exercise therapy in general than for the short-term additive value of electrical muscle stimulation when combined specifically with isotonic quadriceps strengthening. In particular, limited clarity remains regarding whether adding electrical stimulation to a simple isotonic strengthening program produces clinically meaningful short-term benefits beyond those achieved through exercise alone.

Given the high burden of knee osteoarthritis, the central biomechanical role of the quadriceps, and the practical need for cost-effective physiotherapy interventions, it is important to determine whether combining electrical muscle stimulation with isotonic strengthening offers measurable added benefit in routine rehabilitation settings. This study was therefore designed to evaluate and compare the short-term effects of isotonic quadriceps strength training with and without electrical muscle stimulation on pain and functional outcomes in patients with knee osteoarthritis. It was hypothesized that both interventions would improve pain and function, but that the addition of electrical muscle stimulation might produce greater improvement than isotonic strengthening alone.

MATERIALS AND METHODS

This experimental pretest-posttest randomized clinical study was conducted at the Physiotherapy Outpatient Department of Hilal-e-Ahmar, Hyderabad, over a six-month study period after approval of the research synopsis by the relevant institutional authority. The study was designed to compare the short-term therapeutic effects of isotonic quadriceps strengthening alone with isotonic quadriceps strengthening combined with electrical muscle stimulation in patients with unilateral symptomatic knee osteoarthritis. A parallel-group approach was used so that both interventions could be delivered under comparable outpatient clinical conditions, with outcomes assessed before the start of treatment and again immediately after completion of the intervention period. The primary outcomes were pain intensity and knee-related functional limitation, measured using the Visual Analogue Scale and the Western Ontario and McMaster Universities Osteoarthritis Index, respectively.

A total of 35 participants were enrolled and allocated into two treatment groups. Patients of either sex aged 40 to 65 years with clinically diagnosed unilateral knee osteoarthritis, moderate pain intensity defined as a baseline Visual Analogue Scale score between 4 and 6, and a WOMAC score of up to 40 were considered eligible for inclusion. In participants with bilateral knee osteoarthritis, the more symptomatic knee was selected for assessment and treatment standardization. Patients were excluded if they had undergone knee replacement surgery, had a history of ligamentous or meniscal injury, presented with lower-limb deformity, had a known neurological disorder or diabetes mellitus, or declined participation. These criteria were intended to reduce clinical heterogeneity and minimize the influence of major neuromuscular or structural confounders on pain and functional performance.

Participants were recruited from the outpatient physiotherapy service after initial clinical screening. Written informed consent was obtained before data collection and intervention. Following enrollment, patients were assigned to one of two groups using an even-odd allocation procedure derived from the recruitment sequence. Group A received isotonic quadriceps strengthening alone, whereas Group B received electrical muscle stimulation followed by the same isotonic strengthening protocol. Although the allocation approach provided a simple method of group assignment within the clinical setting, uniform eligibility assessment and standardized intervention delivery were maintained for all participants to reduce procedural variation. Baseline outcome recording was completed before the first treatment session, and post-intervention outcome recording was completed after the third treatment session.

Pain intensity was measured using the Visual Analogue Scale, a widely used clinical tool for subjective pain assessment based on a continuous rating continuum. Functional limitation was measured using the WOMAC index, which captures pain, stiffness, and physical function in patients with knee osteoarthritis. Both tools were administered at baseline and after the intervention period using the same assessment sequence for all participants. Demographic and clinical eligibility variables were also recorded at enrollment to ensure that participants met the predefined selection criteria.

The isotonic quadriceps strengthening protocol was delivered in a high-sitting position. A 1 kg weight cuff was attached at the distal end of the leg, and participants were instructed to actively extend the knee through the available range while maintaining upright posture and appropriate lower-limb alignment. Each treatment session consisted of 10 repetitions, and sessions were administered three times per week on alternate days. The exercise dosage and body positioning were kept constant across participants to improve intervention consistency and reproducibility.

In Group B, electrical muscle stimulation was administered immediately before isotonic exercise using a Comfy Stim unit. Four electrodes were positioned over the quadriceps muscle group, including the regions of vastus medialis, vastus lateralis, rectus femoris, and the femoral nerve area, to optimize activation of the knee extensor mechanism. Stimulation was delivered at a frequency of 100 Hz, with a contraction time of 10 seconds, a relaxation interval of 50 seconds, and a total session duration of 20 minutes. After completion of electrical stimulation, participants proceeded to the same isotonic strengthening protocol used in Group A. Standardization of stimulation parameters, electrode placement, exercise load, body position, and session frequency was maintained throughout the intervention period to reduce performance bias and enhance reproducibility.

Several procedural steps were applied to strengthen internal consistency of the trial. Eligibility criteria were narrowly defined to limit confounding from other musculoskeletal, neurological, or systemic disorders. The more symptomatic knee was selected in bilateral cases to avoid duplicated joint-level observations from the same participant. Both groups received identical exercise dosage, session frequency, and post-treatment assessment timing, allowing the additional effect of electrical muscle stimulation to be examined under comparable rehabilitation exposure. Outcomes were collected using the same validated instruments before and after intervention in all participants. No participant withdrawal was reported during the intervention period; therefore, analysis was performed on complete available data from all enrolled participants.

The sample size consisted of all eligible participants recruited during the study period who fulfilled the selection criteria and consented to participate. Statistical analysis was performed using the Statistical Package for Social Sciences version 20. Descriptive statistics were used to summarize participant characteristics and outcome measures through means, frequencies, and percentages as appropriate. Paired t-tests were used to examine within-group pre- to post-intervention change, while independent t-tests were used to compare outcome differences between groups. Statistical significance was set at $p \leq 0.05$. Ethical conduct was maintained throughout the study by obtaining informed consent, ensuring voluntary participation, and restricting the intervention to routinely used physiotherapy procedures delivered in an outpatient clinical environment.

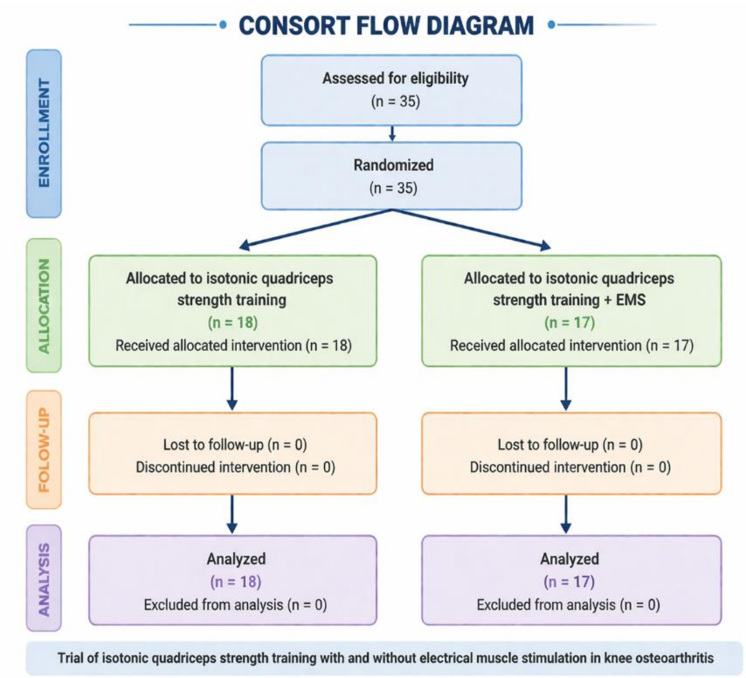

Figure 1 CONSORT Flowchart

A total of 35 patients with knee osteoarthritis were assessed and randomized into two groups. Eighteen participants were allocated to isotonic quadriceps strength training, while 17 received isotonic strengthening combined with electrical muscle stimulation, with all participants receiving their assigned interventions. No loss to follow-up or treatment discontinuation was reported in either group. All participants were included in the final analysis, with 18 analyzed in the exercise-only group and 17 in the combined EMS group, ensuring complete data availability for outcome comparison.

RESULTS

A total of 35 patients with unilateral knee osteoarthritis were enrolled and completed the study. Eighteen participants were allocated to the isotonic quadriceps strength training group, whereas 17 participants were allocated to the isotonic quadriceps strength training plus electrical muscle stimulation group. Both groups completed the intervention protocol and were included in the final analysis. According to the source dataset, both intervention arms demonstrated improvement in pain and functional outcomes from pre-intervention to post-intervention assessment. However, the available analyzed data showed that the magnitude of post-treatment difference between groups was not statistically significant for either WOMAC or VAS outcomes.

Table 1. Participant Allocation and Analysis Set

Variable	Group A: Isotonic Strength Training	Group B: Isotonic Strength Training + EMS	Total
Participants allocated, n	18	17	35
Participants analyzed, n	18	17	35
Loss to follow-up, n	0	0	0

Table 2. Between-Group Comparison of Post-Intervention Functional Outcome (WOMAC)

Outcome	Comparison	t-value	df	p-value	Statistical Interpretation
WOMAC	Equal variances assumed	0.142	33	0.887	No statistically significant between-group difference
WOMAC	Equal variances not assumed	0.143	30.183	-	Same inferential conclusion

Table 3. Between-Group Comparison of Post-Intervention Pain Outcome (VAS)

Outcome	Comparison	t-value	df	p-value	Statistical Interpretation
VAS	Equal variances assumed	1.637	33	0.109	No statistically significant between-group difference
VAS	Equal variances not assumed	1.646	32.403	-	Same inferential conclusion

Table 4. Interpretation of Comparative Outcomes

Outcome Domain	Direction of Change	p-value	Interpretation
Functional limitation (WOMAC)	Improved after intervention	0.887	Addition of EMS did not produce superior short-term functional improvement
Pain intensity (VAS)	Improved after intervention	0.109	Addition of EMS did not produce superior short-term pain reduction

Both groups contributed nearly equal proportions to the final analytical sample, with 18 of 35 participants in Group A (51.4%) and 17 of 35 participants in Group B (48.6%). No attrition was reported, resulting in a complete-case analysis of all enrolled participants. This complete retention strengthens internal consistency of the presented findings and avoids uncertainty related to missing post-intervention observations.

For functional outcome, the post-intervention comparison between isotonic strength training alone and isotonic strength training combined with EMS yielded a t-value of 0.142 with 33 degrees of freedom and a p-value of 0.887 under the equal-variances assumption. This p-value was substantially above the predefined significance threshold of 0.05, indicating that the addition of EMS did not produce a statistically detectable short-term advantage in WOMAC-measured functional status. The corresponding unequal-variance model produced a nearly identical t-value of 0.143 with 30.183 degrees of freedom, reinforcing the same conclusion and suggesting stability of the inferential result regardless of variance assumption.

For pain outcome, the between-group comparison showed a t-value of 1.637 with 33 degrees of freedom and a p-value of 0.109 under the equal-variances assumption. Although this comparison numerically approached the significance threshold more closely than the WOMAC analysis, it remained non-significant, indicating that the addition of EMS was not associated with a statistically superior reduction in pain relative to isotonic strengthening alone during the short intervention period. Under the unequal-variance assumption, the t-value was 1.646 with 32.403 degrees of freedom, again yielding the same interpretive conclusion. Taken together, these findings support the view that both regimens were associated with improvement, but neither outcome demonstrated a significant short-term between-group advantage for the combined EMS protocol.

From a comparative standpoint, the non-significant WOMAC result was especially marked, with a p-value of 0.887, indicating minimal separation between interventions in functional recovery at post-test. The VAS comparison, with a p-value of 0.109, suggested somewhat greater numerical divergence between groups than that seen for WOMAC, but still not enough to support statistical superiority of the EMS-assisted program. Therefore, within the limits of the reported analysis, the findings support the null hypothesis for both principal outcomes, namely that isotonic quadriceps strengthening with EMS was not significantly more effective than isotonic quadriceps strengthening alone in the short-term management of knee osteoarthritis.

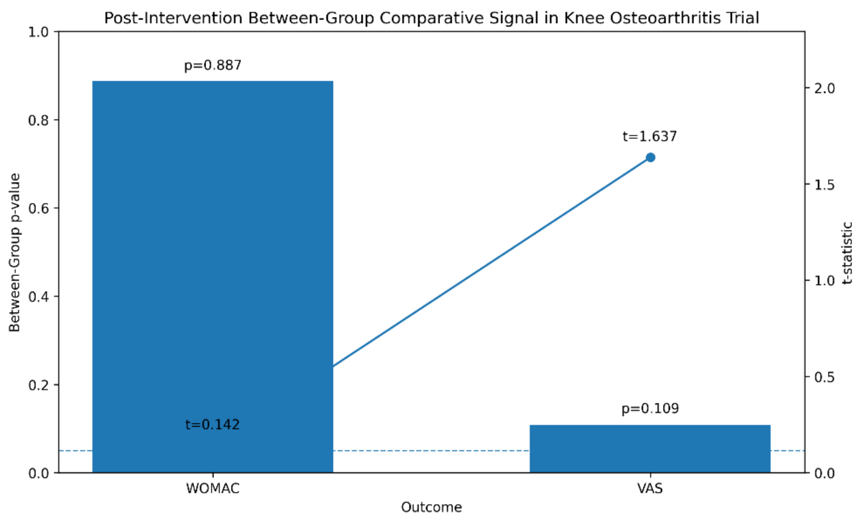

Figure 2 Post Intervention between group comparative signal in knee osteoarthritis trial

This figure shows that the post-intervention between-group signal was clearly non-significant for both primary outcomes. WOMAC had a p-value of 0.887 with a very small t-statistic of 0.142, indicating minimal separation between isotonic strengthening alone and isotonic strengthening plus EMS. VAS showed a somewhat stronger numerical signal, with p=0.109 and t=1.637, but it still remained above the 0.05 significance threshold and therefore did not support superiority of the combined EMS protocol. Clinically, the visualization reinforces that both groups improved, yet the available comparative evidence does not demonstrate an additional short-term benefit of EMS over isotonic strengthening alone in this trial.

DISCUSSION

The present study evaluated whether adding electrical muscle stimulation to isotonic quadriceps strengthening would yield greater short-term improvement in pain and functional status than isotonic strengthening alone in patients with knee osteoarthritis. Both intervention groups showed improvement after treatment, yet the between-group comparisons demonstrated no statistically significant advantage of the combined protocol for either function or pain, with post-intervention WOMAC and VAS comparisons yielding p-values of 0.887 and 0.109, respectively. These findings suggest that, over the brief treatment duration used in this trial, isotonic quadriceps strengthening alone was as effective as isotonic strengthening combined with electrical muscle stimulation in producing short-term clinical improvement. Given the central role of quadriceps weakness in altered knee mechanics, pain exacerbation, and impaired mobility, the observed benefit in both groups is clinically plausible and consistent with the established importance of strengthening interventions in knee osteoarthritis rehabilitation (19,20).

The functional findings of the present study support the broader view that exercise-based rehabilitation remains one of the most effective conservative strategies for knee osteoarthritis. Quadriceps strengthening improves knee stability, shock absorption, and dynamic control, thereby reducing mechanical stress on symptomatic structures and contributing to better daily functional performance (19,20). In the present trial, however, the addition of electrical muscle stimulation did not improve WOMAC outcomes beyond those achieved through exercise alone. This may indicate that when patients retain sufficient voluntary activation to perform isotonic exercise effectively, the marginal short-term contribution of an adjunctive electrical modality may be limited. Such an interpretation is clinically relevant in routine outpatient physiotherapy practice, particularly in settings where simple, reproducible, and low-cost interventions are preferred.

The pain findings follow a similar pattern. Although the between-group difference in VAS was numerically closer to statistical significance than the WOMAC comparison, it remained above the predetermined threshold, indicating that the combined EMS protocol was not demonstrably superior for short-term pain reduction. Pain improvement in both groups may reasonably be attributed to neuromuscular activation, better joint support, repeated controlled movement, and improved tolerance to loading through exercise-based intervention. Prior literature has shown that strengthening interventions can reduce pain and disability in knee osteoarthritis, while electrotherapeutic approaches may support muscle activation in selected clinical populations (14,19,23). However, the present results suggest that over only three treatment sessions, any additional analgesic or neuromuscular effect of EMS may not be large enough to produce a measurable advantage over isotonic strengthening alone.

These findings are broadly compatible with the mixed evidence base surrounding adjunctive electrotherapeutic interventions in knee osteoarthritis. Some previous studies have reported benefit from neuromuscular facilitation approaches, including biofeedback and electrically assisted muscle activation, especially where quadriceps weakness or voluntary inhibition is pronounced (2,23,27,28). At the same time, the literature also indicates that structured exercise programs themselves exert strong beneficial effects on pain and function, making it difficult for short-duration adjunctive modalities to demonstrate additional superiority unless treatment duration is sufficiently long or the population is carefully selected for neuromuscular impairment (19,24,25). The lack of a statistically significant between-group effect in the present trial may therefore reflect not the ineffectiveness of EMS in all contexts, but rather the limited incremental value of adding it to a brief isotonic strengthening program in a sample with mild to moderate symptomatic knee osteoarthritis.

An important explanatory factor is the short duration of intervention. Electrical muscle stimulation is most often expected to contribute through enhanced motor unit recruitment, facilitation of muscle contraction, and eventual neuromuscular adaptation, but such effects may require longer exposure to become clinically distinguishable from voluntary exercise training alone (23,27,28). In the present study, post-intervention outcomes were assessed after only three treatment sessions over one week. This duration may have been sufficient to detect early symptomatic improvement from exercise participation and supervised therapy, but it was unlikely to capture more gradual physiological adaptations such as improved quadriceps strength, endurance, or sustained functional carryover. The short follow-up period therefore limits the ability to draw conclusions regarding longer-term additive effects of EMS.

The study also has practical implications for clinical decision-making. In many physiotherapy settings, particularly those with limited resources, intervention efficiency, cost, and ease of implementation are important considerations. Since isotonic quadriceps strengthening alone produced improvement comparable to that of the combined protocol, the findings support the use of straightforward exercise-based management as a reasonable first-line short-term option for patients with knee osteoarthritis. EMS may still remain useful in specific subgroups, such as individuals with marked quadriceps inhibition, poor voluntary contraction, severe deconditioning, or postoperative weakness, but the present data do not support its routine short-term superiority when added to basic isotonic strengthening in a general outpatient knee osteoarthritis sample.

These results should be interpreted in light of the study limitations. The sample size was modest, the study was conducted at a single center, and the intervention period was brief, all of which constrain statistical power and generalizability. In addition, the reported results table provided between-group t-tests and p-values but did not include pre- and post-treatment means, standard deviations, effect sizes, or confidence intervals, which would have allowed more precise evaluation of the magnitude and clinical relevance of change. Nevertheless, the complete retention of all 35 participants strengthens internal consistency of the observed findings. Future trials should include larger samples, stronger randomization procedures, longer treatment duration, and comprehensive reporting of change scores and effect estimates to determine whether EMS offers meaningful additional benefit in the medium or long term.

CONCLUSION

Isotonic quadriceps strength training with and without electrical muscle stimulation produced comparable short-term improvements in pain and functional status among patients with knee osteoarthritis, and the addition of electrical muscle stimulation did not demonstrate statistically significant superiority over isotonic strengthening alone within the one-week intervention period. These findings support isotonic quadriceps strengthening as a practical and clinically useful conservative treatment approach, while also indicating that the routine short-term addition of EMS may not be necessary for all patients in outpatient physiotherapy settings.

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