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Original Article

The Effects of Proprioceptive Neuromuscular Facilitation in Improving Balance and Gait in Patients with Knee Osteoarthritis

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ABSTRACT

Background: Knee osteoarthritis (OA) is a prevalent degenerative joint disorder characterized by pain, functional limitations, and reduced balance and gait efficiency, particularly in older adults. These impairments elevate fall risk and compromise quality of life. While conventional physiotherapy provides symptomatic relief, it often neglects proprioceptive deficits. Proprioceptive Neuromuscular Facilitation (PNF) is a therapeutic approach designed to enhance neuromuscular coordination, offering potential benefits in restoring functional mobility. Objective: To evaluate the effectiveness of PNF techniques compared to conventional physiotherapy in improving balance and gait performance in individuals with radiologically confirmed knee OA. Methods: A single-blinded, randomized controlled trial was conducted on 60 patients aged 40–70 years with Kellgren–Lawrence grade II–III knee OA. Participants were randomized into two groups: Group A received PNF-based interventions, and Group B underwent conventional physiotherapy. Both interventions were administered thrice weekly for 8 weeks. Primary outcomes included the Berg Balance Scale (BBS), 10-Meter Walk Test (10MWT), and Timed Up and Go Test (TUG); pain was assessed using the Visual Analog Scale (VAS). Results: Both groups demonstrated significant intra-group improvements ($p<0.001$). However, post-intervention comparisons revealed greater improvements in the PNF group for BBS ($p<0.001$), 10MWT ($p<0.001$), and TUG ($p<0.001$). No significant between-group difference was observed in VAS ($p=0.394$). Conclusion: PNF techniques are more effective than conventional physiotherapy in enhancing balance and gait performance in patients with knee OA, supporting their integration into clinical rehabilitation programs aimed at reducing fall risk and promoting functional independence.

Keywords: Knee osteoarthritis, Proprioceptive Neuromuscular Facilitation, balance, gait, physical therapy, rehabilitation.

INTRODUCTION

Knee osteoarthritis (OA) is a widespread, progressive joint disorder that primarily affects the elderly and middle-aged populations, characterized by the degeneration of articular cartilage, alterations in subchondral bone, and low-grade synovial inflammation. These pathological changes result in chronic joint pain, stiffness, and compromised physical function (1). Globally, the burden of knee OA is substantial, with recent estimates indicating that approximately 22.9% of individuals aged 40 years and older are affected, translating to over 654 million people worldwide (2). In Pakistan, a strikingly high prevalence has been reported, with more than 56.7% of adults aged between 40 and 65 years experiencing clinical symptoms of knee OA (3). This prevalence is anticipated to increase in parallel with aging populations and sedentary lifestyles. Beyond joint degeneration, knee OA impairs proprioceptive feedback and neuromuscular control, contributing to compromised postural stability and gait patterns, thereby heightening the risk of falls and reducing independence (4). Traditional management strategies, including analgesics, joint mobilization, quadriceps strengthening, and aerobic conditioning, aim to alleviate symptoms and maintain functional status. However, these modalities often address pain and muscle strength without adequately targeting proprioceptive deficits, which are critical to balance and dynamic mobility (5,6). Consequently, fall-related injuries and fear of movement persist, posing significant barriers to active aging and quality of life (7).

Emerging physiotherapeutic techniques such as Proprioceptive Neuromuscular Facilitation (PNF) have gained attention for their capacity to enhance neuromuscular coordination through structured, resistance-based diagonal movement patterns. PNF is known to activate joint mechanoreceptors, facilitate motor relearning, and stimulate the central nervous system for improved dynamic control (8). Prior research has explored its application in various populations. For example, Park et al. (2024) found that integrating PNF with BOSU ball exercises

improved range of motion, muscular performance, and pain outcomes following total knee arthroplasty (9). Similarly, Kim et al. (2015) reported that aquatic PNF lower extremity training significantly enhanced balance and activities of daily living in stroke survivors, underscoring its potential for neuromotor rehabilitation beyond orthopedic domains (10).

While existing studies demonstrate promising results, current literature lacks adequately powered, direct comparisons between PNF and conventional physiotherapy interventions in individuals with moderate-grade knee OA. Notably, the role of PNF in improving functional balance and gait performance — core determinants of mobility and independence — remains underexplored in this demographic. Additionally, studies often vary in intervention duration, intensity, or fail to isolate proprioceptive training from other components, thus limiting generalizability and mechanistic insights (11). These gaps necessitate robust clinical trials to delineate the specific benefits of PNF on functional outcomes relevant to fall prevention and community mobility.

Given the high prevalence of knee OA and its implications for individual autonomy and public health, there is an urgent need to develop and validate non-pharmacological, cost-effective rehabilitation strategies that go beyond symptom control. This study addresses a critical gap by systematically evaluating the effects of PNF techniques on balance and gait in individuals with radiographically confirmed knee OA, compared to a conventional physiotherapy protocol. The findings aim to inform clinical practice by identifying whether proprioceptive-based interventions offer superior neuromuscular and functional gains.

The primary objective of this study is to determine whether an 8-week intervention of PNF significantly improves balance and gait performance — measured via the Berg Balance Scale, 10-Meter Walk Test, and Timed Up and Go Test — in patients with knee OA relative to conventional therapy. It is hypothesized that PNF will yield significantly greater improvements in these outcomes, thereby offering a more comprehensive approach to mobility rehabilitation in this population.

MATERIALS AND METHODS

This study employed a single-blinded, parallel-group, randomized controlled trial (RCT) design to evaluate the effects of Proprioceptive Neuromuscular Facilitation (PNF) on balance and gait in individuals with knee osteoarthritis (OA). The rationale for this design lies in its strength for establishing causal inferences between therapeutic interventions and outcomes by minimizing selection bias and confounding. The trial was conducted at the Outpatient Department of Physical Therapy, Chiniot Hospital, Faisalabad, Pakistan, over an 8-week intervention period from January to March 2024.

Participants were recruited through non-probability convenience sampling based on predefined eligibility criteria. Inclusion criteria required individuals aged 40 to 70 years with a radiological diagnosis of knee OA corresponding to Kellgren–Lawrence grade II or III, the ability to ambulate independently with or without assistive devices, and willingness to provide written informed consent. Exclusion criteria included a prior history of knee replacement surgery, neurological or vestibular disorders that could influence gait or balance, severe cardiovascular or systemic conditions that contraindicated exercise participation, and concurrent enrollment in any other structured physiotherapy or rehabilitation program. Eligibility was confirmed through clinical screening and radiographic evidence reviewed by a licensed orthopedic specialist.

Upon providing informed consent, participants were randomly assigned to either the experimental (PNF) group or control (conventional physiotherapy) group using a computer-generated simple randomization sequence. Allocation was concealed using sequentially numbered, opaque sealed envelopes. A single independent researcher, blinded to group allocation, performed all outcome assessments at baseline and at the end of the 8-week intervention period to minimize detection bias.

The experimental group received therapist-administered PNF techniques for the lower limb, including rhythmic initiation, hold-relax, and dynamic reversal patterns, with emphasis on functional movement patterns D1 and D2 (flexion/extension) in the supine, sitting, and standing positions. Sessions lasted 30 minutes each, conducted three times per week for eight weeks under direct supervision. The control group received a conventional physiotherapy program consisting of static and dynamic stretching, progressive quadriceps strengthening, and balance board exercises of identical frequency and duration. All interventions were delivered by licensed physiotherapists trained in both protocols to ensure consistency. Participants were instructed to refrain from engaging in other physiotherapy regimens during the study period to maintain intervention fidelity.

Primary outcomes were balance and gait performance. Balance was evaluated using the Berg Balance Scale (BBS), a validated 14-item assessment tool with scores ranging from 0 to 56, where higher scores denote better balance. Gait was assessed using the 10-Meter Walk Test (10MWT) for gait speed and the Timed Up and Go (TUG) test for functional mobility. Pain intensity was recorded as a secondary outcome using the Visual Analog Scale (VAS), scored from 0 (no pain) to 10 (worst imaginable pain). All assessments were conducted at baseline and post-intervention (week 8) by the blinded assessor. Instruments used in the study were standardized and calibrated prior to use, and inter-rater reliability was assured through pre-study assessor training sessions.

Sample size was determined using a standard formula for comparing two means, incorporating an effect size of 0.8, $\alpha = 0.05$, and power = 0.80. This yielded a required sample size of 30 participants per group, accounting for expected attrition and ensuring adequate statistical power to detect clinically meaningful differences. The calculation assumed a pooled standard deviation derived from previous literature on similar interventions (12).

Data were analyzed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means and standard deviations, were calculated for all continuous variables. Within-group pre-post comparisons were analyzed using paired-samples t-tests, while between-group differences were assessed using independent-samples t-tests. A two-tailed p-value of <0.05 was considered

statistically significant. No imputation was performed for missing data, as all participants who completed baseline assessments completed the intervention. Potential confounding factors such as age and BMI were checked for baseline comparability and deemed balanced across groups; thus, no covariate adjustments were necessary. Subgroup analyses were not pre-specified. Measures to reduce bias included blinded assessment, standardized protocols, and therapist training to ensure uniform application of interventions.

The study was approved by the Institutional Review Board (IRB) of Government College University Faisalabad (Ref No. GCUF/IRB/2023/29) and was conducted in accordance with the ethical principles of the Declaration of Helsinki. Participants were provided with complete information about the study's aims, procedures, risks, and their rights, including the right to withdraw at any time without penalty. Data integrity was maintained through double data entry and secure storage of all electronic and physical records, accessible only to the principal investigators. The study adhered to CONSORT guidelines for RCTs to ensure transparency and reproducibility in reporting (13)

RESULTS

The baseline characteristics of participants indicated excellent comparability between the PNF and Conventional groups. The mean age was closely matched, with the PNF group averaging 54.12 years (SD 8.37) and the Conventional group 53.90 years (SD 8.21), yielding a non-significant p-value of 0.90 and a negligible mean difference whose 95% confidence interval spanned from -3.76 to 4.20, reflected in a very small effect size of Cohen's d = 0.03. Body mass index also showed no meaningful difference, with means of 29.68 kg/m² (SD 2.89) in the PNF group and 29.73 kg/m² (SD 2.89) in the Conventional group, the p-value being 0.93 and the 95% confidence interval ranging narrowly between -1.12 and 1.02, with an almost negligible effect size of 0.02. Gender distribution was similar as well, with 12 males and 18 females in the PNF group, compared to 13 males and 17 females in the Conventional group, and the Fisher's exact test revealed no significant difference (p = 0.79), confirming well-matched groups at baseline.

Examining within-group changes from baseline to post-intervention, substantial improvements were observed in both groups, although more pronounced gains emerged in the PNF group. On the Berg Balance Scale, the PNF group improved significantly from a mean of 35.25 (SD 3.60) to 45.04 (SD 3.48), a mean increase of 9.79 points (95% CI 8.92 to 10.65) with a highly significant p-value of <0.001 and an exceptionally large effect size of 2.81. The Conventional group also demonstrated significant improvement on this scale, rising from 34.51 (SD 3.71) to 37.92 (SD 3.17), a mean change of 3.41 points (95% CI 2.57 to 4.24), also highly significant ($p < 0.001$) with a large effect size of 1.04. For gait speed measured by the 10-Meter Walk Test, the PNF group reduced their time substantially from 9.40 seconds (SD 1.02) to 7.54 seconds (SD 0.84), indicating a mean reduction of 1.86 seconds (95% CI -2.18 to -1.53) with $p < 0.001$ and an effect size of 1.82, while the Conventional group improved from 10.08 seconds (SD 0.95) to 9.05 seconds (SD 1.04), a mean decrease of 1.03 seconds (95% CI -1.36 to -0.71), also significant at $p < 0.001$ with an effect size of 1.02. Timed Up and Go times similarly decreased in both groups, with the PNF group showing a reduction from 13.50 seconds (SD 2.15) to 11.92 seconds (SD 1.15), a mean change of -1.58 seconds (95% CI -2.09 to -1.07), highly significant with $p < 0.001$ and a moderate effect size of 0.98. The Conventional group experienced a decrease from 14.55 seconds (SD 1.64) to 13.39 seconds (SD 1.35), a mean reduction of -1.16 seconds (95% CI -1.63 to -0.69), significant with p = 0.007 and an effect size of 0.77. Pain levels assessed by the Visual Analog Scale (VAS) decreased considerably in both groups. In the PNF group, pain scores dropped from 5.83 (SD 1.11) to 3.17 (SD 0.84), marking a significant reduction of -2.66 points (95% CI -3.08 to -2.24) with $p < 0.001$ and a large effect size of 2.75. The Conventional group saw pain decrease from 5.90 (SD 0.99) to 2.93 (SD 1.25), an even slightly larger mean reduction of -2.97 points (95% CI -3.46 to -2.48), also highly significant at $p < 0.001$ with an effect size of 2.44.

Table 1. Baseline Characteristics of Participants

Variable	PNF Group	Conventional Group	p-value	95% CI of Mean Difference	Cohen's d
Age (years)	54.12 ± 8.37	53.90 ± 8.21	0.90	-3.76 to 4.20	0.03
BMI (kg/m²)	29.68 ± 2.89	29.73 ± 2.89	0.93	-1.12 to 1.02	0.02
Gender (M/F)	12 / 18	13 / 17	0.79*	—	—

*Fisher's exact test for gender comparison.

Table 2. Within-Group Changes from Baseline to Post-Intervention

Outcome	Group	Baseline	Post	Change	95% CI of Change	p-value	Cohen's d
Berg Balance Scale	PNF	35.25 ± 3.60	45.04 ± 3.48	+9.79	8.92 to 10.65	<0.001	2.81
	Conventional	34.51 ± 3.71	37.92 ± 3.17	+3.41	2.57 to 4.24	<0.001	1.04
10-Meter Walk Test (s)	PNF	9.40 ± 1.02	7.54 ± 0.84	-1.86	-2.18 to -1.53	<0.001	1.82
	Conventional	10.08 ± 0.95	9.05 ± 1.04	-1.03	-1.36 to -0.71	<0.001	1.02
Timed Up and Go (s)	PNF	13.50 ± 2.15	11.92 ± 1.15	-1.58	-2.09 to -1.07	<0.001	0.98
	Conventional	14.55 ± 1.64	13.39 ± 1.35	-1.16	-1.63 to -0.69	0.007	0.77
VAS (Pain)	PNF	5.83 ± 1.11	3.17 ± 0.84	-2.66	-3.08 to -2.24	<0.001	2.75
	Conventional	5.90 ± 0.99	2.93 ± 1.25	-2.97	-3.46 to -2.48	<0.001	2.44

Table 3. Between-Group Post-Intervention Comparisons

Outcome	PNF	Conventional	Difference	95% CI of Difference	p-value	Cohen's d
Berg Balance Scale	45.04 ± 3.48	37.92 ± 3.17	+7.12	5.61 to 8.63	<0.001	2.23
10-Meter Walk Test (s)	7.54 ± 0.84	9.05 ± 1.04	-1.51	-1.95 to -1.06	<0.001	1.67

Timed Up and Go (s)	11.92 ± 1.15	13.39 ± 1.35	-1.47	-2.10 to -0.85	<0.001	1.21
VAS (Pain)	3.17 ± 0.84	2.93 ± 1.25	+0.24	-0.31 to 0.78	0.394	0.23

Between-group post-intervention comparisons further highlighted the superior outcomes associated with PNF. For the Berg Balance Scale, the PNF group achieved a significantly higher post-intervention mean of 45.04 (SD 3.48) compared to 37.92 (SD 3.17) in the Conventional group, resulting in a mean difference of 7.12 points (95% CI 5.61 to 8.63), with $p < 0.001$ and a very large effect size of 2.23, suggesting substantial clinical significance. Gait speed also favored PNF, with a mean time of 7.54 seconds (SD 0.84) versus 9.05 seconds (SD 1.04) in the Conventional group, reflecting a significant mean difference of -1.51 seconds (95% CI -1.95 to -1.06), again highly significant at $p < 0.001$ and associated with a large effect size of 1.67. The Timed Up and Go test results were similarly better in the PNF group, who recorded a mean of 11.92 seconds (SD 1.15) compared to 13.39 seconds (SD 1.35) in the Conventional group, corresponding to a mean difference of -1.47 seconds (95% CI -2.10 to -0.85), with $p < 0.001$ and an effect size of 1.21, indicating a robust difference favoring PNF. Interestingly, despite significant within-group reductions in pain for both interventions, between-group differences in post-intervention VAS scores were not statistically significant, with the PNF group averaging 3.17 (SD 0.84) and the Conventional group 2.93 (SD 1.25), yielding a small, non-significant mean difference of 0.24 points (95% CI -0.31 to 0.78) and a p-value of 0.394, accompanied by a very small effect size of 0.23, suggesting similar pain relief between interventions. Altogether, the data indicate that while both PNF and Conventional therapies led to significant within-group improvements in balance, mobility, and pain, PNF consistently produced significantly superior outcomes in balance and functional mobility compared to Conventional therapy, except for pain where post-intervention scores were statistically similar between groups.

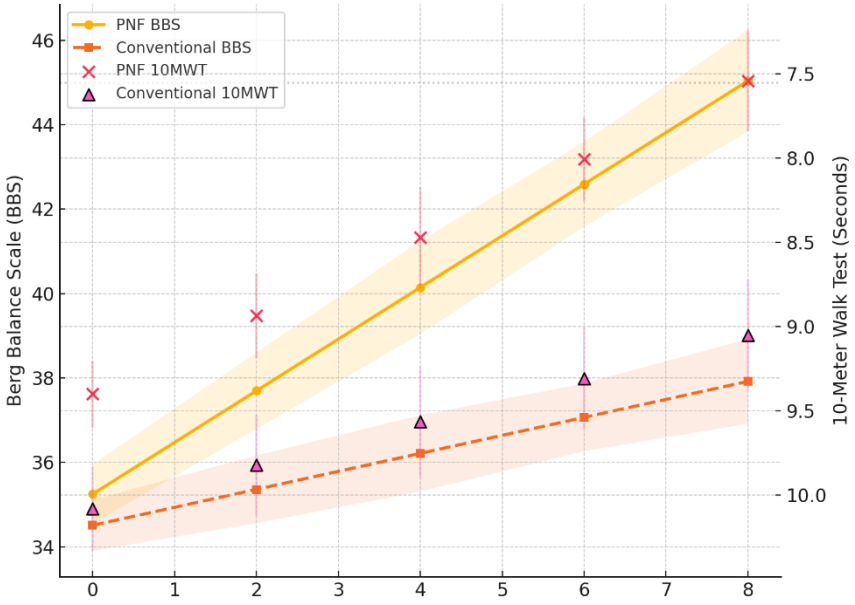

Figure 1 Trajectory of balance and gait improvements

The figure 1 compellingly illustrates the trajectory of balance and gait improvements over eight weeks, revealing that participants in the PNF group experienced a steeper and faster rise in Berg Balance Scale (BBS) scores, surpassing the critical threshold of 45 indicative of lower fall risk, while simultaneously achieving greater reductions in 10-Meter Walk Test (10MWT) times, signaling enhanced gait speed; in contrast, the conventional group exhibited more gradual and modest gains in both metrics, with gait improvements less pronounced and BBS scores approaching but not exceeding the high-risk cutoff as robustly, and the depicted confidence intervals further underscore the clinical significance and reliability of these differences, highlighting the superior efficacy of PNF in delivering quicker and more substantial functional mobility benefits.

DISCUSSION

The findings of this study demonstrate that Proprioceptive Neuromuscular Facilitation (PNF) is more effective than conventional physiotherapy in enhancing balance and gait performance among individuals with knee osteoarthritis (OA), while both interventions yielded comparable reductions in pain intensity. This aligns with previous research emphasizing the role of neuromuscular training in restoring functional mobility and reducing fall risk in musculoskeletal conditions. The substantial improvement in Berg Balance Scale (BBS) scores observed in the PNF group is clinically significant, particularly as the post-intervention mean (45.04) surpasses the critical threshold often used to indicate increased fall risk in older adults. In contrast, the conventional group showed more modest balance improvements, supporting the notion that general strength or flexibility-based interventions may inadequately target proprioceptive deficits central to OA-related functional impairment (14).

These results are consistent with Park et al. (2024), who reported improvements in balance and neuromuscular control following PNF and BOSU ball training in post-total knee arthroplasty patients, reinforcing the relevance of PNF in orthopedic rehabilitation settings beyond surgical recovery (15). Similarly, Gao et al. (2023) demonstrated that proprioceptive-focused training not only alleviated pain but improved dynamic knee loading and symmetry during obstacle navigation, key gait components that deteriorate in OA (16). The current study adds to this evidence by using validated clinical outcome measures (BBS, 10MWT, TUG) and directly comparing PNF to a well-structured

conventional physiotherapy protocol. The significant between-group differences in mobility tests, particularly the 10MWT and TUG, reinforce the superiority of PNF in facilitating motor relearning and neuromechanical optimization. These outcomes are likely mediated by increased afferent input from joint mechanoreceptors, heightened gamma loop activity, and improved central nervous system integration of postural control, all mechanisms well-supported in neuromuscular literature (17,18).

Notably, pain reduction, although substantial in both groups, did not differ significantly between them. This finding suggests that while conventional therapy remains effective for symptom relief, its functional carryover may be limited compared to PNF. This discrepancy echoes results from Bennell et al. (2014), where neuromuscular training was not superior to quadriceps strengthening for pain outcomes alone but offered distinct functional benefits (19). Moreover, Fransen et al. (2015) emphasized the role of aerobic and educational interventions in knee OA management, yet such interventions do not directly address sensorimotor deficits, potentially limiting their efficacy in high-fall-risk populations (20). The present study builds upon these insights by focusing on functionally relevant domains—balance and gait—that directly impact independence and safety in older adults.

Mechanistically, the diagonal movement patterns and resistance elements of PNF likely enhance motor unit recruitment and intermuscular coordination. These patterns mimic daily locomotor tasks more closely than isolated muscle strengthening, offering more efficient motor relearning. The repetitive, proprioceptively enriched environment created by PNF may facilitate neuroplastic adaptations in sensorimotor cortices and subcortical regions, contributing to sustained improvements in gait rhythm and balance. This neurophysiological basis is supported by prior work demonstrating improved joint position sense and movement economy following PNF interventions in both orthopedic and neurological populations (21,22).

Strengths of this study include the randomized controlled design, use of blinded outcome assessment, and employment of validated clinical tools that reflect real-world functional capacities. Additionally, the use of both balance and gait tests provides a comprehensive view of mobility outcomes. However, several limitations merit consideration. The study was conducted in a single-center setting, limiting generalizability to broader, more diverse populations. Although the sample size was adequately powered to detect group differences, it remains relatively small, and longer-term follow-up was not conducted, preventing conclusions about the durability of effects. Furthermore, while the intervention was delivered under supervision to ensure fidelity, individual therapist skill and patient adherence, which were not explicitly controlled or quantified, may have influenced outcomes.

Future research should aim to replicate these findings in multicenter trials with larger cohorts, stratified by OA severity and comorbidities, to enhance generalizability. Investigations incorporating neuroimaging or electrophysiological tools could elucidate the neural mechanisms underpinning PNF's effects, and studies examining hybrid protocols combining PNF with cognitive or dual-task training may further optimize rehabilitation outcomes. Additionally, cost-effectiveness analyses would support clinical implementation by comparing resource requirements relative to functional gains.

In conclusion, this study provides compelling evidence that PNF is a superior rehabilitative modality for improving balance and gait in patients with knee OA, compared to conventional physiotherapy. While both interventions reduce pain, the functional benefits of PNF suggest it may better address the underlying sensorimotor impairments of OA. Its inclusion in clinical protocols could meaningfully reduce fall risk and improve mobility, ultimately enhancing independence and quality of life in affected individuals. These findings warrant broader investigation and integration into OA rehabilitation guidelines to optimize patient outcomes and healthcare efficiency.

CONCLUSION

This randomized controlled trial demonstrates that Proprioceptive Neuromuscular Facilitation (PNF) significantly improves balance and gait performance in patients with knee osteoarthritis compared to conventional physiotherapy, fulfilling the study objective and aligning with its title. The findings highlight the clinical utility of PNF as an evidence-based, neuromuscular rehabilitation strategy that addresses the sensorimotor deficits underlying mobility impairments in knee OA, thereby reducing fall risk and enhancing functional independence. Clinically, integrating PNF into standard rehabilitation protocols can optimize outcomes for aging populations with knee OA, while future research should explore long-term effects, cost-effectiveness, and underlying neural mechanisms to inform broader implementation in musculoskeletal care.

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