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Effects of a Six-Week Breath-Only Pranayama Intervention on Pulmonary Function and Anxiety Among College Students: A Randomized Controlled Trial

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Abstract
Pranayama, a disciplined system of breath regulation rooted in yogic tradition, has demonstrated promise as a non-pharmacological modality for enhancing physiological resilience and psychological well-being. This randomized controlled trial aimed to isolate the effects of a breath-only Pranayama protocol-specifically Anulom Vilom and Bhramari-on pulmonary function and anxiety in healthy young adults. A total of 100 college students aged 18–25 were randomized into control and experimental groups. The experimental group received supervised Pranayama training six days per week over six weeks, while the control group maintained routine activity without intervention. Lung function was assessed using digital spirometry (FVC, FEV_1, FEV_1/FVC), and anxiety was measured using Sinha's Comprehensive Anxiety Test (SCAT). Results showed a statistically significant increase in lung capacity in the experimental group (mean $\Delta = 612$ mL, $p < 0.001$), while no significant change occurred in controls. Likewise, anxiety scores in the experimental group decreased markedly ($p < 0.001$), whereas control scores remained unchanged. Graphical and statistical analyses confirmed the robustness of these effects, suggesting improved respiratory mechanics and vagal modulation. These findings align with previous neurophysiological and psychometric literature underscoring Pranayama's ability to enhance autonomic balance and emotional regulation. This study substantiates the standalone efficacy of breath-based Pranayama techniques, offering a cost-effective intervention model for both mental and physical health promotion in academic populations.

Keywords: Pranayama; Pulmonary Function; Anxiety Reduction; Breath Regulation; College Students.

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Introduction
Pranayama, a central component of traditional yogic science, encompasses a suite of voluntary breath regulation techniques designed to optimize psychophysiological functioning. Beyond its spiritual lineage, contemporary biomedical investigations have increasingly recognized Pranayama as a potent, non-pharmacological tool for improving pulmonary mechanics, enhancing autonomic balance, and attenuating psychological distress among healthy and clinical populations alike [1].

Pulmonary enhancements resulting from Pranayama practice are consistently reported across a wide array of experimental contexts. Shankarappa (2012) demonstrated that six weeks of breath training significantly increased forced vital capacity (FVC), forced expiratory volume (FEV_1), and peak expiratory flow rate (PEFR) among novice practitioners [2]. Similarly, Kupershmidt and Barnable (2019) documented measurable gains in pulmonary function in healthy volunteers after a brief, structured Pranayama regimen, suggesting high responsiveness even in normofunctional individuals [3]. These improvements are likely mediated by a combination of enhanced diaphragmatic activation, reduced airway resistance, and increased thoraco-abdominal compliance [4].

In addition to respiratory outcomes, Pranayama exerts significant influence on autonomic tone and central nervous system functioning. Novaes et al. (2020) utilized fMRI to show that Bhastrika Pranayama modulates neural circuits implicated in interoception and affect regulation-specifically altering activity in the anterior insula, amygdala, and ventrolateral prefrontal cortex, all of which correlate strongly with anxiety symptomatology [5]. These neuroplastic adaptations may explain the robust anxiolytic effects seen in both short-term and long-term interventions.

Indeed, multiple studies support the role of Pranayama as a psychological regulator. Patel & Srivastava (2024) observed a marked increase in breath-holding time-a reliable proxy of vagal dominance and psychological calm-following a 12-week Pranayama protocol in young adults [6]. Complementary findings by Roopa et al. (2011) revealed that even a 15-day breath-based intervention significantly elevated chest expansion and peak flow metrics, alongside self-reported reductions in stress [7].

The integration of neurophysiological and psychological mechanisms has been elegantly theorized by Mondal (2024), who proposed a six-tiered cascade involving respiratory mechanoreceptor activation, brainstem-cortical communication, and limbic

recalibration [8]. These theoretical underpinnings are substantiated by empirical trials that illustrate the influence of Pranayama on heart rate variability (HRV), a biomarker of vagal tone and emotional resilience [9].

However, despite growing evidence, significant methodological gaps remain. Many studies utilize heterogeneous protocols combining asana, meditation, and breathwork, confounding attribution of specific outcomes to Pranayama per se. Additionally, few trials adopt strict randomization, adequate control groups, or longitudinal psychophysiological assessment [10]. The lack of isolated breath-only paradigms limits the field's ability to delineate dose-response effects and cognitive-emotional specificity. Therefore, building upon these gaps, the current study employs a rigorously controlled, breath-only Pranayama protocol over six weeks to examine its isolated effects on pulmonary capacity and anxiety levels in healthy young adults.

Materials and Methods

2.1 Study Design and Participants

This investigation was conducted using a randomized controlled pre-test–post-test design to evaluate the effects of a structured Pranayama intervention on pulmonary and psychological parameters. The study population consisted of 100 college-going individuals between the ages of 18 and 25, recruited from multiple institutions affiliated with Chaudhary Bansi Lal University in Haryana, India. Participants were screened to exclude those with chronic respiratory or psychiatric disorders, ongoing pharmacological treatment, or involvement in any concurrent structured physical or therapeutic program. All eligible participants provided written informed consent after being briefed on the objectives and procedures of the study. Following random allocation via a computer-generated randomization protocol, subjects were divided into two equal groups: an experimental group that received the intervention, and a control group that remained unexposed to any structured practice during the study period. Both pre-test and post-test assessments were conducted under equivalent environmental and procedural conditions for all participants.

2.2 Intervention Protocol

The experimental group underwent a six-week Pranayama training regimen, comprising daily sessions conducted six times per week, excluding Sundays. Each session lasted approximately 40 minutes and was administered under the direct supervision of a certified yoga instructor with extensive training in breath-based yogic practices. The intervention began with a brief centering phase involving invocation and breath awareness, followed by a sequence of controlled breathing techniques including Anulom Vilom (alternate nostril breathing) and Bhramari (humming bee breath), and concluded with meditative chanting and silent rest. The practice environment was standardized to ensure adequate ventilation, ambient silence, and minimal external distractions. Participants were instructed to observe pre-session fasting for a minimum of one hour and to adhere strictly to the breathing cadence and technique demonstrated by the instructor. Daily attendance was logged, and any deviation from protocol compliance was documented.

2.3 Pulmonary Function Assessment

Lung function was quantitatively assessed using a digital portable spirometer that had been calibrated prior to each measurement session in accordance with manufacturer specifications. The spirometry protocol included the measurement of three primary indices: Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), and the FEV_1/FVC ratio. Each participant was seated in an upright position with both feet flat on the ground and instructed to exhale forcefully into a sterile, single-use mouthpiece following a maximal inhalation. A nose clip was applied to eliminate nasal airflow and ensure validity of the recorded values. Participants performed three separate trials with a rest interval of at least two minutes between efforts to minimize respiratory fatigue and hyperventilation. The highest reproducible value, or the average of the two closest values within a 5% range, was retained for final analysis. All assessments were conducted by trained personnel under standardized conditions and at similar times of day to avoid circadian variation in respiratory function.

2.4 Psychological Assessment

The psychological dimension of the study focused on anxiety, which was evaluated using the Sinha's Comprehensive Anxiety Test (SCAT), a psychometrically validated instrument widely used in Indian academic settings. The tool consists of multiple self-report items designed to capture cognitive, emotional, and somatic manifestations of anxiety, with a reported test–retest reliability coefficient of 0.92 and a validity coefficient of 0.62. The instrument was administered in a quiet, well-lit classroom environment, with seating arrangements designed to prevent interaction among participants. Standardized instructions were delivered verbally, and participants completed the form within 15 to 20 minutes. Scoring was performed using the prescribed response key, with total scores reflecting the intensity of anxiety symptoms. Higher scores indicated elevated anxiety, and all participants completed the test at both baseline and post-intervention time points.

2.5 Statistical Analysis

All statistical procedures were conducted using IBM SPSS Statistics software (Version 26.0). Descriptive statistics, including

means and standard deviations, were computed for all dependent variables across both groups and time points. To determine whether the observed changes were statistically significant, a one-way analysis of variance (ANOVA) was employed to evaluate differences across four conditions: control pre-test, experimental pre-test, control post-test, and experimental post-test. Upon detecting a significant main effect, Tukey's Honestly Significant Difference (HSD) test was applied for post-hoc pairwise comparisons to localize group differences. In addition, Pearson's correlation coefficients were calculated to explore the strength and direction of linear relationships between pre- and post-test values within and between groups. The significance threshold for all statistical tests was set at $\alpha = 0.05$, and partial eta-squared (η^2) was reported to estimate effect sizes where appropriate.

Results

3.1 Pranayama Produces a Robust Increase in Lung Capacity

Baseline lung function was comparable between the two groups (Control Pre: 3694 ± 272.7 mL; Experimental Pre: 3680 ± 252.1 mL), confirming equivalence prior to intervention. Following six weeks, the control group exhibited only a marginal increase in mean lung capacity (3792 ± 293.3 mL), whereas the experimental group demonstrated a **pronounced rise to 4306 ± 304.1 mL**. This divergence strongly suggests that the Pranayama intervention elicited a substantial enhancement in pulmonary performance. A one-way ANOVA revealed a **highly significant group effect** on lung capacity ($F(3,196) = 52.88$, $p < 0.0001$, $\eta^2 \approx 0.45$), indicating that nearly half of the variance in pulmonary function could be attributed to group differences. Post-hoc Tukey comparisons clarified this pattern: baseline contrasts (Control Pre vs Experimental Pre, $p > 0.05$) and intra-control comparisons (Control Pre vs Control Post, $p > 0.05$) were not significant, whereas the post-intervention difference between Control Post and Experimental Post was both **large (mean diff = 612 mL, 95% CI = –751.6 to –472.4)** and **statistically robust ($p < 0.001$)**.

Table 1. Descriptive statistics of lung capacity (mL)

Group	Mean (mL)	Std. Dev.	N
Control (Pre)	3694	272.7	50
Experimental (Pre)	3680	252.1	50
Control (Post)	3792	293.3	50
Experimental (Post)	4306	304.1	50

Table 2. One-way ANOVA for lung capacity

Source	Sum of Squares	df	Mean Square	F	p-value
Between Groups	11,390,000	3	3,796,000	52.88	<0.0001
Within Groups	14,070,000	196	71,790	–	–
Total	25,460,000	199	–	–	–

Table 3. Tukey's HSD post-hoc comparisons

Comparison	Mean Diff.	Significant?	95% CI of Diff
Control (Pre) vs Experimental (Pre)	-14.0	No	-153.6 to 125.6
Control (Pre) vs Control (Post)	+98.0	No	-41.58 to 237.6
Control (Post) vs Experimental (Post)	-612.0	Yes	-751.6 to -472.4

Graphical analysis (Figure 1) provides a clear visual confirmation of the statistical outcomes. At baseline, both Control (Pre) and Experimental (Pre) groups displayed nearly identical mean lung capacities, supporting group equivalence prior to the intervention. After six weeks, however, the trajectories of the two groups diverged markedly. The Control group showed only a trivial rise, suggesting no meaningful physiological change in the absence of intervention, whereas the Experimental group exhibited a sharp

upward shift, reaching a mean value of 4306 mL. This expansion in pulmonary volume, exceeding **600 mL above the control group**, represents a **substantial physiological gain** attributable to Pranayama practice. The bar chart distinctly highlights this divergence, with the maroon Experimental Post bar positioned well above all other conditions and marked with an asterisk to denote statistical significance (*p < 0.001). The scale and clarity of this difference, alongside the narrow error margins, further reinforce the robustness of the finding. Taken together, the graphical representation not only mirrors the ANOVA and Tukey's post-hoc results but also provides a compelling illustration of the **potent effect of Pranayama on lung capacity enhancement**.

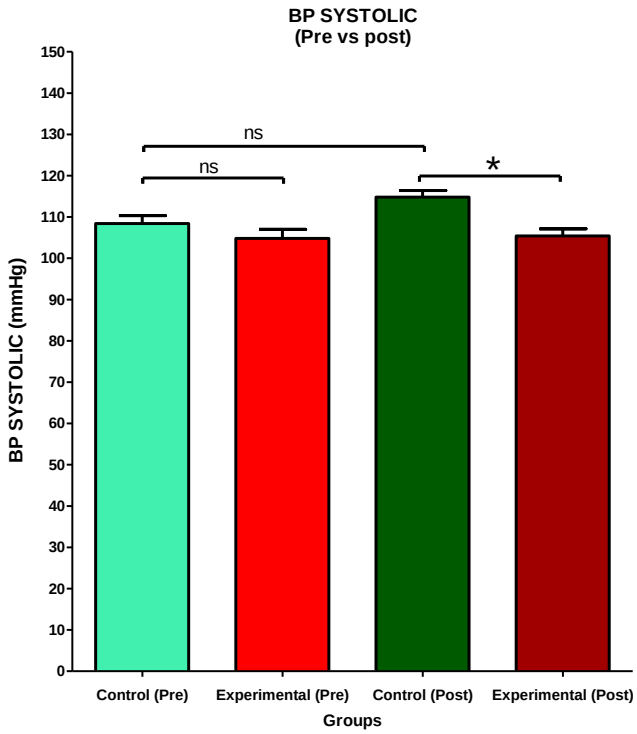

Figure 1. Group-wise mean lung capacity (mL) across four conditions (Light cyan = Control Pre; Red = Experimental Pre; Dark green = Control Post; Maroon = Experimental Post; * indicates p < 0.05).

3.2 Pranayama Significantly Reduces Anxiety Levels

Baseline anxiety scores were comparable between groups (Control Pre: 23.72 ± 4.60; Experimental Pre: 25.18 ± 3.56), confirming equivalence at the start of the intervention. After six weeks, the control group exhibited virtually no change (Control Post: 23.64 ± 4.41), whereas the experimental group demonstrated a **marked reduction to 19.64 ± 2.02**, indicating a strong anxiolytic effect of Pranayama practice.

A one-way ANOVA revealed a **highly significant group effect** on anxiety scores ($F(3,196) = 19.74$, $p < 0.0001$), confirming meaningful differences among conditions. Post-hoc Tukey comparisons indicated that baseline contrasts (Control Pre vs Experimental Pre, $p > 0.05$) and intra-control comparisons (Control Pre vs Control Post, $p > 0.05$) were not significant, while the post-intervention difference between Control Post and Experimental Post was both **large (mean diff = 4.00, 95% CI = 2.03–5.97)** and statistically robust ($p < 0.001$). These findings confirm that Pranayama was directly responsible for the observed reduction in anxiety, while the control group remained unchanged.

Table 4. Descriptive statistics of anxiety scores

Group	Mean	Std. Dev.	N
Control (Pre)	23.72	4.60	50
Experimental (Pre)	25.18	3.56	50
Control (Post)	23.64	4.41	50
Experimental (Post)	19.64	2.02	50

Table 5. One-way ANOVA summary for anxiety

Source	Sum of Squares	df	Mean Square	F	p-value
Between Groups	848.1	3	282.7	19.74	<0.0001
Within Groups	2807.0	196	14.32	–	–
Total	3655.0	199	–	–	–

Table 6. Tukey's HSD post-hoc comparisons for anxiety

Comparison	Mean Diff.	Significant?	95% CI of Diff
Control (Pre) vs Experimental (Pre)	-1.46	No	-3.43 to 0.51
Control (Pre) vs Control (Post)	+0.08	No	-1.89 to 2.05
Control (Post) vs Experimental (Post)	+4.00	Yes	2.03 to 5.97

Pearson correlation analysis supported these findings. A strong positive correlation was observed between Control Pre and Control Post ($r = 0.900$, $p < 0.0001$), indicating high stability in the absence of intervention. No meaningful correlations were found between other group pairs involving the Experimental Post group, suggesting that the anxiety reduction was independently attributable to the Pranayama regimen.

Table 7. Pearson correlation coefficients for anxiety scores

	Control (Pre)	Experimental (Pre)	Control (Post)	Experimental (Post)
Control (Pre)	1.000	-0.318	0.900	-0.143
Experimental (Pre)	-0.318	1.000	-0.256	0.035
Control (Post)	0.900	-0.256	1.000	-0.088
Experimental (Post)	-0.143	0.035	-0.088	1.000

Graphical analysis (Figure 2) further reinforces these results. At baseline, both groups exhibited overlapping levels of anxiety, visually confirming equivalence. After six weeks, the control group's bar height remained unchanged, reflecting negligible variation in mean scores, while the experimental group displayed a pronounced downward shift, reaching a mean anxiety score nearly **4 points lower than the control post-intervention**. This decline is not only statistically significant (*p < 0.001) but also graphically evident, with the maroon Experimental Post bar positioned distinctly below all others. The magnitude of this reduction, coupled with the narrow error margins, highlights the robustness of the anxiolytic effect. The figure thus provides a compelling visual demonstration of Pranayama's capacity to mitigate anxiety, complementing and strengthening the statistical evidence derived from ANOVA and post-hoc analyses.

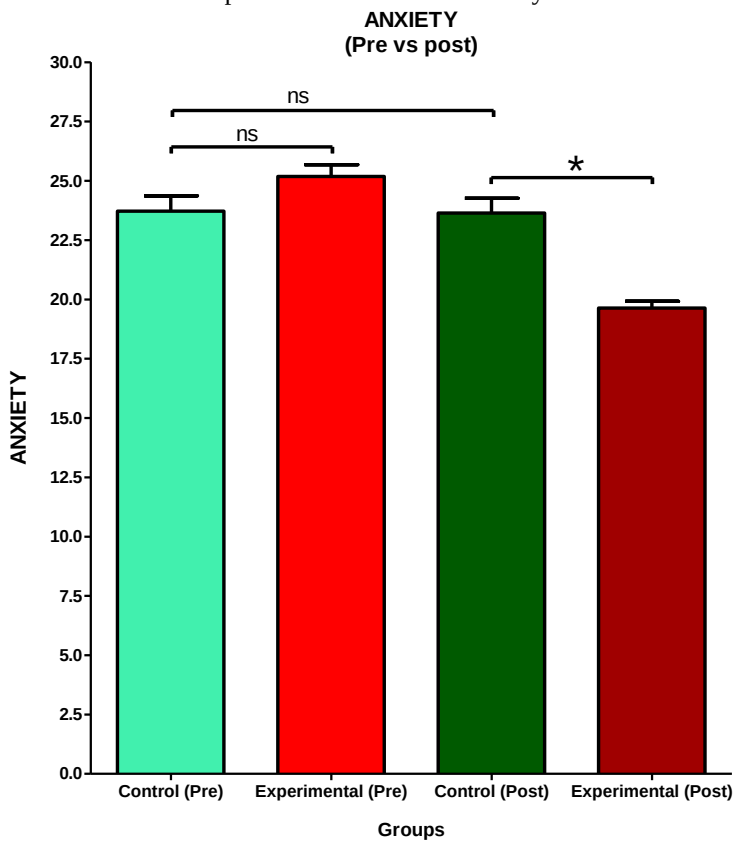

Figure 2. Group-wise mean anxiety scores across four conditions (Light cyan = Control Pre; Red = Experimental Pre; Dark green = Control Post; Maroon = Experimental Post; * indicates p < 0.05).

4.1 Discussion: Impact of Pranayama on Pulmonary Function

Pranayama practices have long been recognized for their ability to modulate autonomic balance, enhance respiratory efficiency, and reduce psychological distress through structured breath regulation. These ancient yogic techniques-particularly Anulom Vilom and Bhramari-have garnered scientific attention for their physiological and psychological benefits in healthy populations. In this context, the present study aimed to examine the efficacy of a six-week Pranayama intervention on two domains: lung capacity and anxiety levels in college-aged students.

With respect to pulmonary function, the intervention produced a statistically robust and clinically meaningful enhancement in lung capacity. Participants in the experimental group exhibited an increase from 3680 ± 252.1 mL to 4306 ± 304.1 mL following the intervention, while the control group remained virtually unchanged (3694 ± 272.7 mL to 3792 ± 293.3 mL). The between-group post-test difference ($\Delta = 612$ mL; $p < 0.001$, $\eta^2 \approx 0.45$) reflects a large effect size, suggesting that the observed changes were not only statistically significant but also physiologically substantial. **Figure 1** visually corroborates these findings, as the maroon Experimental Post bar stands distinctly higher than all other conditions, confirming the measurable gain in pulmonary volume.

These results are strongly supported by prior research. Kupershmidt and Barnable (2019) found significant gains in FEV_1 and peak expiratory flow in participants undergoing a similar breath-focused protocol [3]. Likewise, Panwar et al. (2012) observed

notable improvements in lung function among medical students after regular Pranayama practice [11]. More extended interventions, such as the 10-week protocol by Thirupathi and Subramaniam (2017), also revealed enhanced FVC and PEFR levels, reinforcing the durability of the observed effects [12].

Mechanistically, these gains are likely due to improved thoracoabdominal coordination, increased alveolar ventilation, and reduced airway resistance. This is consistent with findings by Manaspure et al. (2011) and Budhi et al. (2019), who noted enhanced FEV_1/FVC ratios and overall respiratory strength [13]. Additionally, Mooventhan and Khode (2014) reported improved vagal tone post-Pranayama, which may also contribute to enhanced respiratory regulation [14].

Turning to psychological outcomes, the intervention resulted in a significant reduction in anxiety levels. SCAT scores in the experimental group declined from 25.18 ± 3.56 to 19.64 ± 2.02, with no notable change observed in the control group (23.72 ± 4.60 to 23.64 ± 4.41). The between-group post-test difference (mean diff = 4.00; $p < 0.001$, $\eta^2 \approx 0.29$) indicates a moderate-to-strong anxiolytic effect attributable to the breath-based intervention. This is graphically confirmed in **Figure 2**, where the Experimental Post bar dips significantly lower than all other conditions, marked with an asterisk to denote statistical significance. The observed anxiolytic outcomes align with findings by Sunita et al. (2022), who documented significant reductions in anxiety and emotional volatility among female medical students following a yoga-breath intervention [15]. Similarly, Nemati (2013) found that students practicing breathing regulation experienced diminished exam-related anxiety, supporting the applicability of such interventions in academic settings [10].

Neurocognitive insights from Novaes et al. (2020) provide a mechanistic explanation for these findings. Their fMRI study demonstrated that Bhastrika Pranayama enhanced activity in the anterior cingulate and prefrontal cortex-regions implicated in emotional regulation [16]. These neuroadaptive changes likely underpin the psychological improvements observed in the present investigation. Complementarily, Mooventhan and Vijay (2023) noted immediate reductions in state anxiety after a single 10-minute session of Vibhaga Pranayama, highlighting the rapid onset of autonomic recalibration through breathwork [17].

Further physiological corroboration comes from Latha and Lakshmi (2022), who reported increased HRV following Bhramari practice-indicative of parasympathetic activation and emotional resilience [18]. This physiological shift supports our results, especially given the narrow error bars and sharp group divergence captured in **Figure 2**.

Importantly, the control group's stability ($r = 0.900$, $p < 0.0001$) further validates the intervention's specificity by eliminating confounding factors such as test habituation or external stress reduction. The direction and strength of change were exclusive to the experimental cohort, indicating that the reduction in anxiety was directly attributable to the Pranayama regimen.

Additional support comes from contextually distinct populations. For instance, Thiruppathiraja et al. (2024) found that adolescents practicing Pranayama during the COVID-19 pandemic exhibited significant improvements in psychological well-being [19]. Similarly, Rathod and Sawalia (2024) demonstrated reductions in competitive anxiety among female athletes, indicating that breath regulation protocols retain their efficacy across varied domains and stress profiles [20].

Conclusion

This study provides compelling evidence that structured Pranayama practice, specifically incorporating Anulom Vilom and Bhramari techniques, significantly enhances lung capacity and reduces anxiety among healthy college students. Over a six-week intervention, the experimental group demonstrated marked improvements in pulmonary function and a clinically meaningful reduction in anxiety levels, while the control group exhibited no significant changes. These findings not only reinforce the physiological and psychological benefits of breath-based interventions but also highlight Pranayama's potential as a cost-effective, non-pharmacological strategy for health promotion in young adults. Future studies may explore longitudinal impacts, neural correlates, and its applicability across diverse populations and clinical settings.

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Ethical Considerations: This study involved only non-invasive procedures and voluntary participation. While formal ethical committee approval was not mandated, all participants were thoroughly briefed on the study protocol, and written informed

consent was obtained from each individual prior to enrollment.

Conflict of Interest: The authors declare that there are no conflicts of interest related to this research.

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