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## REVIEW ARTICLE

# The Effect of Therapeutic Exercises in Children and Adolescents with Pronation Distortion Syndrome: A Systematic Review

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**Abstract.** This study aimed to review the effect of therapeutic exercises in children and adolescents with PDS. A systematic review was conducted according to the PRISMA guidelines. The search used selected keywords from inception to January 2026 to search PubMed, Scopus, Web of Science, SID, Magiran, and IranMedex databases for original and peer-reviewed articles. Google Scholar was also searched for additional records. The quality of the included studies was assessed using the Joanna Briggs Institute checklist. After searching the mentioned databases, 2837 articles were identified. Ultimately, nine articles were selected for this review based on the inclusion criteria. The findings revealed that corrective exercise programs, including game-based and structured interventions, improve balance, proprioception, muscle activation, strength, postural sway, and body posture. These findings provide a useful contribution to the field and offer a foundation for evidence-based practice and future research in the management of pronation-related disorders.

**Keywords:** Therapeutic Exercises, Children, Pronation Distortion Syndrome, Flatfoot, Adolescents



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## Introduction

Lower limb pronation distortion syndrome (PDS) is a frequently observed postural distortion of the lower extremity, primarily affecting the front region of the leg (Hertling & Kessler, 2006). PDS may lead to pain and disturbances in the tarsal, distal, and proximal parts of the foot (Lee & Emam, 2020). Individuals with PDS have a flatfoot deformity, knee valgus, and internal rotation of the hip due to excessive foot pronation (Alahmri et al., 2022), with a 35.9% prevalence (Minhas et al., 2024). In this abnormality, the muscles of the tibialis posterior, peroneals, soleus, iliotibial band, short head of the biceps femoris, hip adductors, and psoas become functionally overactive, while the gastrocnemius and soleus muscles, tibialis anterior, extensor hallucis longus, and the external rotators of the hip become inhibited (Karski et al., 2020). In addition, PDS may predispose individuals to Achilles tendon injuries, plantar fasciitis, posterior tibial tendonitis, and ankle sprains (Holmes & Delahunt, 2009), patellar tendinopathy, patellofemoral pain syndrome, Anterior Cruciate Ligament (ACL) injuries, and Lower Back Pain (LBP) (Moen et al., 2009). Moreover, individuals with PDS are at risk of developing plantar pain, knee pain, foot injuries, stress fractures, and deficits in ankle proprioception and balance (Chinpeerasathian et al., 2025; Sabouri et al., 2026). Associated movement impairments include limited dorsiflexion at the talocrural joint, reduced strength of the foot and ankle supinator muscles (Sabouri et al., 2025), intrinsic foot musculature, hip external rotators (Chen et al., 2021), and reduced functional movement screening scores (Pourmatin et al., 2025), all of which contribute to the restrictions observed in these individuals. This condition in both athletic and general populations underscores the clinical need for effective interventions that address not only symptoms but also underlying biomechanical abnormalities.

Therapeutic exercises are primary to conservative management strategies for PDS, aiming to restore optimal musculoskeletal alignment (Porto et al., 2024), enhance neuromuscular control, and correct aberrant movement patterns (Ebrahimi, Sheikhhoseini, et al., 2025). These exercises typically involve a combination of strengthening weak musculature, stretching overactive or shortened structures, and re-education of functional movement patterns (MASON & ORAON, 2024). The conceptual basis for therapeutic exercise in PDS draws on the principles of kinetic chain dynamics and motor control (Hashemi et al., 2025; Najafi et al., 2018), suggesting that improvements at the segmental level can yield beneficial adaptations throughout the entire biomechanical system. It has become evident that corrective exercises may lead to changes such as increased muscle activity (Najafi et al., 2018), postural sways (A Golchini & N Rahnama, 2020), isometric strength (A Golchini et al., 2021), balance (A. Golchini et al., 2021), and body posture (Ali Golchini & Nader Rahnama, 2020) in individuals with PDS. Furthermore, game-based corrective exercises have shown promising in proprioception (Hashemi et al., 2025), lower limb alignment (Yalfani et al., 2023), and Q-angle (Rahmani et al., 2025).

Despite the growing recognition of PDS as a clinically relevant biomechanical abnormality and the widespread use of therapeutic exercise as a primary conservative intervention, important gaps remain within the current body of literature. Although several individual studies have reported positive effects of corrective and game-based exercise programs, the majority of available evidence has either focused on general populations or has not clearly differentiated findings across specific subgroups. Consequently, the extent to which these findings can be generalized to particular populations, especially children and

adolescents, remains uncertain. More importantly, there is a lack of population-specific synthesis of evidence for vulnerable or distinct groups, including children with developmental or musculoskeletal disabilities who may present with altered neuromuscular control, balance impairments, or structural deviations that differ from typically developing peers. To date, major reviews and analytical studies in this field have not adequately incorporated research conducted in West Asia. As a result, the existing body of evidence relies predominantly on data derived from Western countries, where sociocultural norms, physical activity patterns, school-based physical education systems, and healthcare infrastructures differ substantially from those of West Asian societies. Therefore, this study systematically reviews the effectiveness of therapeutic exercises in functional outcomes in individuals with PDS. We applied the PICO framework (Population, Intervention, Comparison, and Outcomes) to filter, select, and review the literature (Amir-Behghadami & Janati, 2020).

### **Method and Materials**

**Search Strategy.** This systematic review adhered to the PRISMA reporting guidelines (Page et al., 2021). A comprehensive literature search was performed in PubMed, Scopus, Web of Science, SID, Magiran, and IranMedex, covering all records available from database inception through January 2026. In addition, Google Scholar was explored to identify supplementary studies. The search strategy was developed based on the keywords outlined in Table 1 and implemented using Boolean operators. Searches were carried out in English-language databases using English terms, but in Persian-language sites, their Persian translations were used.

**Inclusion and exclusion criteria.** The inclusion criteria encompassed original, peer-reviewed studies that investigated the effects of therapeutic exercise interventions in children and adolescents aged 9-16 years with PDS. Eligible articles were published in either Persian or English and examined functional outcomes (e.g., balance, proprioception, strength) and/or musculoskeletal disorders (e.g., flatfoot). Studies that were unrelated to the research objective, conference abstracts, systematic reviews, or investigations lacking quantitative outcome measures were excluded from the review.

**Study selection.** In the present review, two reviewers (P.J. and SN.H.) independently screened article titles and abstracts in accordance with the predefined inclusion criteria and PRISMA methodological standards, using a standardized data extraction form developed in Microsoft Excel (Page et al., 2020). The supervising author addressed and assessed discrepancies between the researchers (E.E.). All retrieved records were imported into EndNote 20, which was subsequently used to identify and eliminate duplicate entries.

**Data extraction and quality assessment.** Data extraction was performed independently by two reviewers (SE.M. and SN.H.) using a standardized Excel-based form, after which the extracted information was compared to assess consistency. Any disagreements were reviewed and resolved by the supervising author (E.E.). From each eligible study, the following information was recorded: first author, publication year, study design, sample size, participant characteristics (including age, sex, and relevant indices), key assessment methods and measurement instruments, and principal findings (Table 2). Risk of bias was

independently evaluated by two reviewers (E.E. and P.J.) using the Joanna Briggs Institute (JBI) Critical Appraisal tools (Crommert et al., 2011), with the appropriate checklist selected according to each study's design. Studies that achieved the lowest appraisal scores relative to the included articles were categorized as low quality during the methodological assessment (Table 3).

**Table 1. Search strategy used for this study**

Variable	Keywords
therapeutic exercises	("Exercise" OR "Training" OR "Protocol" OR "Rehabilitation" OR "physical therapy" OR "therapeutic exercise" OR "exercise therapy" OR "Exercise Movement Techniques" OR "physiotherapy" OR "corrective exercise")
Pronation distortion syndrome	("pronation distortion syndrome" OR "distortion syndrome" OR "pronation syndrome" OR "lower limb malalignment" OR "postural distortion" OR "PDS")
Children and adolescents	("Student*" OR "Schoolchild*" OR "Adolescent*" OR "Youth*" OR "Teen*" OR "Child*" OR "School*" OR "High school*" OR "Secondary school*" OR "Primary school*" OR "Elementary school*")

## Findings

The comprehensive search of the selected databases identified 2837 records. After duplicate entries were removed (n = 2661) in accordance with the predefined inclusion and exclusion criteria, 176 records remained for the screening process, as illustrated in the study flow diagram (Figure 1). Of these, 9 studies ultimately met the eligibility requirements and were included in the review.

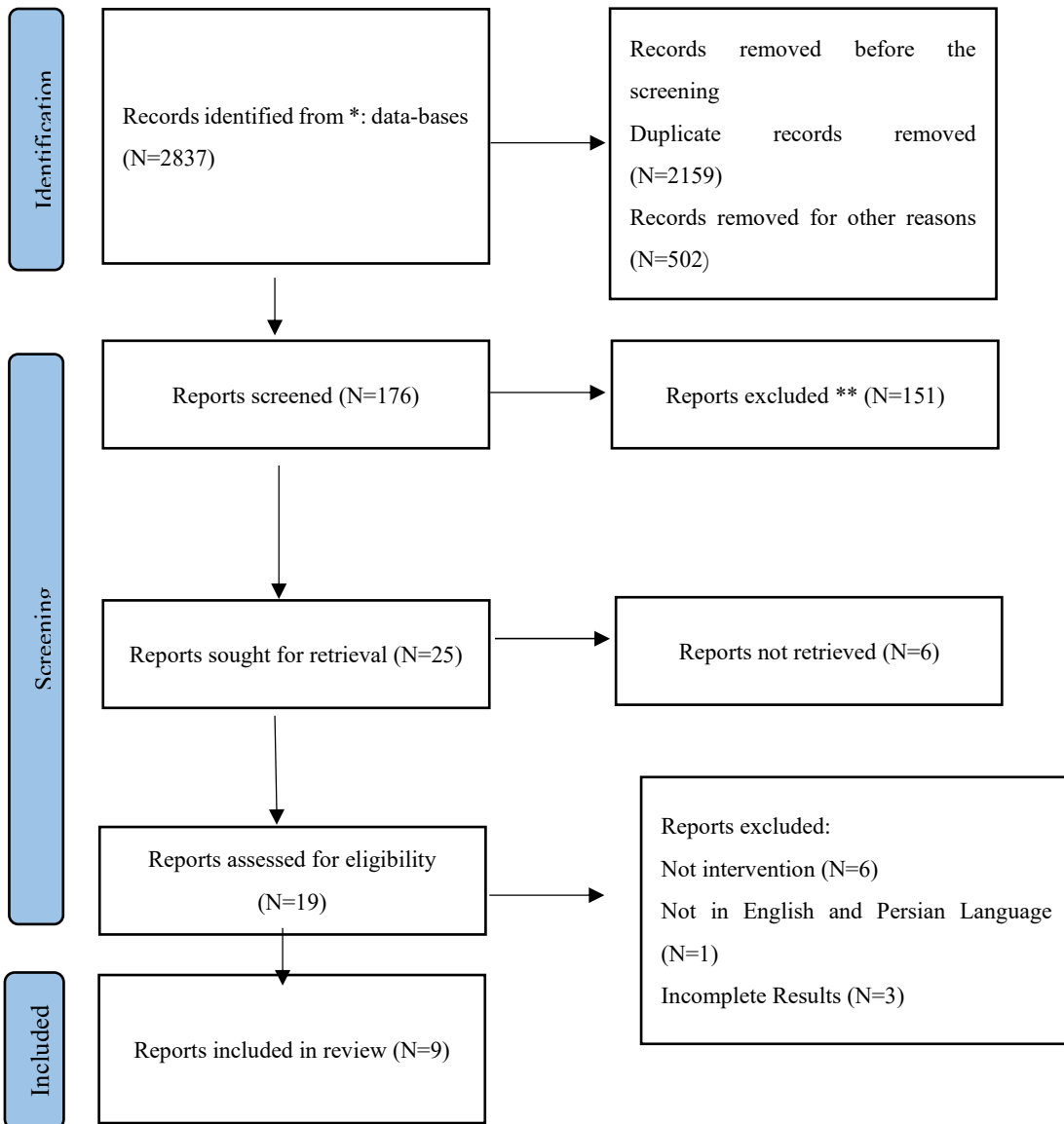


Figure 1. Flow diagram for eligible studies

**Table 2: The eligible studies characteristics**

Study	Sample size	Participants characteristics	Intervention	Outcome	Results
Hashemi et al. 2025 (Hashemi et al., 2025)	EG=15 CG=15	Female students aged 10-12 with PDS	EG= 6 weeks of corrective CG= daily activities	Balance (Y-balance), Proprioception (goniometer)	Balance↑, Proprioception ↑
Rahmani et al. 2024 (Rahmani et al., 2025)	EG=15 CG=15	Male students aged 9-11 with PDS	EG= 8 weeks of corrective games CG= daily activities	Q-angle (goniometer) and foot arch (navicular drop)	Flatfoot ↓ Q-angle ↑
Yalfani et al. 2023 (Yalfani et al., 2023)	EG= 20 CG= 20	Girls aged 7-12 with PDS	EG= 8 weeks of corrective games CG= daily activities	Balance (Y-balance), Proprioception (Goniometer) Foot arch (navicular drop)	Balance ↑, Proprioception ↑, Flatfoot ↓
Golchini et al. 2021 (A. Golchini et al., 2021)	EG=15 CG=15	Male students aged 10-16 with PDS	EG= 12 weeks Systematic Corrective Exercises CG= daily activities	balance (flamingo tests), Dynamic balance (star balance test)	Static and dynamic balance ↑
Golchini et al. 2021a (A Golchini et al., 2021)	EG=15 CG=15	Male students aged 10-16 with PDS	EG= 12 weeks Systematic Corrective Exercises CG= daily activities	Isometric strength (digital dynamometer)	Strength ↑
Golchini et al. 2020 (A Golchini & N Rahnama, 2020)	EG=15 CG=15	Male students aged 10-16 with PDS	EG= 12 weeks Systematic Corrective Exercises CG= daily activities	Postural sway	Body sway ↓ Ground reaction force ↓

Golchini et al. (Ali Golchini & Nader Rahnama, 2020)	EG=15 CG=15	Male students aged 10-16 with PDS	EG= 12 weeks Systematic Corrective Exercises CG= daily activities	Flatfoot (navicular drop), Knock-knee (caliper), Lumbar lordosis (flexible ruler)	Flat foot ↓ Knock-knee ↓ lumbar lordosis ↓
Golchini et al. (Golchini & Rahnama, 2019)	EG=15 CG=15	Male students aged 10-16 with PDS	EG= 12 weeks Systematic Corrective Exercises CG= daily activities	Proprioception (electro-goniometer)	Proprioception ↑
Najafi et al. (Najafi et al., 2018)	EG=15 CG=15	Female students aged 13-16 with PDS	EG= 8 weeks of corrective CG= daily activities	Muscle activity (EMG)	Muscle activity responsible for balance ↑

↑ significantly increased ↓ significantly decreased, EMG: Electromyography EG: Experimental group, CG: Control group

### Qualitative Data Synthesis

**The effect of therapeutic exercises on functional outcomes.** Across the reviewed studies, therapeutic and corrective exercise interventions demonstrated consistent positive effects on functional outcomes in students with PDS. Hashemi et al. (2025) showed that six weeks of corrective exercises and rope skipping improved balance and proprioception in female students (Hashemi et al., 2025). Similarly, Yalfani et al. (2023) reported that game-based corrective exercises resulted in an increased balance and proprioception (Yalfani et al., 2023). In a series of studies by Golchini et al. (2021, 2020, 2019), systematic corrective exercise programs lasting 12 weeks consistently led to meaningful improvements in static and dynamic balance (A. Golchini et al., 2021), proprioception (Golchini & Rahnama, 2019), muscle strength (A. Golchini et al., 2021), and reductions in body sway (A. Golchini & N. Rahnama, 2020). In addition, Najafi et al. (2017) found that eight weeks of corrective exercises enhanced muscle activity associated with balance control in female adolescents (Najafi et al., 2018). Overall, the qualitative synthesis of the evidence indicates that therapeutic and corrective exercise programs are effective in improving balance, proprioception, muscle activation, strength, and postural sway in children and adolescents with PDS.

**The effect of therapeutic exercises on body posture.** The reviewed studies indicate that therapeutic and corrective exercise interventions have a beneficial effect on body posture among students with PDS. Rahmani et al. (2024) and Yalfani et al. (2023) demonstrated that eight weeks of corrective games led to significant improvements in lower-limb postural alignment, including flatfoot and Q-angle (Rahmani et al., 2025; Yalfani et al., 2023). In addition, Golchini et al. (2020) found that a 12-week corrective exercise

program significantly reduced the severity of flatfoot, knock-knee, and excessive lumbar lordosis in male students aged 10–16 years (Ali Golchini & Nader Rahnama, 2020). In a nutshell, the qualitative synthesis of the evidence suggests that therapeutic exercises are effective in improving body posture and correcting common postural deformities such as flatfoot, knock-knee, and lumbar lordosis in children and adolescents with PDS.

**Table 3. Critical appraisal results of eligible systematic reviews**

	Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Overall Score
1	Hashemi et al. 2025	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	8
2	Rahmani et al. 2024	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	8
3	Yalfani et al. 2023	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	8
4	Golchini et al. 2021	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
5	Golchini et al. 2021a	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
6	Golchini et al. 2020	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
7	Golchini et al. 2020a	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
8	Golchini et al. 2019	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
9	Najafi et al. 2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	8

## Discussion

The main findings of the current review indicate that structured therapeutic and corrective exercise programs consistently improve balance, proprioception, muscle activation, strength, and postural control, while also reducing common postural deformities such as flatfoot, knee valgus, and excessive lumbar lordosis. The convergence of these findings supports the notion that targeted exercises, including systematic corrective exercises and game-based ones, address muscle imbalances (Seidi et al., 2020), joint alignment, and sensorimotor control effectively mitigate the functional deficits commonly observed in PDS (Ebrahimi, Mozafari, et al., 2025).

From a theoretical perspective, the positive effects observed in the included studies can be interpreted through the lens of kinetic chain and motor control theories. PDS is characterized by altered alignment and

muscle activation patterns throughout the lower extremity, and therapeutic exercises appear to restore more optimal force distribution and joint mechanics (Ali Golchini & Nader Rahnama, 2020; Yalfani et al., 2023). Strengthening inhibited muscles, stretching overactive structures, and retraining functional movement patterns likely enhance proprioceptive input and postural stability (Shibata, 2020), leading to improvements in balance and alignment (Ghodsinezhad et al., 2025; Shahani et al., 2024). In a broader context, these findings reinforce the importance of addressing underlying biomechanical dysfunctions rather than focusing solely on symptomatic relief, particularly during critical periods of growth and development. For instance, the activation of the posterior tibialis increases the medial longitudinal arch height, thereby reducing the medial collapse of the foot (Kamiya et al., 2012). Simultaneously, gluteus medius and maximus strengthening stabilize the hip in the frontal and transverse planes (Ebert et al., 2017), mitigating compensatory knee valgus and internal tibial rotation, which are commonly observed in PDS. Studies included in this review consistently report that after a structured exercise program, participants demonstrate improved foot posture (Rahmani et al., 2025), decreased navicular drop (Yalfani et al., 2023), and enhanced lower limb alignment (Ali Golchini & Nader Rahnama, 2020), reflecting the positive effects of targeted strengthening on musculoskeletal mechanics. In addition, stretching the overactive musculature in PDS, such as psoas, iliotibial band, and adductors, through corrective exercises, helps normalize soft tissue length and restore joint mobility, allowing proper loading patterns during stance and gait (Alam et al., 2019; Lakkadsha et al., 2022). From a biomechanical perspective, improved dorsiflexion facilitates better tibial progression over the foot during midstance, while hip abductor flexibility allows controlled pelvic stabilization (Wei et al., 2025), reducing dynamic knee valgus and associated pronation moments (Mousavi et al., 2024).

Beyond structural realignment, neuromuscular control is a critical component in managing PDS. Individuals with PDS often exhibit impaired proprioception and delayed muscle activation, which exacerbate abnormal kinematics (Yazdani et al., 2019). Therapeutic exercises, particularly those incorporating balance and proprioceptive training, enhance the sensorimotor system's ability to detect and respond to positional changes (Golchini & Rahnama, 2019; Hashemi et al., 2025). Improved proprioception leads to more efficient activation of stabilizing muscles during dynamic activities, which is crucial in controlling excessive pronation moments (Ebrahimi, Nourbakhsh, et al., 2025; Winter et al., 2022). Furthermore, integrated dynamic movement in a systematic corrective exercise program, such as Single-leg balance, Lunges, and Single-leg squat, stimulates the reflexive activation of intrinsic foot muscles and hip stabilizers, contributing to improved lower limb alignment and reduced compensatory movements (Ali Golchini & Nader Rahnama, 2020; A Golchini et al., 2021). Moreover, therapeutic exercises may exert their effects by modulating fascial tension and restoring optimal force transmission along superficial front (SFL) and back lines (SBL) (Myers, 2009). Strengthening weak muscles along the SFL improves load distribution and anterior chain stability, while stretching or myofascial release along the SBL reduces compensatory posterior pull, thereby normalizing lower limb mechanics and reducing strain across the kinetic chain (Schleip et al., 2013). This perspective highlights that PDS is not only a local foot or ankle problem but a manifestation of fascial and muscular imbalances across integrated myofascial pathways.

Despite the overall positive evidence, several limitations should be considered when interpreting the results of this review. First, the number of included studies is relatively small, and most trials involve modest sample sizes, which may limit generalizability. Generalizing findings without direct evidence may therefore lead to inappropriate clinical recommendations, suboptimal intervention design, or unintended adverse outcomes. Second, although risk of bias was assessed, some studies exhibit methodological weaknesses such as limited blinding and lack of long-term follow-up, which may influence the robustness of reported effects. These limitations suggest that the magnitude and durability of exercise-induced improvements should be interpreted with caution.

Clinically, the findings support the use of therapeutic and corrective exercise programs as first-line conservative interventions for children and adolescents with PDS. Such programs may not only improve functional performance and posture but also potentially reduce the risk of future musculoskeletal injuries associated with prolonged malalignment. Also, integrating structured corrective exercise programs into school-based physical education or preventive health initiatives may represent a cost-effective strategy for addressing postural abnormalities in youth. Future research should prioritize the design and implementation of regionally grounded studies in West Asia, with particular emphasis on children and individuals with disabilities. Given the sociocultural, environmental, educational, and healthcare differences between Western countries and West Asian societies, locally conducted research is essential to establish context-specific evidence and improve external validity. Studies that account for regional physical activity patterns, school-based exercise structures, rehabilitation accessibility, and cultural attitudes toward corrective exercise will enhance the applicability and sustainability of intervention programs.

## **Conclusion**

Therapeutic exercises are effective in managing PDS by addressing both the structural and neuromuscular contributors to excessive pronation. The systematic review provides robust evidence that multi-faceted, targeted exercise interventions result in significant improvements in foot posture, lower limb alignment, and overall functional outcomes. These findings provide a useful contribution to the field and offer a foundation for evidence-based practice and future research in the management of pronation-related disorders.

## **Declarations**

***Authors' Contribution:*** All authors contributed to the conceptualization, methodology, project administration, resources, and formal analysis. All authors helped in the investigation. All authors contributed to data curation. All authors approved the final version of the manuscript.

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***Conflicts of Interest:*** The authors have no conflicts of interest.

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