

THE VAULT IN JUNIOR FEMALE GYMNASTICS- A SYSTEMATIC REVIEW

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Abstract: The aim of our study was to conduct a literature review of research focusing on the vault event in female artistic gymnastics. This apparatus represents one of the most dynamic and technically demanding elements in gymnastics, requiring a high level of speed, explosive strength, coordination, and precise technique. Understanding the factors that contribute to successful vault performance is essential for improving training methods and enhancing gymnasts' performance and safety. **Material and Methods:** To conduct this review, we followed the PRISMA 2020 guidelines for systematic reviews, which include a structured process for identifying, screening, and selecting relevant studies. Searches were performed in several scientific databases and academic journals using keywords related to vault, gymnastics, female athletes, and training. **Results:** The exclusion criteria applied to the studies were as follows: studies in which the vault was analyzed in relation to other sports (n = 89), studies that included male athletes together with female gymnasts (n = 57), studies focusing on other age groups that were not relevant to the target population (n = 30), and studies that were not available as open access (n = 13). After the full selection process, a total of 17 studies met all the inclusion criteria and were included in the final analysis. **Conclusions:** The results of the included studies indicate that most training interventions aimed at improving vault performance focus on enhancing lower limb power, speed, and trunk endurance in gymnasts. Plyometric exercises, strength training, and specific technical drills were frequently highlighted as effective methods for improving take-off force and body control during the vault. The practical implications of this study emphasize the importance of implementing targeted and specific training programs that can optimize performance and contribute to the safe development of gymnasts' technical abilities.

Keywords: *the vault, female gymnastics, junior, training, literature review.*

Introduction

The vault is one of the key events in women's artistic gymnastics, having a significant impact on final scores and on the functional development of junior-level gymnasts. The aim of this article is to provide a systematic review of the specialized literature on the vault in junior female artistic gymnastics, focusing on technical, biomechanical, methodological, and safety aspects. The analysis highlights the importance of gradual progression in difficulty, the development of specific physical capacities, and the use of age-appropriate evaluation criteria. The results support the need for a long-term perspective in gymnast development, where performance is subordinated to health and technical stability.

Women's artistic gymnastics is recognized as one of the sports with the highest levels of technical and aesthetic complexity. The vault occupies a distinct position in competitions

due to its short execution time and maximal effort intensity. For junior gymnasts, the vault is not only a competitive event but also a fundamental tool for developing core motor abilities such as explosive strength, speed, and neuromuscular coordination (Sands et al., 2011).

Specialized literature emphasizes that performance at the senior level is strongly influenced by the quality of training during the junior period. Early introduction of incorrect technical models or excessive workloads can lead to functional limitations and increased risk of chronic injuries (Campbell et al., 2019). In this context, an in-depth analysis of existing research is necessary to inform methodological decisions in junior gymnast preparation.

The vault consists of a rapid sequence of biomechanical phases, each playing a critical role in execution success. The run-up allows the accumulation of kinetic energy, which is

subsequently converted into potential energy during the flight phase. Studies indicate that entry velocity is one of the most important predictors of vault performance (Brüggemann, 1994).

The trampoline or springboard contact involves an extremely rapid stretch-shortening cycle, demanding advanced neuromuscular capabilities. At the junior level, this phase must be carefully controlled to avoid overloading passive structures. Hand support on the vaulting table contributes to redirecting mechanical impulse, and the efficiency of this action depends on upper limb strength and scapular stability (Farana et al., 2023).

Vault training for junior gymnasts should adhere to long-term training principles. The literature recommends using technical progressions, starting with simple vaults and progressing to higher-difficulty elements only after basic execution has been stabilized (Kalinski et al., 2017).

A frequently highlighted aspect is the need to individualize training according to biological rather than chronological age. Differences in maturation can significantly influence the ability to adapt to workload and injury risk.

Explosive lower-limb strength is considered a key physical determinant for vault performance. Studies show the effectiveness of controlled-volume plyometric exercises integrated into a well-structured general training program (Bompa & Buzzichelli, 2019). Additionally, short-distance speed and intermuscular coordination play an essential role in optimizing the run-up phase.

Flexibility and joint mobility are often underestimated, yet the literature demonstrates significant correlations between movement amplitude and technical execution quality, particularly during the flight and landing phases (Sands et al., 2011).

Injuries in women's artistic gymnastics frequently occur during the junior period, when technical demands increase rapidly. The vault is associated with a higher risk of injuries to the ankles, knees, and lumbar spine (Campbell et al., 2019).

The literature emphasizes the importance of monitoring training load, limiting the number of repetitions, and using safety equipment.

Educating athletes on proper landing technique is also considered an essential preventive measure.

The FIG Code of Points for women's artistic gymnastics highlights a differentiated approach for junior levels, emphasizing correct execution and safety (FIG, 2017). Studies suggest that visual feedback and video analysis are effective tools in the learning and technical correction process (Farana et al., 2023).

Materials and Method

The review was carried out in accordance with the PRISMA statement, an updated guideline for reporting systematic reviews (Page et al., 2021). Research words used were: vault, junior, female gymnastics, training. The systematic review was conducted by analyzing literature within the domains of sports science and artistic gymnastics. Sources included empirical research studies, review articles, specialized textbooks, as detailed below:

- in the Web of Science database, the initial search generated 2230 articles, and the specific search, 125;
- in the Google Scholar database, the initial search recorded 2799 results, and when the filters were introduced, 234 articles;
- in the case of the PubMed database, the first search generated 233 articles, and then, when the narrowed search was applied, 35 articles were generated;

Thus, in total, 394 articles were identified that studied the vault in junior female gymnastics. Before our review, we eliminated 188 duplicate studies, which led to a reduction in their number to 205.

We decided to exclude 189 studies, for the following reasons:

Reason 1 – the vault was studied in relation to other sports (n=89)

Reason 2 – the vault was also studied in male athletes (n=57)

Reason 3 – the vault was used for other age groups (n=30)

Reason 4 – Studies that were not open access (n=13)

The final articles, which met all the inclusion criteria, were 17 in number and are presented, in much more detail, in Table 1. Studies were

included if they met the following criteria, namely works that address: jumping

biomechanics, training methods for young athletes, and injury prevention.

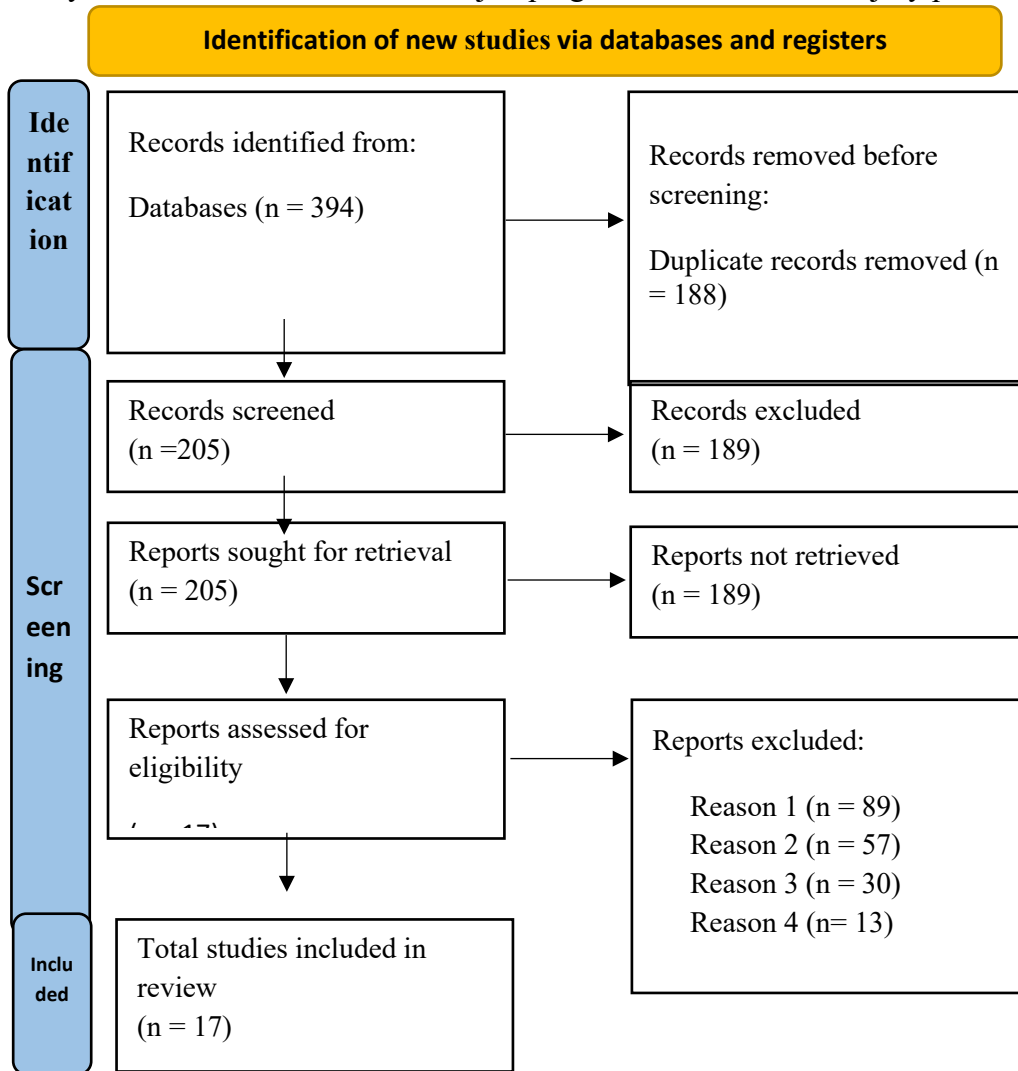


Fig.1. PRISMA flow diagram for updated systematic reviews (<http://www.prismastatement.org/PRISMAStatement/PRISMAStatement>)

Results

We selected the articles that met the selection criteria and then these were subjected to a more detailed analysis, presented in Table 1.

Table 1. *Relevant studies on the vault in junior female gymnastics*

Article	Purpose	Research Design	Results
Hall et al., 2016	This study aimed to examine the effects of incorporating plyometric training (PT) into habitual gymnastics training (HT) on performance variables associated with the handspring vault (HV).	The research was a quantitative one, including a experimental plyometric training group	The findings suggested that two additional hours of plyometric training increased the power output of muscles specific to vaulting movements, resulting in improvements in vault performance.
Fernandes et al., 2016	The aim of the present study was to critically review, organize, and systematize the most relevant kinematic variables associated with vault	Systematic review	Kinematic variables appear to be strongly dependent on the vault group and should be considered essential factors in the optimization of technical

	performance.		performance.
Kalinski et al., 2016	An analysis of major international competitions held between 2008 and 2015 revealed that a high proportion of athletes competed in vault qualifications only at events featuring Individual All-Around Finals and Individual Event Finals, specifically at the World Championships in 2009 and 2013. In contrast, at other major competitions, approximately 20% of elite gymnasts participated in vault qualification rounds.	Statistical research	In conclusion, the results suggest that both physical capacities and competitive strategies play a crucial role in vault performance at the elite level.
He et al., 2022	The purpose of this study was to examine the factors contributing to the emergence of vault as a comparatively dominant event within women's artistic gymnastics.	586 female gymnasts	The results suggest that this shift was strongly influenced by the introduction of the new vaulting table and the implementation of the open-ended scoring system.
Bradshaw & Rossignol, 2004	The aim of this study was to identify the anthropometric and physical factors that contribute to high-difficulty performance in floor tumbling and vaulting.	20 female gymnasts, aged 8–14 years	For predicting floor tumbling performance, the strongest model incorporated age, vault run-up velocity, and reduced ground contact time during the handstand push-off.
Schärer et al., 2023	The present study examined age-related differences in 33 youth female gymnasts.	Correlational study	These findings suggest that the effective translation of physical conditioning into gymnastics-specific performance, such as flight height, is highly age-dependent.
Kochanowicz et al., 2016	The purpose of this study was to examine the relationship between body strength and the competition scores awarded in gymnastics.	42 gymnasts, aged 9–11 years	In conclusion, while lower-limb power contributes to vault performance, the biomechanical factors—specifically the hip joint angle during the second flight phase and the timing of hand contact with the vault—proved to be the most critical indicators of the scores awarded in competition.
Moeskops et al., 2022	This study investigated the effects of a 10-month neuromuscular training	43 participants Experimental research	Incorporating NMT into gymnastics training enhanced various isometric and dynamic kinetic measures.
Crețu et al., 2012	In optimizing the Tsukahara vault, methodological emphasis is placed on achieving ideal flight trajectories, increasing the height and length of the second flight phase, and extending flight time.	Case study	The application of quantitative video-based technical analysis in gymnastics, particularly for junior athletes, supports a biomechanically informed approach to training. This methodology provides a scientific foundation for technical preparation, ensuring that training interventions are both objective and practically implementable.

Moeskops et al., 2021	The aim of this study was to examine young female gymnasts influence on vaulting vertical take-off velocity	120 gymnasts aged 5–14 years	Sprint speed and SLJ performance improve substantially between the early prepubertal and late prepubertal years in young female gymnasts.
Zhao et al., 2024	The present study aimed to analyze critical performance variables.	16 elite Chinese female gymnasts	Optimizing run-up rhythm and refining pedaling technique could enhance the execution of more difficult vault maneuvers in elite female gymnasts.
Bradshaw & Le Rossignol, 2002	The purpose of this study was to determine the prerequisites for each female gymnast.	20 female gymnasts	High vault run-up speed during handstand push-offs were indicative of superior floor tumbling ability.
Koh & Sujac, 2005	This study examines differences in mechanical variables during the pre-flight phase of the Yurchenko layout vault between two performance levels: a local gymnast representing Singapore at the 2003 South East Asian Games and Olympic-level gymnasts.	For the local gymnast, the mean shoulder flexion angle was greater than that reported for Olympic gymnasts, whereas the body angle of attack was smaller	Overall, the data indicate that the local gymnast’s pre-flight technique exhibits minimal similarity to that of Olympic-level performers. These empirical findings provide valuable insights into the technical requirements for higher-level Yurchenko vault execution.
Boylan et al., 2025	Injuries in artistic gymnastics often result from poorly managed acute and/or chronic biomechanical loads. This scoping review aimed to identify current biomechanical methods used to monitor training load in WAG.	Sixteen studies published over the past 15 years met the inclusion criteria. Biomechanical load was primarily assessed using force plates and/or inertial measurement units (IMUs).	A comprehensive understanding of the biomechanical loads experienced by gymnasts is critical for optimizing training prescriptions and implementing effective injury prevention strategies.
Pritchard et al., 2024	The purpose of this study was to assess the impact of skill modifications during women’s artistic gymnastics program.	Nine gymnasts (four beginner and five advanced) completed three trials of up to 24 skill progressions, each comprising a primary skill and two progressive safety modifications. Motion data were collected using mouthpiece sensors equipped with accelerometers and gyroscopes, recording at 200, 300, and 500 Hz during each skill execution. Peak-to-peak linear and rotational kinematics were calculated for contact phases, and peak rotational kinematics were determined for non-contact phases. A mixed-effects model was used to examine differences in head motion based on modification status within skill categories.	Results indicated that timer skills (drills simulating full skill performance) produced the highest median changes in linear acceleration (ΔLA) and rotational acceleration (ΔRA) across all skill categories, with 132 skill performances exceeding 10 g ΔLA during contact phases. Safety modifications were associated with significant reductions in head kinematics during contact phases of timers, floor skills, bar releases, and vault skills. These findings suggest that gymnasts are exposed to both direct and indirect head accelerations at levels comparable to those observed in other youth contact sports.
Forminte et al., 2021	This study investigated the relationship between physical preparation indicators and competition performance in junior female gymnasts aged	Six junior gymnasts, aged 13–15 years and selected from the national team of Deva, participated in this study. Physical fitness was evaluated	The analysis demonstrates strong correlations between measures of physical preparation and competition performance in junior female gymnasts,

	13–15 years.	using ten standardized fitness tests. Competition results were collected from three national competitions (C1–C3). Descriptive statistics, including mean and standard deviation, were calculated. Nonparametric tests were applied, including the Wilcoxon Signed Rank Test for paired data (Z), the Kruskal-Wallis Chi-Square test, and Spearman’s rank correlation coefficient (R) to examine relationships between variables.	highlighting the importance of targeted physical training in enhancing performance outcomes.
Bacciotti et al., 2017	This review synthesizes the existing literature on elite female gymnasts.	Systematic review.	The traits that predicted competitive success or distinguish gymnasts at different competitive levels are very important

Conclusions

The literature highlights a broad consensus regarding the critical role of the vault in the development of junior female gymnasts, while also noting several methodological debates related to the optimal timing of technical progression and the appropriate difficulty level for this age group. The vault is widely recognized as one of the most biomechanically demanding events, producing ground reaction forces that can exceed the gymnast’s body weight multiple times (Brüggemann, 1994; Moeskops et al., 2020).

A central focus in the literature is the relationship between run-up speed and vault performance. Biomechanical evidence indicates that approach velocity is a significant predictor of flight height and duration. However, at the junior level, uncontrolled increases in speed may compromise execution quality and landing safety (Hernández-Beltrán et al., 2023). Consequently, many authors recommend prioritizing technical stability over maximal velocity during training.

Training should also be adapted to the gymnast’s biological maturity. Individual differences in somatic and neuromuscular development can substantially influence the ability to tolerate plyometric loads and

repeated impacts, which are inherent to vaulting (Lloyd & Oliver, 2012). In this context, there are certain situations in which athletes are counterbalanced and neutralized in their strongest capacities, lacking sufficient natural resources to adapt to changing task demands when training requirements exceed their biological readiness (Cosma, Orțănescu, & Cosma, 2014). Consequently, several studies suggest using biological age rather than chronological age as a methodological reference for designing training programs.

The literature further underscores the link between technical difficulty and injury risk. Premature introduction of high-difficulty vaults is associated with a higher incidence of overuse injuries, particularly in the ankle and knee joints (Campbell et al., 2019; DiFiori et al., 2014). As a result, methodical progression based on technical stability and postural control is emphasized over immediate competitive demands.

Modern technologies play an increasingly important role in vault training. Two- and three-dimensional video analysis is frequently highlighted as an effective tool for evaluating biomechanical parameters and providing objective feedback (Bradshaw & Hume, 2012). Integrating these technologies into training is particularly beneficial at the junior

level, where early error correction can have long-term performance benefits.

There is also a paradigm shift in performance evaluation for junior gymnasts, moving from outcome-based assessments toward a process-oriented perspective. The FIG Code of Points reflects this trend, penalizing execution deficiencies and unstable landings, thereby encouraging the development of safe and technically correct skills (FIG, 2017). Research indicates that technical stability developed during the junior period is a strong predictor of athletic longevity (Sands et al., 2011).

Finally, the literature highlights the importance of a multidisciplinary approach to training. Effective performance and injury prevention require collaboration among coaches, strength and conditioning specialists, and sports medicine professionals (Balyi et al., 2013). In this context, the vault serves not only as a competitive element but also as an indicator of training quality.

In summary, vault training in junior female artistic gymnastics should be guided by scientific principles and integrated into a long-term development strategy. Premature progression or overemphasis on difficulty can compromise performance and increase injury risk, potentially leading to early sport dropout (Debanne & Fontayne, 2009). While competitive trends favor increasing difficulty, the literature emphasizes careful, progressive training adapted to individual athlete characteristics, particularly in the transition to high-difficulty vaults (Potop et al., 2015).

However, the current body of research is limited by the small number of longitudinal studies focusing exclusively on junior gymnasts and by methodological heterogeneity across studies, which restricts the generalizability of recommendations. Nonetheless, these findings provide a robust framework for evidence-based programming of vault training at the junior level.

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