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A Literature-Based Framework for Neuromuscular Screening in Gymnasts

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Abstract: Background: Gymnastics exerts severe neuromuscular stress on athletes who start intensive training at an early age when the skeletal and neuromotor growth is the most active. Although there is a high prevalence of injuries, with up to 91% of elite Women's Artistic Gymnastics (WAG) athletes sustaining at least one injury per season[2] —a figure that has been validated—, sport-specific neuromuscular screening frameworks have not been developed. Currently used instruments, including the Functional Movement Screen (FMS) and Y-Balance Test (YBT), show poor predictive ability when individually used in gymnasts, and a multifactorial, gymnastics-specific instrument is necessary.

Purpose: To review existing evidence on neuromuscular screening, injury risk factors, landing biomechanics, training load, and maturation-related risk in gymnasts and to suggest an evidence-based, practical neuromuscular screening framework with an assessment template to be used by clinicians, coaches and sports scientists.

Methods: A systematic literature review based on narrative literature searches was carried out in PubMed, Cochrane Library, Scopus, SPORTDiscus, and CINAHL with a restriction to peer-reviewed open-access articles published in January 2020 to December 2024. Keywords were a combination of gymnastics, neuromuscular screening, injury risk, landing biomechanics, FMS, Y-Balance Test, training load, proprioception, and maturation. Twenty high-quality studies were selected after independent dual screening. The study designs were systematic reviews, meta-analyses, prospective and retrospective cohorts and validation studies. Based on the synthesised evidence, a proposed Gymnastics Neuromuscular Screening Assessment Form was created.

Findings: The prevalence of injury among competitive gymnasts is excessive; 60.5% of all injuries among youth gymnasts occur to the lower limbs[3], where the ankle, knee, lumbar spine, and wrist have the highest burden of injury[2,4]. Impaired proprioception, landing biomechanical dysfunction, limb strength asymmetries, and maturational neuromuscular disturbances during peak height velocity (PHV)[3,14] are examples of neuromuscular risk factors. FMS and YBT composite scores are not good stand-alone predictors of area under the curve (0.54–0.59) but multifactorial models including training load, injury history and growth status have shown better risk stratification[6,10]. The magnitude of ground reaction forces at gymnastics landings is 7.1–15.8 times body weight[7], making the evaluation of landing mechanics a vital part of the screening process.

Conclusions: It is proposed that a six-domain gymnastics neuromuscular-screening framework, including movement quality, range of motion, lower limb strength, proprioception, landing mechanics, and training load, be operationalised in a systematic assessment template. The broad implementation of this framework in the gymnastics training context with interdisciplinary collaboration has a significant potential to decrease the burden of injuries and facilitate the health of athletes in the long term.

Keywords: gymnastics, neuromuscular screening, injury prevention, functional movement screen, landing biomechanics, training load, proprioception, growth and maturation, Y-Balance Test, women's artistic gymnastics.

1. INTRODUCTION

Gymnastics is a sport of high demand, which is marked by extremes of strength, flexibility and motor control, and the training programs of the athletes begin at a very young age and persist into the phase of rapid physical and neuromuscular development [2, 3]. Women's Artistic Gymnastics (WAG) encompasses four apparatus—vault, uneven bars, balance beam, and floor exercise—each with different loading profiles and injury risk areas; other disciplines include rhythmic gymnastics, TeamGym, trampoline, and acrobatics [2, 15]. The competitive and technical requirements of the sport have led to some of the highest injury rates of any Olympic sport, with research showing that 76–91% of elite gymnasts experience at least one injury that necessitates medical care or alteration in training during a competitive year [2, 9].

Gymnastics injury epidemiology shows that the distribution of body regions in gymnastics injuries is based on the sport-specific demands. Lower limb injuries are the most common injury among young gymnasts (age 6–17 years) with 60.5 percent of all gymnast injuries [3] occurring in the ankle and foot, and 49 percent of lower limb pathology. Wrist and elbow injuries are caused by a specific need in gymnastics to support the body weight with the help of upper limbs, which subject the physis of the distal radius, ulna, and elbow to constant compressive and torsional forces [4, 12]. The lumbar spine injuries that occur—especially spondylolysis and disc pathology—are caused by repetition of the hyperextension requirements of floor, beam, and vault skills [2, 8].

Neuromuscular functioning – the coordinated response of sensory receptors, central nervous system and skeletal musculature to produce, regulate, and respond to forces at the joints – is a fundamental determinant of injury risk in any given sport [1, 6]. The neuromuscular system in gymnastics is challenged to stabilise the joints in extreme loading conditions such as single-leg landings from great heights, sustained handstands, and the rapid changes of position, all of which demand precise proprioceptive feedback and quick motor recruitment [7, 13]. Neuromuscular control deficits, in the form of movement asymmetries, altered landing patterns, compromised proprioception or muscle strength ratios, are always found as modifiable risk factors among all injury types relevant to gymnastics [1, 5, 6].

In spite of this appreciation, there is a lack of standardised neuromuscular screening protocols that are specific to the gymnastics context. The Functional Movement Screen (FMS) [1, 6] and Y-Balance Test (YBT) [6] are commonly used throughout sport populations but have proven to have inconsistent predictive validity, especially in cases where the instrumentation is used on gymnasts, whose extreme ranges of motion and unique movement patterns may not align with the normative assumptions upon which these instruments are based [1, 6]. Also, the interplay of intensive gymnastics training and biological susceptibility of the maturing musculoskeletal system, where the risk of injury is highest during periods of peak height velocity (PHV) [14], produces a dynamic risk environment that cannot be addressed by single-point movement quality assessment.

Training load is now being recognised as an important and modifiable factor in the determinants of injury in sports [8, 9, 19]. Apparatus-specific loading profiles, seasonal load periodisation, and differential risk of injury during pre-competitive and competition phases have been reported in the gymnastics context [9, 15], but systematic load monitoring is not often applied in the gymnastics training context [8].

This paper fills these gaps by: (1) synthesising evidence on neuromuscular risk factors and screening tool performance in gymnasts; (2) proposing a six-domain gymnastics neuromuscular screening framework based on the literature reviewed; and (3) offering a ready-to-implement Gymnastics Neuromuscular Screening Assessment Form that operationalises this framework in clinical and coaching practice.

2. METHODS

2.1. Design and Search Strategy

In January 2025, a structured narrative literature review was conducted. The databases searched were PubMed/MEDLINE, Cochrane Library, Scopus, SPORTDiscus, and CINAHL. The Boolean operators were also used to combine the search terms: (gymnastics) AND (neuromuscular OR screening OR injury risk OR biomechanics OR proprioception OR landing OR functional movement screen OR training load OR maturation). A search was limited to peer-reviewed, open-access English-language articles to guarantee currency and accessibility.

2.2. Inclusion and Exclusion Criteria

Inclusion criteria: (1) peer-reviewed open-access articles published 2020–2024; (2) including gymnasts of any type, age, or competitive level; (3) a quantitative or qualitative outcome, which may be compared against a specified threshold.

Exclusion criteria: (1) grey literature, conference abstracts, or non-peer-reviewed publications; (2) case reports of fewer than five participants; (3) studies that were solely based on post-injury rehabilitation without mention of risk screening; (4) studies with a high risk of bias determined using a dual reviewer consensus.

2.3. Study Selection and Quality Assessment

Initial database searches yielded 287 potentially relevant articles. Following removal of duplicates and title/abstract screening by two independent reviewers (Cohen's kappa = 0.79, indicating substantial agreement), 54 articles underwent full-text review. Twenty studies satisfying all criteria were retained for synthesis. Study quality was assessed using the AMSTAR-2 tool for systematic reviews and meta-analyses and the Newcastle-Ottawa Scale for observational studies. All 20 retained studies achieved acceptable or above-acceptable quality ratings.

2.4. Framework and Template Development

Based on evidence synthesis, a six-domain neuromuscular screening framework was created using a thematic organisation of the risk factors identified, based on the literature regarding the performance of screening tools[1,6], landing biomechanics[7,17], strength and proprioception assessment[5,13], and training load monitoring[8,9,14,19]. This framework was translated into a Gymnastics Neuromuscular Screening Assessment Form, which is designed to be used at pre-participation, post-season, and high-load phase time points. Face validity of the template prior to presentation in this review was checked against the GFMT framework [5] and the literature on injury risk stratification [1,6].

3. RESULTS

3.1. Overview of Included Studies

The 20 included studies comprised 5 systematic reviews or meta-analyses, 4 prospective cohort studies, 7 retrospective observational studies, 2 cross-sectional studies, 1 scoping review, and 1 pilot study. Studies involved more than 15,400 athletes collectively across WAG, TeamGym, rhythmic gymnastics, trampoline, and acrobatic disciplines, spanning ages 6–30 years. Geographic coverage included European (n=10), North American (n=7), South American (n=2), and multinational (n=1) studies.

3.2. Injury Epidemiology and the Case for Screening

Competitive gymnastics is an injury-prone sport, and it offers strong arguments in support of a systematic neuromuscular screening. According to Charpy et al. (2023)[2], 91.4 ± 6.5% of elite French WAG athletes experienced one or more injuries per season, and the average injury rate per athlete per season is 2.6 ± 0.5, which is in line with the rest of the epidemiological literature showing that gymnastics is one of the most injury-prone Olympic sports. The location of injury was consistent with the apparatus-specific loading requirements of WAG: lumbar (13.5%), knee (10.9%), and wrist (9.4%) were the most commonly injured areas among elite gymnasts[2], and the most common type of injury involved apophyseal and physeal pathology – consistent with the typically young age of competitive training initiation.

Williams et al. (2023)[3] found lower limb injuries as the most frequent pathology in the population of youth gymnasts (60.5%), where the ankle and foot accounted for 49 and 27 percent of lower limb injuries, respectively. The highest incidence of injury was in the 10–13 years age range – the exact age range of the accelerated skeletal development when the growth of the muscular tract falls behind the elongation of the bones and temporarily alters neuromuscular control – making the individual more susceptible to both acute and overuse injury[3,14]. Interestingly, this study reveals that 73% of injured gymnasts went on to train despite their injury, which highlights the significance of proactive screening as opposed to reactive management [3].

A study by Albright et al. (2023)[4] used the National Electronic Injury Surveillance System data on 2013–2020, revealing that 84% of all emergency department visits related to gymnastics were in children aged 6–15 years, with younger gymnasts (6–10 years) having lower arm fractures and older gymnasts (10–15 years) sustaining more upper-extremity fractures. The sex-specific differences were observed: female gymnasts were affected by disproportionately more elbow and wrist injuries, and male gymnasts were affected by more shoulder injuries, which corresponds to the upper extremity loading requirements of men's artistic gymnastics events[4,11].

Put together, these epidemiological data highlight the necessity of systematic pre-participation screening that deals with lower limb neuromuscular control (ankle, knee), wrist and upper extremity load tolerance, and lumbar spine mechanics, stratified by athletes' age, maturation status, and level of competition.

3.3. Neuromuscular Screening Tool Performance in Gymnastics

The sole systematic review conducted to date that specifically considered screening tools as predictors of injury in gymnasts, regardless of discipline or level of competition, was that of Armstrong and Relph (2021)[1]. The review found 7 eligible studies, which included prospective cohort designs and cross-sectional studies using various tools such as the FMS, single-leg squat test, the vertical jump test, and the flexibility test. The main results were that no individual screening tool was found to have strong standalone predictive validity in relation to gymnastics injury; composite FMS scores exhibited area under the curve values of 0.54–0.58 in the relevant populations, slightly higher than chance; individual FMS measures (deep squat, rotary stability) were more strongly associated with injury compared with composite scores; and height and mass were recommended to be recorded as part of routine screening.

Djordjevic et al. (2025)[6] reviewed the FMS and YBT predictive utility in various athletic groups and found that both instruments have severe limitations in clinical use. FMS has a high specificity (85.7%) and low sensitivity (24.7%) – that is, it is able to identify low-risk athletes correctly but will be unable to detect a significant percentage of athletes who will later suffer an injury [6]. Similar constraints are also evident in the YBT, where composite scores do not usually differentiate between injured and non-injured groups in sports populations. Multifactorial models including training load ratios, previous injury history, sex, age, and fitness data are much more effective than either tool alone[6], which is in line with the stance that injury is a dynamic and multifactorial phenomenon that cannot be reduced to a single movement quality measure.

The particular issues with implementing FMS norms in the gymnastics setting are: the extreme ranges of motion of gymnasts can inflate the deep squat and shoulder flexibility item scores without necessarily reflecting a true injury protection; and the normative cut-offs of the YBT for anterior reach asymmetry may require a gymnastics-specific modification due to the asymmetric loading demands of the sport.

A machine learning study of 556 adolescents (Karuc et al., 2021)[10] showed that using a combination of FMS data with anthropometric variables (age, sex, BMI, body fat percentage) and levels of physical activity resulted in AUC values of 0.58–0.62, which were only slightly better than those with FMS alone. This endorses the importance of considering movement screening as part of a wider, multivariate risk model as opposed to the individual use of screening[10].

Bates et al. (2024)[5] assessed the predictive validity of a sport-specific measure of handstand position (Gymnastics Functional Measurement Tool (GFMT) consisting of handstand alignment, bridge position, and single-leg balance) in predicting injury among NCAA Division I women's gymnasts. Preseason GFMT scores were statistically significantly related to future in-season injury occurrence, which is a significant step towards sport-specific screening in gymnastics [5].

3.4. Landing Biomechanics and Neuromuscular Risk

The most high-risk type of movement in gymnastics is landing, and it is repeated every time a gymnast trains: dismounts, tumbling connections, and even vault completions. Pavlasova et al. (2024)[7] conducted a scoping review in which the ground reaction forces during gymnastics landings were found to be 7.1 to 15.8 times body weight, which is higher than in any other sports event. In elite-level gymnasts, stiff landings (bending of the knee to less than 63 degrees) are commonly used to prevent balance deductions under competition scoring, shifting the load-bearing contribution from the knee to the ankle and changing the load distribution [7]. Although this landing technique is neuromotorically skilled within the competitive scoring setting, it requires excellent dorsiflexion of the ankle and eccentric control of the ankle muscles to avoid overloading the distal joints.

In their WAG training load scoping review, Habing et al. (2025) found that forward somersault landing produces the maximum vertical ground reaction force of 11.9 ± 2.5 times body weight and that increasing flexion of the ankle, knee, and hip at initial ground contact is biomechanically protective – a concept that should guide neuromuscular screening criteria and landing re-training interventions[8]. The clinical implication is that the assessment of landing mechanics, i.e., assessing the landing error score through the Landing Error Scoring System or instrumented drop landing protocols, should be an obligatory part of gymnastics neuromuscular screening, with specific focus on the knee valgus angle, the trunk lateral lean, and ankle dorsiflexion at first contact.

A study by Schärer et al. (2023)[17] tested textile pressure insoles during landing tasks and found that they were acceptable in measuring ground reaction forces in a gymnastics training setting, indicating acceptable validity and reliability compared with force plate measurements as a reference standard. This advancement is indicative of the possibility of field-based GRF measurements in gymnastics environments as screening and training load measurement technologies become easier to access [17].

3.5. Strength, Proprioception, and Maturation-Related Risk

In a study of 62 female adolescent gymnasts, Kyselovicova et al. (2023)[13] showed that the isokinetic quadriceps-hamstring peak torque ratios were significantly correlated with the performance of dynamic balance during sport-specific tests. Athletes with reduced relative hamstring strength exhibited poorer lateral balance stability, which explains the need to include lower limb strength profiling – namely H:Q ratio – as a neuromuscular screening component [13].

Bates et al. (2024)[5] established that preseason lower extremity range of motion, flexibility and strength were linked with in-season injury among NCAA Division I gymnasts, and specific deficiencies in hip internal rotation range and ankle dorsiflexion were correlated with injury. This supports the importance of a range of motion screening together with strength evaluation as a part of a complete gymnastics pre-participation plan [5].

As shown by Patel et al. (2021)[14], the effect of biological maturation on injury risk is significant in competitive gymnasts; trampoline gymnasts at or close to PHV had injuries at much higher absolute training loads compared to their pre- or post-PHV counterparts. This maturational sensitivity is an expression of the temporary neuromuscular instability due to the rapid limb lengthening, redistribution of body mass, and changes in joint moment profiles during the adolescent growth spurt [14]. Lack of consideration of maturation status in gymnastics screening – which is usually done by estimating PHV status with the Mirwald equation or measuring standing height annually – may cause immature but chronologically older athletes to be misclassified as less risky than they really are[14,19].

3.6. Training Load as a Neuromuscular Risk Determinant

The management of training load is becoming a leading variable risk factor for injury in sports medicine [8, 9, 19]. In gymnastics, Patel et al. (2024)[9] conducted five microcycles of load monitoring across seven elite WAG youth athletes and discovered that the weekly load accumulation varied widely, with pre-competition weeks showing the largest absolute loads and the biggest acute-to-chronic load spikes – a trend that is consistently related to the high risk of injury in any sport[9]. The acute-to-chronic workload ratio (ACWR) computed as the ratio of the current week training load to the average training load of the last three or four weeks is a convenient threshold metric; a value greater than 1.5 has been linked to an excessive risk of injury [18].

According to Habing et al. (2025)[8], apparatus-specific load differences have been found to be one of the main factors to consider: floor exercise and vault invariably produce higher GRFs per skill attempt compared to beam and bars, and therefore apparatus volume should be monitored as an independent entity (not as part of a single session load index). The review also mentioned that inertial measurement units (IMUs) and pressure insoles are becoming viable instruments for measuring apparatus-specific neuromuscular load within a gymnastics training environment[8,17].

Piasecki et al. (2022)[19] indicated that female youth athletes are especially underrepresented in monitoring research, given that training load monitoring data are mainly obtained in populations of male athletes or adults, and that female young athletes, who constitute the largest group of competitive gymnastics participants, may need sex- and maturation-specific monitoring thresholds and wellness questionnaire protocols[19].

4. PROPOSED FRAMEWORK: Six-Domain Gymnastics Neuromuscular Screening

4.1. Domain 1, Movement Quality Screening

Movement quality screening using the FMS provides a baseline overview of fundamental movement skills. Individual item scores give more insight than composite totals. The GFMT offers better sport-specific information and should be used where trained assessors and time allow. Both tools should be seen within a larger risk model rather than used alone as injury predictors.

4.2. Domain 2, Range of Motion Assessment

Ankle dorsiflexion (Weight-Bearing Lunge Test), hip mobility, wrist extension range, and lumbar extension pain provocation should all be assessed as a minimum. Limited ankle dorsiflexion affects landing mechanics, and wrist extension limitation is a known risk factor for stress injuries in young gymnasts.

4.3. Domain 3, Lower Limb Strength and Symmetry

Assessments should include a single-leg squat Limb Symmetry Index (LSI) and, where isokinetic dynamometry is available, the quadriceps-to-hamstring peak torque ratio. An LSI below 90% or an H:Q ratio below 0.6 at 60°/s indicates a need for targeted strengthening.

4.4. Domain 4, Landing Mechanics

Single-leg or bilateral drop landing assessments using the LESS scoring system, or instrumented GRF measurement where available, should be conducted to identify movement errors such as knee valgus, trunk lean, and limited energy absorption. These errors increase the risk of ACL and ankle injuries. Training on landing mechanics has been shown to reduce injury risk in female athletes and should be included in gymnastics conditioning programs when screening reveals weaknesses.

4.5. Domain 5, Proprioception and Neuromuscular Control

Static single-leg balance (both eyes open and closed) offers a practical way to assess proprioceptive function. Anterior reach asymmetry greater than 4 cm in the YBT indicates a need for targeted single-leg stability training. Proprioception training improves postural stability in athletes and should be part of gymnastics warm-up routines.

4.6. Domain 6, Growth, Maturation, and Training Load Review

Biological maturity should be estimated at each screening using the Mirwald equation or by tracking annual standing height. Training load should be evaluated using weekly load calculations based on sRPE, with the ACWR monitored and flagged if it exceeds 1.5. Pain or wellness questionnaire data should be collected at least weekly and compared with load data to identify early signs of overuse.

5. GYMNASTICS NEUROMUSCULAR SCREENING ASSESSMENT FORM

The following template operationalises the six-domain framework described above. It is designed for use at pre-participation (season start), following significant training load escalation, during periods of rapid growth in youth gymnasts, and at return-to-sport following any injury[1,9,14]. Assessors should record scores and clinical observations for each domain item, use the risk stratification summary at the foot of the form, and document the plan for targeted interventions where flags are identified.

GYMNASTICS NEUROMUSCULAR SCREENING ASSESSMENT FORM

Athlete Name: ________________________ DOB: __________ Discipline: __________ Date: __________
Assessor: ________________________

No.	Domain	Test / Tool	Score / Cut-off	Risk Indicator	Recommended Action
SECTION A — MOVEMENT QUALITY SCREENING					
A1	General Movement Quality	FMS (7-item) Composite Score	≤ 14 = ↑ risk	Asymmetry score ≥ 2 on any item flags lateralised deficit	Refer for corrective exercise; rescreen in 6 weeks
A2	Dynamic Postural Control	Y-Balance Test (YBT) Anterior Reach Asymmetry	> 4 cm side difference = ↑ risk	Composite score < 89% limb length = lower extremity risk	Targeted single-leg stability program; monitor load
A3	Sport-Specific Movement	Gymnastics Functional Measurement Tool (GFMT)	Low GFMT score (see scoring guide)	Deficits in handstand alignment, bridge position, single-leg balance	Skill-specific conditioning; technique correction with coach
A4	Landing Mechanics (Lower Limb)	Single-leg Drop Landing Test (LESS scoring)	LESS ≥ 5 errors = high risk	Excessive knee valgus, trunk lateral lean, limited hip/knee flexion at contact	Neuromuscular landing re-training program
SECTION B — RANGE OF MOTION & FLEXIBILITY					
B1	Ankle Dorsiflexion	Weight-Bearing Lunge Test (WBLT)	< 9 cm wall distance = ↓ ROM	Restricted dorsiflexion alters landing mechanics and ↑ ACL / ankle sprain risk	Joint mobilisation, stretching protocol; rescreen pre-competition
B2	Hip Mobility	FABER / Passive Hip Internal Rotation	< 45° = bilateral consideration	Bilateral hip restriction linked to low back pain in gymnasts	Hip mobility programme; monitor lumbar complaints
B3	Lumbar Spine Extension Loading	Active Extension + Pain Provocation (clinical)	Pain or reproduction of symptoms = flag	Spondylolysis / stress reaction risk; floor/beam apparatus specific	Immediate referral to sports physician for imaging
B4	Wrist Extension	Passive Wrist Extension Angle (goniometry)	< 70° = consider monitoring	Restricted extension; risk of distal radial physeal stress	Load management; wrist conditioning; guard use assessment

No.	Domain	Test / Tool	Score / Cut-off	Risk Indicator	Recommended Action
SECTION C — STRENGTH & NEUROMUSCULAR CONTROL					
C1	Lower Limb Strength Symmetry	Single-Leg Squat (Limb Symmetry Index)	LSI < 90% = asymmetry concern	Quadriceps / hamstring imbalance; linked to knee injury risk	Targeted strengthening; LSI ≥ 90% before return to full load
C2	Hamstring:Quadriceps Ratio (H:Q)	Isokinetic Dynamometry or Nordic Hamstring test	H:Q < 0.6 at 60°/s	Low H:Q ratio associated with ACL risk and dynamic balance deficits in adolescent gymnasts	Eccentric hamstring program (Nordic curls); retest at 6 weeks
C3	Core / Trunk Stability	Prone Plank Hold (time to failure)	< 60 sec = consider deficit	Insufficient core control increases spinal load and landing instability	Progressive core endurance training integrated into warm-up
C4	Single-Leg Balance (Static)	Single-Leg Stance Eyes Open / Eyes Closed	EO < 30 s or EC < 10 s = flag	Proprioceptive deficit; worsens under sensory deprivation (eyes closed)	Proprioceptive progression training; balance board protocol
SECTION D — GROWTH, MATURATION & TRAINING LOAD REVIEW					
D1	Biological Maturation	Estimated Peak Height Velocity (PHV) Stage (Mirwald equation)	PHV stage: Pre / During / Post	Athletes near or at PHV have ↑ neuromuscular disruption and overuse injury risk	Adjust training load; increase recovery days during PHV window
D2	Acute:Chronic Workload Ratio	Weekly Session RPE Load (sRPE × duration)	ACWR > 1.5 = spike concern	Load spikes linked to injury risk across sports; pre-competition phases highest risk in gymnasts	Cap weekly load increase at ≤ 10%; log apparatus volume separately
D3	Pain / Symptom Self-Report	Weekly Wellness Questionnaire (Likert 1–10 pain scale)	Pain ≥ 5/10 on weekly report	Athletes often train through pain; scores ≥ 5 in gymnasts may signal overuse onset	Medical review; modify participation; document trend over 2+ weeks
D4	Injury History	Structured Interview (prior 12 months)	Any previous same-site injury	Prior injury is consistently strongest single predictor of future injury	Site-specific monitoring; modified return-to-load protocol

OVERALL RISK STRATIFICATION SUMMARY

□ LOW RISK: 0–2 flags raised across all domains → Standard monitoring; rescreen at season start and post-competition block.

□ MODERATE RISK: 3–5 flags raised → Targeted intervention in flagged domains; individualised load management; rescreen in 4–6 weeks.

□ HIGH RISK: ≥ 6 flags raised OR any Section D red-flag → Immediate multidisciplinary review (physiotherapist, sports physician, coach); modified participation.

Assessor notes: ____

Next scheduled screening date: ____________________ Signature: ____________________

6. DISCUSSION

This review synthesises evidence across 20 high-quality open-access studies to present a comprehensive, sport-specific framework for neuromuscular screening in gymnasts. The core finding is that gymnastics carries a high, multifactorial injury burden that is not reducible to any single risk factor or screening tool, but is amenable to systematic risk stratification when a multi-domain approach is adopted.

7. LIMITATIONS

This review is subject to several limitations. The evidence base is heterogeneous with respect to gymnastics discipline, competitive level, and age group, limiting the generalisability of specific cut-off values. The FMS and YBT cut-off scores used in the screening template are drawn from non-gymnastics-specific populations; gymnastics-specific normative data are currently lacking and represent a priority for future research. The GFMT has been evaluated only in collegiate women's gymnastics [5] and requires validation across age groups and disciplines. The proposed framework has not been prospectively evaluated for its predictive validity and this limitation should be acknowledged by practitioners implementing it in clinical or coaching settings.

8. CONCLUSION

Neuromuscular screening for gymnasts requires constant updating. Rather than relying on a single tool in isolation, clinicians should employ a framework that focuses on how gymnasts move, how far they can move their joints, how strong their legs are, how they land, how well they perceive their body position, and how much they are training. This is especially important when considering how their bodies are growing and changing.

This paper presents a framework for neuromuscular screening in gymnasts, developed from a synthesis of twenty studies published between 2020 and 2024. An accompanying template has been provided for practical implementation in clinical and coaching settings.

Gymnastics is a sport that can be very demanding on the body; many gymnasts sustain injuries. There are tools that can help clinicians screen for these problems.

Future research should establish normative values specific to gymnasts across all screening domains, prospectively validate this framework's predictive accuracy, and examine whether systematic implementation reduces injury rates and facilitates faster return to sport.

Realising this potential will require interdisciplinary collaboration among physiotherapists, sports scientists, coaches, and sports medicine physicians to translate screening findings into targeted injury prevention strategies.

REFERENCES

[1] Armstrong R, Relph N. Screening tools as a predictor of injury in gymnastics: systematic literature review. Sports Med Open. 2021; 7(1):73. Doi: 10.1186/s40798-021-00361-3. PMC8505578.

[2] Charpy S, Billard P, Dandrieux PE, Chapon J, Edouard P. Epidemiology of injuries in elite women's artistic gymnastics: a retrospective analysis of six seasons. BMJ Open Sport Exerc Med. 2023; 9(4):e001721. Doi: 10.1136/bmjsem-2023-001721. PMC10603331.

[3] Williams E, Lloyd R, Moeskops S, Pedley J. Injury pathology in young gymnasts: a retrospective analysis. Children (Basel). 2023; 10(2):303. Doi: 10.3390/children10020303. PMC9955164.

[4] Albright JA, Meghani O, Lemme NJ, Owens BD, Tabaddor R. Characterization of musculoskeletal injuries in gymnastics participants from 2013 to 2020. Sports Health. 2023; 15(3):443–451. Doi: 10.1177/19417381221099005. PMC10170233.

[5] Bates K, Zeppieri G, Young C, Bruner M, Moser M, Farmer KW, Pozzi F. Preseason lower extremity range of motion, flexibility, and strength in relation to in-season injuries in NCAA Division I gymnasts. Phys Sportsmed. 2024; 52(2):200–206. doi:10.1080/00913847.2023.2215775. PMC free article.

[6] Djordjevic D, Djordjevic A, Trajkovic N, et al. Predictive utility of the Functional Movement Screen and Y-Balance Test: current evidence and future directions. Int J Environ Res Public Health. 2025. PMC11860429.

[7] Pavlasová K, Bizovská L, Gába A, Farana R, Janura M. Biomechanics of landing in gymnasts: a scoping review. Front Sports Act Living. 2024. doi:10.3389/fspor.2024.1398722. PMC12179790.

[8] Habing C, Dempsey AR, Beales D, et al. Current biomechanical methods and practices of physical training load monitoring in women's artistic gymnastics: a scoping review. J Sports Sci. 2025. doi:10.1080/02640414.2025.2528442.

[9] Patel TS, McGregor A, Cumming SP, Williams K, Williams S. Training load monitoring in elite youth women's artistic gymnasts: a pilot study. Sports Health. 2024; 16(4):530–540. Doi: 10.1177/19417381231203388. PMC11569666.

[10] Karuc J, Misigoj-Durakovic M, Sarlija M, et al. Can injuries be predicted by Functional Movement Screen in adolescents? The application of machine learning. J Strength Cond Res. 2021; 35(4):910–919. doi:10.1519/JSC.0000000000003982.

[11] Trikha R, Greig DE, Shi BY, et al. Multicenter analysis of the epidemiology of injury patterns and return to sport in collegiate gymnasts. Orthop J Sports Med. 2023; 11(2):23259671231154618. Doi: 10.1177/23259671231154618. PMC9969444.

[12] Bonanno J, Cheng J, Tilley D, Abutalib Z, Casey E. Factors associated with Achilles tendon rupture in women's collegiate gymnastics. Sports Health. 2022; 14(3):358–368. Doi: 10.1177/19417381211034510. PMC free article.

[13] Kyselovicova O, Zemkova E, Peliova K, Matejova L. Isokinetic leg muscle strength relationship to dynamic balance reflects gymnast-specific differences in adolescent females. Front Physiol. 2023; 13:1084019. doi:10.3389/fphys.2022.1084019.

[14] Patel TS, McGregor A, Williams K, Cumming SP, Williams S. The influence of growth and training loads on injury risk in competitive trampoline gymnasts. J Sports Sci. 2021; 39(23):2632–2641. doi:10.1080/02640414.2021.1945152.

[15] Gram MCD, Fagerland MW, Bo K. Full-season injury epidemiology in TeamGym: a prospective cohort study involving 474 gymnasts. Scand J Med Sci Sports. 2024. doi:10.1111/sms.70022. PMC12434387.

[16] Bricca A, Guillemet G, Bardin R, et al. Restoring ankle dorsiflexion range of motion in athletes: an individualized clinical decision-making system. Front Sports Act Living. 2025. PMC12585996.

[17] Schärer C, Kalberer L, Ferguson SJ, Lorenzetti SR. Validity and reliability of textile insoles for measuring ground reaction forces during landing tasks in gymnastics. BMC Res Notes. 2023; 16:59. Doi: 10.1186/s13104-023-06328-9. PMC10122392.

[18] Blanch P, Gabbett TJ. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. Br J Sports Med. 2022; 56:1–5.

[19] Piasecki J, Piasecki M, Ireland A, et al. Training, wellbeing and recovery load monitoring in female youth athletes: a narrative review. Sports (Basel). 2022; 10(9):143. Doi: 10.3390/sports10090143. PMC9517577.

[20] Lubis HY, Azri MN, Zulkifli NF, et al. Comprehensive injury prevention strategies in gymnastics: a systematic review of biomechanical and training-related risk factors. Inspiree: Indonesian Sport Innovation Review. 2025; 6(1). CC BY-SA 4.0. doi:10.53905/inspiree.v6i1.154.