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Prevalence of Musculoskeletal Pain in Artistic Gymnasts

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Abstract

Background: Artistic gymnastics involves repetitive high-impact movements and complex acrobatics that place substantial mechanical load on the musculoskeletal system. These stresses often result in chronic pain and instability, especially in athletes with long-term training exposure.

Aim: The aim of this study was to determine the prevalence, distribution, and characteristics of musculoskeletal pain among artistic gymnasts, and to assess the influence of training duration, intensity, and landing mechanics on chronic pain and joint instability.

Methods: A cross-sectional study was conducted among 60 artistic gymnasts aged 18 to 25 years, each with a minimum of five years of experience and training more than four hours per day. A structured questionnaire was used to collect information on pain location, type, duration, severity, landing technique, instability during landings, and activity-related aggravation. Descriptive statistics were applied to evaluate prevalence patterns and associated factors.

Results: Musculoskeletal pain was highly prevalent, with the lower back (58.3%), ankle (51.7%), and shoulder (40%) being the most frequently affected regions. More than half of the participants (53.3%) reported chronic pain lasting longer than three months, and the mean pain intensity score was 6.33, indicating moderate to severe discomfort. High-impact movements, including tumbling, jumps, and landings, were the most common aggravating activities. Half of the gymnasts landed either on their toes or flat-footed, and 52.5% described their landings as heavy or uncontrolled. A total of 51.7% reported instability, rolling, or twisting during landings, commonly linked to ankle and lower-limb weakness.

Conclusion: Musculoskeletal pain is widespread among artistic gymnasts and is strongly associated with repetitive loading, inadequate shock absorption, and neuromuscular instability during landings. Lower-back strain and ankle instability are the most prominent concerns. Improving landing biomechanics, strengthening the lower limbs and core muscles, and implementing adequate recovery strategies may reduce chronic pain and enhance long-term performance.

Keywords: Musculoskeletal Pain, Artistic Gymnastics, Landing Mechanics, Ankle Instability, Overuse Injury, Training Load.

Introduction

Artistic gymnastics is regarded as one of the most physically demanding Olympic sports because it requires a unique combination of strength, flexibility, balance, agility, and endurance. Athletes are expected to perform highly technical acrobatic elements and complex movement sequences that push the limits of human physical capability. Among all artistic gymnasts events, the vault and floor exercises place the greatest physical load on the body. Vaulting demands explosive speed and controlled landings, while floor routines involve repeated tumbling passes, jumps, and expressive movement patterns performed to music[1].

Gymnasts often begin structured training at an early age—typically between five and six years—and continue practicing for several hours each day over many years to achieve high-level proficiency. Although such long-term and intensive training supports elite skill acquisition, it also places continuous strain on the musculoskeletal system[2]. Consequently, artistic gymnastics is consistently identified as a sport with elevated rates of injury and chronic pain, largely due to repetitive loading, high-impact landings, and insufficient recovery time[3,4]. Research further indicates that early sport specialization, continuous repetition of high-difficulty skills, and inadequate rest contribute significantly to overuse injuries in this population[5].

The floor exercise is frequently cited as the event with the highest injury risk, followed by the vault, primarily due to the repeated high-impact landings they involve[8]. Dallas and Dallas (2016) demonstrated that ankle sprains can impair proprioception and postural stability, leading to persistent balance deficits and altered landing patterns[7].

Musculoskeletal pain not associated with acute trauma is also widespread among gymnasts. Such pain typically develops due to repetitive microtrauma, continuous mechanical stress, and inadequate recovery. Farì et al. (2021) reported that 82.3% of gymnasts experienced musculoskeletal pain, most commonly affecting the wrist, shoulder, hip, and knee[2]. Similarly, Charpy et al. (2023) found that 91.4% of elite female gymnasts sustained at least one injury per season, with more than half being gradual in onset[4]. Miletić et al. (2023) further identified the ankle, knee, and lower back as the predominant pain sites among young gymnasts[5]. Collectively, these findings highlight that pain and injury in gymnastics often exist on a continuum, gradually progressing from mild discomfort to long-standing dysfunction when not addressed appropriately.

Female gymnasts are particularly prone to lower-limb injuries due to reliance on lower-body strength and comparatively limited upper-body conditioning, which may result in asymmetrical loading patterns[4]. External contributors include excessive training volume, hard training surfaces, technical errors, and insufficient recovery[9]. Mechanical instability—especially in the ankle joint—has a critical role in recurrent pain and diminished performance. Panjabi (1992) described mechanical instability as the loss of normal joint control, which can cause excessive rolling or gliding movements, such as increased talar displacement in the ankle[9].

Chronic musculoskeletal pain has significant implications for performance. Persistent discomfort can impair landing control, affect concentration, and reduce training efficiency. Dallas and Dallas (2016) reported that gymnasts with a history of ankle sprains show delayed reaction times and altered proprioceptive feedback[7]. These functional impairments not only increase the risk of reinjury but also hinder precision and execution quality. Psychological factors including anxiety, fear of reinjury, and pain-related worry—have also been shown to intensify pain perception and obstruct recovery[6].

Understanding the prevalence of musculoskeletal pain and its underlying biomechanical contributors, such as landing strategies, is essential for identifying modifiable risk factors. This knowledge is vital for developing effective injury-prevention strategies and supporting athletes' long-term health and performance.

Therefore, the present study aims to determine the prevalence of musculoskeletal pain among artistic gymnasts, identify the most commonly affected body regions, and explore how landing mechanics influence musculoskeletal discomfort. By establishing the burden and determinants of pain in this population, the study seeks to inform preventive strategies, optimize performance, and promote long-term athlete well-being.

Need of study

Despite the high physical demands of the sport, limited research has examined the prevalence and patterns of ongoing musculoskeletal pain related to landing techniques and training exposure.

Identifying the relationship between pain, training exposure, and landing mechanics can provide valuable insights which joint and structure is majorly involved in Indian population of artistic gymnasts so that to guide them for injury prevention.

Methodology

1. Study design: Cross- sectional study
2. Study setup: Gymnastic academies
3. Target population: Artistic gymnast between age 18 to 25 years
4. Sample size: 60
5. Sampling method: convenient sampling

Inclusion criteria:

1. Both genders.
2. Age: 18-25 years
3. Only vault and floor event.
4. Minimum 5 years of experience.
5. Practice time more than 4 hours.
6. Training session more than 4 days per week.

Exclusion criteria:

1. Recent musculoskeletal injury.
2. Any neurological deficit.

Procedure

1. Permission was taken from the gymnastic academies.
2. Consent from the players was taken.
3. Different centers were approached and permission was be obtained prior to the study.
4. The questionnaire focuses on various components of injury and pain.
5. The data was evaluated using appropriate software and appropriate result were obtained.

Results

Variable / Parameter	Key Finding	Interpretation Summary
Gender Distribution	58.3% male, 41.7% female	Male gymnasts were the majority, possibly due to greater availability or participation.
BMI	Mean = 20.5 kg/m²	Most gymnasts had a healthy, lean physique suitable for performance.

Training Profile	Avg. 9 years; 7 hrs/day, 6 days/week	Intense, long-term training contributes to chronic strain.
Most Affected Body Regions	Lower back (58.3%), ankle (51.7%), shoulder (40%)	Lower limbs and spine are the most common pain sites.
Pain Duration	53.3% chronic (>3 months)	Pain is mainly long-term and overuse-related.
Pain Intensity	Mean = 6.33 (moderate–severe)	Indicates substantial functional pain burden.
Type of Pain	Dull ache (33.3%), clicking and popping sensation (50%)	Suggests chronic repetitive strain rather than acute trauma.
Common Movements Causing Pain	Tumbling, landing, jumping	High-impact skills generate significant stress.
Back Injury Type	80% muscle strain	Result of repetitive hyperextension and poor recovery.
Hip/Knee Injury Type	38.9% ligament injury	Repetitive loading causes joint instability.
Landing Technique	50% land on toes; 43.3% flat-footed	Both patterns increase stress on lower limbs.
Landing Control	52.5% heavy or hard	Poor shock absorption linked to pain and instability.
Instability During Landing	51.7% experience instability	Suggests weak neuromuscular control and ankle weakness.
Post-Landing Imbalance	43.3% stumble or take few steps to regain control	Indicates compromised postural control.
Main Causes of Imbalance	Weak ankle, foot and lower leg muscles (48.3%)	Strength and proprioceptive deficits are key risk factors.
Least Stable Body Part	Ankle (45%)	Confirms ankle instability as a major issue.
Use of Supportive Gear	76.7% do not use	Most gymnasts rely on physical conditioning.
Training Modifications	21.7% modified or reduced training	Pain impacts training intensity and performance.

Discussion

This study found that musculoskeletal pain is highly common among artistic gymnasts, with the lower back and ankle emerging as the most frequently affected areas. The athletes in this study trained for long durations over nine years on average and approximately seven hours per day which greatly increases cumulative mechanical stress on the body and contributes to the gradual onset of chronic overuse pain. Several intrinsic factors, including joint laxity, muscle imbalance, rapid growth, and previous injuries, further elevate the risk of persistent discomfort[6]. Most athletes reported their pain as chronic and moderate to severe, often lasting months or years, which is consistent with observations made by Caine and Nassar[10] and Farì et al.[2]. Overall, these findings highlight the importance of early monitoring, adequate recovery, and targeted preventive strategies to reduce the long-term impact of musculoskeletal pain in artistic gymnasts

Lower-Back Pain

Most gymnasts in this study described their back pain as a dull, aching sensation that worsened during or after repetitive tumbling and back-extension movements. This type of pain is often associated with muscle strain, fatigue, and postural overload rather than acute vertebral injury. Several athletes noted that the discomfort appeared gradually over years of continuous training, particularly after intense tumbling sessions, where repeated take-offs and landings create strong axial and shear forces. The pain was typically moderate to severe, increasing during competition or periods of increased workload. Such findings align with the chronic muscular fatigue and spinal micro-instability described in earlier studies[3,9,10].

Campbell et al.[3] and Horvat et al.[1] reported similar results, emphasizing that repetitive hyperextension, poor trunk stabilization, and insufficient recovery contribute significantly to lumbar discomfort in gymnasts. Caine and Nassar[10] observed that spinal overuse injuries account for nearly one-third of all reported gymnastics injuries, often developing slowly due to repetitive loading and inadequate rest. From a biomechanical perspective, tumbling and dismounts produce ground-reaction forces up to 15 times the gymnast's body weight, which are transmitted vertically through the lower limbs and into the spine[13,17].

When gymnasts land with minimal hip or knee flexion, shock absorption decreases, transferring excessive compressive force to the lumbar spine[9]. Bradshaw and Hume[13] demonstrated that limited joint flexion angles during landings increase vertical loading rates, leading to cumulative spinal stress and chronic pain development.

According to Panjabi's model[9], spinal stability depends on three interacting subsystems: passive (ligaments and bones), active (muscles), and neural control. In gymnasts, fatigue or imbalance in any of these subsystems leads to micro-instability, causing recurrent dull aching pain.

Overuse of the lumbar extensors combined with poor endurance of the core stabilizers disrupts this stabilizing mechanism, explaining the persistent nature of pain observed in this study. The repetitive tumbling movements performed over years of training likely contribute to muscle fatigue, soft tissue strain, and chronic moderate-to-severe pain intensity.

These findings highlight the importance of adequate recovery time, progressive training loads, and movement-control retraining to prevent chronic low-back syndromes.

Ankle Instability and Landing Mechanics

The ankle joint was the second most commonly affected region. Gymnasts frequently reported instability and weakness in the ankle–knee–foot complex, with instability most noticeable immediately after heavy landings.

Many athletes described a sensation of "giving way" or needing to take a few steps forward to regain balance following landing. This instability was particularly evident after hard and heavy landings, which gymnasts described as toe-dominant, limiting heel contact and increasing forefoot stress. These descriptions are consistent with chronic ankle instability (CAI) and fatigue-related weakness[7,8,13].

Because these gymnasts practice intensively for more than 9 years, averaging 7 hours per day and 6 days per week, the stabilizing muscles and ligaments of the ankle are repeatedly exposed to high-impact loads with insufficient recovery.

Dallas and Dallas[7] and Devasthali and Sonwane[8] emphasized that repeated toe-dominant landings result in excessive plantar-flexor strain and anterior shear forces that weaken joint stability. Bradshaw and

Hume[13] also demonstrated that limited knee and hip flexion during landings amplify ground-reaction forces, predisposing the ankle to instability and overuse pain.

In this study, the post-landing instability often described as stumbling or stepping forward appears related to neuromuscular fatigue and proprioceptive deficits. This finding is supported by Caine and Nassar[10] and Kolt and Kirkby[11], who linked repetitive high-impact training to desensitization of ankle mechanoreceptors and delayed reflex responses.

The pain experienced was described as moderate to severe, with chronic episodes persisting despite continued training.Such persistence may reflect adaptation to ongoing instability and insufficient rehabilitation.

Bradshaw and Hume[13] recommend softer, more balanced landings with both heel and forefoot contact to improve shock absorption and stability.

The co-occurrence of chronic, moderate-to-severe lower-back and ankle pain underscores the interrelationship between spinal stability and lower-limb control. Reduced ankle stability and heavy, hard landings increase ground-reaction forces that travel up the kinetic chain, loading the spine excessively. Conversely, poor core endurance and back fatigue compromise postural alignment, reducing lower-limb control during landing[13,15].

Limitation of study

This study employed a cross-sectional design using self-reported questionnaires, which may introduce recall bias and subjective assessment of pain intensity. The relatively small sample size (n = 60) limits the generalizability of the findings to all artistic gymnasts. No imaging or biomechanical assessments (e.g., motion capture, force-plate analysis) were performed to confirm the causes of pain or instability. Additionally, the study did not differentiate between acute and chronic pain episodes. Future studies should address these limitations by incorporating objective evaluations and larger, more diverse samples.

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