

EPIDEMIOLOGY OF INJURIES AND ASSOCIATED RISK FACTORS IN ATHLETES PARTICIPATING IN 2022 AEROBIC GYMNASTICS WORLD CHAMPIONSHIP

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Abstract

Exercise is described as a preventive and therapeutic strategy against various diseases. However, competitive sports practice is associated with an increased risk of injuries, particularly with specialization and more intense training at younger ages. Given the importance of surveillance and epidemiological studies to protect athletes' health, our study aimed to describe the prevalence of injuries among athletes at the 2022 Aerobic Gymnastics World Championship (WCH) and to understand the intrinsic and extrinsic risk factors that may contribute to these injuries. Athletes participating in WCH 2022 were invited to complete a retrospective injury questionnaire covering the past 12 months of their training schedule. Descriptive statistic data were used to analyze all variables in the study. Seventy-three percent of athletes reported sustaining injuries, with an average of 1.6 ± 1.5 injuries occurring one to three times in the past year. The most common injuries were muscle injuries, joint sprains, stress fractures, and contusions, with the lower limbs being the most affected, followed by the upper body and trunk. Regarding injury risk factors, a significant number of athletes reported experiencing psychological stress ($p=0.043$) and concerns about individual protection equipment ($p=0.042$). Given that the type of injury and affected body region seem to be related to sports-specific movements, the impact absorption of the floor and footwear should be studied further. Additionally, injury prevention measures should include coping strategies to manage stress effectively.

Keywords: sport; traumatology; competition; elite.

INTRODUCTION

According to the "Extreme Exercise Hypothesis," increasing exercise volume leads to a curvilinear decrease in health risks, with the benefits being partially lost when exercise exceeds the optimal dose (Eijssvogels, Thompson, and Franklin 2018). However, this theory was recently

challenged by Runacres et al. (2021), who demonstrated that athletes tend to live longer and have a reduced incidence of cardiovascular and cancer mortality compared to the general population. While athletes' health outcomes and life expectancy are not compromised by training

volume and intensity, the increased exposure time during practice and competition does lead to a higher occurrence of injuries (Caparrós et al. 2016).

Among top-level athletes, injuries not only hinder sports performance but are also recognized as a risk factor for psychological distress (Haugen 2022) and are a major cause of premature career termination (Arundale, Silvers-Granelli, and Snyder-Mackler 2018; Ristolainen et al. 2012). Moreover, some athletes do not fully recover after an injury, which can lead to repeated trauma in the same area and, subsequently, a more severe condition (Bitchell et al. 2020). In gymnastics, acute injuries tend to increase with the risk and challenges of the exercises, while chronic injuries are often associated with skill level development and increased workout load (Meeusen and Borms 1992).

Studies on intrinsic factors in aerobic gymnastics (AER) report that height, weight, and age are associated with an increased risk of injury, while performance level and sport equipment (such as the floor) are suggested as important extrinsic factors (Caine and Nassar 2005). The first epidemiological study in Aerobic Gymnastics (AG) was conducted by Navarro et al. (2003), followed by the study of Fetterplace (2004). Fetterplace found 61 injuries among senior gymnasts participating in the Federation of International Sports, Aerobics, and Fitness competition, with the lower limbs being the most affected (52.4%), particularly the ankle/foot (29.5%), wrist (13.1%), and lower part of the thigh (13.1%). Later, Navarro et al. (2004) showed that muscle injuries are the most frequent, followed by joint and bone tissue injuries. Regarding risk factors, Navarro et al. (2005) reported a high percentage of injuries (88%) among athletes who did not use adequate floor, particularly during jumps and jumps involving falls with bracing arms and splits. Although protective materials may reduce the occurrence of these injuries, Abalo and Gutiérrez (2009) found that their use is not very popular among AG athletes. In line with the International Olympic Committee's (2020) stance that

injury epidemiological studies are essential for protecting athletes, collected data provide the basis for developing injury prevention programs. Based on this concern, international federations and research centers have applied injury surveillance in major events (for references, see Soligard et al. 2017). However, to the best of our knowledge, only one study has addressed this issue in adult world top-level AG athletes (Fetterplace 2004).

Therefore, we aimed to describe the prevalence of injuries among athletes at the 2022 Aerobic Gymnastics World Championship (WCH) and to understand the related intrinsic and extrinsic risk factors. This information will be an important tool for developing specific injury prevention plans and programs for this sport. Based on previous studies, we hypothesize that top-level aerobic gymnastics athletes will report a large number of acute and chronic injuries in the lower extremities (Fetterplace 2004), particularly affecting muscle tissue (Navarro et al. 2004), due to factors such as anthropometrics, age, floor characteristics, and protection equipment (Caine and Nassar 2005; Navarro et al. 2005).

METHODS

All male and female gymnasts who participated in the 2022 Aerobic Gymnastics World Championship were eligible to complete the survey. Out of a total of 259 athletes from 32 countries, 189 agreed to answer the questionnaire. Therefore, sample selection was performed through an auto-selection method. Participants were excluded if they were under 18 years old at the time of the competition or did not confirm their informed consent. The inclusion criteria defined athletes who participated in the 2022 Aerobic Gymnastics World Championship.

The cross-sectional research design was previously approved by the Anti-Doping, Medical, and Mental Health Commission of the Fédération Internationale de Gymnastique (FIG). An email was sent to all

delegations one month before the competition, outlining the research aims and procedures. The injury questionnaire and data collection process were structured based on retrospective designs for Sports Injury Surveillance Studies (Mukherjee 2015) and previous studies (Fuller et al. 2006; International Olympic Committee Injury and Illness Epidemiology Consensus Group et al. 2020; Prieto-González et al. 2021).

The instrument comprised 29 close-ended and open-ended questions, available in three languages (Portuguese, Spanish, and English), and was divided into three sections:

1. *Sample data:* This section included questions about age, sex, body weight, and height.
2. *Injury-related intrinsic and extrinsic risk factors:* This section focused on sport-specific data, such as aerobic gymnastics experience (years), training sessions per week, number of competitions, categories, and various questions related to training and competition risk factors.
3. *Injury characterization:* Athletes who reported injuries continued to answer questions about the number and type of injuries suffered in the last 12 months, the body region affected, and the mechanism of injury (e.g., acute/chronic, during training/competition, alone/collision).

Athletes' responses were collected using Survio Software, accessible on various electronic devices (tablets, computers, and phones). All data was anonymous and confidential, and Survio Software adheres to privacy protection regulations, as detailed at <https://www.survio.com/en/privacy-policy>. During the data collection process, research team members were present to ensure the completeness and accuracy of all fields, to clarify any doubts, and to enhance participation rates and the validity of responses (Mukherjee 2015). Additionally,

the questionnaires were administered during training sessions at the sport event facilities, after podium training, to avoid psychological stress related to the competition.

The sample size was calculated with a 5% margin of error and a 99% confidence interval from a population of 314 athletes, establishing a minimum required size of 187 subjects. Descriptive statistical analysis was conducted for all study variables using SPSS software (version 28.0). The dependent variables included injury characteristics (e.g., number, type, body part affected, mechanisms) during the 2021-2022 season, while the independent variables encompassed sample data (age and sex) and internal and external risk factors (e.g., training experience, safety equipment, training equipment and facilities, nutrition, stress). Data were organized and presented in frequency distributions, and Pearson's correlation was performed to test the relationships between risk factors and the presence or absence of injuries.

RESULTS

A total of 189 athletes from the World Aerobic Gymnastics Championship (WCH) completed the questionnaire and met all inclusion criteria. The respondents were predominantly female (n=139), with average age of 21.2 years as seen in Table 1.

Sport-specific data (Table 2) show that aerobic gymnasts typically begin their practice between the ages of 6 and 13 years. On average, their training schedules include six sessions per week, each lasting approximately three hours, totaling about 17.9 to 16.5 hours per week. During the 2022 competition season, these athletes participated in an average of six competitions and competed in more than one category (2.6 ± 1.1 and 2.6 ± 1.3 categories, respectively).

Table 1.

Characterization of 2022 Aerobic Gymnastics WCH athletes (n=189)

| Parameters | |
|------------------------|-------------|
| Sex % (n) | |
| Female | 73.5% (139) |
| Male | 26.5 % (50) |
| Age, years (Mean ± SD) | 21.2 ± 4.1 |
| Height, cm (Mean ± SD) | 165.6 ± 8.2 |
| Weight, Kg (Mean ± SD) | 59.1 ± 8.6 |

Table 2.

Injury risk-factors reported by injured or not-injured athletes that participated in the 2022 Aerobic Gymnastics WCH

| Risk Factors | Athletes with Injuries (Mean ± SD) | | Athletes without Injuries (Mean ± SD) | |
|------------------------------------|---------------------------------------|------------|--|-----------|
| | Yes, % (N) | No, % (N) | Yes, % (N) | No, % (N) |
| Years of AG practice | 11.1 ± 5.2 | | 12.3 ± 4.9 | |
| Age of time of specialization | 9.9 ± 3.9 | | 8.4 ± 3.5 | |
| Frequency (n ^o /week) | 5.9 ± 1.7 | | 6.3 ± 2.2 | |
| Duration (hours/week) | 17.9 ± 10.4 | | 16.5 ± 5.3 | |
| Competitions (2022 season) | 6.2 ± 2.9 | | 5.9 ± 2,5 | |
| Number Categories (2022 season) | 2.6 ± 1.1 | | 2.6 ± 1.3 | |
| Individual Strength | | | | |
| Conditioning | 86.0 (104) | 14.0 (17) | 91.3 (42) | 8.7 (4) |
| Exercises to Prevent Injuries | 95.9 (116) | 4.1 (5) | 91.3 (42) | 8.7 (4) |
| Warm Up | 100 (121) | 0 (0) | 97.8 (45) | 2.2 (1) |
| Cool-Down | 89.3 (108) | 10.7 (13) | 82.6 (38) | 17.4 (8) |
| Individual Protection ^a | 91.7 (111) | 8.3 (10) | 73.9 (34) | 26.1 (12) |
| Good Sport Facilities | | | | |
| Equipment's | 81.8 (99) | 18.2 (22) | 91.3 (42) | 8.7 (4) |
| Good Sport Facilities | 65.3 (79) | 34.7 (42) | 73.9 (34) | 26.1 (12) |
| Training Load adapted to athletes | 87.6 (106) | 12.4 (15) | 93.5 (43) | 6.5 (3) |
| Individual balance diet | 69.4 (84) | 30.6 (37) | 69.6 (32) | 30.4 (14) |
| Psychologic Stress ^b | 54.5 (66) | 45.5 (55) | 37.0 (17) | 63.0 (29) |
| Recurrent injuries | 57.9 (70) | 38.8 (47) | 0 (0) | 0 (0) |
| Other sport practice | 14.9 (18) | 85.1 (103) | 17.4 (8) | 82.6 (38) |

^avs. with and without injuries, p= 0.002^bvs. with and without Injuries, p= 0.043

Injury Risk Factors: Both injured and non-injured athletes reported experiencing psychological stress (p = 0.043) and noted the use of individual protection equipment (p = 0.002). Nearly all athletes performed warm-up and cool-down routines, engaged in individualized strength conditioning, and practiced exercises designed to prevent injuries. Additionally, respondents reported having good training conditions, including

adequate facilities, equipment, and manageable training loads.

Seventy-three percent of athletes (n=121/167) reported sustaining injuries one to three times (1.6 ± 1.5) in the past 12 months (Table 3). Injuries affected various tissues, with muscle injuries and ligament injuries being the most commonly reported (85.8% and 69.2%, respectively). Muscle injuries (including strains, tears, and ruptures) and joint sprains were most

frequent. These injuries predominantly occurred acutely (42.7%), during training (74.6%), and without collision (80.9%) (Table 4).

Lower extremities were the most affected by injuries, followed by upper body and trunk regions (Figure 1). Among the

lower body injuries, the ankle, knee, and foot were most frequently reported. In the upper extremities, the shoulder, wrist, and hand were commonly affected. In the trunk region, injuries were mainly reported in the hip and lumbar spine

Table 3.
Characterization of 2022 Aerobic Gymnastics WCH athletes' injuries

| | |
|---|---------------|
| Injured athletes % (n) | 72,3% (121) |
| Injured Number (Mean \pm SD) | 1.6 \pm 1.5 |
| Tissue/ Injury type (%) | |
| Muscle/Tendon (n = 132) | |
| Muscle injury | 85.8 % |
| Muscle contusion | 19.8% |
| Muscle compartment syndrome | 6.6% |
| Tendinopathy | 44.9% |
| Tendon rupture | 17.2% |
| Nervous (n = 25) | |
| Brain/spinal cord injury | 48.0% |
| Peripheral nerve injury | 52.0% |
| Bone (n = 40) | |
| Fracture | 17.5% |
| Bone stress injury | 47.5% |
| Bone contusion | 35.0% |
| Cartilage/Synovium/Bursa (n = 46) | |
| Cartilage injury | 28.3% |
| Arthritis | 21.7% |
| Synovitis/Capsulitis | 21.7% |
| Bursitis | 28.3% |
| Ligament/Joint capsule (n = 65) | |
| Join Sprain (ligaments tear or acute instability episode) | 69.2% |
| Chronic instability | 30.8% |
| Superficial tissues/Skin (n = 43) | |
| Contusion (superficial) | 53.5% |
| Laceration | 14.0% |
| Abrasion | 32.6% |

Table 4.
Mechanisms o of 2022 Aerobic Gymnastics WCH athletes' injuries

| Mechanism of Injury | |
|--------------------------|-------|
| Load type (n = 96) | |
| Acute | 42.7% |
| Overuse | 34.4% |
| Acute and overuse | 22.9% |
| Place (n = 110) | |
| Training | 74.6% |
| Competition | 4.2% |
| Training and Competition | 21.2% |
| Contact (n = 121) | |
| Alone | 80.9% |
| With another athlete | 10% |
| With an object | 9.1% |

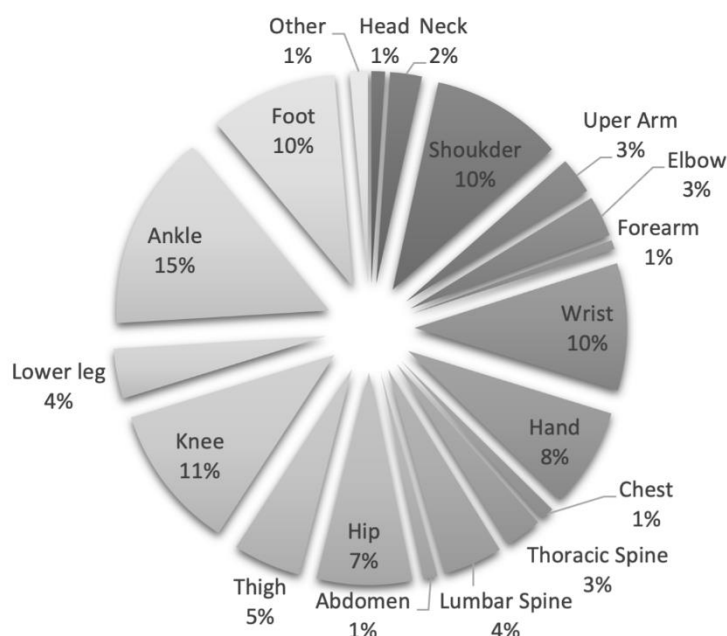


Figure 1. Number of body parts injured reported by athletes in the 2022 Aerobic Gymnastics WCH

DISCUSSION

In AG, athletes must demonstrate high levels of strength, endurance, and flexibility during demanding choreography that requires coordination and speed (Abalo, Gutiérrez-Sánchez, & Vernetta, 2013). High-impact exercises and the use of aerobic equipment, such as floors and footwear, have been suggested as potential contributors to increased injury rates, particularly in the lower limbs (Abalo et al.,

2013). According to our questionnaire, more than seventy percent of athletes reported injuries in the past 12 months, with over fifty percent of these being recurrent. Previous studies have shown that gymnasts often resume practice before fully recovering or continue to train and compete despite ongoing symptoms (Caine et al., 1989; Harringe, Renström, & Werner, 2007; Kolt & Kirkby, 1999; Sands, Shultz, & Newman, 1993), which may explain the observed results.

Among the risk factors, we found that 54.5% of injured athletes experienced psychological stress from coaches, friends, family, or themselves. Since stress and anxiety can influence the risk, frequency, and severity of injuries (Pal, Kalra, & Awasthi, 2021), coping strategies are crucial for protecting athletes. Additionally, life-related stress should be considered in preventive programs, as it is a significant predictor of injury in non-elite gymnasts (Kolt & Kirkby, 1999). Thus, both injury history and stress factors (including major life events and previous injuries) should be incorporated into surveillance systems and preventive measures for top-level AG athletes.

Beyond physical and psychological health, nutrition plays a crucial role in both injury risk and the recovery process (Smith-Ryan et al., 2020). Dietary recommendations include: i) identifying individual caloric requirements; ii) increasing protein intake to prevent muscle loss and maintain strength during immobilization; and iii) using supplements to address caloric intake and nutrient deficiencies (Close et al., 2019). Top-level gymnasts are particularly at risk for eating disorders due to the sport's aesthetic demands and rigorous training sessions (Silva & Paiva, 2015; Tan et al., 2016). Our results show that 30% of aerobic gymnasts still do not follow a balanced diet, highlighting the need for nutritional education to promote healthier eating choices.

Additionally, while the use of individual protective equipment was reported by many injured athletes, suggesting an increased concern for injury prevention, it remains crucial to address other factors. As noted in previous studies (Abalo & Gutiérrez, 2009), injury processes were predominantly traumatic and occurred during training. Therefore, the condition of sport facilities, such as the floor, should be scrutinized. Our findings support earlier theories of a higher incidence of lower limb injuries, followed by upper extremities (Fetterplace, 2004; Navarro et al., 2005), due

to the impact absorption demands (Navarro et al., 2004). Despite changes in the AG Code of Points over the years, muscle injuries, tendinopathies, joint sprains, stress fractures, and contusions affecting the ankle, foot, knee, wrist, and shoulder remain prevalent. This suggests that these injuries are closely related to the fundamental movements of the sport.

To develop and implement effective injury prevention programs, a four-step framework that identifies the injury problem and its etiology has been proposed (Van Tiggelen et al., 2008). Our study aimed to update trends in injury and associated risk factors among elite AG athletes, which may assist technical and medical teams in establishing measures to prevent injuries, thereby improving performance and extending athletes' careers.

In the current study, we observed that the type and location of injuries appear to be related to specific sports movements. Psychological stress and the use of individual protective equipment were identified as major risk factors. Consequently, preventive intervention programs should incorporate coping strategies to manage stress and examine the impact of floor and sport footwear on injury risk to improve impact absorption. Additionally, with artificial intelligence emerging as a promising methodology for identifying athletes at high risk of injury and detecting risk factors (Van Eetvelde et al., 2021), future studies in AG should consider integrating this technology.

CONCLUSION

The current study offers new insights into injury patterns and risk factors among elite world AG athletes. Our findings reveal that acute injuries, such as muscle strains and joint sprains, remain common in this sport. These injuries may be attributed to sport-specific movements and equipment. Additionally, psychological stress is frequently reported among elite gymnasts, alongside concerns regarding individual

protection measures. Therefore, future studies should focus on the development of AG equipment, psychological support, and comprehensive recovery strategies for injured athletes.

LIMITATIONS

The survey mode presents limitations due to auto-selection bias, which may affect the representativeness of the sample relative to the target population. Additionally, memory recall bias is a concern, as retrospective injury studies rely on self-reported data based on athletes' recollections. This could lead to an underestimation of injury incidence, as athletes might predominantly recall more significant injuries while overlooking less severe ones.

Disclosure Statement

The authors report no conflict of interest

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