

Injuries in Competitive Austrian Gymnasts

Klaus Greier, Clemens Drenowatz, and Johannes Mairoser

ABSTRACT

Background: Competitive gymnastics is a physically demanding sport that requires flexibility, coordination, endurance and strength. The biomechanics of the sport also result in a specific injury profile.

Methods: A total of 30 gymnasts from the Austrian national team (21.9 ± 3.9 years) and 25 competitive gymnasts not affiliated with the national team (22.8 ± 6.4 years) provided information on their injuries of a 3-year period (2018-2020) via an online survey. The injury rate per 1000 hours of training was calculated and injuries were stratified by severity, injured body structure and the localization of the injury. Mann Whitney U and Chi-square tests were used to examine differences between national team and non-national team gymnasts.

Results: A total of 64 injuries were reported, which resulted in 0.4 injuries per 1000 hours of training. There was no difference in injury rate per training hours; national team members, however, reported significantly more injuries per person compared to their non-national team peers (1.4 ± 1.1 vs. 0.8 ± 1.0 ; $p=0.04$). The most common tissue affected by injuries were tendons and ligaments (59%) while muscle injuries were the least common injuries (11%). Almost half of the injuries (47%) affected the lower extremities, with ankle injuries being the most common ones. Roughly 80% of injuries were considered minor to moderate and could be treated via outpatient care. Across the different disciplines of gymnastics most injuries were reported during floor routines (36%) followed by vault (16%).

Conclusion: Injury risk was directly associated with training volume. Severe injuries, however, were rare even in highly competitive gymnasts.

Keywords: competitive gymnastics, injury risk, training, floor gymnastics, sports injuries.

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I. INTRODUCTION

Gymnastics has its origins in Germany with Friedrich Ludwig Jahn (1778-1852) being considered the “father of gymnastics”, as he was the most important pioneer of gymnastics (Prohl, 2009). Competitive gymnastics of today, however, have very little in common with the original forms. Above all, the level of performance has undergone tremendous development over the past several decades. In order to be able to compete at the highest levels, gymnasts need to engage in a large volume of training at high intensities. This excessive training puts a considerable strain on the musculoskeletal system, which increases the risk for both acute and chronic injuries (Grim & Engelhardt, 2016; Boschert, 2016). Various studies have shown injury rates of 1.4 to 8.5 injuries per 1000 hours of training (Bak *et al.*, 1994; Caine *et al.*, 2003; Caine & Nassar, 2005; Desai *et al.*, 2019; Harringe *et al.*, 2007; Marshall *et al.*, 2007). Nevertheless, compared to ball sports or martial arts, competitive gymnastics has a low risk of injury based on relative and absolute injury frequencies (Kirialanis *et al.* 2002; Zetaruk *et al.*, 2005; Knobloch *et al.*, 2006; Greier, 2012; Greier *et al.*, 2013).

The pronounced increase in performance in competitive gymnastics is largely due to the actions of the World Gymnastics Federation (Fédération Internationale de Gymnastique, FIG), which evaluates performance based on aesthetics and technical difficulty. The final score, therefore, is a combination of two parts, which evaluates execution (E-score) and difficulty (D-score) of the performed elements within a gymnastics routine. All elements in competitive gymnastics are graded according to difficulty in the so-called Code de Pointage and assigned a specific point value (Boschert, 2016; Fédération Internationale de Gymnastique, 2021a; Fédération Internationale de Gymnastique, 2021b). Competitive gymnastics has been part of the Olympic program since 1896 in men and 1928 in women. Some of the disciplines within gymnastics are specific to men or women. In women, the Olympic all-around competition consists of 4 disciplines (balance beam, uneven bars, floor and vault; Fig. 1).

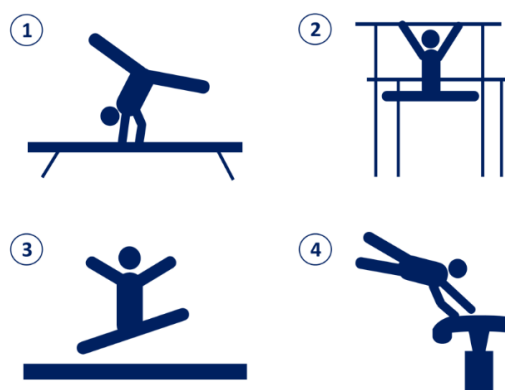


Fig. 1. Olympic all-around disciplines in women (1 balance beam, 2 uneven bars, 3 floor, 4 vault) (Source: Greier).

The Olympic all-around event for male gymnasts consists of 6 disciplines (Keith, 2013) (high bar, parallel bars, floor, vault, rings and pommel horse; Fig. 2).

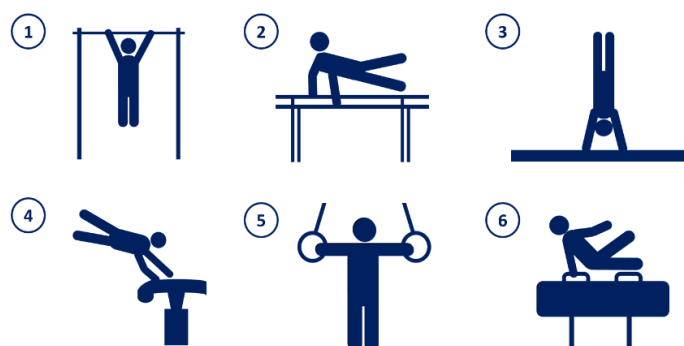


Fig. 2. Olympic all-around disciplines in men (1 high bar, 2 parallel bars, 3 floor, 4 vault, 5 rings, 6 pommel horse) (Source: Greier).

In Austria there are about 450 gymnastics clubs with over 90,000 members. Nevertheless, competitive gymnastics has not been at the forefront in Austrian sports. As competitive gymnastics is a technically demanding sport, training must begin in early childhood (d'Hemecourt & Luke, 2012). At the elite level gymnasts are classified by the framework of the Austrian national team squad, which has minimal sex-specific differences. Male gymnasts are separated into A and B squads with the A squad representing the highest performance level (ÖFT, 2021a). Female gymnasts within the national team, on the other hand, are separated into three categories (ÖFT, 2021b).

Most injuries in competitive gymnastics are the result of excessive active and passive impact forces during jumps and landings as well as strong tensile loads due to acceleration and centrifugal forces (Boschert, 2016). A recent meta-analysis, which included 22 studies from nine countries examined type, severity and progression of the injuries. The results indicated a higher injury risk in older and heavier gymnasts but also showed a direct association with the number of training hours and, accordingly, performance level (Campbell *et al.*, 2019). Data on causes, type and frequency on injuries in Austrian gymnasts, however, remain limited. The purpose of this study, therefore, was to provide information on injuries that Austrian competitive gymnasts suffered over a three-year period (between 2018 and 2020).

II. METHODS

A. Participant

In order to be included in the study, participants had to participate in competitive gymnastics for at least 3 years. Women needed to be at least 16 years of age while the minimum age for men was 18 years, as these are the minimum age requirements specified by FIG regulations. Participants were divided into national team members and competitive gymnasts that were not part of the national team (non-national team). The criteria for the national team group were membership of squad A or B for men and levels 1 or 2 for women. Non-national members needed to participate in the Austrian national championships in order to be eligible for participation.

In addition to age and gender, participants reported their average training time in hours/week. Further, participants provided information on injuries suffered in the context of gymnastics over a period of 36

months (between 2018 and 2020). In the present study injuries were defined as an acute physical damage sustained in the context of competitive gymnastics that led to consultation with a physician. The cause of the injury and equipment were reported by gymnasts while the diagnosis was based on the physician's evaluation. Reported injuries were divided into three groups according to severity. Severity I required only a single medical treatment while severity II injuries required multiple outpatient medical treatments, and severity III injuries required inpatient treatment (Greier & Leimlehner, 2014).

B. Design

Information on injuries in active Austrian competitive gymnasts was obtained via an online survey that was distributed via staff and coaches of the Austrian professional association for gymnastics (österreichischer Fachverband für Turnen). The questionnaire has been validated previously in martial arts athletes (Greier *et al.*, 2013).

C. Statistical Analyses

Interval scaled data are presented as means with standard deviation. The number of injuries per thousand trainings hours was calculated and Mann Whitney U-tests were used to examine differences between national team and non-national team gymnasts. In addition, chi-square tests were used to examine differences by injury type and the injured body structure. All statistical analyses were carried out with SPSS 26.0 (IBM, Armonk, NY) and statistical significance was set at $p < 0.05$.

III. RESULTS

A total of 55 competitive gymnasts completed the questionnaire, of which 30 were members of the national team (53.3% women) and 25 were non-national team gymnasts (44.0% women). Across the entire sample, participants were 22.4 ± 3.8 years of age and engaged in an average training volume of 19.7 ± 6.4 per week. There was no difference in age and years of participation in competitive gymnastics between national team and non-national team members. Training volume, however, was significantly higher in national team members (Table I).

TABLE I: AGE, TRAINING VOLUME AND YEARS OF PARTICIPATION IN COMPETITIVE GYMNASTICS IN NATIONAL TEAM MEMBERS (N=30) AND NON-NATIONAL TEAM MEMBERS (N=25). VALUES ARE MEAN WITH STANDARD DEVIATION

	National Team	Non-National Team
Age (years)	21.9±3.9	22.8±6.4
Training Volume (hours/week) *	23.7±4.4	14.9±3.9
Participation in Competitive Gymnastics (years)	15.1±3.6	13.0±5.3

* $p < 0.001$.

A total of 64 injuries were reported across the entire sample (Table II). The number of injuries reported by national team gymnasts was more than double the number of non-national team members (43 vs. 21) and 73% of national team gymnasts reported at least one injury that was attributable to gymnastics. In non-national team members only 52% reported at least one injury that was attributable to gymnastics. The average injury rate per person was 1.2 ± 1.1 , with higher rates in national gymnasts (1.4 ± 1.1) compared to non-national team gymnasts (0.8 ± 1.0) ($p = 0.04$). Relative to training volume, no difference in injury rate, however, was observed between national team and non-national team gymnasts (0.4/1000 hours of training in both groups). There was also no significant sex-difference in injury rate per person (1.3 ± 1.1 in women vs. 1.1 ± 1.1 in men).

Most injuries (86%) occurred during training with injuries of tendons and ligaments being the most common ones in both groups. In fact, 33% of national team gymnasts and 21% of non-national team gymnasts reported at least one ankle injury during the 36 months observation period. Muscular injuries were the second most likely injury in national team gymnasts while these were not reported in non-national team gymnasts (Table II).

TABLE II: ABSOLUTE AND RELATIVE FREQUENCIES BY INJURY TYPE IN COMPETITIVE GYMNASTICS

Type of Injury	Nationalteam N (%)	Non-National Team N (%)	Total N (%)
Bone fractures	5 (11.6)	3 (14.3)	8 (12.5)
Tendon and ligament injuries	24 (55.8)	14 (66.7)	38 (59.4)
Sprains	3 (7.0)	1 (4.8)	4 (6.3)
Muscular injuries	7 (16.3)	0 (0.0)	7 (10.9)
Other	4 (9.3)	3 (14.3)	7 (10.9)

Across the entire sample half of the injuries required only a single treatment. In national team gymnasts grade 2 injuries, which require multiple outpatient treatments were the second most common injuries while injuries requiring inpatient care were the second most common injuries in non-national team gymnasts

(Table III). Nevertheless, national team gymnasts displayed a higher prevalence of moderate to severe injuries (grade 2 and 3) compared to non-national team gymnasts ($p < 0.05$).

TABLE III: ABSOLUTE AND RELATIVE FREQUENCIES BY INJURY SEVERITY IN COMPETITIVE GYMNASTS

Injury severity	Nationalteam N (%)	Non-National Team N (%)	Total N (%)
Grade 1	20 (46.5)	12 (57.1)	32 (50.0)
Grade 2	15 (34.9)	4 (19.1)	19 (29.7)
Grade 3	8 (18.6)	5 (23.8)	13 (20.3)

Grade 1... single medical treatment required; Grade 2... multiple outpatient medical treatments required; Grade 3... inpatient medical treatment required.

The majority of injuries occurred at the lower (46.9%) and upper extremities (42.2%) (Fig. 3). The shoulder was the most commonly affected structure in upper extremity injuries (16%) and ankle injuries were the most common injuries in the lower extremities (25%). While ankle injuries were the most common injuries in both groups of gymnasts, shoulder injuries were more common in national team gymnasts compared to non-national team gymnasts (18.6% vs. 9.5%). Non-national team gymnasts, on the other hand, reported a higher prevalence of knee injuries. Injuries to the wrist were also more common in non-national team athletes while the prevalence of injuries to the fingers was similar in both groups.

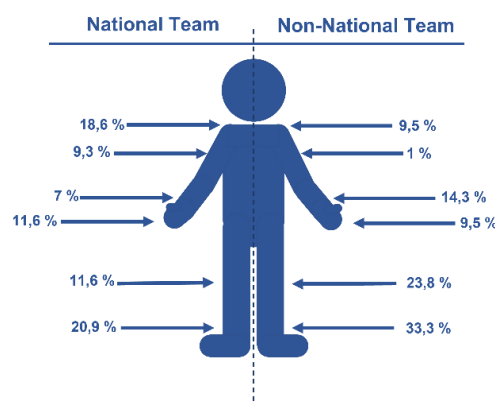


Fig. 3. Relative distribution of common acute injuries by body part in national team and non-national team gymnasts (injuries to the trunk, spine and head not listed due to low prevalence) (Source: Greier).

Nearly every second injury occurred during a specific gymnastics element (45.2%), followed by landing actions (30.3%). Jumping, equipment collisions and falls each accounted for less than 10%. There were no significant differences between the performance classes in the cause of injuries.

Examining injuries across disciplines, more than one third of injuries (35.9%) occurred during floor routines. Injuries were also likely to occur at the vault (15.6%), the pommel horse (12.5%) and the uneven bars (10.9%). Less than 10% of the injuries occurred during routines on the balance beam (9.4%) parallel bars (6.3%), high bar (4.7%) and rings (4.7%).

IV. DISCUSSION

The present study examined the injury history of 55 Austrian competitive gymnasts over a three-year period via an online questionnaire. A total of 64 injuries were reported, which resulted in an exposure-time related injury rate of 0.4 injuries per 1000 hours of training. Most injuries (86%) occurred during training and affected tendons and ligaments (59.4%), with the ankle being the most commonly injured body part. Across gymnastics disciplines most injuries (36%) occurred during floor routines.

The injury rate in the present study was considerably lower compared to previous studies, which reported injury rates between 1.4 and 8.5 injuries per 1000 hours of training (Bak *et al.*, 1994; Caine *et al.*, 2003; Caine *et al.*, 2005; Desai *et al.*, 2019; Harringe *et al.*, 2007; Marshall *et al.*, 2007; Paxinos *et al.*, 2019; Thomas & Thomas, 2019). Some studies also reported that more injuries occurred during competition (Marshall *et al.*, 2007; Hart *et al.*, 2018; Kruse *et al.*, 2021) while others confirmed the results of the present study that more injuries occurred during training (Kolt & Kirkby, 1999; Heitkamp & Horstmann, 2005). The variability in the results across studies may be explained by differences in training volumes, performance levels and age of the study populations as well as inconsistent definitions of injuries. Compared to other sports such as ball games and martial arts, competitive gymnastics, nevertheless, has been shown to have a relatively low injury risk (Zetaruk *et al.*, 2005; Kirialanis *et al.*, 2003; Kirialanis *et al.*, 2015). The injury risk in martial arts, for example, has been shown to be 3 times that of competitive gymnastics (Greier *et al.*, 2013). Severe injuries are also less common in gymnastics (Kirialanis *et al.*, 2002,

Kirialanis *et al.*, 2015, Greier & Leimlehner, 2014, Campbell *et al.*, 2019). In the present study almost 80% of injuries required only outpatient care. The higher prevalence of moderate to severe injuries in national team gymnasts compared to their non-national team peers may be attributed to the greater technical difficulty and potentially higher external forces that the body is exposed to. The high prevalence of ankle injuries has been attributed to the large amount of landing and dismounting elements that are performed in gymnastics (Marshall *et al.*, 2007; Thomas & Thomas, 2019; Hart *et al.*, 2018; Seegmiller & McCaw). With landings and take-offs being common during floor routines it is also not surprising that floor exercises were associated with the highest injury risk even though they are performed on suspended floor constructions (Sands, 2005). Shoulder injuries were also common, particularly in national team gymnasts. The lower injury rate in non-national team gymnasts may again be attributed to the difficulty of the gymnastics elements performed and the external forces experienced. Particularly during routines on the rings and high bar high tensile loads can occur due to acceleration and centrifugal forces (Boschert, 2016; Caine & Nassar, 2005; Gerhardt *et al.*, 2014). Injuries to the wrist, on the other hand, are attributed to high loads during supporting elements, which are performed at any level. Excessive loads due to high repetitions of such elements may also result in overuse injuries that are commonly referred to as “gymnast wrist” (Wolf *et al.*, 2017).

Despite the relatively low injury risk of competitive gymnastics there remain continued efforts to reduce the injury risk by constantly trying to improve and develop safe gymnastics equipment. Elastic floors and mats with high shock absorption properties minimize ground reaction forces during landing elements. Further, foam pits are used to provide a safe space for learning new, more difficult gymnastics elements (Sands, 2005). Various studies also showed that injuries occur commonly during gymnastics elements that are already well mastered (Heitkamp & Horstmann, 2005; Kirialanis *et al.*, 2003), which indicates to a lack of concentration during the exercise routine rather than lack of physical preparedness (Caine & Nassar, 2005). The training, therefore, should be variable in order to avoid undue central fatigue (Kolt & Kirkby, 1999).

Additionally, a comprehensive, age- and performance-specific training is a critical component in long-term injury prevention. Such a training should aim for the development and perfection of all sport-specific requirements and should facilitate a reliable mastery of gymnastics elements during competition (Schwabowski *et al.*, 2010). Such a training further includes the systematic development of high stress-tolerance of all components involved in the sport (Weineck, 2007). Besides physical conditioning and specific skill training, proprioceptive training exercises on balance disks that improve intra-muscular coordination have been successfully implemented to reduce ankle and knee injuries in other sports like volleyball (Verhagen *et al.*, 2004). The implementation of such exercises could also be valuable in gymnastics. Finally, regular medical examinations by certified physicians are recommended. These examinations should already take place when entering competitive gymnastics training and continue with annual check-ups, with a special focus on the musculoskeletal system (possibly including x-ray). This allows to identify developing or underlying existing problems early and provides the opportunity to take corrective actions.

A. Limitations and Strengths

Some limitations of the present study should be considered when evaluating the results. Data was collected via an online survey, which has an inherent risk of reporting bias. Given a 3-year observation window, it can also be difficult to remember all injuries, particularly if they were only minor. The long observation period along with stringent inclusion criteria, on the other, may also be a strength of the study as it may reflect the injury risk in general, rather than during specific training periods. Nevertheless, the small sample size and voluntary participation, may limit generalizability of the results. The low number of participants, however, may also be attributed to the low number of competitive gymnasts in Austria and the fact that details on the type and cause of injuries were collected should be considered a strength of the study.

V. CONCLUSION

Overall the results of this study indicate a relatively low injury risk of competitive gymnastics compared to other sports such as ball games and martial arts, particularly concerning severe injuries. Within the different disciplines of gymnastics most injuries occurred during floor routines followed by vault. Tendons and ligaments were the most affected body structures and the ankle was the most affected body part. There was also a direct association between training volume and injury risk. Training loads, therefore, need to be carefully monitored to minimize the injury risk. The increasing difficulty of gymnastics elements further warrants continued efforts regarding the development and improvement of gymnastics equipment to minimize the injury risk in competitive gymnastics.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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