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ORIGINAL STUDY

Musculoskeletal injuries among elite artistic and rhythmic Greek gymnasts: A ten-year study of 156 elite athletes

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Data on elite gymnast injuries outside North America is sparse. We report the injuries recorded over a period of 10 years in 156 Greek elite male and female gymnasts. A total of 2390 injuries were reported for a rate of 1,5 new injuries per year per athlete. Most commonly affected areas were the hip (18.5%), the ankle (16.5%), the lumbar spine (16%) and the foot (16%). The most frequent diagnosis was tendinitis (32%), followed by low back pain (20%), and sprains (12%). Fifteen athletes (9%) sustained serious injuries that required surgery. Rhythmic gymnasts had significantly more overuse type injuries compared to artistic gymnasts (p = 0.049). Gymnastics is a sport with a high incidence of musculoskeletal pathology that needs proper documentation in order to establish preventive measures.

Keywords : Gymnastics ; Injury ; Rythmic ; Artistic ; Elite athletes.

INTRODUCTION

Gymnastics is a very demanding sport that requires the precise performance of difficult acrobatic exercises from an early age *(6)*. The sport includes a variety of disciplines governed by the Fédération Internationale de Gymnastique (FIG). Current FIG disciplines include Artistic Gymnastics (Olympic sport since 1896) divided in Men Artistic Gymnastics (MAG) and Women Artistic Gymnastics (WAG), Rhythmic Gymnastics (female discipline added in the 1984 Olympic Games) and new additions like Trampoline (included in the Olympic Games since 2000), Acrobatic and Aerobic Gymnastics, Parkour and Gymnastics for All.

All gymnastic disciplines include acrobatic elements that require strength, flexibility, agility, coordination, and endurance. Given the difficulty and acrobatic character of the exercises, injuries are to be expected. Injury incidence has been reported to range between 1.4 to 8.5 injuries per 1000 hours of training *(1,2,3,4,5,7,9,12,14,15)*. Despite the fact that all Olympic disciplines have

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both artistic and acrobatic elements, their routines differ considerably. Rhythmic Gymnastics has calisthenics and dancing elements that are related to overuse injuries, while Artistic and Trampoline Gymnastics have more of dynamic and acrobatic routines that predispose to acute trauma *(3,11,8,20)*. Lower limp sprains or strains are common *(2,19,20)*, while severe injuries with lengthy absence from training are not rare *(8,20)*.

FIG strives to improve both the safety and the quality of routines through regular changes to the rules reflected in the Code of Points published every 4 years *(4)*. Understanding the incidence and the biomechanics of injuries is a constant pursuit to a safer sport *(6)* and many authors have already contributed *(1-21)*. Although genetic and cultural differences among nations may affect both the rate and the anatomic distribution of injuries there are few studies on elite gymnasts outside North America *(4,8,18)*.

Gymnastics is one of the most developed Olympic sports in Greece. Hellenic Gymnastics Federation runs a yearlong campus where lodging and training is provided to selected elite athletes. Training for both Artistic (MAG and WAG), Trampoline and Rhythmic Gymnastics is performed in a sports hall built for the 2004 Olympic Games in Athens. Medical facilities located inside the building are staffed by a sports medicine trained physician and a physiotherapy team. Each time an athlete seeks medical care, a medical record is created, that includes symptoms, anatomic area affected, injury mechanism and treatment.

In this retrospective review we present the injuries sustained by Greek elite Artistic (MAG, WAG), Trampoline and Rhythmic gymnasts over a period of 10 years including the preparation for the 2008, 2012 and 2016 Olympic Games.

ence of implant instability in this cohort.

MATERIALS AND METHODS

Between the years 2007-2017 a total of 156 gymnasts were selected for the National Team. These were 116 female (73 Rhythmic and 43 WAG) and 40 male gymnasts (MAG) aged between 14 and 36 years (mean age 20.5 SD: 3.42) including Olympic, World Games and European Championship medalists. A small number of trampoline athletes (9 female and 5 male) were included in the artistic gymnast study groups (WAG and MAG). All athletes were competing at an international level and training was intense. Artistic and trampoline gymnasts trained for at least 3 hours per day, 6 days per week (18-24 hours/week) while rhythmic gymnasts trained for at least 5 hours per day, 6 days per week. During preparation for championships or World and Olympic Games the athletes trained for at least another 8-12 hours per week for 2-6 months prior to the event.

The medical records of the athletes of this period were retrospectively reviewed. Each injury was either seen immediately by the team physician or referred later for evaluation by the physiotherapists. Injury location, running diagnosis and treatment plan were always documented. An injury was recorded as new only if it had occurred at least 2 weeks after full recovery from a previous one to the same area or involved another part of the body. As acute were characterized those injuries with an acute onset related to a specific traumatic event. Data was analyzed by using SPSS 21.0 (SPSS Inc, Chicago, IL). Statistical analysis included descriptive statistics and ANOVA to determine differences in injuries between rhythmic and artistic gymnasts. Level of significance was set to a=0.05.

RESULTS

A total of 2390 new injuries were recorded during that period. This represents a rate of 1,5 new injuries per year per athlete. Looking at the cumulative data of all disciplines included in this study (WAG, MAG and Rhythmic), the anatomic areas most frequently affected were the hip (18,5%), the ankle (16,5%), the lumbar spine (16%), the foot (16%) and the knee (11%) (Fig 1). Most injuries could not be related with an acute traumatic event and were characterized as overuse (69%). The main pathology seen in these 156 athletes over this 10 year period was tendinopathy (32%). Back pain was the second most common diagnosis (20%) followed by ligament sprains (12%) and tears (11%) (Fig 2). Average time lost to training after an acute injury

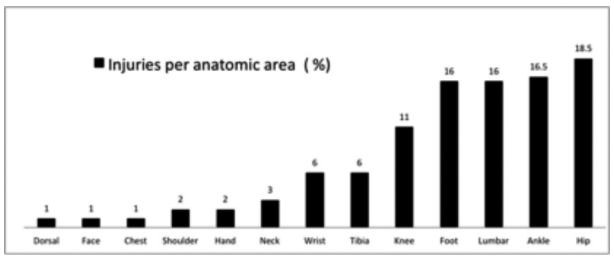

Fig. 1. — Injury distribution per anatomic area

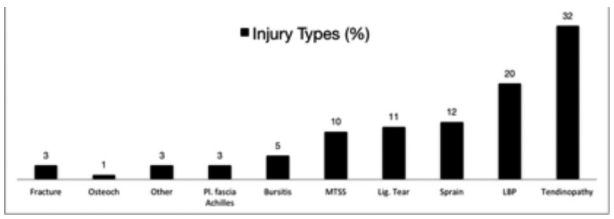

Fig. 2. — Injury types. (Osteoch: Osteochondritis (eg Sever's, Osgood-Schlatter's), Pl.fascia Achilles: Plantar fasciitis and Achilles insertion tendinopathy, MTSS: Medial Tibia Stress Syndrome, LBP: Low back Pain)

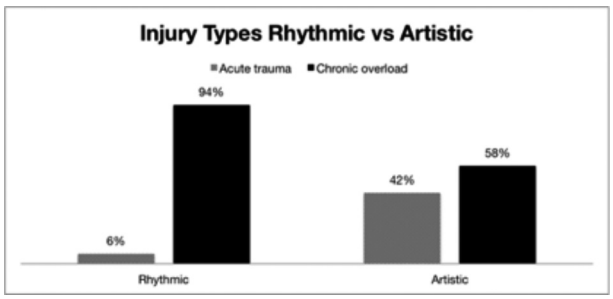

Fig. 3. — Overuse and acute injuries distribution among rhythmic and artistic gymnasts

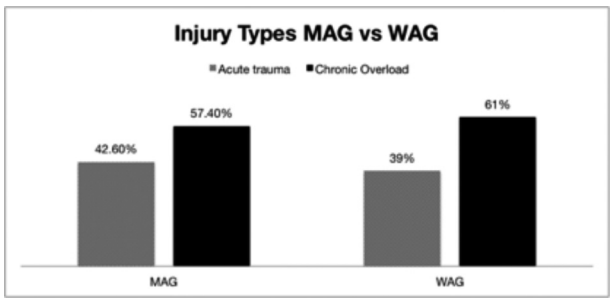

Fig. 4. — Acute and overuse injuries in artistic gymnastics. No significant difference was noted in male (MAG) (p=0.474) and female (WAG) (p=0.49) artistic gymnasts

was 2,5 days (5 training sessions), since most elite athletes usually "train through" their injury.

Rythmic gymnasts (73: all female) had mainly overuse injuries (94%) and the area mostly affected was the hip (26,5%) followed by the lumbar spine (20%). The most frequent diagnosis was tendinopathy (42,6%). There was a statistically significant difference in the rate of overuse injuries compared to artistic gymnasts (MAG and WAG combined) (p = 0.049) (Fig 3).

Artistic gymnasts (40 male (MAG) and 43 female (WAG)) had both acute (42%) and overuse injuries (58%). The most frequent injury was ligament sprains (30%) followed by tendinopathy (16%) and low back pain (12,5%). No significant difference was detected either in acute or overuse injuries between male (p = 0.474) and female artistic gymnasts (p = 0.49) (Fig 4).

Serious injury that needed hospitalization and/or surgery was a rare (9%) but devastating event for both the athlete and his family. Fractures were very rare (1%). Table I summarizes the 15 cases of serious trauma treated during that period including a case of complete paraplegia after a fall from a trampoline in premises outside the official campus. Other less common injuries (3%) were head injuries, skin lacerations and toenail pathologies.

DISCUSSION

Gymnastics is a sport characterized by intense training of skeletally immature athletes *(6)*. Time allocated for training per week by elite gymnasts ranges between 7-36 hours for females and 10-33 for male athletes *(4,5)*. Due to the increasing difficulty of exercises determined by the Code of Points published by FIG *(4)* there is rising concern regarding the rate of injuries and the long term effects on the health of gymnasts. Although several systematic reviews have reported on gymnastics injuries, data from countries other than North Europe and America are still sparse *(4,8,18)*.

We have found overuse injuries to be significantly more common in rhythmic than in artistic gymnasts (p = 0.049), a finding that can be explained by the repetitive nature of rhythmic gymnasts routines. No significant difference was found in both acute and

Tabel I. — Severe Injuries. Discipline, injury mechanism, treatment and final outcome expressed with the highest competition that the gymnast participated following treatment of his injury.

	Sport	Mechanism of injury	Type of Injury	Treatment	Competition
1	MAG	Knee dislocation, tear of patella tendon ACL and both menisci	Fall from high bar	Open repair	Recreational sports No competition
2	MAG	Open patella fracture with chondral defect	Fall from high bar	Open repair	Commonwealth Games 2010
3	MAG	ACL tear	Exit from rings	Arthroscopic repair	International Grand Prix
4	MAG	ACL tear	Exit from parallel bars	Arthroscopic repair	National Games
5	WAG	ACL tear	Landing from vault	Arthroscopic repair	International Grand Prix
6	WAG	ACL tear	Floor landing	Arthroscopic repair	International Grand Prix
7	Rhythmic	PCL tear	Fall accident	Brace	Olympic Games 2012
8	WAG	Bankart	Landing from vault	Arthroscopic repair	International Grand Prix
9	MAG	SLAP	Rings	Arthroscopic repair	International Grand Prix
10	Rhythmic	Ankle instability	Floor	Brostrom	International Grand Prix
11	Rhythmic	Femoral neck fracture	Floor	Conservative	Olympic Games 2012
12	MAG	Lesser tuberosity avulsion	Fall on parallel bars	Open repair	European Championships
13	Rhythmic	Greater trochanter avulsion	Floor	Conservative	Olympic Games 2008
14	WAG	Severe Scheuermann kyphosis	Repetitive trauma	Spinal fusion	Recreational sports No competition
15	Trampoline	T10 fracture paraplegia	Exit from trampoline	Spinal fusion	Paraplegic

WAG: Women Artistic Gymnastics, MAG: Men Artistic Gymnastics

overuse injury rates between male (p = 0.474) and female (p = 0.49) artistic gymnasts.

In total, we had 15 cases of severe trauma and two cases of grade 2 concussion after falls from the apparatus (one female gymnast fell from the beam and one male gymnast fell from the high bar). The athletes were given first aid on site and then transferred to a local hospital for evaluation and treatment. This low incidence of serious trauma and head injuries is probably explained by the fact that elite gymnasts have very good control of their body and are able to cushion their fall *(4,5,17)*. Many authors have already reported serious trampoline injuries *(8,13,16)* and we had one female athlete becoming a permanent paraplegic after a trampoline accident. One rare case of lesser tuberosity avulsion in an adolescent gymnast has been already reported *(18)*.

In our series the predominant injury was chronic tendinitis (32%). Low back pain was the second most common pathology (20%). The most commonly affected area in our study was the hip (18.5%), followed by the ankle (16.5%) and the lumbar spine (16%). Our data is in accordance with the existing literature in that the most frequently injured body part is the lower leg (combined hip and ankle injuries in our study) *(1,2,3,4,5,7,8,11,17,19)*. However, we have found the lumbar spine to be the next most

frequently injured part, which is in contrast with the literature that considers the upper extremity as second in frequency *(4,5,17,21)*. This difference may be due to the greater number of rhythmic gymnasts in our study that perform mainly floor exercises that have been linked with spinal pathology *(6,9,10,13,17)*.

Strength of this study is the fact that these data was collected over a period of ten years by the same medical team that took care of these 156 elite athletes. This allowed the athletes to be closely monitored and diagnoses to be confirmed over time. However our data is incomplete since very few details on the specific exercise during which the injury occurred were recorded. A standardized form of injury recording was not available since the beginning of data collection. Other limitations of this study include its retrospective nature and the inability to document the actual training hours for each athlete. Because of that we were unable to calculate incidence rates of specific injuries. Future research will be greatly facilitated if all Federations employ a standardized methodology. This will help to examine how the FIG Code of Points affects the rate and nature of injuries and also the long-term outcome of these injuries to the athletes' health and quality of life.

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