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Injury incidence, mechanism and diagnosis in top-level teamgym: a prospective study conducted over one season

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The aim of this study was to evaluate injury incidence, mechanism and diagnosis in Swedish teamgym. Sixteen male and 26 female gymnasts with international experience were prospectively followed during one season of training and competition. Injuries leading to a modified participation or total absence from gymnastics during 1 week or more were registered. Twenty-seven of the 42 gymnasts sustained 42 injuries. The injury incidence was 2.2/1000 gymnastics hours. No gender differences were found. Sixty-two percent of the injuries were located to the lower extremity, 28.5% to the back and 9.5% to the upper extremity. The most common injury was ankle sprain and the most frequent mechanisms were joint compression and joint rotation. The majority of the injuries occurred in the landing phase of the gymnastics skills and 50% of the injuries were reported at the end of the training session. Eighteen injuries occurred while the gymnasts were in a negative state of mood such as stressed or afraid. Injury prevention programs should be developed with respect to these findings. Special emphasis must be placed on the landing phase of the gymnastics skills as this phase seems to be critical.

Teamgym is a fairly new and popular form of gymnastics originating from Scandinavia. Among the gymnastics disciplines, teamgym attracts the highest number of gymnasts in Sweden and the sport is rapidly spreading in Europe. The 1st European Championships took place in Finland in 1996. The sport differs in several ways from the most known form of gymnastics, artistic gymnastics. Artistic gymnastics is an individual sport, while teamgym is a team sport with 6–12 members in each team. The events in teamgym include tumbling, trampette and floor program and are the same for males and females, while in artistic gymnastics some of the events for male and female gymnasts differ from each other. Each event in teamgym is performed by the team members simultaneously. The floor program is performed during approximately 3 min and by the entire team. Three series of tumbles and three different vaults are performed by at least six of the team members, in a row one by one, and the team receives a total score for each event.

In contrast to teamgym, artistic gymnastics has been closely studied with respect to injuries, and the types and mechanisms of injuries are quite well known (Caine et al., 1989; Lindner & Caine, 1990; Dixon & Fricker, 1993; Sands et al., 1993; Wadley & Albright, 1993; Bak et al., 1994; Kolt & Kirkby, 1999). For successful injury prevention it is important to identify the injury incidence, mechanism and diagnosis as well as the degree of injury severity (Meeuwisse, 1991; Van Mechelen et al., 1992; Kujala et al., 1995; Parkkari et al., 2001). Since teamgym in many ways differs from artistic gymnastics, there is a need for studying teamgym as a sport of its own. Only a few studies have been published on teamgym (Bak et al., 1994; Harringe et al., 2004). Bak et al. (1994) reported a significantly higher proportion of overuse injuries in teamgym gymnasts (tumbling gymnasts) compared with other categories of gymnasts, and the lower extremity was found to be the most common region for injuries, which is in agreement with Harringe et al. (2004). The aim of the present study was to evaluate injury incidence, mechanism and diagnosis in teamgym.

Material and methods

Subjects

Forty-two gymnasts, 16 males and 26 females, representing two of the top gymnastics teams in Sweden participated voluntarily in the present study. All gymnasts had international experience. Anthropometrics and training data are shown in Table 1. The

gymnasts were prospectively followed during one season (August–May) of training and competition and injuries were registered with respect to injury mechanisms and diagnosis. At the start of the study the subjects filled out a form regarding injuries and remaining symptoms from earlier injuries.

Registration of injuries

Injuries leading to a modified participation or total absence from gymnastics during 1 week or more were included in the study. All injured gymnasts were examined by the same sports physiotherapist with great experience of teamgym and each injury was registered with respect to injury mechanisms and diagnosis. Injuries that needed further evaluation were referred to, and examined by, a sports orthopedic surgeon, and when necessary examined with x-ray, magnetic resonance imaging (MRI) and/or arthroscopy. Only repeated injuries to the exact anatomic structures were considered to be re-injuries. In the majority of the cases the sports physiotherapist was in the gymnasium when the injury occurred, and an examination and interview with the gymnast was conducted at the time of injury. If the physiotherapist was not present the gymnast and coach filled out an injury protocol and contacted the physiotherapist for a clinical examination within 24 h after the injury occurred. Injuries that occurred outside gymnastics were not included in the study. The gymnasts answered questions such as how the injury occurred, in which skill and during which event as well as at what time during the training, competition or exhibition session.

To find out when in the skill the injury occurred, each skill, for example a full in half out on the trampette, was divided into four phases; the "run-up phase" – running toward and entering the trampette, the "takeoff phase" – leaving the trampette, the "specific skill" – the twists and somersaults, and the "landing phase" – touching the landing mat. The gymnasts were also asked whether they considered the skill in which they were injured to be a new skill for themselves or one that they were familiar with. They estimated how well they knew the skill in a three-grade scale: "very well," "well" or "poor." Furthermore, they were asked in which state of mood they were at the time of injury. The following alternatives were

Table 1. Anthropometrics and training data for the gymnasts ($n = 42$)

	Male gymnasts ($n = 16$)	Female gymnasts ($n = 26$)
Age (years)	21.8 (1.9)	18.0 (2.4)
Height (cm)	178.9 (4.1)	161.4 (7.0)
Weight (kg)	77.1 (9.6)	54.4 (6.4)
Body mass index (kg/m^2)	24.1 (2.8)	20.8 (1.7)
Gymnastics experience (years)	15.1 (3.0)	12.8 (3.3)
Training sessions/week	4.0 (0.5)	4.3 (0.5)
Training hours/week	11.0 (2.0)	11.0 (1.5)
Warm-up/training session (min)	14.2 (5.3)	15.9 (2.9)
Stretch/training session (min)	14.2 (10.2)	16.4 (8.2)

Values are expressed in mean (SD).

Table 2. Injury location, mechanisms and diagnosis in male and female gymnasts sustained during one season of training and competition

Injury location	Male gymnasts ($n = 16$)	Female gymnasts ($n = 26$)	Mechanisms*	Diagnosis	Additional examination
Lower extremity					
Foot		1	*41*	N suralis entrapment	
		1	*16*	Peroneus longus tendon sub luxation†	MRI
	1		*14*	Collateral ligament DIP MTP I tear	
Ankle joint	2	5	*17, 18, 22, 23, 25, 26, 36*	Fibulo-talare ant. ligament tear	X-ray
		1	*20*	Achilles tendon injury	X-ray
	1	1	*2, 40*	Deltoideum ligament injury	MRI
		1	*24*	Fibulo-talare anterior ligament tear and cuboid bone fracture	X-ray
		2	*4, 15*	Internal joint injury (cartilage)	
	1	1	*1, 11*	Ligament tear and cartilage damage†	MRI
Lower leg	2		*34, 39*	Medial tibial syndrome	
Knee joint	1		*38*	Meniscus tear†	Arthroscopy
		3	*19, 21, 29*	Collateral ligament tear (medial & lateral)	X-ray, MRI
		1	*3*	Anterior cruciate ligament and meniscus tear†	Arthroscopy
	1		*30*	quadriceps muscle strain	
Spine					
Lumbar spine	2	6	*9, 10, 12, 13, 27, 28, 35, 37*	Muscle and ligament strains, "low back pain"	MRI
Thoracic spine	1		*32*	Muscle strains Th8–Th12	
		1	*6*	Ligament strain costo-transversal joint	
Cervical spine	1		*31*	Muscle strain	
	1		*33*	Whiplash	
Upper extremity					
Shoulder joint	1	1	*7, 42*	Impingement syndrome	MRI
Elbow joint		1	*8*	Internal joint injury	
Hand	1		*5*	Collateral ligament MCP II tear	

*The numbers refer to Table 3.

†Required surgery.

A gymnast may have more than one injury ($n = 42$).

MRI, magnetic resonance imaging.

given to the gymnasts: not concentrated, concentrated, tired, alert, stressed, afraid or other feelings. The gymnasts were asked to define other feelings.

Statistics

The results are presented as proportions and percentages. Injury incidence was calculated as injuries/1000 gymnastics hours and a 95% confidence interval was estimated. Gymnastics hours include hours in training, competition and exhibition as one unit. Cross tabulations and χ^2 test were used to detect possible relationships between injury and injury mechanisms.

The study was approved by the local Ethical Committee at the Karolinska Institutet, Stockholm, Sweden.

Results

Symptoms at the start of the season

Twenty-four gymnasts reported symptoms from 26 injuries at the start of the study. Sixty-nine percent ($n = 18$) of these symptoms were located to the lower extremity, 19% ($n = 5$) to the back and 12% ($n = 3$) to the upper extremity. Sixteen of these gymnasts sustained another injury during the season, of which eight injuries were considered to be re-injuries. Eighteen gymnasts entered the study without any problems and 11 of those sustained an injury during the season.

Injuries during the season

Twenty-seven of the 42 gymnasts sustained 42 injuries during one season of training and competition. Of these injuries, 62% ($n = 26$) were to the lower extremity, 28.5% ($n = 12$) to the back and 9.5% ($n = 4$) to the upper extremity. Four injuries to the lower extremity required surgery. Injuries and their diagnosis are presented in Table 2. The injury incidence was 2.2 injuries/1000 gymnastics hours for males (95% confidence interval 1.1–3.4) as well as for females (95% confidence interval 1.4–3.0). Considering both male and female gymnasts the injury incidence was 2.2 injuries/1000 gymnastics hours with a 95% confidence interval equivalent to 1.6–2.9.

Injury mechanisms

Fifty-two percent ($n = 22$) of the injuries occurred during the "landing phase," 21.5% ($n = 9$) during "takeoff" and 5% ($n = 2$) during the "run-up" for tumbling and vaulting. Another 21.5% ($n = 9$) of the injuries occurred in different parts of the "specific skill." While analyzing the injuries, four different mechanisms for injury could be recognized. These were joint rotation, joint compression, hyperextension and overuse. When combinations of these mechanisms were detected, the main mechanism was registered.

Joint compression is here defined as a force compressing two or more bones of a joint. An example of this is a back somersault not completed at landing, a so-called under-rotation. In this study it resulted in cartilage damage to the ankle joint.

Joint rotation is here defined as one part of the joint being fixed, while the other rotates. An example of this is a twist, which is not completed at landing. The rotation continues while the foot is stuck to the landing mat. In this study it resulted in ligament injuries to the ankle joint.

Hyperextension is here defined as a joint mobilizing over its normal range of motion. An example of this is an uncontrolled takeoff from the trampette. In this study it resulted in hyperextension of the lower back and muscle injuries.

Overuse is here defined as an injury or a symptom that has been gradually developed over a period of time. An example of this is performing landings and takeoffs on various types of surfaces. In this study it resulted in medial tibial syndromes.

Dividing the injuries into these mechanisms, 38% ($n = 16$) were due to joint compression, 24% ($n = 10$) to joint rotation, 17% ($n = 7$) to hyperextension and 21% ($n = 9$) to overuse (Table 3).

No statistic correlations between injury mechanisms and diagnosis were found in the present study.

Injury occasion

Fifty-two percent ($n = 22$) of the injuries were sustained during tumbling, 28.5% ($n = 12$) during trampette and 9.5% ($n = 4$) during the floor program. One injury occurred during warm-up and three of the injuries occurred after a period of tumbling and vaulting.

Seventy-one percent ($n = 30$) of these injuries occurred during training, 19% ($n = 8$) during exhibition and 10% ($n = 4$) during competition. Twenty-six percent ($n = 11$) of the injuries occurred at the beginning of the session and 24% ($n = 10$) at mid-session. Thirty-three percent ($n = 14$) of the injuries occurred at the end of the session and another 17% ($n = 7$) were reported at the end of the session with a gradual increase of symptoms during the whole practice session.

Experience of injury occasion

The gymnasts were asked how well they knew the skill in which they were injured and in which state of mood they were when the injury occurred. In 34 (of 42) injury cases these questions could be answered.

In 47% ($n = 16$) of the cases the gymnasts reported that they knew the skill "very well," in 35% ($n = 12$) "well" and in 18% ($n = 6$) "poorly." Eight of the skills were considered new to the gymnasts and in six

Table 3. The four categories of injury mechanisms found when analyzing the injury charts including the gymnastic skills and the event in which the gymnasts were injured

Joint compression ($n = 16$)		Joint rotation ($n = 10$)		Hyperextension ($n = 7$)		Overuse ($n = 9$)	
Landed on the trampette/Tr	*1*	Full in half out/Tr	*17*	Take-off double/Tr	*27*	Training landings/Tr	*34*
Half out fliffies/Tr	*2*	Half out fliffies/Tr	*18*	Take-off front somersault/Tr	*28*	Training twists/Tr	*35*
Half out fliffies/Tr	*3*	Half out fliffies/Tr	*19*	Front somersault/Tu	*29*	Training camp/Tr, Tu	*36*
Tsukahara/Tr	*4*	Take-off double twist/Tu	*20*	Front somersault/Tu	*30*	Various training/Tr, Tu	*37*
1 1/2 front somersault/Tr	*5*	Double twist/Tu	*21*	Front somersault/Tu	*31*	Various training/Tr, Tu	*38*
Take-off handspring/Tu	*6*	Double twist/Tu	*22*	Double back somersault/Tu	*32*	Take-off hard surface/Tu	*39*
Take-off handspring/Tu	*7*	Round-off/Tu	*23*	Hesitation back handspring /Tu	*33*	Training soft surface/Fl	*40*
Take-off handspring/Tu	*8*	Round-off take-off/Tu	*24*			Training soft surface/Fl	*41*
Handspring front somersault/Tu	*9*	Round-off twist/Tu	*25*			Training planché/Fl	*42*
Side somersault/Tu	*10*	Warm-up on mat edge	*26*				
Take-off/Tu	*11*						
Take-off back somersault/Tu	*12*						
Double back somersault/Tu	*13*						
Double back somersault/Tu	*14*						
Double twist/Tu	*15*						
High jump/Fl	*16*						

The numbers (in italics) refer to the diagnoses in Table 2 ($n = 42$).
Tr, trampette; Tu, tumbling; Fl, floor programme.

of those skills the gymnasts reported that they were under high stress at the time of injury. Regarding the state of mood the answers were grouped as "positive," "negative" and "as usual." Answers such as happy, alert and concentrated were regarded as "positive feelings," while tired, stressed, afraid, not concentrated and/or out of focus were regarded as "negative feelings." Answers such as there was nothing different from other occasions, OK and as usual were regarded as "as usual." All together 53% ($n = 18$) of the injuries occurred while the gymnasts were in a negative state of mood. In 32% ($n = 11$) of the cases the gymnasts felt "as usual" and in 12% ($n = 4$) they were in a positive state of mood. In one case the gymnast was playing around.

Discussion

The overall injury incidence in the present study was 2.2/1000 gymnastics hours for males as well as females. This is somewhat lower than an earlier publication on Danish teamgym (Bak et al., 1994). The higher the level of gymnasts, the lower the injury incidence reported in artistic gymnastics (Lindner & Caine, 1990; Kolt & Kirkby, 1999). The gymnasts in the present study were high-level gymnasts with international experience, which might explain the lower injury incidence. Another possible explanation could be that each injury in the present study was carefully examined and registered by a sports physiotherapist, in some cases also by a sports orthopedic surgeon, in contrast to the Danish study, where the injuries were self-reported supervised by the coaches. Twenty-four gymnasts entered this study with symptoms from previous injuries. This is well in line with an earlier study on teamgym reporting that more than 50% of the gymnasts at high-level competitions do compete in spite of symptoms from injuries (Harringe et al., 2004). Furthermore, one-fifth of the injuries in the present study were considered to be re-injuries which is fairly low compared with earlier studies on artistic gymnastics and teamgym (Caine et al., 1989; Harringe et al., 2004).

The ankle joint was the most frequently injured part of the body, with ligament injuries and cartilage damage being the most common diagnoses. In previous studies on teamgym, a high prevalence of injuries to the lower extremity has been reported (Bak et al., 1994; Harringe et al., 2004). Studying each event in teamgym, it is obvious that the ankle is exposed to high loads because all events are performed with takeoff and landing on the feet. The majority of injuries occurred in the tumbling event and at landings, with joint compression and joint rotation representing the most common injury mechanisms. In the tumbling event three or more tumbles follow in a row and the last skill is the most difficult and demanding one. Just a small mistake somewhere along the tumbles will most likely affect the ankle during the landing phase. Under- or over-rotation of somersaults and twists has to be reduced in order to lower the injury rate of the ankle joint.

The low back was the second most common site for injury in the present study, and muscle strains and ligament injuries represented the majority of those diagnoses. In artistic gymnastics it is well known and a common concern that gymnasts suffer from back problems (Caine et al., 1989; Swärd et al., 1990, 1991; Dixon & Fricker, 1993; Sands et al., 1993; Wadley & Albright, 1993; Kolt & Kirkby,

1999) and the re-injury rates have been proven high both in artistic gymnastics and in teamgym (Caine et al., 1989; Harringe et al., 2004).

Eighteen of the injuries in this study occurred when the gymnasts were in a negative state of mood expressing feelings such as fear, stress or out of focus. However, the state of mood in the present study was collected immediately after the injury incidence, which to some extent could have influenced the gymnasts' answers. It would have been more valuable, but for practical reasons difficult, to have had the gymnasts reporting their state of mood before they were injured. Each training session lasts for about 2–3 h and in order to receive valuable estimations the gymnasts would actually have had to express their state of mood before each run-up for a gymnastics skill.

The majority of injuries occurred at the end of the gymnastics session when the gymnasts might have been fatigued. Stress or fatigue could most probably have a negative impact on the motor control and consequently lead to injury. Moreover, eight of the injuries were sustained while performing skills that the gymnasts regarded as new to them. It is important to be prepared mentally as well as physically while performing difficult skills, and even more while performing skills that are considered new. Mental training could be one complement in preparing a new skill. Another way could be to perform the most difficult skills at the beginning of the training session. There is, however, always a need for maximal concentration during gymnastics performance, so the strategies for training have to be analyzed in accordance with the ability of each gymnast. The higher the level of performance, the more difficult motor skills, individual strategies for training and performing have to be developed. The individual strategies might be overseen in teamgym as it is a team sport. However, each gymnast's performance is important for the team result.

Further studies are needed, both epidemiological and clinical experimental, in order to establish well-defined injury prevention methods.

Perspectives

The ankle joint and the low back represented the most common sites for injuries in top-level teamgym. In the majority of the cases there were ligament and muscle injuries. The injuries occurred mostly during the landing phase of the gymnastics skill, with joint compression and joint rotation as the primary injury mechanisms. Most injuries occurred at the end of the gymnastics session and when the gymnasts were in a negative state of mood expressing feelings such as fear, stress or out of focus. These mechanisms suggest that it is important for teamgym gymnasts to be both mentally and physically prepared and these findings should be taken into consideration when providing teamgym with injury prevention programs.

Key words: gymnastics, motor control, prevention, sports injuries.

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