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Descriptive Epidemiology of Collegiate Women's Gymnastics Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 Through 2003–2004

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Objective: To review 16 years of National Collegiate Athletic Association (NCAA) injury surveillance data for women's gymnastics and identify potential areas for injury prevention initiatives.

Background: In the 1988–1989 academic year, 112 schools were sponsoring varsity women's gymnastics teams, with approximately 1550 participants. By 2003–2004, the number of varsity teams had decreased 23% to 86, involving 1380 participants. Significant participation reductions during this time were particularly apparent in Divisions II and III.

Main Results: A significant annual average decrease was noted in competition (−4.0%, $P < .01$) but not in practice (−1.0%, $P = .35$) injury rates during the sample period. Over the 16 years, the rate of injury in competition was more than 2 times higher than in practice (15.19 versus 6.07 injuries per 1000 athlete-exposures; rate ratio = 2.5, 95% confidence interval [CI] = 2.3, 2.8). A total of 53% of all competition and 69% of all practice injuries were to the lower extremity. A participant was almost 6 times more likely to sustain a knee internal derangement injury in competition than in practice (rate ratio = 5.7, 95% CI = 4.5, 7.3) and almost 3 times more likely to sustain an ankle ligament sprain (rate ratio = 2.7, 95% CI = 2.1, 3.4). The majority of competition injuries (approximately 70%) resulted from either landings in floor exercises or dismounts.

Recommendations: Gymnasts with a previous history of ankle sprain should either wear an ankle brace or use prophylactic tape on their ankles to decrease the risk of recurrent injury. Preventive efforts may incorporate more neuromuscular training and core stability programs in the off-season and preseason conditioning to enhance proper landing and skill mechanics. Equipment manufacturers are encouraged to reevaluate the design of the landing mats to allow for better absorption of forces.

Key Words: athletic injuries, injury prevention, knee injuries, ankle injuries

The National Collegiate Athletic Association (NCAA) conducted its first women's gymnastics championship in 1982. In the 1988–1989 academic year, 112 schools were sponsoring varsity women's gymnastics teams, with approximately 1550 participants. By 2003–2004, the number of varsity teams had decreased 23% to 86, involving 1380 participants.[1] Significant participation reductions during this time were particularly apparent in NCAA Divisions II and III.

SAMPLING AND METHODS

Over the 16-year period from 1988–1989 through 2003–2004, an average of 21.1% of schools sponsoring varsity women's gymnastics programs participated in annual NCAA Injury Surveillance System (ISS) data collection (Table 1).The sampling process, data collection methods, injury and exposure definitions, inclusion criteria, and data analysis methods are described in detail in the ''Introduction and Methods'' article in this special issue.[2]

RESULTS

Competition and Practice Athlete-Exposures

The average annual numbers of competitions, practices, and athletes participating for each NCAA division, condensed over the study period, are shown in Table 2. The 3 divisions averaged a similar number of annual competition and practice participants. Annually, Divisions I and II averaged approximately 14 more practices and 1 more competition than Division III.

Injury Rate by Activity, Division, and Season

Competition and practice injury rates over time combined across divisions with 95% confidence intervals (CIs) are displayed in Figure 1. A significant average annual decrease was seen in competition (−4.0%, $P < .01$) but not in practice (−1.0%, $P = .35$) injury rates over the sample period. Over the 16 years of the study, the risk of injury in a competition was more than 2 times higher than the risk of injury in practice (15.19 versus 6.07 injuries per 1000 athlete-exposures [A-Es], rate ratio = 2.5, 95% CI = 2.3, 2.8).

The total number of competitions and practices and associated injury rates condensed over years by division and season (preseason, in season, and postseason) are presented in Table 3. Over the 16-year period, 495 injuries from more than 3300 competitions and 2244 injuries from more than 30 000 practices were reported. Competition injury rates were higher in Division I than in Division III (16.61 versus 7.55 injuries

Table 1. School Participation Frequency (in Total Numbers) by Year and National Collegiate Athletic Association (NCAA) Division, Women's Gymnastics, 1988–1989 through 2003–2004*

Academic Year	Division I Schools		Division II Schools		Division III Schools		All Divisions		
	Participating	Sponsoring	Participating	Sponsoring	Participating	Sponsoring	Participating	Sponsoring	Percentage
1988–1989	8	69	4	20	5	23	17	112	15.2
1989–1990	10	68	3	21	2	19	15	108	13.9
1990–1991	16	67	4	19	5	17	25	103	24.3
1991–1992	21	69	5	12	5	15	31	96	32.3
1992–1993	18	67	3	10	2	14	23	91	25.3
1993–1994	22	68	3	10	1	14	26	92	28.3
1994–1995	16	67	5	10	4	13	25	90	27.8
1995–1996	15	69	1	8	4	19	20	96	20.8
1996–1997	17	67	3	8	4	16	24	91	26.4
1997–1998	17	68	2	7	3	16	22	91	24.2
1998–1999	4	67	1	7	2	16	7	90	7.8
1999–2000	12	67	2	7	3	16	17	90	18.9
2000–2001	11	67	1	7	5	16	17	90	18.9
2001–2002	15	66	3	7	2	16	20	89	22.5
2002–2003	12	64	2	7	3	15	17	86	19.8
2003–2004	6	64	2	7	2	15	10	86	11.6
Average	14	67	3	10	3	16	20	94	21.1

*"Participating" refers to schools that provided appropriate data to the Injury Surveillance System; "Sponsoring" refers to the total number of schools offering the sport within the NCAA divisions.

Table 2. Average Annual Competitions, Practices, and Athletes Participating by National Collegiate Athletic Association Division per School, Women's Gymnastics, 1988–1989 Through 2003–2004

Division	Competitions	Athletes per Game	Practices	Athletes per Practice
I	12	10	103	12
II	12	10	103	12
III	11	9	89	13

per 1000 A-Es, rate ratio = 2.2, 95% CI = 1.5, 3.1, $P < .01$). Across all divisions, in-season competition injury rates were higher than postseason rates (15.55 versus 10.82 injuries per 1000 A-Es, rate ratio = 1.4, 95% CI = 0.98, 2.12, $P = .07$).

Body Parts Injured Most Often and Specific Injuries

The frequency of injury to 5 general body areas (head/neck, upper extremity, trunk/back, lower extremity, and other/system) for competitions and practices with years and divisions combined is shown in Table 4. A total of 69.3% of all competition and 52.8% of all practice injuries were to the lower extremity. Upper extremity injuries accounted for another 11.5% of competition injuries and 17.8% of practice injuries. Injuries to the head and neck represented 6.7% of competition injuries and 5.6% of practice injuries.

The most common injured body part and injury type combinations for competition and practices with years and divisions combined are shown in Table 5. All injuries that accounted for at least 1% of reported injuries over the 16-year

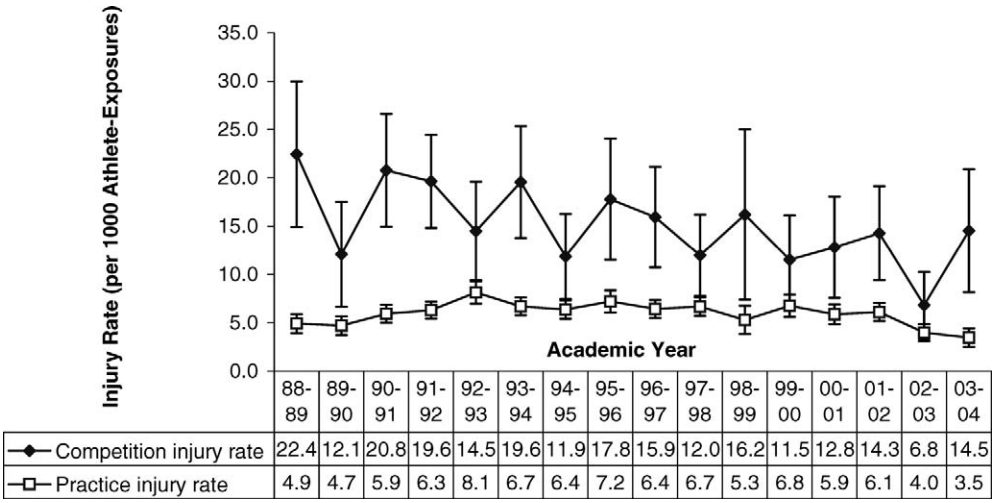

Figure 1. Injury rates and 95% confidence intervals per 1000 athlete-exposures by competitions, practices, and academic year, women's gymnastics, 1988–1989 through 2003–2004 (n = 495 competition injuries and 2244 practice injuries). Competition average annual change = −4.0%; time trend, $P < .01$, 95% confidence interval = −6.3, −1.6. Practice average annual change = −1.0%; time trend, $P = .35$, 95% confidence interval = −3.0, 1.1.

Table 3. Competition and Practice With Associated Injury Rates by National Collegiate Athletic Association Division and Season, Women's Gymnastics, 1988–1989 Through 2003–2004*

	Total No. of Competitions Reported	Competition Injury Rate per 1000 Athlete-Exposures	95% Confidence Interval	Total No. of Practices Reported	Practice Injury Rate per 1000 Athlete-Exposures	95% Confidence Interval
Division I						
Preseason	33	16.95	3.39, 30.51	12 015	8.80	8.32, 9.27
In season	2125	16.95	15.21, 18.70	8277	4.15	3.75, 4.55
Postseason	216	11.63	6.54, 16.73	1205	2.18	1.40, 2.96
Total Division I	2375	16.61	14.96, 18.26	21 497	6.70	6.38, 7.01
Division II						
Preseason	8	11.38	0.00, 33.67	2294	7.01	6.06, 7.97
In season	437	15.22	11.60, 18.84	1741	4.39	3.49, 5.30
Postseason	27	16.81	0.34, 33.28	189	3.15	0.82, 5.79
Total Division II	473	15.23	11.73, 18.72	4224	5.82	5.16, 6.47
Division III						
Preseason	8	0.00	0.00, 0.00	2060	4.23	3.44, 5.02
In season	386	7.98	5.12, 10.83	2091	2.67	2.03, 3.32
Postseason	70	5.58	0.00, 11.89	292	1.17	0.02, 2.32
Total Division III	464	7.55	4.97, 10.12	4443	3.35	2.86, 3.84
All Divisions						
Preseason	49	15.84	4.11, 27.58	16 369	7.96	7.57, 8.34
In season	2948	15.55	14.13, 16.97	12 109	3.93	3.61, 4.25
Postseason	313	10.82	6.74, 14.91	1686	2.11	1.47, 2.76
Total	3314	15.19	13.85, 16.53	30 164	6.07	5.82, 6.33

*Wald χ^2 statistics from negative binomial model: competition injury rates did not differ among divisions ($P = .08$) but did differ within season ($P < .01$); practice injury rates did not differ among divisions ($P = .28$) but did differ within season ($P < .01$). Postseason sample sizes were much smaller and had higher variability than preseason and in season sample sizes because only a small percentage of schools participated in the postseason tournament in any sport, and not all of those were a part of the Injury Surveillance System sample. Numbers do not always sum to totals because of missing division or season information.

Table 4. Percentage of Competition and Practice Injuries by Major Body Part, Women's Gymnastics, 1988–1989 Through 2003–2004

Body Part	Competitions	Practices
Head/neck	6.7	5.6
Upper extremity	11.5	17.8
Trunk/back	9.5	19.1
Lower extremity	69.3	52.8
Other/system	3.0	4.7

sampling period were included. In competitions, knee internal derangements (20.0%) and ankle ligament sprains (16.4%) accounted for the majority of injuries. In practices, ankle ligament sprains (15.2%), knee internal derangements (8.7%), and low back strains (6.1%) accounted for most of the reported injuries. Concussions represented 2.3% of practice injuries and 2.6% of competition injuries. A participant was nearly 6 times more likely to sustain a knee internal derangement in competition than in practice (3.04 versus 0.53 per 1000 A-Es, rate ratio = 5.7, 95% CI = 4.5, 3.4) and almost 3 times as likely to sustain an ankle ligament sprain in competition as in practice (2.48 versus 0.93 per 1000 A-Es, rate ratio = 2.7, 95% CI = 2.1, 3.4).

Mechanism of Injury

The 2 injury mechanisms, other contact with an object (such as apparatus or floor) and no contact, in competitions and practices with division and years combined, are displayed in Figure 2. The majority of competition injuries (70.7%) resulted from other contact, primarily during landings. This category was also the leading mechanism for practice injuries.

Severe Injuries: 10+ Days of Activity Time Loss

The top injuries that resulted in at least 10 consecutive days of restricted or total loss of participation and their primary injury mechanisms combined across divisions and years are presented in Table 6. For this analysis, time loss of 10+ days was considered a measure of severe injury. A total of 39.0% of competition and 32.0% of practice injuries restricted participation for at least 10 days. In both competitions and practices, knee internal derangements and ankle ligament sprains accounted for the highest percentage of more severe injuries. A total of 25% of ankle sprains were recurrences (data not shown).

Competition Injuries

The competition event or apparatus used at the time of injury combined over the years is shown in Figure 3. Floor exercise and vault accounted for the largest number of competition injuries. The competition event or apparatus used at the time of injury, the most common types of injuries associated with those activities, and whether the injuries occurred during mounting, the routine, or the dismount are described in Table 7. Knee internal derangement was the most common injury in all events, most often occurring during the dismount, except in tumbling routines during floor exercise.

Table 5. Most Common Competition and Practice Injuries, Women's Gymnastics, 1988–1989 Through 2003–2004*

Body Part	Injury Type	Frequency	Percentage of Injuries	Injury Rate per 1000 Athlete-Exposures	95% Confidence Interval
Competitions					
Knee	Internal derangement	99	20.0	3.04	2.44, 3.63
Ankle	Ligament sprain	81	16.4	2.48	1.94, 3.02
Lower back	Muscle-tendon strain	16	3.2	0.49	0.25, 0.73
Unspecified†	Unspecified	14	2.8	0.43	0.20, 0.65
Upper leg	Muscle-tendon strain	14	2.8	0.43	0.20, 0.65
Head	Concussion	13	2.6	0.40	0.18, 0.62
Knee	Hyperextension	13	2.6	0.40	0.18, 0.62
Lower leg	Muscle-tendon strain	12	2.4	0.37	0.16, 0.58
Heel/Achilles tendon	Contusion	10	2.0	0.31	0.12, 0.50
Foot	Ligament sprain	9	1.8	0.28	0.10, 0.46
Neck	Muscle-tendon strain	9	1.8	0.28	0.10, 0.46
Elbow	Dislocation	8	1.6	0.25	0.08, 0.42
Heel/Achilles tendon	Muscle-tendon strain	8	1.6	0.25	0.08, 0.42
Knee	Contusion	8	1.6	0.25	0.08, 0.42
Elbow	Ligament sprain	7	1.4	0.21	0.06, 0.37
Shoulder	Muscle-tendon strain	7	1.4	0.21	0.06, 0.37
Ankle	Fracture	6	1.2	0.18	0.04, 0.33
Ankle	Muscle-tendon strain	6	1.2	0.18	0.04, 0.33
Foot	Contusion	6	1.2	0.18	0.04, 0.33
Foot	Fracture	6	1.2	0.18	0.04, 0.33
Pelvis, hip	Muscle-tendon strain	6	1.2	0.18	0.04, 0.33
Patella	Patella or patella tendon injury	5	1.0	0.15	0.02, 0.29
Patella	Subluxation	5	1.0	0.15	0.02, 0.29
Shoulder	Subluxation	5	1.0	0.15	0.02, 0.29
Upper back	Muscle-tendon strain	5	1.0	0.15	0.02, 0.29
Practices					
Ankle	Ligament sprain	342	15.2	0.93	0.83, 1.02
Knee	Internal derangement	195	8.7	0.53	0.45, 0.60
Lower back	Muscle-tendon strain	137	6.1	0.37	0.31, 0.43
Unspecified†	Unspecified	92	4.1	0.25	0.20, 0.30
Upper leg	Muscle-tendon strain	82	3.7	0.22	0.17, 0.27
Pelvis, hip	Muscle-tendon strain	61	2.7	0.17	0.12, 0.21
Shoulder	Muscle-tendon strain	56	2.5	0.15	0.11, 0.19
Head	Concussion	51	2.3	0.14	0.10, 0.18
Lower leg	Stress fracture	49	2.2	0.13	0.10, 0.17
Neck	Muscle-tendon strain	46	2.0	0.12	0.09, 0.16
Patella	Patella or patella tendon injury	42	1.9	0.11	0.08, 0.15
Lower back	Ligament sprain	39	1.7	0.11	0.07, 0.14
Foot	Contusion	37	1.6	0.10	0.07, 0.13
Shoulder	Tendinitis	33	1.5	0.09	0.06, 0.12
Foot	Ligament sprain	32	1.4	0.09	0.06, 0.12
Elbow	Ligament sprain	28	1.2	0.08	0.05, 0.10
Toe(s)	Ligament sprain	28	1.2	0.08	0.05, 0.10
Upper back	Muscle-tendon strain	27	1.2	0.07	0.05, 0.10
Lower leg	Muscle-tendon strain	26	1.2	0.07	0.04, 0.10
Shoulder	Subluxation	23	1.0	0.06	0.04, 0.09

*Only injuries that accounted for at least 1% of all injuries are included.
†"Unspecified" indicates injuries that could not be grouped into existing categories but that were believed to constitute reportable injuries.

COMMENTARY

Overall, competition injury rates in collegiate women's gymnastics during the past 16 years have significantly decreased (by 4% per year, on average) for competitions. A total of 36.4% of all injuries in competitions were knee internal derangements or ankle ligament sprains. In practices, 23.9% of all injuries are knee internal derangements or ankle ligament sprains. Gymnasts were 6 times more likely to sustain a knee internal derangement and almost 3 times more likely to sustain an ankle ligament sprain in competition than in practice. Female gymnasts had a 3-times-greater rate of injury during preseason practices compared with in-season practices. Almost one third of all competition injuries occurred during the floor routine. For nonfloor events, dismounts accounted for most of the injuries.

These results are consistent with those from previous research on women's gymnastics, although direct comparisons are difficult because of variations in study methods. The lower extremity was the injured body site reported most often by certified athletic trainers, which is consistent with previous findings.[3–8] Kolt and Kirkby[3] noted that elite gymnasts reported the most common location of injury to be the ankle

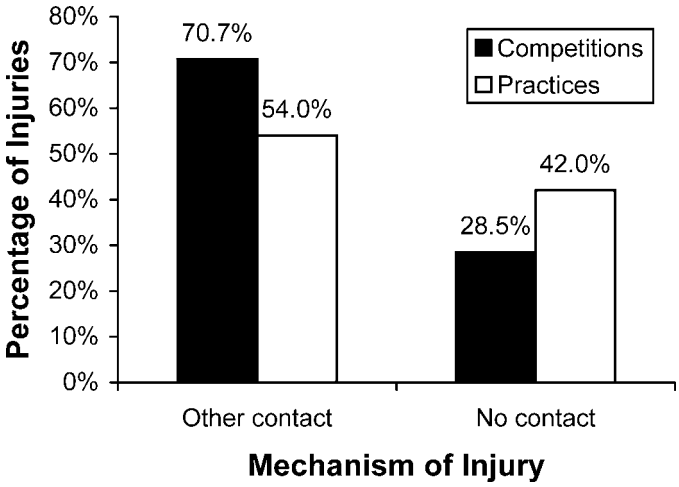

Figure 2. Competition and practice injury mechanisms, all injuries, women's gymnastics, 1988–1989 through 2003–2004 (n = 495 competition injuries and 2244 practice injuries). "Other contact" refers to contact with items such as the floor, the mat, or equipment. Injury mechanism was unknown for 1% of game injuries and 3% of practice injuries.

and foot (30.7%), followed by the knee (16.3%), elbow and forearm (12.4%), and wrist and hand (9.8%). Almost all investigators studying women's gymnastics reported that most injuries were incurred in the ankle and foot.[3–8] Caine and Nassar[5] found that ankle sprains were the most commonly reported injury by gymnasts participating in the 2002–2004 USA Gymnastics National Women's Artistic Championships. The majority of ankle injuries resulted from falls on dismounts and tumbling during floor routines. Gymnasts constantly land from great heights while twisting and rotating, leading to the high rates of both initial and recurrent ankle injuries. One recommendation may be for gymnasts with a previous history of ankle sprains to wear either an ankle brace or prophylactic tape on the ankle to try and decrease the risk of injury. In addition, athletes with a previous history of ankle sprains should either brace or tape their ankles during competitions to try and decrease the injury rates during competition.[9]

Time loss due to injury is difficult to measure because gymnasts tend to modify their training to avoid potential physical deconditioning.[3] Kolt and Kirkby[3] reported that elite gymnasts modified a significantly greater number of practice sessions than did subelite gymnasts, either because of pressure from coaches or fear of physical deconditioning. In the current study, 39% of competition and 32% of practice injuries restricted participation for at least 10 days, with knee internal derangements and ankle ligament sprains accounting for the highest percentage of time-loss injuries. Similarly, Caine et al[4] reported that 33.3% of injuries had a time loss of between 8 and 21 days, and 25.9% had a time loss of more than 21 days.

Another area of injury concern in female gymnasts is the lower back. Gymnasts place a considerable amount of stress on the lower back as a result of repetitive flexion, hyperextension, rotation, and compressive loading of the spine on landings. Several researchers[10–12] have suggested that anterior column spine problems, such as anterior vertebral endplate fractures, are more common than posterior column spine problems. However, these specific types of injuries cannot be distinguished in the ISS data, so we cannot determine if they are

Table 6. Most Common Competition and Practice Injuries Resulting in 10+ Days of Activity Time Loss, Women's Gymnastics, 1988–1989 Through 2003–2004

Body Part	Injury Type	Frequency	Percentage of Severe Injuries	Most Common Injury Mechanism
Competitions (39.0% of all injuries required 10+ days of time loss)				
Knee	Internal derangement	75	38.9	Other contact*
Ankle	Ligament sprain	23	11.9	Other contact*
Other		95	49.2	
Total		193		
Practices (32.0% of all injuries required 10+ days of time loss)				
Knee	Internal derangement	119	16.5	Other contact*
Ankle	Ligament sprain	105	14.5	Other contact*
Other		499	69.0	
Total		723		

*Indicates landing.

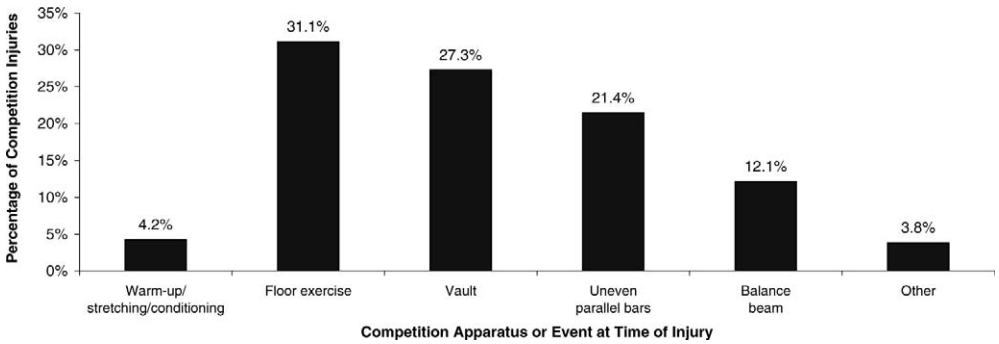

Figure 3. Competition apparatus or event at time of injury, women's gymnastics, 1988–1989 through 2003–2004 (n = 495).

Table 7. Most Common Competition Injuries Associated With An Apparatus or Event, Women's Gymnastics, 1988–1989 Through 2003–2004 (n = 495)*

Apparatus or Event	Most Common Competition Injury	Injuries Associated with Each Apparatus or Event, %	Most Frequent Activity for This Injury on Apparatus or in Event
Floor (n = 154)	Ankle ligament sprain	25	Routine
	Knee internal derangement	21	Routine
Uneven parallel bars (n = 106)	Knee internal derangement	19	Dismount
	Elbow dislocation	7	Routine
Balance beam (n = 60)	Knee internal derangement	15	Dismount
	Ankle ligament sprain	15	Dismount
Vault (n = 135)	Knee internal derangement	22	Dismount
	Ankle ligament sprain	16	Dismount

*Warm-up/other (n = 40).

more common in NCAA gymnasts. Low back strains were the third most common practice injury, accounting for 6.1% of all practice injuries and 3.2% of competition injuries. However, these data may not fully capture the entire burden of low back injuries in gymnastics, because for many chronic low back problems, the athlete may not be restricted (no time loss) and, thus, the injury would not be captured by the time-loss definition used in the ISS. The new Web-based ISS has been adapted to capture both time-loss and non–time-loss injuries; future analyses may provide a better picture of the epidemiology of low back injuries in this population.

During the regular season, competition injury rates were 4 times higher than practice injury rates. Sands et al[13] suggested that increased competition injuries may be due to the higher level of fatigue athletes develop when performing full routines in season. In another study, Sands[14] proposed that gymnasts may be more protected in practices than in competitions because during practice, they often land in foam pits, on softer mats, or with the aid of spotting belts and bungee devices. Although spotting is now allowed in competition, the higher injury incidence in competition than in practice warrants a reevaluation of competition rules and performance environment. When one reviews the judging of the competition, the trend over the years has been to reward a higher degree of tumbling, creating a need for the gymnast to add more saltos and full twists. This has caused a decrease in the artistic aspect of gymnastics, and dance skills have been devalued. If the artistic aspect and dance skills were to be given greater value, then gymnasts would have an option to perform fewer high-risk skills and still have the potential for high scores.

The risk of injury was 2 times greater during preseason than in-season practice sessions. Preseason practice is typically the time to learn new skills for the competition season. These new skills may contribute to an increase in injuries over in-season practice sessions. Gymnasts not fully recovered from injuries during the preseason may decrease their practice time and repetition of skills during in-season practices, which may in turn decrease injury rates. Another explanation for the increased injury rate in the preseason may be decreased physical conditioning and fatigue from increased training intensity. Gymnasts may begin the preseason in a deconditioned state, compared with their fitness levels at the end of the previous season. Strength and conditioning coaches should provide gymnasts with a physical conditioning program during the off-season to maintain their fitness level year-round. As a result, gymnasts should begin the preseason in good physical condition, allowing coaches to implement a progressive training program that includes practicing old skills, learning new skills, modifying routines, and then performing full routines.

The results of this study are consistent with those of previous researchers,[4,13,15,16] who reported that floor exercise was associated with the greatest number of injuries. One would expect to see this finding in gymnasts who either compete in the all-around or specialize in floor exercise as a result of the repetitive landings that occur in floor exercise routines. Furthermore, gymnasts spend a considerable amount of time training in tumbling, completely separate from other floor components. The forces at the ankle that are required during tumbling take-offs and landings range from 5.0 to 17.5 times a gymnast's body weight, which may contribute to increased incidence and severity of ankle injuries.[17]

The vault also contributes to more than one quarter of all gymnastic injuries. Most injuries occur to the knee and ankle during vault dismounts. During the 2002–2003 season, the vault horse was switched to the vault table. The design of the new vault table allows gymnasts to propel themselves higher up and further out, creating the potential for more difficult and risky vaults to be attempted and executed. Therefore, an increase in ankle and knee injuries may be due to greater ground reaction forces during landing. Wrist injuries may decrease because the vault table does afford a greater ''sweet spot'' for hand contact on the table than the horse. Overall, we expect to see a decrease in injuries on the preflight due to hand contact and an increase in injuries on the postflight due to foot contact. However, research on the safety of the current vault table design and its influence on injuries has yet to be conducted.

Although injury rates over the past 16 years have declined for competitions, further prevention interventions are needed. Over the past decade, the use of the ''sting mat'' has been approved in competitions as a way to soften landings. When a gymnast lands on a new landing mat, she tends to skip on top of the mat and then sink into the mat, producing a very fast oscillatory action of the feet before sinking into the mat. With the use of the sting mat, the athlete avoids the skipping aspect because the soft mat absorbs some of the forces. Bruggemann[10] reported that sting mats reduced the compressive forces on the spine during landings by 20%. Equipment manufacturers may assist in reducing injuries by reevaluating the landing mats and changing the surface of the mat to one that incorporates the absorption properties of a sting mat as a top layer on the landing mats.

The majority of injuries in collegiate gymnasts are suffered during the dismount. In gymnastics, bonus points are scored for more difficult maneuvers and can enhance the routine's start value. This leads us to question the risk:benefit ratio of this system. A greater deduction for a fall on the dismount might encourage better and safer landing strategies and improvement in overall task execution. Increasing the penalty for poorly performing the skill reduces the gymnast's desire to perform the more difficult skills until she is confident in performing the skill.

The results of this study have potential with regard to the development of preventive measures as well as for numerous future research studies. First, investigators should examine the vibration components of the floor exercise platform and beam, vault, and uneven bars dismount safety mats to improve the absorption of the repetitive impacts from landings. Second, further study is needed in the design of the balance beam to assist in the absorption of forces. The balance beam has been improved from the original wood beam to a padded beam with reflex shock absorption in the legs of the beam to help absorb the forces applied through this piece of equipment. However, few authors have examined the optimal stiffness and shock-absorbing capacity of the apparatus. Third, future researchers need to examine the new vaulting table to determine if it has decreased the number of injuries compared with the old vault horse.

In conclusion, overall injury rates during the past 16 years have decreased for competitions. The ankle, knee, and lower back appear to be the most commonly injured areas in collegiate female gymnasts, with athletes facing a 6-times-greater likelihood of sustaining knee internal derangement in competition than in practice. Most injuries occur during dismount or tumbling during the floor routine. Preventive efforts may incorporate more neuromuscular training programs and core stability programs in the off-season and preseason conditioning to enhance proper landing and skill mechanics. In addition, many sports incorporate the use of taping and bracing to prevent ankle injuries. It may be beneficial for the sport of gymnastics to encourage this method of assisting in injury prevention. Equipment manufacturers are encouraged to reevaluate the design of landing mats to allow for better absorption of landing forces.

DISCLAIMER

The conclusions in the Commentary section of this article are those of the Commentary authors and do not necessarily represent the views of the National Collegiate Athletic Association.

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