Injury Patterns and Injury Rates in the Circus Arts

An Analysis of 5 Years of Data From Cirque du Soleil

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Background: Human circus arts are gaining increasing popularity as a physical activity with more than 500 companies and 200 schools. The only injury data that currently exist are a few case reports and 1 survey.

Hypothesis: To describe injury patterns and injury rates among Cirque du Soleil artists between 2002 and 2006.

Study Design: Descriptive epidemiology study.

Methods: The authors defined an injury as any work-related condition recorded in an electronic injury database that required a visit to the show therapist. Analyses for treatments, missed performances, and injury rates (per 1000 artist performances) were based on a subset of data that contained appropriate denominator (exposure) information (began in 2004).

Results: There were 1376 artists who sustained a total of the 18 336 show- or training-related injuries. The pattern of injuries was generally similar across sex and performance versus training. Most injuries were minor. Of the 6701 injuries with exposure data, 80% required ≤7 treatments and resulted in ≤1 completely missed performance. The overall show injury rate was 9.7 (95% confidence interval, 9.4-10.0; for context, published National Collegiate Athletic Association women's gymnastics rate was 15.2 injuries per 1000 athlete-exposures). The rate for injuries resulting in more than 15 missed performances for acrobats (highest risk group) was 0.74 (95% confidence interval, 0.65-0.83), which is much lower than the corresponding estimated National Collegiate Athletic Association women's gymnastics rate.

Conclusion: Most injuries in circus performers are minor, and rates of more serious injuries are lower than for many National Collegiate Athletic Association sports.

Keywords: injury; acrobat; musician; circus

Although there are significant benefits to physical activity,[**] there is also an associated increased risk of injury. Injury patterns and injury rates are specific to the type of activity being performed, and therefore the development of prevention programs requires an understanding of the specific causes of injury that are present within each activity. The first step in any injury prevention program is to describe the injury pattern, injury severity, and incidence associated with the activity.[3,28]

Historically, clinicians have focused on injury risks for traditional activities such as baseball, hockey, athletics, and swimming. Recently, others have noted that activities within the performing arts also stress the musculoskeletal system.[7,8,12] Of the many performing arts, modern circus artists (without animals) may be the most closely related to sport as artists often have training in gymnastics and acrosport. For example, more than 1000 artists in the Cirque du Soleil (a company with 17 current shows)

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perform a wide variety of athletic acts that include tethered and untethered aerial maneuvers, diving and swimming maneuvers, martial arts, dance, and Chinese acrobatic arts. A worldwide registry[16] reports that there are more than 500 companies dedicated to circus arts, and they are practiced in at least 19 countries. In addition to their regular show schedules, these companies regularly perform more than 200 festivals or events per year. The infrastructure includes at least 216 circus schools and 19 federations dedicated to circus arts. These numbers reflect only official circus arts, and the numbers are greater if one also includes street artists.

Despite the large numbers of circus artists and trainees, the only reference related to training or performance-related injuries in circus artists that we could find in PubMed or Embase using a broad-based search strategy ("circus" AND "injury") was 1 case report of a proximal fibular stress fracture[2]; we are also aware of references related to the specific act of sword swallowing.[29] Given the importance of physical activity, the increasing popularity of circus arts and circus shows, the unique environment in which the artists work, and the unknown patterns/risk of injury, a better understanding of the injury patterns and rates is required to develop appropriate and effective injury prevention programs. We therefore approached Cirque du Soleil (Cirque) who provided us with access to all the injury data and work records required. We hope the results of this descriptive historical cohort study will help other investigators/clinicians study and prevent injuries of circus artists around the world.

METHODS

We obtained data from the Cirque injury database. Cirque is 25 years old, currently has 17 shows, and has performed at the Academy Awards and the World Aquatic Championships. According to our research ethics committee, because this project uses historical data in the records of a private company, and those data were not gathered for research purposes, it therefore falls under a category of quality assurance that is exempt from a requirement for formal research ethics approval.

Each show in Cirque has 2 or 3 certified rehabilitation therapists (athletic trainer/therapist or physiotherapist/physical therapist) who have recorded injury-related information in an electronic database since 2002. We defined an injury as any visit to the therapist for a new work-related complaint (eg, sprained ankle while skiing would be excluded). This is equivalent to the "medical attention injury" definition suggested by others.[9-11]

We extracted the de-identified data from the database. We categorized injuries according to anatomical location and injury type similar to that recommended by published consensus statements.[9-11] Duplicate injuries were deleted (eg, 2 injuries to the same artist on the same date with the same location and injury type), and exacerbations were considered as part of the initial injury. If an event resulted in multiple injuries (eg, knee injury and ankle injury), each injury was considered a separate injury in the analysis. Because the Cirque database was originally designed as a management tool, some of the data did not immediately lend themselves for a complete analysis. For example, if an injury category was ambiguous (eg, "irritation"), we searched the electronic medical record manually, and the injury/treatment was recategorized appropriately or marked as "other." For anatomical locations, trunk refers to nonspine injuries, spine refers to thoracolumbar and sacroiliac joint injuries, and spinal neck injuries are considered under head and neck injuries. If specific information about an artist was lacking in the database, the performance medicine department or human resources department provided the missing information using other sources. Finally, we categorized artists as acrobatic, nonacrobatic, or musician. Artists perform many roles within a performance. Any artist who participated in an act that required an acrobatic coach was defined as acrobatic (eg, acts requiring gymnastics, diving, martial arts, aerial movements); any artist who participated as a musician was considered a musician (Cirque performances all use live music with the exception of the tribute show to the Beatles called "LOVE," and these artists do not generally perform any form of acrobatic maneuver); all other artists were considered nonacrobats (eg, dancers, jugglers, swimmers, clowns, and characters in a show that do not perform gymnastic or martial arts or aerial movements).

Injury Rates

Exposure data (number of performances) necessary to calculate injury rates (number of injuries/number of exposures) and treatments were not available for the entire data set of injuries. In August 2004, Cirque began to electronically record which artists participated in which performances and whether they were able to perform as expected or only partially. The start date for the implementation of the software varied for each show (range, August 2004 to May 2006) and is not collected for artists with certain types of contracts. Therefore, analyses related to the injury rates as well as the consequences of injury (number of treatments per injury and number of missed performances) were calculated on a subset of the full data set that contained information on the number of performances for each artist (ie, exposure data). These analyses are limited to show-related injuries because training sessions are not documented within the electronic database, and therefore training injury rates could not be calculated.

Consequences of Injury

With respect to the number of treatments per injury, we considered an injury to be fully resolved as of the date of the last encounter with a therapist for that injury. Although some consensus statements suggest that an injury is healed once the subject returns to unrestricted activity,[10,11] we preferred our definition because athletes often "play hurt," and therefore the consensus definition may grossly underestimate the consequences of injury. We excluded all

"treatments" that were entered to document a "no-show" or to add a comment about a consultation with a physician. We considered the first visit to the therapist as a treatment, even if it consisted only of an evaluation (ie, every injury had at least 1 treatment). Finally, some injuries had long periods without treatment. We considered the original injury healed when there was no treatment for a period of 3 months and considered subsequent treatments as part of a new injury.

With respect to the number of performances missed or altered due to injury, the data were entered as part of the process to determine an artist's pay or injury compensation. The pattern of injuries in the entire data set and the subset of data used to calculate rates were compared to ensure comparability and found to be very similar.

ANALYSIS

Patterns of Injury: Full Data Set of Injuries

We describe the patterns of injuries separately by anatomical location and type of injury[11] for (1) male and female performers, (2) training and performances, and (3) acrobatic, nonacrobatic, and musician-related injuries. We report the proportion of injuries within each category along with the 95% confidence intervals (95% CIs) calculated using bootstrapping techniques[30] to account for repeated injuries within the same artist but did not conduct any formal statistical significance testing.

Consequences of Injury and Injury Rates: Subset of Data With Exposures

Within the subset of show-related data that documented the consequences of injury and exposure information, we summarized the number of treatments and missed performances associated with injuries using the median (50th percentile) and 80th percentile. We then described injury rates per 1000 artist-performances using standard methods.[21] Because our exploration of the data distribution showed that the overall mean rate was very unstable if we included artists with fewer than 3 performances, these 16 artists were excluded from this part of the analysis in accordance with accepted statistical principles. We describe the heterogeneity of individual injury rates by plotting the injury rate against the number of exposures. Individuals with very few exposures will have only a few injuries, and a difference between 2 injuries and 4 injuries (doubling of the injury rate) can easily occur by chance. Therefore, one expects a very high variability in injury rates among individuals with few exposures, and this must be accounted for when interpreting the results.

We compared injury rates per 1000 artist-performances for male and female performers and for acrobatic artists versus nonacrobatic artists versus musician artists using rate ratios and 95% CI in a quasi-Poisson regression analysis because the data were overdispersed. We also analyzed sex- and role-specific rates (in a quasi-Poisson regression analysis) to determine the independent effects of each on injury rates. All analyses were done in R Statistical Package 2.4.1.

RESULTS

Patterns of Injury: Full Data Set

Patterns of injury were derived from the entire database of injuries. There were 18 336 show- or training-related events that resulted in injuries to 1376 Cirque artists (534 [38.8%] female artists and 842 [61.2%] male artists; 1107 acrobats, 107 musicians, and 162 nonacrobats) between January 1, 2002, and December 31, 2006. Of these, 40.2% occurred in female artists and 59.8% in male artists. Of the 18 336 events causing injury, most were minor, 17 740 caused a single injury, 279 caused 2 injuries, and 10 events caused 3 or 4 injuries.

There were no clinically relevant differences in the gross anatomical pattern of injuries between the sexes or performance versus training (see online Appendix 1, Figure 1, for this article at http://ajs.sagepub.com/supplemental/). Differences between acrobatic and nonacrobatic acts were minimal. The locations for musician-related injuries were quite different, with more head and neck injuries and fewer lower extremity injuries.

When we examined the distribution of upper extremity injuries in more detail (see online Appendix 1, Figure 2, top, for this article at http://ajs.sagepub.com/supplemental/), the shoulder was the most commonly injured area, and there were only slight differences by sex and training/performance. Musicians' injuries were distributed more distally compared with those of acrobats and nonacrobats, and musicians were the only group to have a significant number of forearm injuries. In the lower extremity (see online Appendix 1, Figure 2, bottom, for this article at http://ajs.sagepub.com/supplemental/), injuries were more evenly distributed, with the knee and ankle having the highest proportions. Female artists had more hip/groin injuries, but other categories had only minor differences. Although musicians had a significantly higher proportion of their lower extremity injuries to the ankle (presumably from running on stage as part of an act or backstage during the show), lower extremity injuries were only a small proportion of total injuries in this group (see online Appendix 1, Figure 1, for this article at http://ajs.sagepub.com/supplemental/).

Similarly, there were minimal differences in the patterns of types of injury between the sexes or performance versus training (see online Appendix 1, Figure 3, for this article at http://ajs.sagepub.com/supplemental/). Injuries to the joints and ligaments, contusions, and lacerations were less common among musician-related injuries. An overview of the types of injuries according to anatomical location is provided in Table 1. The most common injuries were strains and sprains to the upper and lower extremities. Of the 10 events that caused 3 or 4 injuries, 4 resulted in a fracture and/or a concussion.

TABLE 1
Frequency of Injuries, Cross-classified by Anatomical Location and Type[a]

Type	Head and Neck (n = 2611)	Trunk (n = 901)	Spine (n = 3885)	Upper Extremity (n = 4214)	Lower Extremity (n = 6347)	Other (n = 378)
Central/peripheral nervous system (n = 142)	121	1	2	10	6	2
Contusions/lacerations (n = 1622)	254	143	81	369	771	4
Fractures and bone stress (n = 160)	17	10	7	51	74	1
Joint (nonbone) and ligament (n = 3868)	557	89	1026	822	1373	1
Muscle and tendon (n = 7559)	880	246	1431	2059	2603	340
Other (n = 4985)	782	412	1338	903	1520	30

[a] The total number of injuries was 18 336.

TABLE 2
Injury Rates for All Artists, Female Artists and Male Artists for All Injuries Combined, and by Anatomical Location[a]

	Artists							
	All		Female		Male		Reference[b]	
	Rate	95% CI	Rate	95% CI	Rate	95% CI	Injury Rate Ratio	95% CI
All combined	9.7	9.4-10.0	10.2	9.7-10.6	9.4	9.1-9.8	0.93	0.82-1.04
Head and neck	1.4	1.3-1.5	1.4	1.2-1.6	1.3	1.2-1.5	0.95	0.79-1.15
Trunk	0.5	0.4-0.6	0.6	0.5-0.8	0.4	0.3-0.5	0.64	0.49-0.86
Spine	1.9	1.8-2.0	2.3	2.1-2.5	1.7	1.5-1.8	0.73	0.62-0.87
Upper extremity	2.2	2.1-2.4	2.1	1.9-2.3	2.3	2.1-2.5	1.08	0.90-1.28
Lower extremity	3.5	3.4-3.7	3.5	3.3-3.8	3.5	3.3-3.8	1.00	0.85-1.18
Other	0.2	0.1-0.2	0.2	0.1-0.2	0.2	0.1-0.2	1.00	0.44-2.23

[a] Injury rates are injuries per 1000 artist-performances. CI, confidence interval.
[b] Reference female artists = 1.0.

Consequences of Injury and Injury Rates: Subset of Data With Exposures

Data analyses related to the number of treatments, missed performances, and injury rates were carried out on the subset of the show-related data that included exposure information as described in the "Methods" section (there is no training-related exposure information to calculate training-related injury rates). There were 966 artists (348 female and 618 male artists) with 6701 show-related injuries and 38 224 treatments included in this analysis. Most of the injuries incurred by Cirque artists require relatively few treatments and result in few missed or altered performances (see online Appendix 2 for this article at http://ajs.sagepub.com/supplemental/). For example, 50% of injuries required ≤2 treatments and did not result in any missed or altered performances. In addition, 80% of injuries required ≤7 treatments and resulted in ≤1 completely missed performance and ≤2 altered performances. These numbers were relatively stable over all anatomical locations (data not shown) and whether the injury occurred during an acrobatic act or nonacrobatic act; musician-related injuries had a similar number of treatments but fewer missed or altered performances.

The overall and anatomical location-specific injury rates are shown in Table 2 for all artists combined and for male and female artists separately. Overall, female artists had a slightly higher injury rate than did male artists for all injuries, but the magnitude of the difference was small.

There was considerable heterogeneity in injury rates. There were 14 of 348 (4.0%) female and 32 of 618 (5.2%) male artists with rates greater than 30 injuries per 1000 artist-performances. A plot of the injury rate against the number of exposures for each artist is shown in Appendix 1, Figure 4 (inset is an enlargement for low injury rates, see online Appendix for this article at http://ajs.sagepub.com/supplemental/). As expected, the injury rates are unstable (very heterogeneous) when there are few exposures and then stabilize as the number of exposures increases. The solid line represents the overall injury rate shown in Table 2.

The injury rate for acrobatic artists was 11.2 (95% CI, 10.9-11.6) injuries per 1000 artist performances. Compared with acrobats, nonacrobatic artists had a lower injury rate

TABLE 3
Frequency of Injuries With 10 or More Missed Performances, Cross-classified by Anatomical Location and Type[a]

Type	Neck (n = 25)	Low Back (n = 33)	Shoulder (n = 50)	Knee (n = 38)	Ankle (n = 44)	Other (n = 104)
Fractures/bone stress (n = 18)	0	0	0	1	1	16
Joint (nonbone) and ligament (n = 125)	8	18	24	19	28	28
Muscle and tendon (n = 97)	11	9	22	5	12	38
Other (n = 54)	6	6	4	13	3	22

[a] The total number of injuries was 294.

(6.8 [95% CI, 6.1-7.4]; rate ratio, 0.60 [95% CI, 0.49-0.73]), than did musicians (4.3 [95% CI, 3.7-4.8]; rate ratio, 0.38 [95% CI, 0.30-0.49]). The rate ratios from the quasi-Poisson regression model that included both sex and role were almost identical to the univariate analyses: male to female, 0.92 (95% CI, 0.82-1.03); nonacrobat to acrobat, 0.60 (95% CI, 0.49-0.73); musician to acrobat, 0.38 (95% CI, 0.30-0.49).

There was a total of 294 of 6701 (4.4%) injuries that resulted in more than 15 missed performances (this represents approximately 10 days and was chosen for comparison with other sports) and occurred in 194 artists (149 acrobats, 41 nonacrobats, and 4 musicians). The injury rates by role were 0.74 (95% CI, 0.65-0.83) for acrobats, 0.35 (95% CI, 0.20-0.50) for nonacrobats, and 0.05 (95% CI, 0.00-0.12) for musicians. Compared with acrobats, the rate ratio for sustaining an injury resulting in more than 15 missed shows was 0.47 (95% CI, 0.26-0.87) for nonacrobats and 0.07 (95% CI, 0.01-0.44) for musicians. The actual 294 injuries were 3 burns/lacerations/abrasions, 10 contusions/acute bursitis/acute tendinopathies, 78 muscles strains/cramps/stiffness, 7 concussions, 21 fractures, 134 joint (nonbone)/ligament injuries, 28 overuse tendinopathies/bursitis, 2 peripheral nerve injuries, and 11 other injuries that could not be unambiguously classified. Table 3 shows the frequencies of fractures/bone stress, joint (nonbone)/ligament injuries, muscle and tendon injuries, and other injuries for the anatomical locations with at least 25 injuries. Of the 16 "other" fractures, there were 8 in the foot, 2 in the hand, 2 in the head and face, and 1 each in the elbow, hip, lower leg, and ribs.

DISCUSSION

Professional circus artists have similar injury patterns across male versus female performers, training versus performance-related injuries, and acrobats versus nonacrobats, although musicians have more head and neck and fewer lower extremity injuries. Most injuries to professional circus artists require few treatments and do not result in missed or altered performances. The overall injury rate for male artists is slightly lower than that of female artists, and acrobats have higher injury rates than do nonacrobats and musicians.

The overall anatomical and injury patterns suggest little difference across sex and training/performance (see online Appendix 1, Figure 1, for this article at http://ajs.sagepub.com/supplemental/). When we examined the distribution of upper and lower extremity injuries in more detail (see online Appendix 1, Figure 2, for this article at http://ajs.sagepub.com/supplemental/), we found that approximately 50% of the upper extremity injuries were to the shoulder. Therefore, injury prevention programs targeting this area would likely have the greatest effect in reducing upper extremity injuries. Although lower extremity injuries were more evenly distributed, prevention programs targeting the knee and ankle would likely produce the most overall benefit.

The differences in upper and lower extremity injuries across sex and training/performance were not great enough to warrant targeting a prevention program, with 2 possible exceptions. Female artists had many more hip/groin injuries than did male artists (presumably because of differences in the acts female acrobats perform compared with those of male acrobats), and musicians' upper extremity injuries were distributed more distally. Future analyses and studies examining the specific causes of these injuries could help strengthen the prevention programs already in place (which include meeting standards for usual equipment design, engineering and industrial design analyses of new equipment designs, artist rotations and management of workload, strength and conditioning prevention programs, rapid and appropriate rehabilitation after an injury). Although musicians had a significantly higher proportion of their lower extremity injuries to the ankle (presumably from running on stage as part of an act or backstage during the show), lower extremity injuries were only a small proportion of total injuries in this group (see online Appendix 1, Figure 1, for this article at http://ajs.sagepub.com/supplemental/), and targeting this area for prevention would not be expected to substantially reduce overall injury rates.

This is the first study to describe injury patterns and rates in modern circus artists. The National Collegiate Athletic Association (NCAA) recently published injury rates calculated from 25 years of data.[15] Of the many sports listed, women's gymnastics is the most closely associated with circus arts (figures for men's gymnastics were not published). The competition injury rate for women's gymnastics was 15.2 injuries per 1000 athlete-exposures, which is much higher than the overall injury rate of Cirque artists. The NCAA did not publish injury rates for high-risk positions within each sport (some gymnastics events are

expected to have higher injury rates than do others). Even so, the injury rate of acrobats (the circus artists most at risk of injury) was only 11.2 (95% CI, 10.9-11.6), which is still considerably lower than the overall rate for women's gymnastics.

To further put the Cirque injury rates in context, game injury rates for women's softball, volleyball, and lacrosse ranged from 4.3 to 7.2 injuries per 1000 athlete-exposures; women's basketball and field hockey were 7.7 and 7.9 injuries per 1000 athlete-exposures, respectively; and women's ice hockey and soccer were 12.6 and 16.4 injuries per 1000 athlete-exposures, respectively. Men's baseball and basketball had injury rates of 5.8 and 9.9 injuries per 1000 athlete-exposures, respectively, and the injury rates for men's lacrosse, hockey, soccer, wrestling, and football ranged from 12.6 to 35.9 injuries per 1000 athlete-exposures.

We are not aware of any similar reviews or large-scale cohort studies for musician-related injuries. With respect to comparisons with the dance literature, different studies report injury rates using different methods. A recent systematic review of cohort studies reported an injury rate of 4.7 injuries per 1000 dance hours in the 1 study that used an injury definition similar to ours (ie, any event in which the subject sought medical attention).[14] This is lower than the injury rate for circus nonacrobats (6.8 injuries per 1000 artist-performances), but our nonacrobatic category is not limited to dancers; it also includes jugglers, swimmers, and when artists work on the set during a performance (removing equipment from stage, tightening of nets, etc).

We also calculated the injury rate for injuries that required an artist to miss more than 15 performances (approximately 10 days). The acrobats represented the highest risk group at Cirque with a rate of 0.74 (95% CI, 0.65-0.83) injuries per 1000 artist performances. The NCAA also published estimates for injuries resulting in more than 10 days missed but only as proportions (overall Cirque proportion, 4.4%); this occurred in 39% of women's gymnastics competition injuries,[23] 18% of men's basketball game injuries,[4] and 27% of women's hockey game injuries.[1] Simply multiplying the estimated proportion of injuries by the game injury rate from the preceding paragraph provides the estimated injury rate per 1000 athlete-exposures in these sports; women's gymnastics is 5.9, men's basketball is 1.8, and women's hockey is 3.4. Therefore, the estimated rate of injuries resulting in more than 10 days missed is considerably less in Cirque compared with many NCAA varsity sports.

Although this is the first report on the epidemiological injury patterns and injury rates among a group of professional artists who are extremely physically active, there are limitations to this study. This study is subject to the limitations of any historical cohort study. However, our data were obtained from electronic records completed by health care professionals as part of their official documentation of a patient visit, as opposed to databases based on billing or the requirement to fill out additional paperwork of little use to the individual clinician. All ambiguous entries were individually searched and recategorized. There were data that were not obtained such as mechanism of injury, and Cirque has since introduced changes to record this information. Some artists without exposure information could not be included in the injury rate analysis. Although the data were obtained from only 1 circus "company", the injury patterns and injury rates represent an overall view from 17 distinct shows. In addition, there are particular challenges to categorizations. Artists perform multiple roles in a show; the corresponding situation in sports is rare (eg, offensive football players rarely play defense). We categorized artists according to their primary role within a show because this seemed the most logical choice.

In conclusion, although Cirque shows are highly athletic and acrobatic, with jumps and tethered and untethered aerial maneuvers, the injury rates are less than those for NCAA women's gymnastics and similar to those of NCAA men's basketball. In addition, the estimated rate of injuries that result in more than 10 missed days is much less.

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