Musculoskeletal Injury Profile of Circus Artists

A Systematic Review of the Literature

H.E.G. Wolfenden, BSc, and M. Angioi, PhD

BACKGROUND: The circus arts involve a high degree of acrobatic, athletic, and aesthetic ability with extreme physical demands placed on performers. An understanding of the injury profile is required to guide prevention. **AIM**: To provide the first systematic review to enhance understanding of circus-related injuries and to provide a foundation for future preventative intervention. **METHODS**: MEDLINE, Scopus, and Web of Science were searched from conception to March 2016 using key search terms relating to circus artists and injury. Studies were limited to English-language human studies and included all levels and ages of circus artists. Risk of bias was assessed using a novel seven-item checklist based on the STROBE statement. **RESULTS**: Eight studies of varying design, populations, outcomes, and quality were analysed. Results suggest that the injury rate is relatively low among professional circus artists at 7.37 to 9.27/1,000 artist exposures. The spine and ankle are frequently injured, and most injuries are to soft tissue structures. In the professional setting, injuries appear minor, resulting in few treatments, few missed or altered performances, and a low risk of re-injury. **CONCLUSIONS**: The spine and ankle should be targeted for preventative interventions in circus artists due to their high frequency of injury. The heterogeneity of studies included in this review highlights the need for consistency within future research, particularly in terms of injury definition and outcome measurements. *Med Probl Perform Art* 2017; 32(1):51–59.

The circus arts involve a high degree of acrobatic, athletic, and aesthetic ability with extreme physical demands placed on the performers.[1] Circus artists undergo intense physical training[1] where extreme ranges of movement, high impact loads, and maximal strength are required in addition to significant aesthetic competence. These physical and aesthetic demands have previously been compared to those required in gymnastics,[1] where extreme ranges of movement have been associated with overuse injuries and high impact loads with acute injuries.[2] With the added interplay of equipment and pair and group work, the potential for injury to circus artists poses a threat, not only to health, but also to career as their bodies hold the key to professional success.[3]

Circus artists cover a wide range of disciplines. They can be broadly categorised into three general groups—acrobats, non-acrobats, and musicians[1]—although more recently other categories have been used—sudden load artists, non-sudden load artists, and musicians.[4] Specifically, sudden load artists are those who incur a "sudden substantial increase in physical compression or distraction loads"[4] and include disciplines such as gymnastics, diving, trampoline, and aerial movements.[1,4] Non-sudden load artists include disciplines such as juggling, dancing, and clowns.[1] The differing physical and technical demands of each disciplines may result in different injury patterns, as seen in other performing artists.[5]

The injury profile of each sport is unique[6] and an understanding of this is required to guide prevention.[7] Van Mechelen[8] first described a three-stage "sequence of prevention" model, which sets out the principle that sporting injuries and their contributing factors must first be identified in order to guide future preventative interventions.[8] The circus arts are an evolving area, both in popularity and injury research,[9] and no known published review is currently available.

Systematic reviews in sports research are prone to the problem of inconsistent injury definition,[10] and circus arts are no exception. Two injury definitions exist: medical attention injury where an injury is defined as one that requires assessment by a qualified medical practitioner,[10,11] and time loss injury where injury is defined by missed training or performance due to injury.[10,11] The medical attention definition may more accurately reflect the overall burden of disease, while use of the time loss definition emphasises significant injuries.[12] Therefore, given the small body of evidence currently available in the circus arts,[9] both definitions were used in this review to help provide a better understanding of the injury profile of circus artists. However, it is important that direct comparisons

From Centre for Sports and Exercise Medicine, William Harvey Research Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, London, UK.

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Address for correspondence: Dr. M. Angioi, Centre for Sports and Exercise Medicine, William Harvey Research Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, Mile End Hospital, Bancroft Road, London E1 4DG, UK. Tel +44 0207 882 5011. m.angioi@qmul.ac.uk.

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between studies should only be made where definitions are consistent.

The main aim of this study was to enhance understanding of circus-related injuries by creating a typical injury profile, which in turn will provide the foundation for future preventative interventions. This systematic review collated, critiqued, and summarised research into 1) incidence 2) aetiology, 3) anatomical location and type of injury, and 4) severity of injury, in order to determine the injury profile of circus artists.

METHODS

Literature Search

Three databases—MEDLINE, Scopus, and Web of Science—were searched from conception to March 2016 using the MESH terms: (circus OR circus artist* OR circus perform* OR circus student* OR cirque OR cirque artist* OR cirque perform* OR cirque student*) and (injury OR injury pattern* OR injury rate* OR injury incidence). Studies were included if they reported injuries to human circus artists irrespective of the injury definition used. Peer-reviewed published studies of randomised control trials, cohort, case-control, or cross-sectional study designs in English language were included. Studies were excluded if they reported injuries to all other performing artists, such as dancers and stage performers. Case reports, letters, conference proceedings, doctoral dissertations, and all other unpublished material were excluded. Any studies pertaining to "circus movement" heart arrhythmias were excluded as such studies are unrelated to the circus arts.

Results from the database searches were downloaded to EndNote web (Clarivate Analytics, Philadelphia, PA, USA; http://endnote.com). Results from each database were compared and duplicates removed. Studies retrieved by the search were initially screened on inclusion criteria by title and abstract. Those that met the inclusion criteria, or where relevance could not be established from the available information, were read in full. The studies included were those that met the inclusion criteria following full text review. Reference lists of included studies were hand-screened for further relevant publications. Two independent reviewers undertook this process; any discrepancies were resolved through consensus discussions.

Data Extraction and Analysis

The methodology of each paper, including injury definition, was extracted for comparison. Population characteristics were also analysed, specifically the standard at which the artists performed and, where possible, age and gender of the population.

Incidence data was extracted from each paper. Where possible, injury incidence was given per 1,000 artist exposures (AE) with 95% confidence intervals (CI). Percentages of injury per anatomical location, injury type, mechanism, and the equipment/specialty involved when the injury occurred were also analysed. Severity of injury in terms of average number of missed performances or treatments required was also extracted.

Quality Assessment—Risk of Bias

Study quality was assessed using Waldén's five-item checklist for risk of bias in observational studies.[13] Waldén's checklist is based on the on the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement,[14] a checklist developed for the reporting observational epidemiological studies rather than assessing their quality.[15] However, it was felt that Waldén's checklist failed to consider the risk of bias for discussion of limitations and potential sources of bias, crucial items for assessing the quality of studies. Therefore, in addition to Waldén's five item checklist, two further items were included from the STROBE statement to ensure completeness when assessing quality and risk of bias. The seven items were:

1) study setting, location, and study period,
2) eligibility criteria, and sources and methods of participant selection,
3) exposure definition and measurement,
4) study outcome definition and measurement,
5) main results and precision,[13] and additionally
6) discussion of limitations and
7) potential sources of bias.

Studies were assessed as having a low risk of bias (1 mark) where items were addressed fully, or a high risk of bias (0 marks) where reporting was lacking or unclear.[13] Out of a possible seven marks, those studies with higher marks demonstrated a lower risk of bias.

RESULTS

Literature Search Results

Initial search of the databases revealed 54 records when limited to English language. Forty-four studies remained after duplicates were removed. After screening, 23 records were removed due to irrelevant title, plus an additional 11 studies that did not meet the inclusion criteria from abstract review. Ten full texts were analysed for inclusion, where 2 were rejected: 1 based on irrelevant outcomes, such as the effect of previous injury on subsequent injury,[16] and the other as the study is only published in abstract form as part of conference proceedings.[17]

Overall, a total of 8 studies were included for analysis: 1 prospective observational study, 1 retrospective questionnaire, and 6 retrospective cohort studies. The process is illustrated in Figure 1.

Quality Assessment—Risk of Bias

All studies, except Orlando et al. (2011),[4] had a low risk of bias when reporting study setting, location, and study

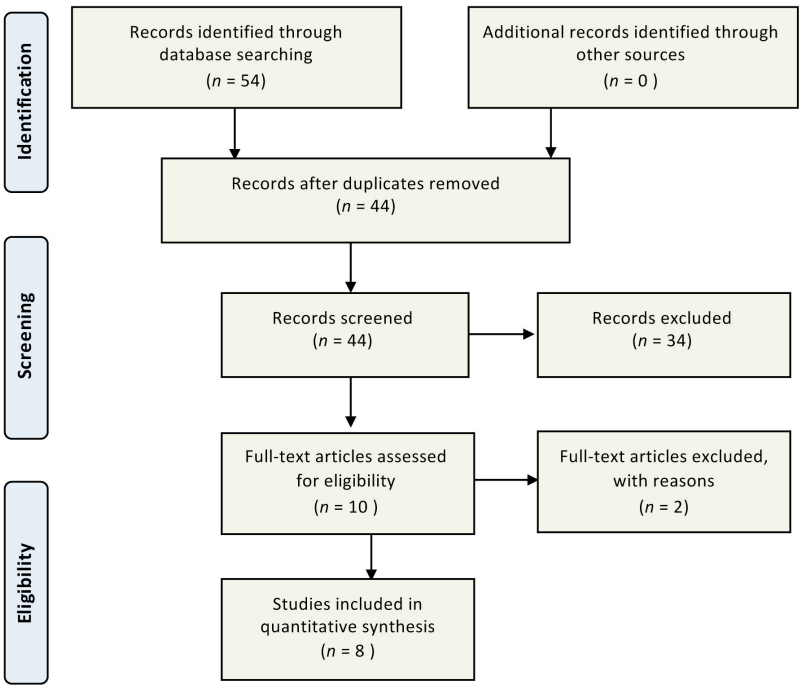

FIGURE 1. Flow diagram of systematic literature search.

period. All studies were deemed at low risk of bias for eligibility criteria of participants and sources and methods of participant selection. For exposure definition and measurement, two studies gave no exposure data,[9,18] while a third gave unclear exposure data, particularly with respect to results,[19] so all three studies were deemed high risk for bias. The remaining studies were deemed at low risk of bias as they gave exposure data per 1,000 hours,[3] per 1,000 AE,[4,20,21] or per 1,000 performances.[1]

All studies, except Long et al.,[18] had a low risk of bias for study outcome definition and measurement. Long[18] was deemed high risk as injuries were self-reported. For main results and precision, five studies[3,9,18–20] lacked precision estimates (i.e., 95% CI) when reporting results, and so were deemed high risk of bias. For item six, discussion of limitations, two studies[3,21] did not acknowledge any limitations, so were deemed high risk. For item seven, identifying sources of bias, five studies[1,3,9,20,21] were deemed high risk, primarily due to the failure to state the authors' conflicts of interest as health care providers within the study setting.

Overall, Orlando[4] and Shrier (2009)[1] had the lowest overall risk of bias (6/7 marks), followed by Shrier (2011),[19] Hamilton (2012),[21] and Hamilton (2011)[20] (5/7 marks). Long,[18] Wanke,[3] and Munro[9] had the highest risk of bias with 4 marks. Table 1 depicts the quality assessment results in detail.

Study and Population Characteristics

All included studies were cohort studies,[1,3,4,19–21] with the exception of Long[18] who used a retrospective questionnaire-based design and Munro[9] who conducted a prospective study. Four studies focused on professionals at Cirque du Soleil,[1,4,20,21] three studies on elite cirque students,[3,9,19] and one study on high-school students participating in extra-curricular cirque activity.[18] There was variation in the injury definition used: time loss injury definition during training and performance,[18] medical attention injury during training,[19] performance,[1] or training and performance,[3,9] and both medical attention and time loss during performance.[4,20,21] Participant numbers in each study varied from 30 participants[18] to 1,376.[1] The two studies by Hamilton et al.[20,21] used the same data sets but had different outcome measures. Full study and population characteristics are reported in Table 2.

Injury Rate

Three studies reported medical attention injuries per 1,000 AE or performances.[1,4,21] AE are equivalent to performances[21] and so direct comparisons can be made, revealing that three studies reported similar results among professional circus artists.[1,4,21] However, when using a time loss definition, for TL-1 injuries,* Orlando[4] reported a reduced injury rate of 0.62/1,000 AE compared to Hamilton.[21] Similarly, for TL-15 injuries, Orlando[4] reported an injury rate of 0.13/1,000 AE, which was lower than Hamilton[21] (0.50/1,000 AE, 95% CI 0.44–0.57). Finally, Wanke[3] reported an injury rate of 0.3/1,000 hrs among circus artists in training.

*Medical attention injuries, injuries resulting in 1-day time loss (TL-1) or 15-day time loss (TL-15).

TABLE 1. Assessment of Quality in Relation to Bias*

	Study Setting, Location, and Study Period	Eligibility Criteria and Sources and Methods of Participant Selection	Exposure Definition and Measurement	Study Outcome Definition and Measurement	Main Results and Precision	Limitations Discussed	Potential Sources of Bias	Total No. of Items with Low Risk of Bias (7 Total)
Long 2011 [18]	1	1	0	0	0	1	1	4
Munro 2014 [9]	1	1	0	1	0	1	0	4
Orlando 2011 [4]	0	1	1	1	1	1	1	6
Shrier 2009 [1]	1	1	1	1	1	1	0	6
Shrier 2011 [19]	1	1	0	1	0	1	1	5
Wanke 2012 [3]	1	1	1	1	0	0	0	4
Hamilton 2012 [21]	1	1	1	1	1	0	0	5
Hamilton 2011 [20]	1	1	1	1	0	1	0	5

*Low risk of bias = 1 mark; high risk of bias = 0 mark.

Both Shrier[1] and Hamilton[21] showed that the risk of injury is greatest for acrobats or sudden load artists followed by non-acrobats and non-sudden load artists and lastly musicians, although risk is insignificantly reduced between Hamilton's sudden load and non-sudden load artists.[21] However, when using the TL-1 injury definition, the risk ratio from sudden load to non-sudden load artists is 0.67.[21] Table 3 depicts full injury rate results.

Anatomical Location and Injury Type

The spine and ankle were the most commonly affected anatomical regions. Long[18] reported that spinal injuries accounted for 22.2% of all injuries, which is in line with Munro[9] and Shrier (2009).[1] Gender differences were accounted by Wanke,[3] who also reported spine injuries in male (15.7%) and female (18.3%) artists in training.

Shrier (2009)[1] reported 34.6% injuries occurred in the lower extremity. Long[18] reported 22.2% injuries occurred to the knee and 11.1% to the ankle. Munro[9] reported 26% of all injuries occurred to the ankle. Wanke[3] reported 18.6% (male) and 17.2% (female) ankle injuries amongst circus artists in training.

Shrier (2011),[19] Shrier (2009),[1] and Wanke[3] identified muscle strains as the most common type of injury at 39.1%, 41.2%, and 28.2%, respectively. This was followed by sprains/ligament injuries reported at 28.2%,[19] 21.1%,[1] and 28.2%[3] of total injuries. Bone injuries, such as fractures, were less common at 2.2%,[19] 0.9%,[1] and 9.2%.[3] Table 4 depicts full results for anatomical location and type of injury.

Activity and Mechanism of Injury

Munro[9] reported that acrobatics/tumbling accounted for 23% injuries, while Wanke[3] found floor acrobatics accounted for 50.3% of injuries. Handstands accounted for 12% of injuries, adagio 11%, and Chinese pole 10%.[9]. Both studies were conducted among circus artists in training.

Only one study, by Wanke,[3] described the mechanism of injury. Falling accounted for 32.4% of male and 33.1% of female injuries, and twisting accounted for 21.1% and 21.6%, respectively, in circus artists in training. Table 5 shows the full results for the aetiology/activity and mechanism of injury.

Severity of Injury

Wanke[3] described a large majority of injuries (83.3%) as minor, based on injury type, resulting costs, and duration of treatment. Shrier (2009)[1] and Hamilton (2012)[21] described severity in terms of number of missed performances and number of treatments required, while Shrier (2011)[19] reported solely number of treatments. In the 2009 study, Shrier[1] reported that 70% of all injuries resulted in no missed performances, 50% of injuries required less than 2 treatments, and 80% of injuries required less than 7 treatments. In 2011, Shrier[19] reported similar results, with 50% of all injuries resulting in less than 2 treatments and 75% requiring less than 5 treatments. Hamilton (2012)[21] reported the median number of treatments for medical attention injuries as 2, for TL-1 injuries as 7, and for TL-15 as 20 treatments. For completely missed performances, the medians were 0 for medical attention injuries, 6 for TL-1 injuries, and 41 for TL-15 injuries.[21] Overall results indicate that the severity of injury is low among circus artists' professionals and students.

In 2011, Hamilton[20] looked at subsequent injuries (i.e., first injury after the indexed injury) among professionals. They found 89.8% of subsequent medical attention injuries were new injuries (injury at different site), 3.8% were local injuries (same site, different type), and 6.5% were recurrent (same site and type). Of the recurrent injuries, 11.3% were exacerbations (injuries that occurred before the injury was fully healed).[20]

DISCUSSION

The main aim of this study was to enhance understanding of circus-related injuries by creating a typical injury profile for circus artists. Overall results revealed that the injury

TABLE 2. Study and Population Characteristics

Study	Type of Study	Duration of Data Collection	Injury Definition Used	No. of Participants	Level of Participants	Participant Characteristics	Outcome Measures
Long 2011 [18]	Questionnaire	1 season ~5 mos	Time loss injury during training and performance	30	High school students, not professional	Mean age 16.3 yrs	No. of injuries No. of participations missed % reported to athletic trainer % concealed injury Reasons for concealment Anatomical location of injury
Munro 2014 [9]	Prospective cohort	1 academic year	Medical attention injury during training and performance	63	Students at Australian National Institute for Circus Arts	Mean age 22 yrs 33 F / 30 M	No. of initial injuries and follow-ups Mechanism of injury Apparatus or activity involved Anatomical location No. of treatment sessions required
Orlando 2011 [4]	Historical cohort	Not stated (start date given but no end point)	Medical attention and time loss injuries during performance only	548	Elite professionals, Cirque du Soleil	378 M (mean age 30.3), 206 F (mean age 25.3) Touring shows	Injury rates pre and post days off
Shrier 2009 [1]	Descriptive epidemiological study	2–4 yrs	Medical attention during performance	1,376	Elite professionals, Cirque du Soleil	534 F / 842 M	Injury rates No. of treatments Anatomical location
Shrier 2011 [19]	Historical cohort study	14 wks	Medical attention injury during training	47	Elite athletes in career transition, training to become Cirque du Soleil artists	30 M / 17 F	No. of injuries Injury risk ratio for psychological predictors Type of injury Number of treatments
Wanke 2012 [3]	Retrospective descriptive epidemiological study	17 yrs	Medical attention injury due to any work-related incident	169	Students of the Berlin state training school	70 M / 99 F Age 11–22 yrs	Injury rate Severity of injury Location where injury occurred % injury sustained during training, rehearsal, performance Specialty in which injury occurred Type of injury Anatomical location of injury Mechanism of injury
Hamilton 2012 [21]	Historical cohort	4 yrs	Medical attention and time loss injuries during performance only	1,281	Elite professionals, Cirque du Soleil	817 M / 464 F	Injury rate
Hamilton 2011 [20]	Historical cohort	4 yrs	Medical attention and time loss injuries during performance only	1,281	Elite professionals, Cirque du Soleil	817 M / 464 F	Subsequent injury rate in relation to type/ location of injury and time from initial injury Consequence of subsequent injury

TABLE 3. Overall Injury Rate and Injury Rate Ratios According to Artist's Role

Study	Injury Definition	Injury Rate	Injury Rate Ratio by Artist's Role
Long 2011 [18]	Time loss	7 reported 1 injury/season 6 reported 2 injuries/season 3 reported 3+ injuries/season	NR
Munro 2014 [9]	Medical attention	351 injuries/academic year	NR
Orlando 2011 [4]	Medical attention TL-1 TL-15	7.37/1,000 AE 0.62/1,000 AE 0.13/1,000 AE	NR
Shrier 2009 [1]	Medical attention	9.7/1,000 performances	Acrobat 1 Non-acrobat 0.6 Musician 0.38
Shrier 2011 [19]	Medical attention	47 injuries/ 14 wks	NR
Wanke 2012 [3]	Medical attention	0.3 injuries/1,000 hrs	NR
Hamilton 2012 [21]	Medical attention	9.27/1,000 AE	Sudden load 1 Non-sudden load 0.98 Musician 0.38
	TL-1	1.86/1,000 AE	Sudden load 1 Non-sudden load 0.67 Musician 0.06
	TL-15	0.50/1000 artist exposures	Sudden load 1 Non-sudden load 0.77 Musician 0.11

NR = Not reported. Hamilton et al. 201120 used a different outcome, subsequent injury rate in relation to type/location, and results are reported in text in the subsection for injury reoccurrence.

rate ranges from 7.37 to 9.7/1,000 AE in professional artists,[1,4,20] with the most common affected anatomical site being the spine[1,3,9,18] followed by the ankle.[1,3,9,18] Soft tissue injuries appeared to be the most observed injury type, more specifically strains[1,3,19] and sprains.[1,3,19] With regards to severity, most injuries appeared minor[3] resulting in few treatments,[1,19,21] few missed or altered performances,[1,21] and a low risk of re-injury.[20]

Gymnastics, which is a comparable sport to cirque in terms of physical demand,[1] has a considerably higher injury rate[22,23] recorded during performances compared to those reported herein. Linder[24] found that the most frequent mechanism of sudden-onset injury in collegiate level gymnasts was a missed move, followed by contact or a fall from apparatus. It follows that circus artist professionals, such as those at Cirque du Soleil, are likely to have specific safety measures in place to prevent these types of injury, hence accounting for the lower injury rate revealed by our review.

Two studies looked at injury rates according to artist's role.[1,21] Shrier (2009)[1] found that the injury rate ratio of acrobats to non-acrobats was 0.6 and acrobats to musicians was 0.38. However, Hamilton (2012)[21] found the injury rate ratio of sudden load to non-sudden load artists was 0.98. This discrepancy could be due to the re-classification of artists' roles within Cirque du Soleil.[20] Additionally, Hamilton[21] used a time loss injury definition to calculate injury rate ratios between artists' roles. The discrepancy between rate ratios with injury definitions could indicate that although sudden load and non-sudden load artists are equally at risk of injury, sudden load artists' injuries are more severe and therefore lead to more missed performances.[21] Another explanation is that for the same injury, sudden load artists may not be able to participate due to greater physical demands of their role compared to non-sudden load artists.[21] Classification into artist role groups is difficult, as many artists have varied roles which may overlap,[1] which is in contrast to similar disciplines, such as gymnastics, where instead there is an early specialization toward specific apparatus. Overall, the results of this review suggest that sudden load artists report higher injury rates compared to their non-sudden load counterparts.

With regard to anatomical location, this review identified the spine[1,3,9,18] and ankle[9,3,18] as being the most commonly affected. The extreme ranges of movement required in cirque puts particular stress on the back,[2] which could explain the high injury rate for the spinal region. The landing movements, where impact forces are often several times that of the artist's body weight,[2] could also explain the high injury rate reported in the ankle region. Ankle injuries are also common in gymnasts, while spinal injuries appear considerably less.[23,25] This could be a reflection of the greater technical and chorographical demands placed on circus artists compared to gymnasts, which might require extreme levels of muscle flexibility. Overall, our results therefore suggest the spine and ankle anatomical areas should be targeted for preventative interventions in the circus arts. Supplementary training to enhance muscle strength of the lower limb and enhance flexibility levels of the spine might

TABLE 4. Anatomical Location and Type of Injury

Study	Anatomical Location (%)			Injury Type (%)
Long 2011 [18]	Male & Female			NR
	Back 22.2			
	Knee 22.2			
	Foot 16.7			
	Ankle 11.1			
	Neck 11.1			
	Shoulder 5.6			
	Elbow 5.6			
	Wrist 5.6			
Munro 2014 [9]	Male & Female	Male*	Female*	NR
	Ankle 26	Forearm 67	Hip 71	
	Lumbar spine 13	Ankle 59	Ankle 41	
	Shoulder 12	Hip 29	Forearm 33	
	Full spine 35			
Wanke 2012 [3]	Male	Female		Strain 28.2
	Ankle 18.6	Full spine 18.3		Sprain 28.2
	Full spine 15.7	Ankle 17.2		Contusion 26.4
	Hand 14.3	Shoulder/upper arm 14		Fracture 9.2
	Foot 12.9	Head/neck 12.9		Wound 3.7
	Lumbar spine 11.4	Cervical spine 10.8		Other 2.4
	Head/ neck 10	Knee 8.6		Luxation 1.8
	Lower arm/wrist 5.7	Lumbar spine 7.5		
	Shoulder/upper arm 4.3	Foot 6.5		
	Trunk 2.8	Hip 3.2		
	Hip 1.4	Trunk 1.1		
	Thigh 1.4	Thigh 1.1		
Shrier 2009 [1]	NR			Strains/tendonopathies 39.1
				Sprains 28.3
				Other 23.9%
				Lacerations/contusions 6.5
				Bone injury 2.2
Shrier 2011 [19]	Male & Female			Muscle/ tendon injury 41.2
	Lower extremity 34.6			Other 27.3
	Upper extremity 23			Joint (non-bone and ligament) injury 21.1
	Spine 21.2			Lacerations/contusions 8.8
	Head/neck 14.2			Fracture and bone stress 0.9
	Trunk 4.9			CNS/PNS 0.8
	Other 2.1			

* % of total injuries to specific anatomical location. NR = not recorded.

help in reducing the injury rate and severity as previously observed in similar disciplines, such as dance.

Our results revealed that soft tissue structures were most susceptible to injury,[1,3,19] with strains being the most common type of injury,[1,3,19] followed by sprains/ligament damage.[1,3,19] These data are similar to those observed in gymnastics, where sprains also account for 27.4% of all injuries.[26] The extreme ranges of movement and high impact loads required in circus artists put particular stress on soft tissue structures, therefore explaining our results.[1,2]

Only one study commented on the mechanism of injury,[3] but given its importance for subsequent injury prevention,[8] we felt it was important to include. "Falling" was the most common mechanism of all injuries in Wanke et al.'s study.[3] This could be a target for future preventative intervention with the addition of safety equipment to prevent falling or minimise the risk of injury. However, when investigating injury settings, Munro[9] found that 23% of all injuries occurred during acrobatics/tumbling while Wanke[3] found 50.3% occurred during floor acrobatics. This discrepancy is likely due to the different group categorisations that these studies used.[9] Wanke[3] used broad, general groups, and the specific definition of the groups is not stated; Munro[9] included narrower classification groups with "acrobatics/tumbling" defined as "ground-based activity only, not involving partner work or direct contact interaction, aerial rigs, or other apparatus/props." This may explain the differences observed within the reported injury setting.

Severity of injury was reported with great variation across five studies. Both Shrier papers found that 50% of medical attention injuries required less than 2 treat-

TABLE 5. Activity and Mechanism of Injury

Study	Activity (%)	Mechanism (%)
Munro 2014 [9]	Acrobatics/tumbling 23 Handstands 12 Adagio 11 Chinese pole 10 Warm-up 8 Teta-board 5% Skipping, hoop diving, trampoline, trapeze, cube, straps, rope, all ≤5	NR
Wanke 2012 [3]	Floor acrobatics 50.3 Tightrope/skipping rope/slack line 10.3 Trapeze 9.1	Falling M 32.4/ F 33.1 Twisting M 21.1/ F 21.6 Overstretching M 14.1 / F 14.4 Being hit M 12.7 / F 12.9 Landing M 11.3 / F 11.5 Pushing M 5.6 / F 5.7 Slipping M 1.4 / F 1.4 Getting caught M 1.4 / F 1.4

NR = not reported.

ments,[1,19] which is in line with Hamilton's results.[21] Moreover, the large majority of injuries resulted in zero missed performances.[1] These findings correlate with Wanke's results, which also reported that 83.3% of injuries were categorised as minor.[3] However, the definition of injury might influence the severity of injury.[27] By definition, time loss injuries will result in missed performances.[10,11] Hamilton[21] found that the median number of missed performances for TL-1 injuries was 6, and they required, on average, 7 treatments. Logically, the severity of TL-15 injuries is increased, resulting in a median of 41 missed performances and requiring 20 treatments.[21]

With regard to injury re-occurrence, Hamilton (2011)[20] found that the large majority of subsequent medical attention injuries were new injuries and not related to the indexed injury. More specifically, only 6.5% of injuries were recurrent (same as the initial indexed injury) with few reported cases of exacerbations (re-injury to an existing injury that has not fully healed). One theory for the low injury re-occurrence could be because Cirque du Soleil has full-time physiotherapists attached to each of the shows within the company.[1] Therefore, it could be expected that injuries are well managed with adequate rehabilitation and strength and conditioning, hence reducing the risk of re-injury.[28]

There were a number of potential limitations that need to be acknowledged. The majority of included studies were historical cohort studies,[1,3,4,19–21] with the exception of Long[18] who used a questionnaire and Munro[9] who conducted the only prospective study. Historical cohort studies are associated with inherent limitations, such as relying on accurate record-keeping[1] and the influence of confounders.[29] Moreover, the questionnaire used by Long[18] was not validated. The main potential risks of bias was from authors' conflicts of interest as health care providers within the study setting,[1,4,9,19–21] which in turn could lead to publication bias.[29] The definition of injury severity varied between the included studies, with one study using a time loss definition of injury,[18] four a medical attention injury definition,[1,3,9,19] and three using both definitions.[4,20,21] Although using a uniform injury definition within sports research would allow for comparison between studies,[8] no firm consensus on which definition to use exists.[27] The medical attention definition may more accurately reflect the overall burden of injuries.[12] This may be particularly important in disciplines, like cirque, where artists are known to conceal their injuries to coaches and/or "play injured."[18,30] However, the time loss definition emphasises significant injuries.[12] Therefore, medical attention definitions may overestimate the true risk of injury while time loss definitions may underestimate, and this must be taken into consideration when interpreting results.

Finally, the level of circus artists in the included studies ranged from recreational cirque artists[18] to professionals at Cirque du Soleil.[1,4,20,21] Injury rates in this review can only be compared among professionals,[1,4,20,21] as studies involving recreational artists and students do not have adequate exposure data for comparison. Therefore, injury rate and severity found in this review study should not be generalised to all levels of cirque artists.

CONCLUSIONS

The injury rate in professional circus artists ranged from 7.37 to 9.7 injuries/1,000 performances. When using the medical attention definition, injuries appeared to be minor, resulting in few missed or altered performances, few treatments, and low risk of re-injury. This review found spine and ankle to be the most common areas injured, with soft tissue structures, in particular muscles and ligaments, most susceptible to injury.

All eight studies reviewed revealed inconsistencies and deficiencies in study design, outcome measures, population characteristics, and quality. Consequently, the injury profile identified in this review must be used with caution. Consistency in future research is needed, particularly in terms of injury definition and outcome measurements, as well as taking into account the level of training (i.e., professionals vs students) in order to allow for comparisons between studies. Appropriate outcome measures would be reporting injuries per 1,000 AE (artists exposures) and anatomical location of injury according to the standardised Orchard Sports Injury Classification System (OSICS).[31] If these areas are standardised in future research, the injury profile of circus artists can be enhanced and therefore better understood.

Overall, our results will inform medical practitioners and other health care professionals as well coaches and artists. By acknowledging the musculoskeletal injury profile revealed herein, specific supplementary training might be implemented and tested by employing robust methodological designs, such as randomized controlled trials, to detect the overall effects on injury rate, type, and severity.

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