EPIDEMIOLOGICAL INVESTIGATION OF INJURIES IN CIRQUE DU SOLEIL

BY
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A Thesis Submitted to the Faculty of Graduate Studies in Partial Fulfillment of the Requirement for the Degree of

MASTER OF SCIENCE

Faculty of Physical Education & Recreation Studies
University of Manitoba
Winnipeg, Manitoba

ISBN 0-612-16234-6

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EPIDEMIOLOGICAL INVESTIGATION OF INJURIES IN CIRQUE DU SOLEIL

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JANET PUNDICK

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements for the degree

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Abstract

Cirque du Soleil's "Mystere" was the focus of this epidemiological investigation into the nature and rate of injury occurrence in the members of the cast. Sixty-two athletes comprised the subject group involved in the 12-month data collection period. Injury report forms and daily exposure sheets were used to collect data, and data was analyzed using the Microsoft Access relational database program. The rate of injury was found to be 531 injuries per 100 athletes, and 10 injuries per 1000 exposures. Females sustained a higher number of injuries (6.4) than the males (5.0) over the data collection period. The highest number of injuries per performer (6.2) was sustained in the trapeze act, while the lowest number of injuries per performer (2.4) was sustained in the Chinese poles act. Fifty-one percent of the injuries occurred during show performance, 9.7 % were sustained during training, and 33 % occurred over a period of time (gradual onset). The act affected most by injury during show performance was the teeterboard act, followed by the trapeze act, while the act affected least by injury was the manipulation act. The body part affected most by acute injury was the ankle, followed by the low back, neck, shoulder, and the knee. The body part affected most by overuse injuries was the shoulder, followed by the low back, knee, lower leg and hip/buttock. The most common injury types were sprains, strains, tendinitis, and contusions respectively. The act that resulted in the highest number of injuries was the teeterboard act (101). Mechanism of injury was considered to be an important factor in analyzing the causes of injuries and suggesting preventative measures, despite the absence of a biomechanical analysis of the various aspects of the show. Insufficient warm-up, previous injury, and return to participation too soon following an injury were considered to be contributing factors associated with injury. Acute injuries were attributed to poor conditioning, poor biomechanical technique, lack of skill, fear of injury, lack of concentration while performing skills, equipment failure, poor communication between two performers, poor spotting, inadequate safety equipment, and interference from props or apparatus. Overuse injuries were attributed to increased training time, over-training, muscle imbalances, inflexibility, postural problems, poor skill biomechanics, previous injury, fatigue, effects from costumes, and effects from apparatus. Use of this database for ongoing tracking of injury and exposure data was determined to be helpful for injury projection/prediction, development of conditioning and

rehabilitation programs that are activity specific, establishment of the necessity of a full-time coaching staff, long term injury tracking, and screening athletes for potential employment.

Acknowledgments

I have a memory, a very clear memory of my mother saying to my father shortly before she passed away, "make sure Janet finishes her Master's degree." It has been that memory and the ever-present support I received from both of my parents that gave me the extra drive that is so often needed during projects like this to strive for completion while lost in the process. It is to my mother that I dedicate this thesis, for teaching me to strive always to do my best, to endure what must be endured, and most of all, to accept the things I cannot change.

Special thanks to Dr. Glen Bergeron for providing a wonderful role model and offering assistance and guidance in many areas of my education beyond this project.

Thanks to my thesis committee who provided valuable assistance: Dr. Marion Alexander and Dr. Alan Kraute.

Thanks to Steven Ragatz, who offered countless hours to assistance in programming and analysis of my data.

Last but not least, thankyou to Cirque du Soleil, especially the artists, without whom this project would not have been possible.

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Chapter One

Introduction

The Cirque du Soleil, a theatrical-acrobatic performance troupe which has created several highly successful productions, has been established for approximately 10 years. In contrast to the traditional Ringling Brothers and Barnum & Bailey extravaganza, this French-Canadian troupe is like a European circus: one ring filled with singular acts. Journal reviews repeatedly boast that Cirque du Soleil is a "grand and etherical, primal theater with an age-old blend of music and motion" (Paskevich, 1994). With each new production created by Cirque du Soleil, the framework remains free-form, one act flowing into another without introductory fanfare. "Mystère," one of the newest creations of Cirque du Soleil which is currently being performed at the Treasure Island Hotel in Las Vegas, Nevada, is their most ambitious project to date. There are 62 artists who together represent the cast of the show. This particular cast of performers has been the subject group used for this 12-month epidemiological study conducted to obtain insight on injury nature, rate and prevention of those who participate in Mystère.

There has been little information compiled regarding the epidemiology of injury related to the performers of Cirque du Soleil. This lack of research has made it difficult for those concerned with the health care of the athletes to be knowledgeable about prevention and treatment of injuries that are incurred as a result of athletic performance. Consequently, the need for such an investigation became evident and would be the focus of this epidemiological study. At the outset of the study, it appeared that several questions merit posing, considering the dangerous nature of the activities that are performed by the athletes during the shows created by Cirque du Soleil. In particular, what types of injuries are experienced by athletes of Cirque du Soleil? How do their activities compare to other sports in terms of overall risk of injury? How frequently do injuries occur? And finally, are these injuries preventable?

The benefits of the knowledge derived from this study will hopefully help to improve the health care of those individuals involved with the Cirque du Soleil; the artists, athletes, supporting medical staff, production personnel, and other similar performing artists.

Statement of the Problem

The problem examined in this study was to determine the nature and rate of injury occurrence of the athletes of Cirque du Soleil's "Mystère", and to track individual athlete "exposure" to injury data over a 12-month period.

The collection and analysis of such information was completed with the aim of facilitating the important goal of reducing the risk and actual incidence of injury incurred by the athletes of Cirque du Soleil. The identification of those individuals at high risk of injury will hopefully be facilitated, and the task of screening potential individuals as athletes may now be simplified as the awareness of common injury rates and patterns has been obtained.

Operational Definitions

Troupe Maison: 'house troupe' which consists of the core artists/athletes in the cast of "Mystère", each member of the troupe maison participates in more than one number in the show, usually including both the teeterboard and Chinese poles act

Teeterboard: an apparatus better known as the Korean Planche, consists of a 14-foot long, 3-inch thick, 1 1\2-foot wide wooden board resting on a central fulcrum; the apparatus is used in similar fashion to a seesaw, but instead of sitting on either end, the athletes jump and perform aerial stunts at the ends of the board, landing either back on the teeterboard or exiting onto a crashmat positioned behind the teeterboard

Exiting: term used to describe a dismount from an apparatus; for example, teeterboard exit

Spotting: the act of assisting an athlete with a stunt, usually done by other athletes, to 'break falls', prevent falls, and reduce the severity of injury when falls do occur

Column: a 'column' is created during the teeterboard act by an athlete standing on the shoulders of another athlete; the athlete on the top of the column is then required to catch another athlete on his shoulders during an exit from the teeterboard, a column may consist of as many as four athletes atop one another's shoulders

Chinese Poles: '3 inch' diameter poles, each standing 18 feet, 6 inches tall, used to perform stunts, climbing, and gymnastic maneuvers; originally designed and used in circus acts in China, successive poles are either arranged in a square configuration or a straight line, and stunts are performed either on one pole alone, or between two poles

Single Pole: sits above the square configuration of four Chinese poles, and is used by one athlete only, who performs balancing stunts (handstands) on top of the single pole

Trampoline: three standard-sized trampolines are secured end-to-end; stunts are performed with all three trampolines lying horizontal as well as with the two lateral trampolines secured at 40 degree angles to the central horizontal trampoline; with the trampolines in this configuration, the athletes can perform stunts on the central trampoline alone, or between the two lateral-winged trampolines without jumping on the central trampoline

Fasttrack: an 80-foot long, 4-foot wide tumbling track, located 2-feet above the floor, upon which athletes perform sequences of tumbling moves and exits

Bungee: aerial act performed by six athletes, each athlete is attached to two bungee cords by a harness secured around their waist and hips; the bungee cords are secured to the grid level (fourth floor) of the theater, and the bungeists are raised and lowered from the grid to a single trapeze bar, this trapeze bar is the point from which various stunts are performed

Manipulation: juggling act, includes balls juggled alone, and balls juggled on a square, sinusoidal-shaped piece of aluminum

Flying Trapeze: aerial act in which athletes perform gymnastic maneuvers in the air between a trapeze bar and a catcher

Main-a-Main: hand-to-hand number performed by two male artists, consists primarily of balancing and strength maneuvers

Stilts: artists walk on metal struts that are secured to their feet; the stilts vary in height from 4-feet to 8-feet; large costumes are worn to give the illusion of giant characters

Taiko: Japanese drums used at various points during the show

Post Dark: a 'dark period' is the term used when the show is not running; "Mystère" is dark on Mondays, and there is a 2-week dark period once every 8 weeks, and a 4-day dark period once every three and a half weeks; 'post dark' is the term used to indicate time after a dark period, for example, one, two, or three weeks post dark

Injury: any condition which required treatment and/or limited participation in a training session or an act in the show

Burden of Injury: the amount of time lost from shows due to injury, illness, or absenteeism; designated as full, partial, minimal or no time lost on daily exposure sheets

Individual Act Descriptions

Teeterboard:

The teeterboard is a 14-foot long, 3-inch thick, 1 1/2-foot wide plank of wood secured to a central fulcrum, upon which it "teeters". The apparatus is used by two athletes simultaneously, one situated at either end of the board. Each athlete reciprocally jumps on his/her end of the board, with the intent of "pushing" their partner at the opposite end of the board, into the air. Several factors determine the vertical distance each athlete will travel as a result of the push. One, the weight of the athlete who is pushing; two, the force with which the athlete (who is pushing) hits the board (force = mass X acceleration); three, the weight of the athlete that is being pushed; and four, the resiliency of the board.

The athletes initially learn to perform simple straight jumps at either end of the board, gradually incorporating gymnastic-type movements while in the air. For example, single, double and triple somersaults, and somersaults with twisting movements are common skills that are routinely practiced by these athletes. As the athletes become more skilled, acrobatic stunts that require aerial movement from one end of the teeterboard to the other, are also practiced. This type of skill is referred to as a "fly". In order for a fly to be performed successfully, three jumpers are required. One teeterboard jumper (TBJ) must travel (fly) from one end of the board to the other, while another TBJ must get on the end of the board the first TBJ left to take his/her place, and the third TBJ must get off the board at the end the first TBJ is traveling to, in order that the first TBJ will have space to land.

During this act in the show, 10-12 athletes take turns jumping, flying, exiting (dismounting) and spotting. In order to prevent fatigue, and simultaneously maintain the momentum (the "teeter") of the board, the athletes "switch" positions without stopping the board. This requires coordination and timing on the part of all the participants of the teeterboard number.

Spotters play a significant role in the prevention of injury to both teeterboard jumpers and exiters. It is common practice that one or two spotters be present at either end of the teeterboard while athletes are jumping, depending on the difficulty of the skills that are being performed. Spotters are required to help control the jumpers landing, and in the event that the jumper appears that he/she may fall on landing, spotters are often required to help reposition the jumper on the teeterboard quickly, so he/she will be in an appropriate position to take their next jump prior to the partner landing on the board. This is merely the amount of time that it takes for the partner to ascend and descend. If the original jumper, or a new jumper (as is the case when jumpers switch positions) is not in correct jumping position by this time, a "dead-board" will result. This loss of momentum in the teeterboard can potentially injure the jumper at either end of the board. If one jumper falls off the board or a new jumper has not successfully switched onto the board at the time the descending jumper lands, the ground reaction forces that are normally consumed by the opposite jumper's body weight being pushed into the air are non-existent. Therefore, the descending jumpers force on landing can be considered to be similar to landing on the stage from approximately a 10-foot jump. The deleterious effects of such a landing are obvious. In such instances, the ability of the spotters to prevent injury to the jumper is minimal.

Two types of exits are performed by the athletes in the teeterboard number, those exits that require landing on a crash mat, and those that require landing on top of a column of athletes situated behind the teeterboard. The difficulty of the exits varies, as does the height of the column to which the athlete performs the exit. Spotters are present to assist the landing of exits both on the crash mat and on top of the column. When an exit is performed to a two-man column, spotters position themselves around the column to protect the exiter as well as the members of the column, in the event that the column should collapse. When an exit is performed to a three-man column, the exiter wears a spotting belt, and spotters are positioned in a similar manner to the 2-man column exit.

Trampoline:

The trampoline number is incorporated into and considered part of the teeterboard act. The apparatus that is used during the show Mystère is a unique piece of equipment that was originally designed specifically for this particular show. Three standard sized trampolines are secured end-to-end and aerial stunts are performed with all three trampolines positioned horizontally, as well as with the two lateral trampolines secured at 40 degree angles to the central horizontal trampoline. With the trampolines secured in this manner, the athletes can perform stunts on the central trampoline, or between the two lateral winged trampolines, without jumping on the central trampoline.

Flying Trapeze:

The flying trapeze number is performed on a trapeze structure that is larger and architecturally different from any designed before it. The complete structure spans the width of the stage (128 feet) and is located three stories above stage level. The safety net under the structure is located 14 feet above the stage, and is 138 feet long, and 63 feet wide.
The act consists of 10 athletes, three who perform as catchers, and seven who perform as flyers. The three catchers are positioned across the structure, one located centrally, one at the left side, and one at the mid-way point between the right side of the structure and the center. Only one trapeze bar is used by the flyers. This swinging bar is located between the right side of the structure and the center catcher. All three of the catchers perform their catches while in an inverted hanging position, by hooking their feet under a stationary horizontal bar and using another stationary horizontal bar positioned behind their knees, as the center of rotation (these two horizontal bars are parallel to one another, 18 inches apart, and are referred to as the trapeze catcher's "chair"). The two outside catchers work on fixed, or stationary, chairs. The main catcher, however, positioned in the center of the structure, catches in the same inverted position, but his chair swings on a fulcrum. This swinging action of the chair increases the distance over which he can catch the trapeze flyers.

After catching a flyer, the catcher must transfer the flyer back to his/her trapeze bar, or to either of the other two catchers. The swinging action of the main catcher's chair enables the catcher to utilize momentum as well as strength to successfully transfer the flyer to his/her next destination. The flyer will "ideally" grasp the catchers wrists with both hands, so that equal weight is distributed across the flyer's upper body. Simultaneously, the catcher will "ideally" grasp the flyer's wrists in a similar manner. A biomechanically correct catch is one in which the contact between the flyer and the catcher is smooth and controlled, and a smooth swing follows the catch. Neither the flyer nor the catcher should have to reach beyond his/her normal range of motion in order to complete the catch, although this commonly occurs. Additionally, the flyer should have completed the aerial movement prior to attempting to grasp the catcher's hands, if the aerial movement is to be performed correctly, and injuries are to be prevented.

Chinese Poles:

The Chinese poles act is a climbing act performed by the troupe maison and four Chinese acrobats who are considered specialists in this type of number.

Each Chinese pole stands 18 feet, 6 inches tall, and is 3 inches in diameter. The pole is used as a climbing apparatus, upon which stunts are performed. During the Chinese poles number, a series of stunts that require both strength and acrobatic skill are performed. Various methods of ascending and descending the poles are practiced. The athletes are taught to climb the poles using both hands and both feet, synonymous to how a monkey would climb a tree. The athletes are also taught to ascend the poles using upper body strength alone. In this type of ascent, the athlete climbs the pole hand-over-hand, while keeping the body held straight and away from the pole. A third type of ascent is referred to as an "inverted hop". Such an ascent is performed with the athlete positioned upside down, grasping the pole between one shoulder and both hands. Initially the body is held in a tuck position. From this position, the athlete opens up his legs (vertically) as if to reach up with his feet, and hops up the pole.

The most common mode of descending the pole is an inverted slide, in which the athlete wraps the pole between his/her legs and slides down by loosening the grip he/she has on the pole. When the athlete has slid to within 4-5 feet of stage level, he/she jumps off the pole to land on the stage in a crouched position.

Incorporated into the act are a series of strength moves and acrobatic skills performed both on and between the Chinese poles, which are arranged in a square configuration. Situated above the 4-pole configuration is a single Chinese pole, upon which an athlete performs a one-hand balancing act. This entire act is performed 40-feet above the level of the stage, without the use of any type of safety equipment.

Bungee:

The bungee act is an aerial act composed of 6 athletes who perform acrobatic stunts while secured to two bungee cords, one at either side of their body. Each athlete wears a bungee belt/harness which consists of a series of straps, one strap which is secured around the waist, and another strap that surrounds the superior aspect of each thigh. The bungee cords are secured to either side of the belt, at approximately the center of gravity of the athlete's body (slightly lower in the females). This creates the center of rotation around which the athlete can turn in order to perform somersaults while bungeeing.

The six athletes are positioned in a circle, and the act commences and terminates with the bungeists being lowered and raised through the theater's ceiling. Each athlete is lowered onto a trapeze bar, which he/she uses as a swing from which to start and finish each aerial stunt. During the number, the athlete uses their arms to pull on the bungee cords (on the ascent of the bounce) as a propulsive mechanism to give momentum and height to the bounce. Throughout the bungee act, which lasts for approximately 14 minutes, the athlete performs a series of bounces, somersaults and swings which are synchronized with the five other bungeists.

Manipulation:

The manipulation act, more commonly referred to as juggling, is performed by three jugglers. The act is divided into two parts, the first of which is a ball juggling demonstration, the second a "shape" manipulating demonstration. The shape that is used in the act is a sinusoidal-shaped piece of aluminum, 3 feet by 3 feet, weighing approximately 2-3 pounds. Throughout the act the shape is continuously rotated manually either anteriorly, posteriorly, or at the juggler's side, and a ball is manipulated around or on the shape.

Hand-to-Hand:

Hand-to-hand, which is also referred to as the main-a-main balancing act, is an act that is performed by two male athletes. Primarily the act can be described as a series of balancing maneuvers in which one athlete, referred to as the porter, supports the body weight of the other athlete. A series of smooth transitions between various body positions are performed by the two athletes throughout the number. Usually the athlete who is being supported is in a handstand (or inverted position), and the porter assumes different positions while simultaneously supporting his partner in the air. The entire act, which lasts for approximately 11 minutes, is performed on a revolving platform which is shaped like a dome. This dome, which has a circumference of 18 feet, revolves at speeds which range from one to two revolutions per minute.

Limitations

The primary limitation of this study is the size of the troop which limits the power of the study. Sixty-two artists/athletes comprise the troupe that perform the show "Mystère" and these individuals were the subject group from which the data was obtained.

Delimitations

There is often a small amount of variation in the athletic roles of the performers each time a new show is created by the Cirque du Soleil. The core components of each show are identical, however. Because of this variation, potential risk factors related to injury may vary in newly created shows.

Significance of the Study

The benefit of analyzing data with regard to injury nature and rate is realized most when one considers the time lost when injury does occur. Therefore, the possibility of reducing both the risk of injury and the actual number of injuries is appealing to the performers, the production personnel, and the medical support staff who work for performing groups such as the Cirque du Soleil.

At the outset of this study, data collection and analysis of this nature had yet to be completed with respect to the theatrical troupe of Cirque du Soleil, or any other circus-like company. Consequently, the implementation of preventative measures, protective-supportive devices, and proper screening procedures, as may be recommended based on the outcome of this study, may be instrumental in reducing injuries in the future. Recommendations from this study may further facilitate the recruitment of the best possible candidates for athletes of the Cirque du Soleil, and reduce the amount of time lost due to injury.

Chapter Two Review of Related Literature

Introduction

Over the past two decades there has been a number of sports injury studies that have applied the principles of epidemiology and clinical medicine to analyze causes and patterns of injuries sustained by athletes. (Allel, Powell, & Buckley, 1979; Keller, Noyes & Buncher, 1987; Lysens, Steverlynch, & van den Auweele, Lefevre & Renson, 1984; McAuley, Hudash, Sheilds, Albrict, Garrick, Requa1987; Thompson, Halpern & Curl, 1987). Gymnastics has been a sport of particular interest to those in the sports medicine field for two reasons; the popularity of the sport, and the inherent risk involved for those participating at the competitive level. The sport of gymnastics will be the main focus for this literature review because of the similarities in fundamental skills required to be a gymnast or an acrobat in a circus. Many of the athletes who are recruited and perform for the Cirque du Soleil are former gymnasts. Some insight into potential circus injury nature and frequency was obtained by reviewing previous epidemiological studies on gymnastics. The current research in this area was the primary focus of this review. The unique differences between the performances undertaken by athletes of the Cirque du Soleil and those participating in traditional gymnastics has also been delineated. These differences themselves supported the need to perform an epidemiological study related to the Cirque du Soleil and its performers.

Epidemiology of Gymnastics Injuries

Epidemiology has been defined as the study of the distribution of injuries and their causative agents (Caine, Cochrane, Caine & Zemper, 1989). The rate of injury, or injury incidence, provides valuable information about the risk of injury to which each athlete is exposed. By reviewing various epidemiological studies, it is evident that injury rates vary greatly between studies conducted on gymnastic injuries, from .12% (Pettrone & Ricciardelli, 1987) to 10,711% (Sands, Shultz & Newman, 1993). These substantial differences can likely be explained by differences in some essential factors of epidemiological research, such as the definition of injury used in the study, the method of data collection, retrospective versus prospective study design, and number of participants. The variability in the control of these factors makes it difficult, if not impossible, to compare injury rate values from different studies.

There has been much more research on women's gymnastics than on men's gymnastics (Meeusen & Borms, 1992). Artistic gymnastics consists of six apparatus for men (floor, pommel horse, rings, vault, parallel bars, and horizontal bar) and four apparatus for women (vault, asymmetrical bars, beam, floor). With the exception of one study (Lowry & LeVeau, 1982), the incidence of injury was always higher for women's gymnastics than for men's. Some studies focused on gymnasts at different levels of skill and competition. The risk of gymnastic injuries seems to be proportional to the level of skill of the athletes. As the level of skill increases, so does the degree of difficulty of the maneuvers performed by the athletes, which inevitably leads to a greater number of injuries (McAuley et al,1987). Garrick and Requa (1980) reported low injury rates for both high school (33 injuries per 100 participants per season) and club level gymnasts (22 injuries per 100 participants per season). In studies that focus upon competitive club, collegiate, and elite performers the injury rate ranges from .7 to 5.3 (injuries per 100 participants per season (Garrick & Requa, 1980; Lowry & Leveau, 1982; Pettrone & Ricciardelli, 1987; Nocini & Silvij, 1982). As gymnasts develop greater skill, they spend more time practicing. Consequently, the exposure time increases, and with it the risk of injury also increases.

Table 2-1 provides an overview of the number of injuries and injury incidence that have been reported in 13 epidemiological studies of various gymnast populations. The study design (prospective vs. retrospective), the number of gymnasts in the subject group, level of competition and the number of injuries that occurred during the data collection period have been outlined.

Table 2-1 Incidence of Gymnastics Injuries

Reference	Design	Number of Participants	Participation Level	Number of Injuries	Incidence[a] (%)
Bak et al. (1993)	Prospective (1yr)	115 women	Subelite	184	85
Caine et al. (1989)	Prospective (1yr)	50 women	Elite	147	294
	Prospective (6m)	31 women	Elite	48	155
Dickson &Fricker (1993)	Retrospective (10 Years)	47 Males	Elite	573 for both	200 F
	Retrospective (10 Years)	74 Females	Elite	573 for both	204M
Garrick & Requa (1978)	Prospective (2yr)	98 Females	High school	39	39.8
	Prospective (2yr)	18 Males	High school	5	28.0
Garrick & Requa (1980)	Prospective (1yr)	24 Females	College	17	71
	Prospective (1yr)	221 Females	High school	73	33
Goodway et al. (1989)	Prospective (1yr)	725 Females	Competitive	93	12.8
Lindner & Caine (1990)	Prospective (3yr)	178 Females	Competitive		30
Lowry &Leveau (1982)	Retrospective	370 Females	Competitive	280	70
	(11months)	21 Men	Competitive	16	76
Pettrone & Ricciardelli (1987)	Prospective (7 months)	542 Females	Competitive	62	5.3
	Prospective (7 months)	2016 Females	Recreational		0.7
Sands et al. (1993)	Prospective (5 year)	37 Females	College	3963	10,711
Snook (1979)	Retrospective (5 years)	70 Females	College	66	14
Vergouwen (1986)	Prospective (3 seasons)	20 Females	Elite	353	930-970
Weiker (1985)	Prospective (9 months)	766 Females	Club	95	12.4
	Prospective (9 months)	107 Males	Club	10	9.3

Overview of injury rate and incidence of 13 epidemiological studies conducted on various gymnastic populations between 1979 and 1993. [a] Incidence expressed as (no. of injuries/no. of participants) X 100

The study by Sands et al. (1993) reported injury rates of 10,711 per 100 participants (Table 2-1). Two other studies (Caine et al., 1989; Vergouwen, 1986) also reported very high injury rates (from 155 to 970) per 100 participants. Pettrone & Ricciardelli (1987) reported the lowest injury rates in their 7-month study on recreational (.7) and competitive (5.3) gymnasts. Weiker (1985) also reported low injury rates in club gymnasts (males, 12.4, females, 9.3) over a 9-month period.

One possible reason that these studies show a large range in injury rate is because they all used different definitions to describe a gymnastic injury. For example, Caine et al. (1989) described an injury as any gymnastics-related incident that resulted in a gymnast missing any portion of a workout or competition. Weiker (1985) described an injury as a problem that caused a gymnast to either miss practice or modify workouts for 2 consecutive days. Sands et al. (1993) considered an injury to be any damaged body part that would interfere with training. Such a description of an injury necessitates the inclusion of even minor injuries in the data collection process, and consequently may have been a contributing factor in the high rate of injury that was reported in this study. 'Time lost from practice' is an injury definition frequently used in epidemiological studies (Meeusen & Borms, 1992). This definition is quite vague when used with gymnastics because often an injured gymnast will simply modify his/her practice session. Depending on the severity of the injury, the gymnast will often train on another apparatus, or do flexibility or other conditioning while an injury is healing (Vergouwen, 1986). This situation commonly occurs with athletes who perform in Mystère. Despite an injury, and depending on the severity of the injury, athletes will modify their participation during training and shows in order to participate to the fullest extent possible, without aggravating the injury. Studies that register even the smallest injuries or discomforts have resulted in 'non-specific' pain being the most common injury mentioned (Caine et al., 1989). This conclusion may not initially appear to be very informative. However, Caine et al.(1989) reported that 92.3% of minor injuries were characterized by a gradual onset which implies a stress related etiology. Therefore, these injuries could be precursors to overuse injuries, and should not be ignored when attempting to determine the causative factors of injury, especially those that develop over a period of time.

When considering injury rates it is important to know the extent to which the gymnasts included in the study were exposed to injury. Several studies report incidence of injury per 1000 hours of exposure (Table 2-2).

Table 2-2 Injuries/1000 Hours of Exposure

Reference		Injury Rate (per 1000 hours of exposure)
Bak et al. (1993)		1.6
Caine et al. (1989)		4.0
Clarke & Buckley (1980)	Females	2.7
	Males	1.5
Lindner & Caine (1990)		0.52
Weiker (1985)	Females	4.3
	Males	1.3
Whiteside (1980)	Females	9.4
	Males	7.7

Rate of injury calculated per 1000 hours of exposure, as published in 6 reports.

The individual hours spent in the gymnasium varied from 1.6 hours/week for the club or recreational level gymnast, to 13.1 hours/week for elite gymnasts (Weiker, 1985). In the Caine et al. (1989) study, gymnasts were training 20-27 hours/week. Caine et al. (1989) also observed a statistically significant difference ($p < 0.05$) between 'high' and 'low injury risk' groups of gymnasts, which could best be distinguished by competition level and maturation level. Gymnasts at the competitive level, both advanced and elite, were considered to be at a high risk of injury, while those who participated at the recreational level were considered to be at a low risk of injury.

The difficulties that arise when comparing various epidemiological studies are evident. The only conclusion that could be drawn about injury rate in gymnastics was that the higher the skill level of the gymnast, the greater their risk of injury.

The importance of having denominator data, for instance, athlete-hours of participation, to establish the relative risk of injury, is evident (Walter, Sutton, McIntosh & Connolly, 1985). Such data makes it possible to determine risk of injury per unit time. For example, Garrick and Requa (1980) noted that 85% of injuries occurred during practice, which represented 99.6% of total participation time, whereas 5% of injuries occurred during competition, which represented only .4% of total participation time. When considered on an hourly basis, the rate of injury per hour was 13 times greater in competition than during practice. Therefore, they concluded that the risk of injury is much higher during competition than during practice. This question is of particular interest for the subject group in this study. More time per week was spent performing during shows than training, which presented the need to determine whether more injuries occurred during shows or during training sessions.

Gymnastics Compared to Other Sports

In studies of sports related injuries, especially in North America, gymnastic injury rates have consistently approached those of American football and wrestling (McAuley et al., 1987). As well, in a 1-year prospective study of patients visiting a sports medicine center (Kannus, Nittymaki & Jarvinen, 1987), women's gymnastics was the most common cause of injury (9%). Mencke and Valentijn (1990) examined 229 athletes over a 3.5-year study, and gymnastics ranked fifth of 27 sports registered (9.2%). Gymnastics was the sixth most common cause of injury among all registered sports disciplines in a 5-year statistical report on injuries at a sports medicine facility (Garrick, 1985). In an epidemiological analysis of sports injuries at the 1984 Olympics, gymnastics accounted for 6.7% of the injuries, fourth of 13 sports (Martin, Yesalis, Foster & Albrict, 1987). Injuries that were incurred by school-aged children during school sports, physical education classes and club sports activities were documented over a 1-year period (Zaricznyj, Shattuck, Mast, Robertson, & Delia, 1980). Non-organized sports and physical education classes produced almost twice as many injuries as organized sports. Gymnastics occupied seventh place with 3.9% of all injuries. However, in organized school sports, gymnastics had the third highest injury to participant ratio (13%) behind football and wrestling.

Again, comparing different studies only has limited value in providing injury information. For example, gymnastics as part of a physical education class is very different than gymnastics at a competitive club level. Similarly, injuries reported at a hospital emergency room or by an insurance company only portray data of acute injuries, leaving the incidence of minor injury and gradual onset injury undocumented. Despite these shortcomings, gymnastics consistently ranks near the top when considering both injury rates and risk in different sports.

Injury Nature

The distribution of injuries in gymnastics does not appear to be substantially different from that of other women's sports when examined according to type of tissue damage (McAuley et al., 1987). Strains and sprains have been reported to account for 47% to 58% of the total injuries, making these the most common injuries. The incidence of these injuries varies from study to study. Vergouwen (1986) stated that the high incidence of sprains, and to a lesser extent strains, occurred during dismounts and vaults. In the study by Caine et al. (1989) slightly more than one-third of the sprains (35.7%) occurred during the dismount and the majority of strains occurred during the first hour of practice (61.5%), suggesting that insufficient warm-up was a factor in injury. The incidence of contusions severe enough to be included in these reports ranged from 11% to 30%, depending on the sensitivity of the study. Vergouwen (1986) stated that the higher percentage of contusions could be attributed to attempting to learn more difficult exercises with a higher risk of injury. Lowry and LeVeau (1982) also stated that the incidence of contusions may be under-reported because a contusion does not necessarily cause any 'time lost from practice.' The incidence of fractures and dislocations, likely the most reliably reported type of injury, ranged from 1.3% (Vergouwen, 1986) to 29% (Pettrone & Ricciardelli, 1987) of total injuries.

It is important to recognize differences in the nature of the onset of symptoms. In most studies the injuries reported occurred suddenly and are considered traumatic. In one descriptive study of college gymnasts, 67 % of the injuries were caused by a single episode of trauma (Snook, 1979). In Weiker's study (1985), 42.9% of all injuries sustained by 873 gymnasts were chronic or overuse in nature, with 80 % of these injuries being confined to the lower extremity. Overuse injuries are characterized by a gradual onset of symptoms. In a sport such as gymnastics, training consists of multiple repetitions of monotonous stereotype movements (Vergouwen, 1986), which can result in excessive, repetitive sub-threshold trauma, with which gymnasts and coaches are very familiar (McAuley et al., 1987). Overuse injuries are commonly the most difficult to document accurately, as shown by Pettrone and Ricciardelli (1987). They reported in their mailed questionnaire study that there were only 11 chronic injuries in 2558 club gymnasts. One possible explanation for such a low documentation of overuse injuries is because these injuries are likely so 'common' for the gymnast that they do not recognize them as injuries, and therefore will not report them in a questionnaire.

Table 2-3 Acute vs. Chronic Injuries (% of Total Injuries)

Reference	Acute	Chronic
Caine et al. (1989)	44.2	55.8
Garrick (1985)	68.7	31.3
Goodway et al. (1989)	52.0	48.0
Lowry & LeVeau (1982)	88.2	11.8
Pettrone & Ricciardeli (1987)	82.3	17.7
Snook (1979)	75.7	24.3
Vergouwen (1986)	71.0	29.0
Weiker (1985)	57.2	42.8

Comparison of the percent of acute vs. chronic injuries in various gymnastic populations.

In all of the studies except Caine et al. (1989), Goodway, McNaught-Davis & White (1989) and Weiker (1985), over 2/3rds of the injuries were acute in nature (Table 2-3).

Just as the incidence of chronic injuries is difficult to assess, reinjuries are also dufficult to differentiate. Martin et al. (1987) stated that athletes with previous injuries to a body part were more likely than others to reinjure the same body part. In Caine et al. (1989) the rate of reinjury was 32.7% and 16 of the 50 girls who participated in the study experienced more than one reinjury. Caine et al. (1989) suggested that the high incidence of reinjury in their study could be the consequence of an underestimation of the severity of the original injury, inadequate rehabilitation and/or premature return to sports activity. Goodway et al. (1989) suggested that because many of the injured gymnasts received inadequate medical treatment, there was a considerable risk of reinjury.

Vergouwen (1986) suggested that when gymnasts perform more difficult elements, the risk of injury may increase because the load during the workout and the number of repetitions of the same movement increases. Consequently, the number of chronic injuries will rise. McAuley et al. (1987) suggested that it would be useful to establish a single definition of injury for this sport that is sensitive enough to identify those early stages of chronic, long-term cumulative injuries.

Anatomical Location of Gymnastic Injuries

There is general agreement in the literature that the anatomical sites most frequently injured are in the lower extremities, accounting for 50% to 66% of all reported injuries (Eisenberg & Allen, 1978; Garrick & Requa, 1980; Kirby, Simms & Symington, 1981; Pettrone & Ricciardelli, 1987; Sands et al., 1993; Snook, 1979 & Weiker, 1985). Injuries to the upper extremities (25% to 31%) and to the trunk and spine (12% to 19%) are reported less frequently (Garrick & Requa, 1980; Lowry & Leveau, 1982; Pettrone & Ricciardelli, 1987; Snook, 1979). Although there are fewer studies on men's gymnastics injuries, the most common injury sites are head, neck, shoulder, and upper arm. This is likely due to the fact that four of the six events in men's gymnastics require predominant use of the upper body (rings, pommel horse, parallel bars and high bar). In women's gymnastics, the lower extremity is the most commonly injured body part (Whiteside, 1980).

Foot and Ankle Injuries

Several authors have cited the ankle as one of the most frequently traumatized joints in women gymnasts (Garrick & Requa, 1980; Garrick, 1982; Pettrone & Ricciardelli, 1987; Snook, 1979). Many ankle injuries are overuse injuries such as plantar fasciitis and Achilles tendinitis. Dorsal impingement of the ankle due to repetitive extreme dorsiflexion of the ankle joint, which often occurs during tumbling and dismounts, can lead to ankle instability, since extreme flexibility or even laxity of the ligaments can predispose athletes to ankle sprains (Lysens et al.,1984). Excessive exercise loads, foot pronation and a tight gastrocsoleus complex can cause heel pain in young gymnasts, which usually manifests as a calcaneal traction apophysitis (Sever's disease) (Taunton, McKenzie & Clement, 1988). Kirby et al. (1981) found that championship level gymnasts had a significantly higher prevalence of foot discomfort than aged-matched controls. Common diagnoses included toe fractures, metatarsal stress fractures, heel pad contusions, and acute strain syndromes.

Lower Leg Injuries

Kirby et al.(1981) also noted that 30 % of their athletes complained of anterior lower leg pain that was aggravated by the running approach to the vault. Szot, Boron & Galaj, (1985) stated that about 10 % of all injuries in gymnastics affect the lower leg. The majority of these injuries are overuse syndromes, such as stress fractures and compartment syndromes.

Knee Injuries

Reports of knee injuries have varied from 14% to 24% (Garrick & Requa, 1980; Jackson, Furman & Berson, 1980 & Kirby et al., 1981). Andrish (1985) followed 170 knee injuries directly related to gymnastics over a 6.5 year period. He found that most knee problems were situated around the patellofemoral articulation, chondromalacia accounted for 36.5% of the total number of injuries. Sprains were the second most common injury, but required surgical treatment more than any other category. Bos & Sol (1982) stated that landing from vaults could cause excessive stress to the knee, with a great risk of injury to the collateral ligaments. Repetitive jumping and landing from dismounts was also found to predispose a young gymnast to a traction apophysitis of the tibial turbercle or Osgood-Schlatter's disease (Taunton et al., 1988).

Hip Injuries

Possible hip injuries sustained by artistic gymnasts include hip contusions, hip strains, and hip pointers (Snook, 1979). Hip problems are more frequent in sports such as ballet (Rovere, Webb, Gristina, & Vogel, 1983). Kirby et al. (1981) noted the 'clicking' or 'snapping' hip as a common problem among dancers, rhythmic gymnastics and female artistic gymnastics, especially when lowering the leg on forward walkover movements.

Back Pain and Injury

Back pain in gymnasts has been proposed to be caused by a number of factors ranging from a hyperlordotic back through vertebral body fractures and disorders of the intervertebral discs (Micheli, 1985). Back problems seem to result not only from single episode macrotrauma, but also from the repeated microtrauma in gymnastic movements such as vaults, twists and dismounts (Hall, 1986; Micheli, 1985). Most documented back injuries have been characterized by a gradual onset of symptoms (Caine et al., 1989; Ciullo & Jackson, 1985; Hall, 1986). Hall (1986) conducted a study to evaluate mechanical factors that were potential contributors to back problems. Lumbar hyperextension and impact forces were quantified for several commonly used gymnastics skills. She found that maximal lumbar hyperextension often occurred close to the time that impact forces were sustained by either the hands or the feet. Since vertebral arch ossification may not yet be complete at the time that young gymnasts start training, the likelihood of spinal injury may be increased by this combination of extreme forces and immature bone formation (Hall, 1986). Micheli (1985) argued that musculotendinous imbalances may partly explain pars interarticularis defects in young gymnasts. Garrick and Requa (1980) recommended maximal conditioning of the abdominal and paravertebral muscles to prevent a hyperlordotic posture.

Shoulder Injuries

The most frequent shoulder problems in gymnasts have been found to be muscle strains and shoulder impingement (Aronen, 1985). Shoulder problems are generally more common in men's gymnastics than women's gymnastics. This likely results from the ring and horizontal bar exercises which include movements of great amplitude and speed, causing high stresses to be placed on the shoulder joints (Aronen, 1985; Szot et al., 1985).

Szot et al. (1985) examined gymnasts who had competed for several years (3 to 20 years of training). By the end of their career, 41.5% of gymnasts had shoulder complaints and 59.8% of these gymnasts had radiological changes ranging from cyst-like formations on the humeral head to degenerative symptoms.

Elbow Injuries

The incidence of injuries to the elbow in gymnastics is rather low, but the injuries reported are very specific (Preist & Weise, 1981). High impact loads are distributed across the elbow joint during various maneuvers because the arms are used for weight-bearing for a considerable portion of the workout time. Preist and Weise (1981) reported 41 acute elbow injuries, of which 56% were fractures, 41% dislocations, and 3% ulnar nerve compressions. Only two of the injuries that they reported were caused by chronic microtrauma.

The occurrence of chronic problems about the elbow has been noted by several authors. Nocini and Silvij (1982) examined a select group of nine past and present Olympic gymnasts with different years of competitive experience. Radiographic changes were found in five of these gymnasts. It was the opinion of these authors that even though they studied a small select group of athletes with no controls, the report did suggest that a cumulative effect of repetitive microtrauma to the elbow may exist even in those competitors without a serious acute injury.

Wrist Injuries

Most gymnasts with wrist pain complain of pain during compression and on impact with rotation, or with forced dorsiflexion as in vault, floor or pommel horse exercises. Several authors diagnose this 'wrist pain' as a wrist impingement (Snook, 1979; Vergouwen, 1986). Because of the weight bearing stresses of compression and rotation, several injury patterns have been detected. These have included ligamentous tears, tears of the triangular fibrocartilage complex and secondary chondromalacia of the different articulations of the wrist (Mandelbaum, Bartolozzi, Davis, Teurlings & Bragonier, 1989). Roy, Caine & Singer, (1985) conducted a three year study of high caliber gymnasts with complaints of distal radial pain. Their definition of a stress reaction was based on a history without acute trauma, minimal swelling, painful and/or limited wrist dorsiflexion, local distal radial pain, and no symptoms of tendinitis, cyst, or joint dysfunction. They found that this condition was related to the time spent in workouts, and that symptoms were exacerbated by forced dorsiflexion of the wrist. These authors presented a therapeutic algorithm in which rest or activity modification plays a significant role. They suggested that gymnasts with wrist pain discontinue any activities that put stress on the wrist. They felt that the tolerance limits of the growth structures could be exceeded if training was continued despite wrist pain.

Risk Factors: Gymnastics Compared to Cirque du Soleil

Factors that contribute to injury in gymnastics, whether they are related to risk factors of injury in Cirque du Soleil athletes or not, are quite varied. Because of the different populations studied, and the differing definitions of injuries and analytical methods used in the studies that were reviewed, it is difficult to establish the definitive factors that cause or contribute to injury in gymnastics from the literature. Various authors have suggested relationships between injury and contributing factors to injury. For example, there appears to be a consensus among several studies that the number of injuries incurred is directly proportional to the level of skill at which the gymnast is competing (Garrick & Requa, 1980; Lowry & Leveau, 1982; Sands et al., 1993; Weiker, 1985). This can likely be explained by two characteristics of higher skill level gymnasts. First of all, the degree of difficulty increases dramatically for all gymnastics events as the gymnast ascends through the ranks of club gymnastics to competitive gymnastics. Secondly, as the gymnasts become more skilled, they spend more hours practicing. Consequently, this increase in exposure time provides more opportunity for injury. Weiker (1985) and Pettrone & Riciardelli (1987) have reported a positive relationship between the amount of time spent in the gymnasium and chronic injury, suggesting that the gymnasts' increasingly long practice periods may result in cumulative microtrauma.

The relationship between skill level and risk of injury to the gymnast is difficult to apply to athletes of the Cirque du Soleil simply because their mere presence as a performer in this company denotes their skill level. All of the artists are considered to be highly skilled athletes, whether their background is from gymnastics, trampoline, stunt or circus school. The relationship between increased number of hours practicing and increased risk of injury may, however, be substantiated. Each athlete spends a significant number of hours per week performing, which is predetermined by the show schedule. There are two shows nightly, performed six nights per week, with Monday being the only day off per week. In addition to performing these twelve shows per week, the artists commonly have 2-3 training sessions per week, which are held as afternoon sessions. An average training session consists of 1 1/2-2 hours of rehearsal.

Rate of injury occurrence during training vs. show performance was determined by this study. It was obvious that much more exposure to injury occurred during shows (because more time is spent in show than training), but it was consistently during training that new and more difficult maneuvers and routines were practiced. This may have increased the likelihood of injury occurrence during training. Because of the different practice/competition, training/show performance schedules that are adhered to by the athletes of the Cirque du Soleil compared to competitive gymnasts, the data that has been previously collected on injury occurrence in practice vs. competition is relatively uninformative. Gymnasts have been found to be at a greater risk of injury during competition than during practice (Garrick and Requa, 1980). They found that 85% of injuries occurred during practice (99.6% of total exposure time) and 15% of injuries occurred during competition (.4% of total exposure time). Therefore, by simple calculation, the gymnast is 13 times more likely to be injured during competition than practice. Cirque du Soleil performers spent a significantly greater amount of time performing in shows than training.

Another factor that has been considered significant to injury risk in gymnastics is the presence of spotters. Weiker (1985) found that spotting vs. non-spotting was the most significant controllable factor in determining the rate of injury. He reported in his study that 80% of the injuries occurred without spotters. Preist and Weise (1981) stated that in 59% of all elbow injuries reported in their study, no spotter was present. In 12 cases (38%), spotters were either inexperienced or malpositioned. Pettrone and Ricciardelli (1987) found that in 65% of the injuries, a spotter was present, and that 35% of the injuries occurred without a spotter. This may suggest that when a gymnast performs a difficult maneuver, a spotter is usually present, but cannot always be of assistance. This situation arises commonly in both the training sessions and shows of "Mystère". Spotters are routinely used when difficult maneuvers are practiced and performed during the shows. Spotting is considered an extremely important part of many of the stunts that are performed, and spotting is incorporated as part of the choreography of both the Chinese poles and teeterboard acts. As is the case in gymnastics, injuries still occur even with the presence of spotters, although their severity and incidence is likely reduced by having spotters present. The ethical ramifications of conducting a study to determine the rate and severity of injury when spotters are not used are evident.

Injury can occur not only to the athlete performing the maneuver but also to those who are spotting the performer. This can create problems, especially in a show such as this because the number of skilled spotters is often limited, and the risk of injury obviously increases when the number of skilled spotters is reduced.

The use or misuse of safety devices as a possible contributing factor to injury in gymnastics has been suggested although documentation is not available on this issue. Gymnastics has a wide variety of injury prevention devices such as tumbling mats, crash pads, landing pits and spotting belts. Lowry and Leveau (1982) suggested that gymnastic clubs with higher injury rates may not be using their safety equipment properly or at all.

The practice of using safety equipment is kept to a minimum during the "Mystère" show, although both spotting belts and crash mats are used more commonly during training. Thick crash mats are routinely used for dismounting during teeterboard, and a safety belt is used only for the most difficult stunts in the show. The presence of spotters is commonly the only safety device utilized for other stunts in the show. The use of more safety equipment would likely be effective in reducing injury, but this reduces the aesthetic appearance of the acts in the show.

A major contributing factor related to the development of injury in gymnastics is repetitive trauma (Snook, 1979). In gymnastics, as has been previously discussed, multiple repetitions of the same maneuver are performed, which may lead to excessive repetitive sub-threshold trauma. This may also be the case in injuries seen in Cirque du Soleil athletes. The athletes are required to perform the same maneuvers repeatedly, twice nightly, without knowing the long term effects of such activity.

It is possible to make some parallels between the sport of gymnastics and the performances of the artists of the show "Mystère", and insight has been gained by reviewing epidemiological literature related to gymnastics. The differences between the two activities, however, are quite evident. The most obvious difference is related to the apparatus that are used in gymnastics and those that are used in the show "Mystère". Gymnasts perform on the floor, vault, bars (parallel and uneven), high bar, pommel horse, beam, and rings. Athletes of "Mystère" perform on the floor (tumbling), teeterboard, Chinese poles, flying trapeze, bungee, trampoline, fasttrack and stilts. The biomechanics of these events are different from gymnastics events, requiring quite different training and skill to perform properly. However, most of the skills performed on these apparatus have their base or roots in gymnastic skills. Because previous biomechanical studies have not been conducted on skills that are performed by these athletes, the analysis of the skills is difficult, but perhaps a possible focus for future research.

Another difference between the sport of gymnastics and the show "Mystère" relates to the variability of individual skill performance that is required. Female gymnasts are required to train/compete on four apparatus and men on six, attempting to become skilled at each apparatus. This is not the case with athletes who perform for the Cirque du Soleil. These individuals are hired because they have the ability to perform a certain act or combination of acts with great skill and consistency. No one athlete is required to participate in all the different numbers of the show. This makes training much more focused and individualized to one act or number. For example, the athletes who perform the flying trapeze number are only required to be present in minimal choreography over and above this main number. They are considered specialists in the flying trapeze, and their training and show performance is concentrated in that number.

Review of Dance Injury Literature

Just as it was difficult to find epidemiological research that directly related to Cirque du Soleil athletes, it was also difficult to obtain information related to research on theatrical dance. One study by Rovere et al., (1983) has been published specifically regarding musculoskeletal injuries in theatrical dance students. This study followed 218 (162 females and 82 males) dance students over a nine month (academic year) period. One hundred eighty-five students (84.9% of total enrolled) sustained 309 dance related injuries. Injury to the ankle occurred most often in this group of dancers, and accounted for 22.2 % of the total injuries. The second most frequently injured body part was the spine (17.6 %) followed by the foot (14.8 %), knee (14.5 %), hip (14.2 %), and shin (5.4%). Of particular interest in this study was the distribution of injuries in the ballet students (N=148) and the modern dance students (N=70). The differences that were reported in injury type and location paralleled the differences in the two dance forms. For example, the ballet dancer's attempted defiance of gravity in jumps, leaps and pleis place excessive stress on the postural muscles of the low back as well as the muscles of the leg, whereas the movements of the modern dancer are angular, more peripheral and often more extreme. As the dancer folds and bends, the head and neck are more likely to move out of sequence with the lower torso. Thus, cervical and upper-back strains occurred approximately twice as often in modern dancers as they did in ballet dancers, and low back strains, hamstring strains, and lower leg pain occurred roughly twice as often in ballet dancers as they did in modern dancers (Rovere et al., 1982).

One recently published study (Garrick & Requa, 1993) provided an analysis of the epidemiology of ballet injuries. The information that was examined was derived from worker's compensation records which were accumulated over three seasons of ballet performance. Over the three season period that was studied, 104 dancers sustained 309 injuries. Overall, there were 2.97 injuries per dancer. The foot (74 injuries, 23.9%), lumbar spine (71, 23.0%) and ankle (41, 13.3%) were the most frequently injured anatomic regions, followed in frequency by the knee (21, 6.8%), leg (19, 6.1%) and the hip (18, 5.8%).

As is evident by the previous review of literature and because there has been no previous epidemiological studies reported that relate to injury rate and nature in circus type activities, it has been difficult to find and review relevant research. This 12-month study will provide a basis for future research on other shows created by Cirque du Soleil, as well as similar productions.

Chapter Three Methods and Procedures

Introduction

This chapter provides an outline of the procedures that were followed during this study. As previously noted, the group of subjects consisted of the cast of artists/athletes who perform the show “Mystère”. This group was the focus of a 12-month epidemiological study conducted to determine the nature and distribution of injuries and their causative factors as they relate to Cirque du Soleil performers. This information will enable the identification of preventive measures as well as more advanced treatment and rehabilitation strategies. Because a study of this nature has yet to be conducted on circus or acrobatic type injuries, the sport of gymnastics has been chosen as the sport which resembles most closely those injuries that may be sustained by the athletes included in this study.

Subjects

The subjects for this study consisted of the 62 athletes who form the cast of Cirque du Soleil’s Mystère. Their ages range from 18-45, and they include both male and female athletes. Each athlete has a primary role in the show, and many athletes also perform secondary roles. For example, each athlete participates in at least one of the six main acts of the show unless he/she is a dancer or an actor. The six main acts include (1) manipulation (the juggling number), (2) Chinese poles (the climbing act performed by the troupe maison and four Chinese specialists), (3) main-a-main (the hand balancing act with two performers), (4) the bungee act consisting of six performers and one alternate, (5) the teeterboard number consisting of performance on the teeterboard, fasttrack and trampoline (also performed by the troupe maison), and (6) the trapeze act (performed by 10 Russian athletes). The transitions between each act are composed of small dance numbers performed by six dancers, and small animation routines performed by seven actors (characters), and one clown. The shows opening and finale consist of short pieces of Taiko drum playing. The finale also incorporates several athletes who have been trained in stilt walking.

A small portion of the "rigging", a term used to describe both technical and mechanical work that is necessary in order for equipment and apparatus utilized in the show to function properly, is done by the athletes themselves. For example, the aerial nature of the flying trapeze act necessitates the use of a safety net below the performers. The safety net requires several guidewires to be secured on and around the stage in order for it to be effective. It is the athletes who are responsible to properly hook and secure these safety wires, and this work is incorporated into the show as part of the choreography.

Instruments and Procedures

Prior to the commencement of any data collection, each athlete was asked to sign a consent form (Appendix A). Data collection was done on a daily basis using 'injury report forms' (Appendix B). These forms were used to compile information about the athlete, the mechanism of injury, injury type and the injured body part. This information was recorded by either of the two Athletic Therapists employed by the Cirque du Soleil at the time the study was conducted. In the event that the athlete was referred to a physician or other health care professional, the injury record was completed by the appropriate individual. Whether the injury occurred during training, show performance (first or second show), or an activity not related to the show, as well as the type of onset of injury (acute, gradual, chronic, recurrence of old injury) was recorded. Daily exposure sheets were used to determine time lost from shows due to injury. These sheets showed, on a daily basis, each athlete's participation in training and shows. Participation in both training and shows was recorded as one of the following; F=full participation, P=partial participation (25-75%), M=minimal participation (>25%), and N=no participation. A letter was also used to indicate the reason the athlete missed the practice or show, as follows: I=injured, S=sick, O=other. For example, if an athlete was injured and not participating in any part of the show, he/she was given the designations "I", denoting the injury, and "N" to indicate that he/she did not participate. The case often arose, as well, when an athlete was injured, but maintained full participation in all of his/her cues. In this case, the athlete's level of participation was recorded as "F" (full) and they were given the designation "I" (injured) on that day. This allowed a record to be kept of the amount of time athletes participated while injured, either fully, partially, or minimally.

One exposure was considered to be equivalent to an athlete participating in one act of a show or one training session. Despite the variability in length and intensity of the training sessions, each session was considered to be equivalent to one exposure. Therefore, it was possible for some of the athletes to have a maximum of five exposures in a single day. For example, such a case arose for those members of the troupe maison when they trained and participated in both the early and late show on the same day. Most of the members of the troupe maison participated in both the Chinese poles act and the teeterboard act, and therefore had two exposures per show.

Twelve shows were performed per week, with Monday being a regular day off. The vacation schedule consisted of six 4-day dark periods, and five dark periods which lasted from 10-15 days. This particular show schedule was designed so that the maximum number of shows could be performed in the 12-month period while still providing sufficient time for the athletes to rest and rehabilitate from injuries.

This data was recorded and entered into the Microsoft Access relational database program used with an IBM-PC computer for collection and analysis. Analysis of variance (one-tailed) was completed on several variables using a P-value significant at 0.05.

Analysis of Results

Descriptive statistics were used to determine the nature and rate of injuries affecting the athletes of "Mystère" over the 12-month period. An injury was defined as "any condition which required treatment and/or limited participation in one training session/show." Information on injury nature (anatomical location of injury, type of tissue damage, etc.) was calculated in terms of absolute number of injuries, and relative percentages of injuries for the cast as a whole and for each individual act. Whether more injuries occurred from overuse or from a single insult, and the incidence of reinjuries has been determined. Injury frequency per performer and injury rate according to gender of the athlete have been calculated. Injuries that occurred in each individual act have been reviewed separately with regard to injury frequency, anatomical location of injury and injury type. Each segment of the show has been considered an individual subgroup. Two subgroups, teeterboard and trapeze, are broken down further to enable a simpler analysis of injury data. For example, injuries that occurred as a result of participation in the teeterboard act are reviewed in three categories: teeterboard jumping, teeterboard exiting, and teeterboard spotting. Similarly, trapeze injuries are considered to be injuries that occurred while the athlete was either trapeze flying or trapeze catching. Those injuries which were determined to be caused by a combination of several aspects of the show, or a general overuse syndrome, are discussed separately. A subsequent section delineates those injuries that resulted from activities not directly related to training or participation in the show Mystère, although they affected the athletes performance.

The rate of injury was calculated by dividing the total number of injuries sustained by the athletes by the total number of training and show exposures, then multiplying this figure by 1000. This approach yielded an injury rate per 1000 exposures. Rate of injury was also calculated by dividing the total number of injuries by the total number of athletes, then multiplying this by 100 to yield injury rate per 100 performers. In order to use injury rate to determine risk of injury of a particular activity, the average number of injuries per performer in each act has been determined. It would be erroneous to imply that the athlete who participates in the teeterboard act is at the same risk of injury as the athlete who participates in the manipulation act. Participation in each act results not only in different injury rates, but also in different types of injury, different anatomical locations of injury, and different severity of injury. For this reason, descriptive analysis has been completed for each part of the show, which provides a clearer profile of injury risk, type, severity, and anatomical location.

Information was obtained regarding the time lost from shows due to injury, illness or absenteeism, which has been referred to as the burden of injury. This was calculated as a percentage of the time lost in a one year period as full loss, partial loss, or minimal loss of participation per year. This information has been presented for the cast as a whole, and by individual act. The burden of injury per act has been presented separately for training and show performance. A breakdown of the burden of injury per act, which affected the training sessions, has been provided. The figures were calculated by dividing the number of training exposures that were affected by injury by the total number of training exposures that occurred over the 12-month period for each act, then multiplying this by 100 to yield figures in percentage (%) terms. A breakdown of the burden of injury per act (including the dancers, the actors and the clown) which affected show performance has also been included. These figures were calculated by dividing the number of exposures affected by injury by the total number of possible show exposures that could have occurred, then multiplying this by 100 to yield the figures in percentage terms.

Information has been provided with regard to the time of injury occurrence, for instance, whether injuries occurred during training, show performance or from overuse. This information was used to determine when the athlete was at the greatest risk of injury; for example, during the first vs. the second show (a possible fatigue factor could be present). Time of injury occurrence has also been presented in relation to dark periods and the number of working days between dark periods. Mechanism of injury data has been provided in Chapter Five along with a description of each act. Recommendations of preventative measures and suggestions as to how the rate and severity of injury may be minimized is also included in the discussion section.

Chapter Four Results

Introduction

The following chapter is an overview of the descriptive statistics that have been compiled from the injury report forms and the exposure charts that were accumulated over the 12-month data collection period. The data has been analyzed with regard to injury rate (number of injuries per 100 participants and per 1000 exposures), burden of injury (the proportion of exposures that were affected by injury, presented for the cast as a whole and for each act of the show, by training and show participation), nature of injury onset and reinjury (acute vs. gradual onset injury), injury location and nature of onset, injury type, and injury frequency (by cast as a whole and by act). The main goal of this chapter is to present the results that have been compiled from this research. A discussion of the various causes and preventative measures that relate to injures in this athletic population has been reserved for the following chapter.

Rate of Injury

The rate of injury, or injury incidence, has been calculated by dividing the total number of injuries sustained during a specific time period by the total number of participants. (Meeusen & Borms, 1992) The rate of injury calculated over the 12-month data collection period in the present study was 329 injuries/62 athletes = 531 injuries per 100 athletes per year. This is a relatively large ratio compared to a majority of the recently published literature, with the exception of the studies by Sands et al. (1993), Vergouwen (1986) and Caine et al. (1989) (Table 2-1). Gymnastics research has led to injury rates between 0.12% and 10,711 %, as previously noted in the review of literature. The large differences in these values are considered and discussed in Chapter Two.

The injury rate per 1000 exposures in the present study was 329 injuries / 32,783 total possible exposures (number of exposures per show multiplied by the number of shows, plus the number of training sessions multiplied by the number of participants in each session) = 0.0010 X 1000 = 10 injuries per 1000 exposures. This injury rate is higher than all other studies that have published rate of injury per 1000 hours of exposure (Table

2-2), although the nature of the exposures in the various studies are not necessarily equal in terms of time or intensity.

Table 4-1 is a list of the number of injuries that were attributed to participation in each act in the show. The number of participants in each act of the show is also provided. From this information, it was possible to determine the average number of injuries per performer in each act. This does not include injuries that occurred during the opening, transitions, or the finale of the show, nor does it include those injuries that were believed to be caused by overuse, or other activities that were not related to performance or training.

Table 4-1 Injury by Role (Rate of Injury)

Role	Frequency (# of Injuries)	Number of Performers	Average # of Injuries Per Performer
Teeterboard	101	22	4.59
Trapeze	62	10	6.20
Dancers	24	6	4.00
Bungee	22	6	3.67
Chinese Poles	22	9	2.44
Manipulation	11	3	3.67
Hand to Hand	7	2	3.50
Stilts	4	10	.040
Taiko	3	23	0.13
Overuse Injuries	25		
Opening, Finale, Transitions	12		
Other	37		

Average number of injuries per performer in each act.

Those athletes who performed in the trapeze act sustained the highest average number of injuries (6.20) per performer, over the 12-month data collection period (Table 4-1). Those that performed in the teeterboard act, which includes fasttrack and trampoline, sustained an average of 4.59 injuries per performer, which is the second highest injury rate per performer. The third highest injury rate per performer was found in the dancers (4.00). Conversely, the lowest injuries rates were found in performance of taiko (0.13) and stilts (0.40). These are not actually considered separate acts, but they are performed by members of the six core acts of the show, and it is consistently the same individuals who perform in these parts of the show. Bungee (3.67), manipulation (3.67) and hand-to hand (3.50) all had higher injury rates than the Chinese poles act, which had the lowest injury rate (2.44) per performer. Analysis of variance reveals that there is a statistical difference between the number of injuries per performer in each act ($p < 0.05$) (Appendix C). A statistically significant difference ($p = 0.05$) was also found when trapeze, as a group, was compared to the remainder of the cast (Appendix D) but not when teeterboard was compared to the remainder of the cast (Appendix E).

Time of Injury Occurrence

Fifty-one percent (168) of all injuries were sustained during either the early or the late show, which represents 80.57 % (26,412/32,783) of the total possible exposure time (early and late show exposures/total exposures). This is equivalent to a rate of 6.36 injuries per 1000 show exposures. Specifically, 74 of the 168 injuries that occurred during show performance occurred during the early show, and 94 injuries occurred during the second show. In percentage terms, 44.04 % of the injuries that occurred during show performance occurred during the first show (22.5 % of total injuries occurred during the first show), and 55.96 % of the show injuries occurred during the second show (28.6 % of total injuries occurred during the second show). Thirty-two (9.7 %) of the injuries occurred during training or conditioning, which represents 19.43 % (6371/32,783) of the total exposures, which is equivalent to a rate of 5.02 injuries per 1000 training exposures. In addition, 33% (109) of the injuries occurred over an extended period of time (gradual onset), which is equivalent to 3.32 gradual onset injuries per 1000 exposures. This indicates that the athlete who performs in the show Mystère has the highest risk of injury during show performance, with the injury risk being slightly higher during the second show, although this was not a statistically significant difference at $p = 0.05$ (Appendix F).

Figure 4-1 illustrates the number of injuries that were recorded per day between dark periods. Day one is the first working day after each dark period, day two the second, and so on. The average number of working days between dark periods was 20, with the shortest number of working days being 15, and the longest number of working days between dark periods being 27.

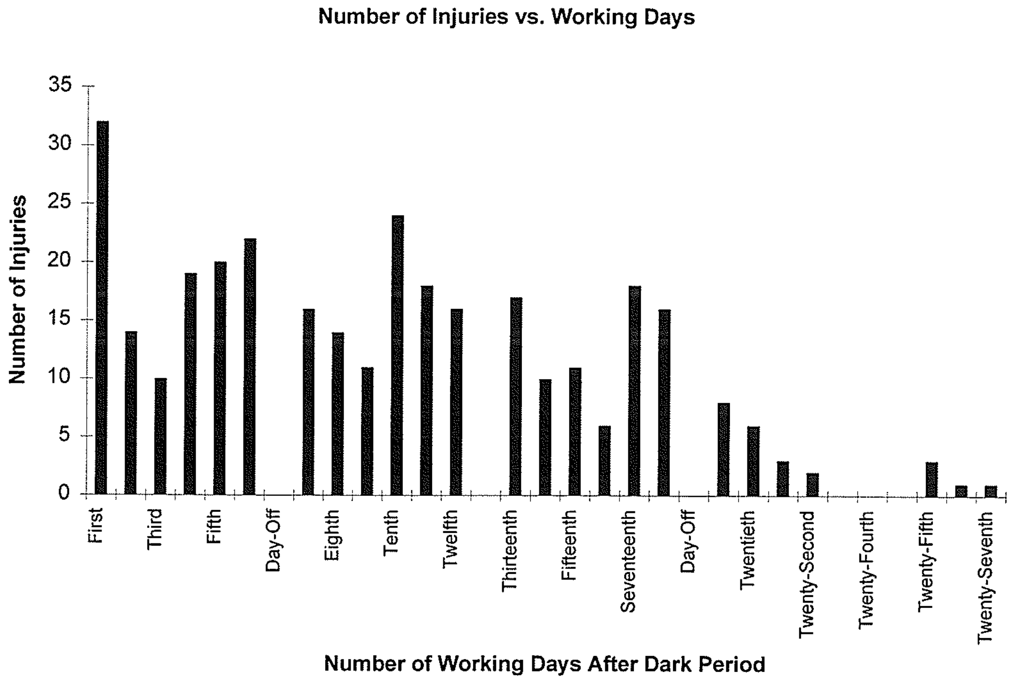

Figure 4-1. Injury vs. Working Days. Number of injuries that occurred per working day following the dark periods.

It is evident from Figure 4-1 that there is some variability in the number of injuries recorded on each successive day between dark periods, although it is on the first day after a dark period that the largest number of injuries occurred. It may also be appropriate to say that more injuries occurred in the first week (six-day work week) between dark periods than later in the time frame between dark breaks. This increase in the number of injuries that occur after dark periods may suggest a de-training effect that the period of time off has on the athletes. On average, 19.5 injuries occurred per day in the first week (six-day working week) following the dark periods, 16.5 injuries occurred per day in the second week, 13 injuries occurred per day in the third week, and 3.2 injuries occurred per day in the fourth week following the dark periods. The average number of injuries that occurred in the fourth week following dark periods is low because there were only two periods over the course of the 12-month data collection period where there were four full weeks of work without a dark period.

Burden of Injury

The 62 athletes had a total of 32,783 possible exposures over the 12-month period. This figure represents the number of exposures that would have occurred in the 12-month period if there were no injuries, no absences, and no lost time due to sickness. It includes all the shows and all of the training sessions for each act, multiplied by the number of participants in each act. Figure 4-2 represents the percentage of total possible exposures designated as 100 % and the percent of those exposures that were affected by injury, designated by the level of participation; full, partial, minimal, or none, for the cast as a whole.

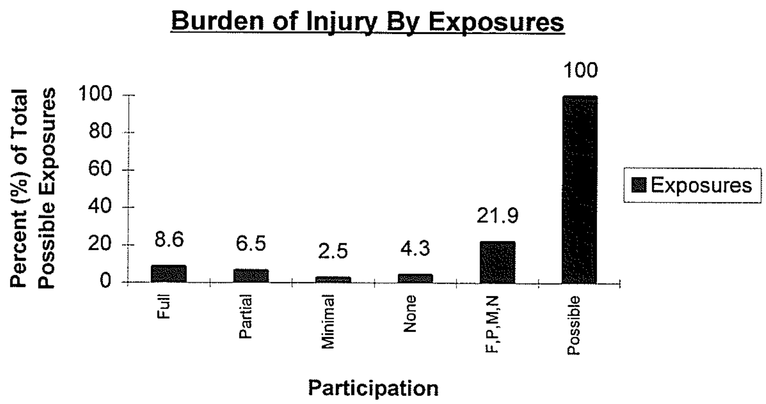

Figure 4-2. Burden of Injury by Exposures. Level of participation (F, P, M, and N) indicated in percent (%) of the total possible number of exposures that occurred over the 12-month data collection period.

Almost twenty-two percent (7,180) of the total possible exposures (32,783) were affected by injury to some extent. Approximately 4.3 % (1,420) of all the possible exposures were missed completely due to injury, 6.5 % (2,131) of the exposures were partial participations, and 2.5 % (820) of the exposures were minimal participations. During 8.6% (2,819) of the total possible exposures, the athlete was injured but participated fully.

Burden of injury for each individual part of the show has been provided in Figures 4-3 and Figure 4-4.

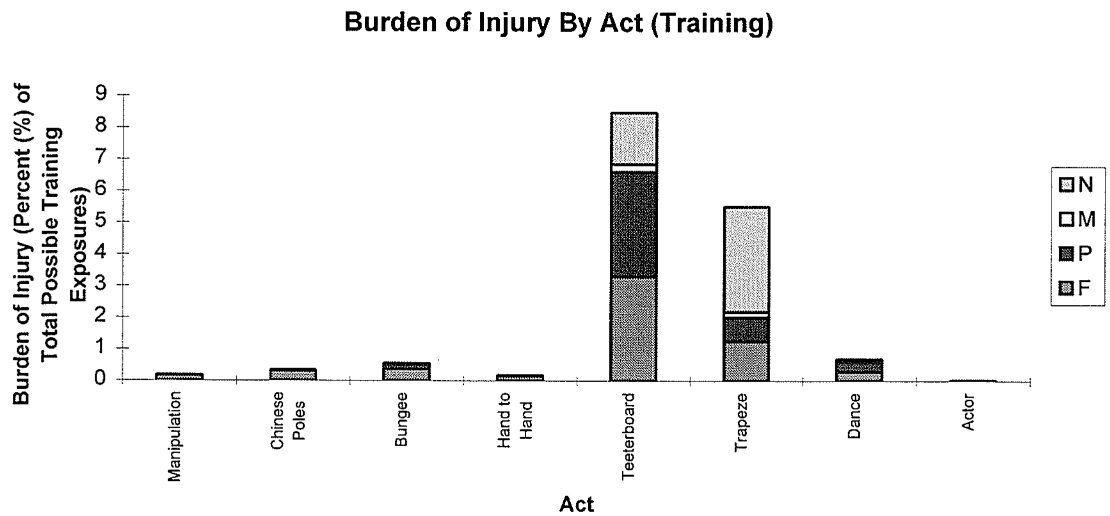

Figure 4-3. Burden of Injury by Act (Training). Burden of injury, designated as (Full, Partial, Minimal, and None), for the training exposure during the 12-month data collection period.

The act that appeared to be affected the most by injury during training was the teeterboard act, followed by the trapeze act (Figure 4-3). Less than 1 % of all training exposures in the manipulation, bungee and hand-to-hand acts were affected by injury.

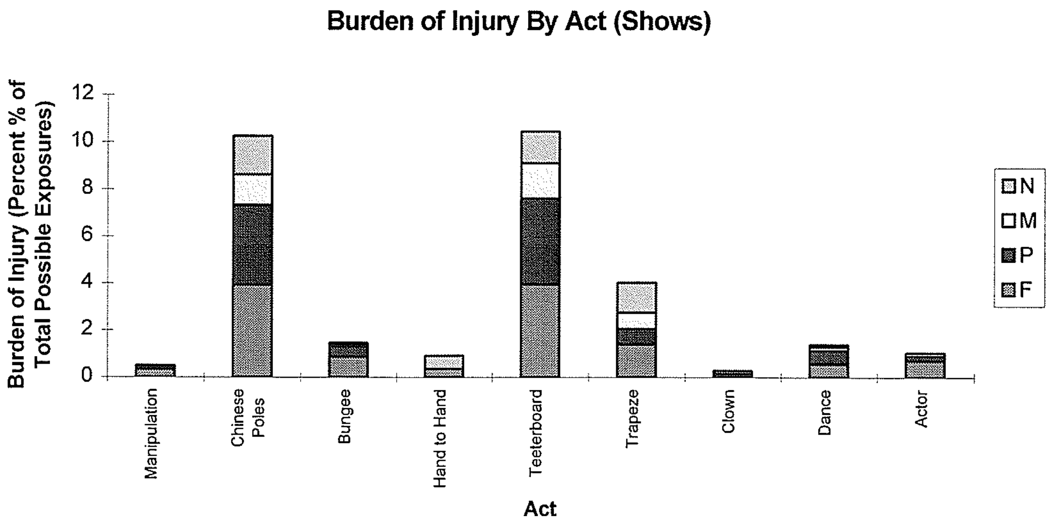

Figure 4-4. Burden of Injury by Act (Shows). Burden of injury, designated as F, P, M, and N, for the shows that occurred during the 12-month data collection period.

The acts affected most by injury (most time lost due to injury) during show performance were the teeterboard and Chinese poles act, followed by the trapeze act. Overall, the act that suffered the least time loss due to injury was the manipulation act, followed by the hand-to-hand act and the bungee act.

Time was also lost from show performance due to sickness and absenteeism. Over the 12-month period, 192 shows were missed due to sickness and 10 individuals missed shows due to absences not related to injury or illness.

Nature of Injury Onset and Reinjury

Table 4-2 refers to the nature of injury onset, sudden vs. gradual, for the 329 new injuries and reinjuries that were sustained during the 12-month data collection period.

Table 4-2 Cross Tabulation of Nature of Injury Onset and Reinjury

Nature of Onset	New Injury		Reinjury		Total Injuries	
	%	N	%	N	%	N
Sudden	76.8	(195)	33.3	(25)	67	220
Gradual	23.2	(59)	66.6	(50)	33	109
Total	100.0	(254)	100	(75)	100	329

Cross tabulation of nature of injury onset, new injury and reinjury, as either sudden (acute) or gradual onset, by the number of injuries (N) and the percent (%) of total injuries.

Of the 254 new injuries that were classified, 195 (76.8%) were of sudden onset, or acute in nature, and 59 (23.2%) were of gradual onset. Of the 75 injuries classified as reinjuries, 25 were traumatic (33.3%), and 50 (66.7%) were characterized as gradual onset, which may suggest the frequent reoccurrence of overuse/chronic injuries. When considering the total number of injuries (329), approximately 33% of the injuries (109) were attributed to gradual onset, overuse type syndromes. This proportion of gradual onset injuries is relatively similar to the distribution of acute and chronic injuries reported in various other studies (Table 2-3).

Anatomical Location of Injury

Table 4-3 is a representation of the distribution of injuries, by anatomical location, for the entire cast. The onset of injury, whether acute or gradual onset in nature, is also provided, along with the percentage (%) of total injuries suffered by each body part. The number of injuries has also been provided by body region; head, face, spine and trunk, upper extremity and lower extremity.

Table 4-3 Injury Location and Nature of Onset

Body region/part	Injury Onset Sudden	Injury Onset Gradual	No. of Injuries	Percentage %
Head	7	0	7	2.1
Face	8	0	8	2.4
Nose	2	0	2	0.6
Dental	6	0	6	1.8
Spine and Trunk	**57**	**34**	**91**	**27.7**
Neck	19	9	28	8.5
Chest	2	1	3	0.9
Upper Back	2	1	3	0.9
Middle Back	11	6	17	5.2
Lower Back	23	17	40	12.2
Upper Extremity	**52**	**28**	**80**	**24.3**
Shoulder	19	23	42	12.8
Upper arm	7	0	7	2.1
Elbow	3	1	4	1.2
Forearm	3	1	4	1.2
Wrist	8	3	11	3.3
Hand	5	0	5	1.5
Finger/Thump	7	0	7	2.1
Lower Extremity	**96**	**47**	**143**	**42.5**
Buttock/Hip	5	11	16	4.9
Groin	0	2	2	0.6
Thigh	4	2	6	1.8
Knee	14	13	27	8.2
Lower leg	9	11	20	6.1
Ankle	41	3	44	13.4
Foot	8	5	13	4
Heel	8	0	8	2.4
Heel	7	0	7	2.1
Toe	7	0	7	2.1
Total	**220**	**109**	**329**	**100.0**

Injury location and nature of onset (acute vs. gradual onset) of the 329 injuries that were sustained by the 62 athletes included in this study.

The body part most susceptible to acute injury was the ankle (41), followed by the low back (23), neck (19), shoulder (19), and the knee (14). The body part most susceptible to gradual onset injury was the shoulder (23), followed by the low back (17), knee (13), lower leg (11) and hip/buttock region (11). When body region is considered, the largest number of gradual onset injuries occurred in the lower extremity (47), followed by the spine and trunk (34) and the upper extremity (28).

As shown in Table 4-3, the injuries were well distributed throughout the body, few anatomical areas were spared. Most notable was the preponderance of injuries to the lower extremity (43.5 %), particularly the ankle (13.4 %). In the upper extremity, the shoulder was the most frequently injured body part (12.8 %), whereas the lower back sustained most of the injuries (12.2%) in the spine and trunk, followed by the neck (8.5%).

In order to obtain a clearer perspective of the distribution of anatomical sites that are injured most frequently by the participants in this study, Figure 4-5 is an illustration of the top ten most frequently injured body parts.

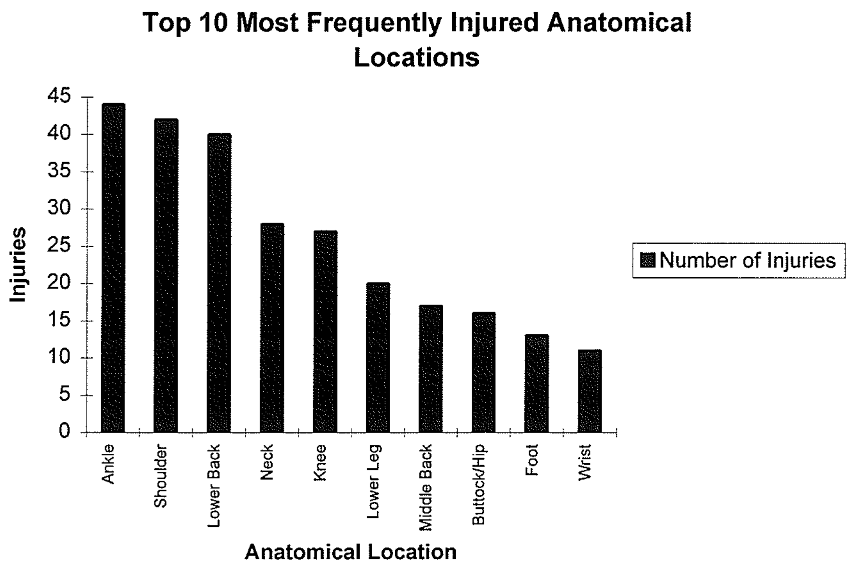

Figure 4-5. Top 10 Most Frequently Injured Anatomical Locations. Graphical representation of the ten most frequently injured anatomical locations represented in absolute number of injuries.

The joint affected most by both acute and gradual onset injuries was the ankle, followed by the shoulder. The low back and the neck followed in injury frequency. The body region affected in almost half of the injuries is the lower extremity (120 injuries, 46.52 %), followed by the trunk and spine (85 injuries, 32.94 %), and the upper extremity (53 injuries, 20.54 %) (Figure 4-5).

Injury Type

Reporting injuries by injury type (e.g. strain, contusion, fracture) provides an overview of the type of tissue damage that commonly occurs in a subject group who performs a particular activity. Figure 4-6 is a representation of the types of injuries that were sustained by the 62 athletes of Mystère, as a group. The types of injuries that are sustained by participation in each individual part of the show are described in detail in the following sections dedicated to analyzing the parts of the show independently.

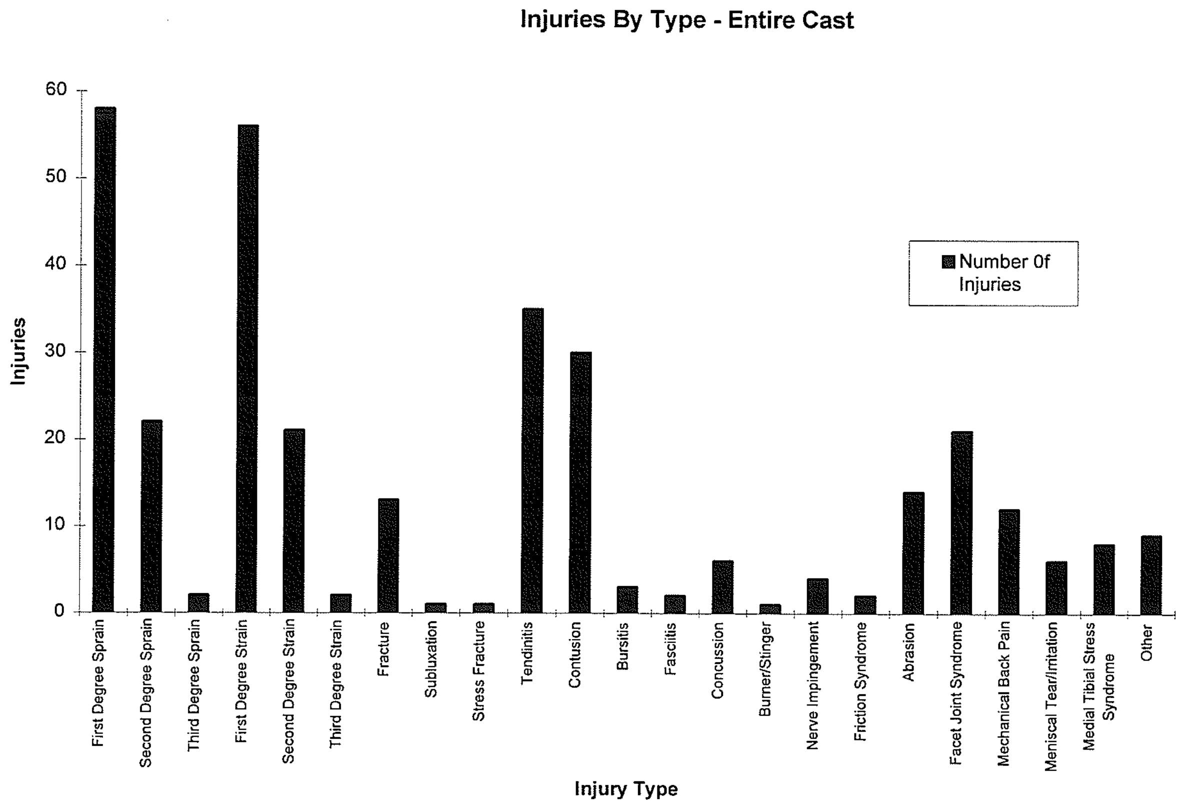

Figure 4-6. Injuries by Type - Entire Cast. Illustration of the total number of injuries by injury type, for the 62 athletes.

The most common types of injuries were first degree sprains (58, 17.63%) and first degree strains (56, 17.02 %), followed by tendinitis (35, 10.64%), contusions (30, 9.12 %), second degree sprains (21, 6.4 %), and facet joint syndromes (21, 6.4 %) (Figure 4-6). Eighty-seven percent of all injuries were soft tissue injuries, 6.69 % were bony injuries, 3.34 % were neurological injuries, and 2.74 % were injuries to other tissues, for example, teeth.

Gender, Injury Frequency, and Severity of Injury

Table 4-4 Injury by Gender (Rate of Injury)

Role	Number of Performers	Total Number of Injuries	Average # of Injuries
Total Cast	62	329	5.3
Females	14	89	6.4
Males	48	240	5.0

Total and average number of injuries per cast member.

Table 4-4 provides information regarding the average number of injuries per cast member, female and male. The difference in the average number of injuries per male and female was not found to be statistically significant at p = 0.05 (Appendix G). The largest number of injuries sustained by a single cast member was 19, followed by one performer with 16, one with 14 injuries, and one with 13 injuries; two performers with 12 injuries, one with 11 injuries, one with 10 injuries, three performers with 9, four performers with 8, three performers with 7, six performers with 6 injuries, six performers with 5 injuries, ten performers with 4 injuries, eleven performers with 3 injuries, three performers with 2 injuries, and three performers with one injury. Every member of the cast of 62 athletes sustained at least one injury.

During the 12-month data collection period, there were no catastrophic injuries to the male or female athletes who participated in the show. Two athletes did, however, retire due to injury, and a total of five injuries prevented training/show participation for a duration of more than two months. There were a total of 28 athletes who reported injuries to the neck region, all of which were soft tissue injuries. Six concussions were reported, two of which required admittance to hospital for further diagnostic investigation. Eight athletes required surgical intervention for an injury that was sustained as a result of participation. A total of 13 fractures were sustained, and four third degree sprains/strains were documented.

Individual Act - Injury Review

Teeterboard Jumping

Over the 12-month data collection period, 47 (of a total 329 injuries) injuries were attributed to teeterboard jumping.

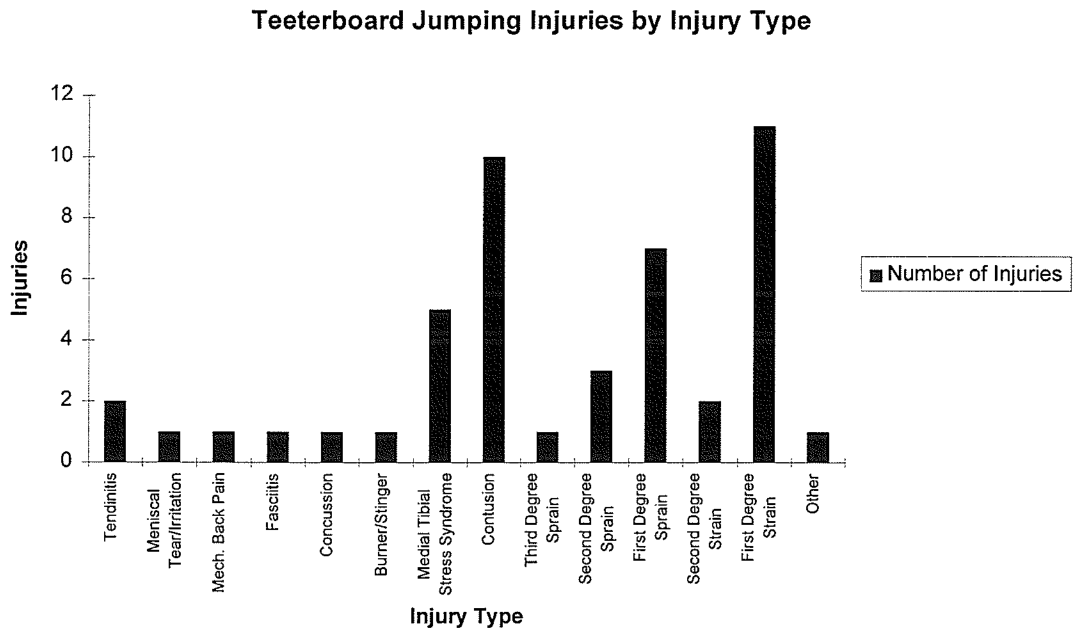

Figure 4-7. Teeterboard Jumping Injuries by Injury Type. (Represented by Actual Number of Injuries)

The most common types of injuries that occurred as a result of teeterboard jumping were muscular strains, followed by contusions and sprains (Figure 4-7). Medial tibial stress syndrome, second degree sprains and strains, and tendinitis followed in frequency.

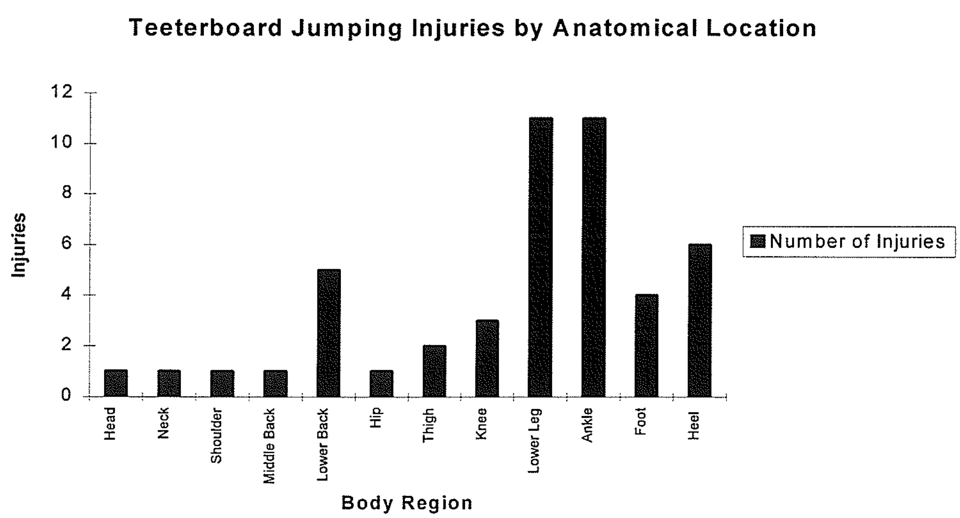

Figure 4-8. Teeterboard Jumping Injuries by Anatomical Location. (Represented by Actual Number of Injuries)

Figure 4-8 illustrates the anatomical distribution of the teeterboard jumping injuries. Of these 47 injuries, 38 were injuries to the lower extremity. One hip, two thigh, three knee, 11 lower leg, 11 ankle, and 10 foot/heel injuries (Figure 4-8) were assessed and treated. Nine were injuries to other parts of the body (one head, one neck, five lower back injuries, one mid-back injury and one shoulder injury).

Teeterboard Exiting Injuries

Fifteen injuries occurred as a result of teeterboard exiting over the 12-month data collection period; 13 acute injuries, and two injuries of gradual onset. Figure 4-9 is a graphical representation of the types of injuries that occurred as a result of teeterboard exiting.

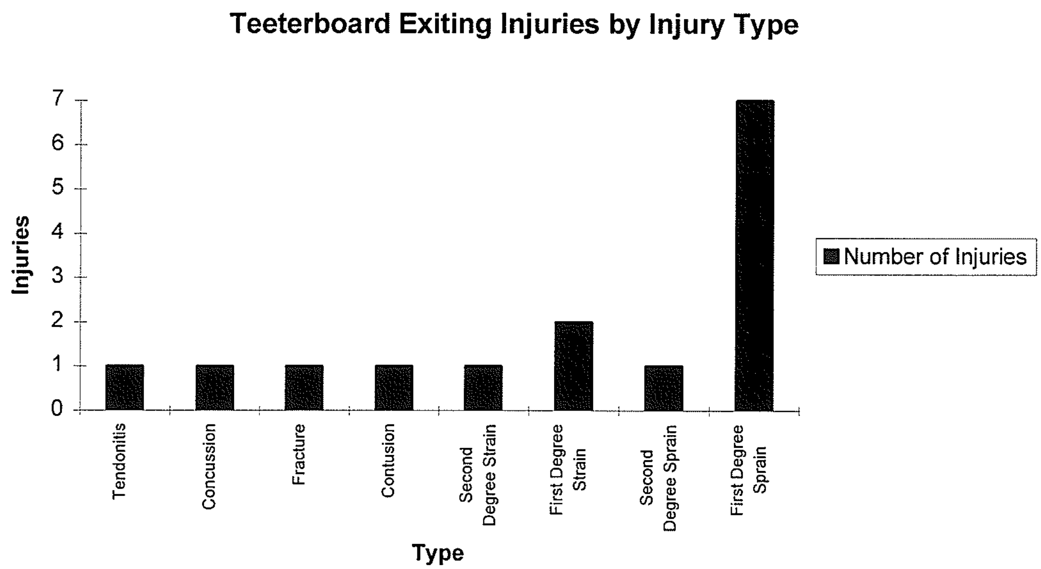

Figure 4-9. Teeterboard Exiting Injuries by Injury Type. (Represented by Actual Number of Injuries)

Sprains (first degree) accounted for 7 of the 15 injuries that occurred. The remainder of the soft tissue injuries were strains (first and second degree), sprains (second degree) and tendinitis injuries (Figure 4-9). One concussion and one fracture were also sustained. Five were upper extremity injuries (four wrist, one shoulder), five lower extremity (three ankle, one knee and one lower leg), one thorax, one neck, one head and two back injuries.

Column

Those athletes who create the column to which exiters dismount are also at risk of injury. A total of nine injuries were sustained by these athletes; three neck, two low back, one middle back, one upper arm, one buttock and one ankle injury. All of these injuries were acute in nature.

Teeterboard Spotting

Ten injuries that were sustained while athletes were spotting other performers. All 10 were acute injuries, five to the upper extremity, one face, two head and one neck injury. Four of the upper extremity injuries were either fractures (two) or sprains (two) of the hand/fingers. The remainder of the injuries were concussions (2), strains (3) and a contusion.

Trampoline

An overview of the 15 injuries that occurred as a result of trampoline jumping reveals a higher number of acute injuries (13 of 15 injuries) compared to gradual onset injuries, although the incidence of upper body to lower body injuries was equal. Two back, three neck, five upper body and five lower body injuries resulted from trampoline jumping.

Fasttrack

The fasttrack, also known as a tumbling track, is an 80-foot long, 5-foot wide apparatus upon which athletes perform sequences of tumbling moves and exits. Over the 12-month data collection period, seven injuries were attributed to performance on this apparatus. The most common acute injury that occurred on the fasttrack was the inversion ankle/foot sprain (three of seven injuries). The other four injuries consisted of a cervical facet joint sprain, bilateral patellar tendinitis, biceps tendinitis, and a chronic wrist injury.

Trapeze

Fifty-three injuries were sustained by seven trapeze flyers, and eight injuries occurred to three trapeze catchers over the 12-month data collection period (Figure 4-10).

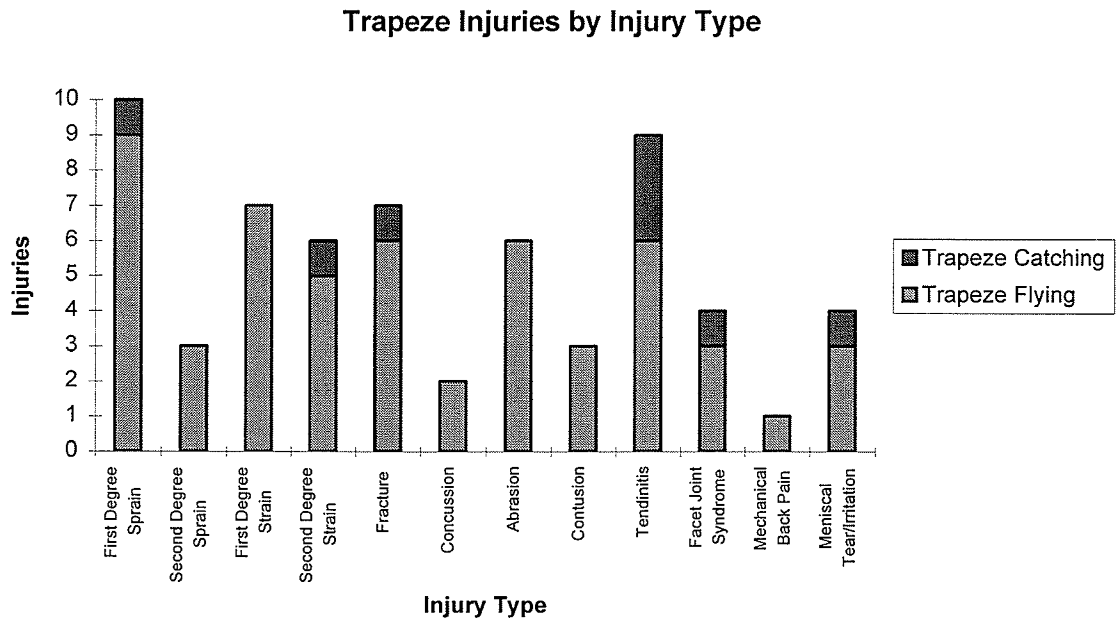

Figure 4-10. Trapeze Injuries by Injury Type. Illustration of the type of injuries that occurred in both trapeze flyers and catchers, represented by actual number of injuries.

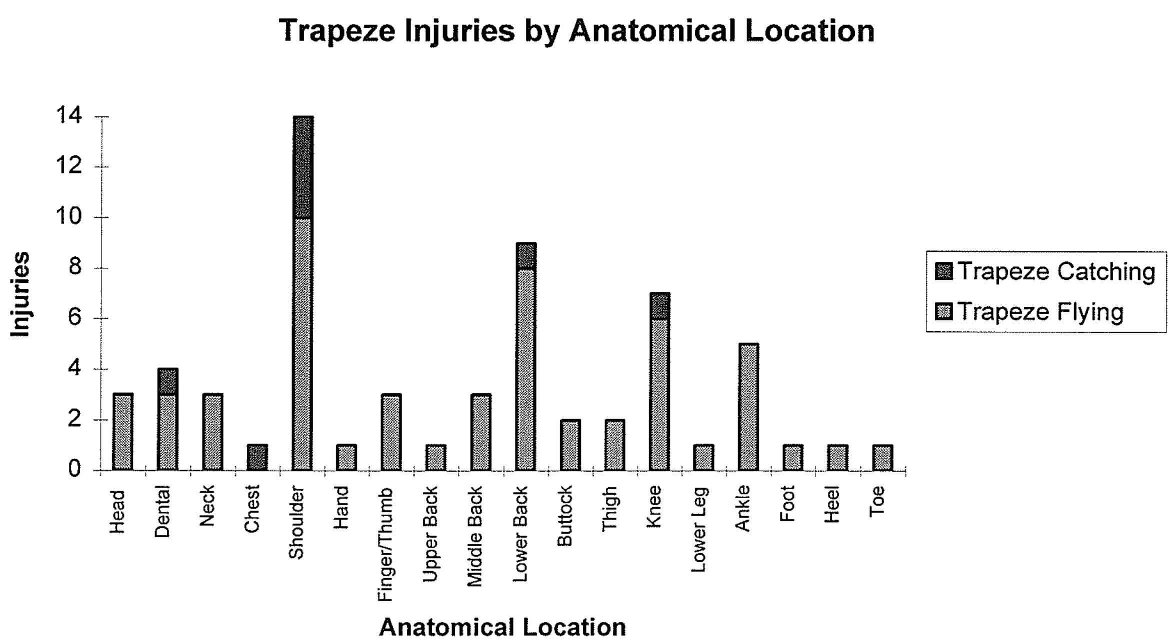

Figure 4-11. Trapeze Injuries by Anatomical Location. Anatomical distribution of injuries in both the trapeze flyers and catchers, represented by actual number of injuries.

The type of injury sustained by the trapeze flyer varied a great deal, although the most common injuries that were sustained were minor sprains (nine) and strains (seven), followed by tendinitis (six), fractures (six), abrasions (six) and second degree strains (five) (Figure 4-11).

If the trapeze flying injuries are considered separately, the shoulder was the most frequently injured body part (10), followed in frequency by the low-back (eight), knee (five), ankle (five), wrist/hand (four), neck (three), middle-back (three), head/concussion (three), dental (three), foot/heel (three), hip/buttock (two), thigh (two), lower leg (one), upper back (one). Injuries to the trapeze catcher (eight) occurred most frequently in the shoulder (four) as well, which accounted for half of the injuries (Figure 4-11). Six injuries of gradual onset and two acute injuries were sustained by the three trapeze catchers. Two of the catchers suffered recurrent episodes of shoulder tendinitis. Biomechanical factors that cause injuries in the flying trapeze artists and trapeze catchers are considered in greater detail in the discussion section in the following chapter.

Dance

Figure 4-12 illustrates the types of injuries that were sustained by the dancers.

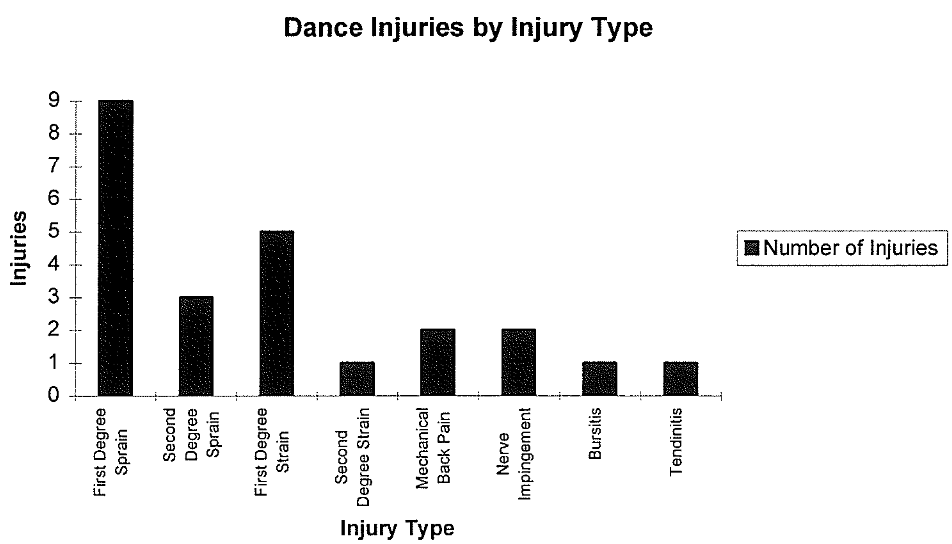

Figure 4-12 Dance Injuries by Injury Type. Represented by Actual Number of Injuries)

The majority of the injuries were first degree sprains (nine), followed in frequency by strains (five) and second degree sprains (three). The remainder of the injuries included mechanical back pain, nerve impingements, and tendinitis/bursitis type of injuries (Figure 4-12).

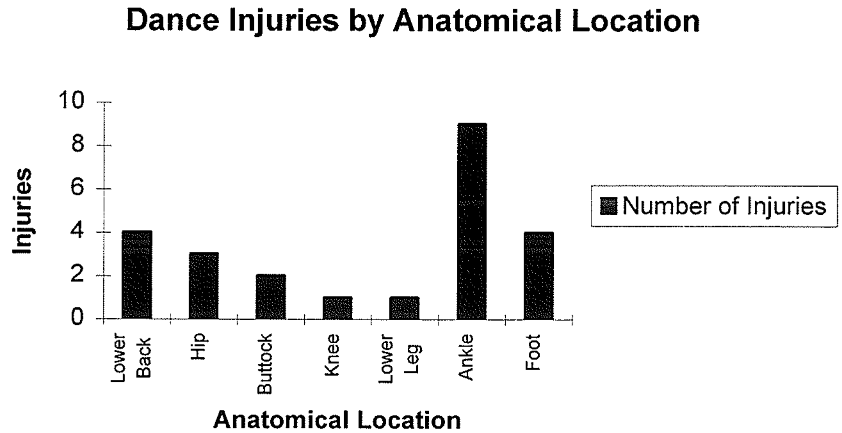

Figure 4-13. Dance Injuries by Anatomical Location. (Represented by Actual Number of Injuries)

The six dancers sustained a total of 24 injuries, 20 of which were lower limb injuries, and four of which were back injuries (Figure 4-13). Inversion ankle sprains, the most common type of injury sustained by these dancers, accounted for eight of the nine ankle injuries.

Back pain and fatigue were also common conditions (three incidences of gradual onset pain, one acute incident) among the dancers. All four back injuries were to the lumbosacral spine.

Hip injuries mainly consisted of musculotendinous injuries. Piriformis syndrome, iliopsoas tendinitis, and trochanteric bursitis were the three overuse hip injuries.

One knee injury was attributed to dancing, a case of pes anserine tendinitis, which was believed to be caused by repetitive plies during dance class. One lower leg injury, tibialis posterior tendinitis, was believed to be caused by a combination of factors which led to the overuse injury

Chinese Poles

Twenty-two injuries were sustained by the 9 athletes who perform the Chinese poles number. The various types of injuries that occurred are illustrated in Figure 4-14.

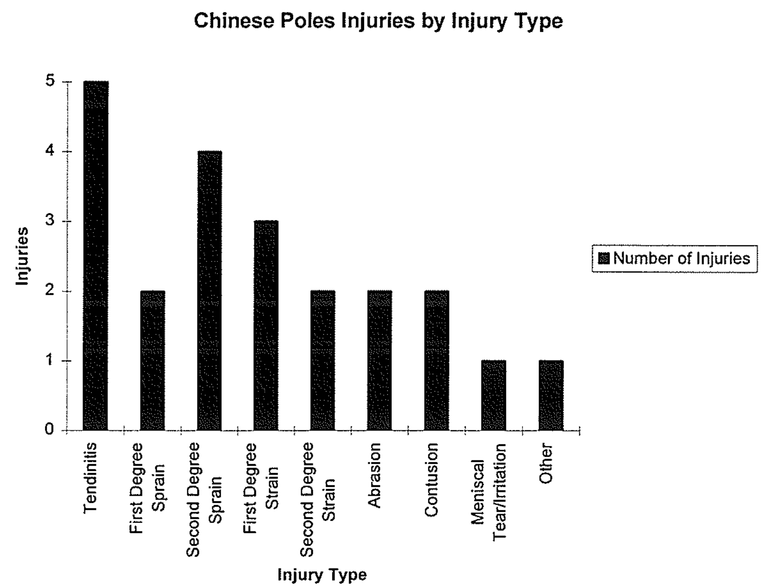

Figure 4-14. Chinese Poles Injuries by Injury Type. (Represented as Actual Number of Injuries)

The most common type of injury was classified as tendinitis (five), which is a gradual onset injury, followed by sprains (five) and strains (five) of varying degrees (Figure 4-14). Two abrasions, two contusions and one meniscal tear also occurred.

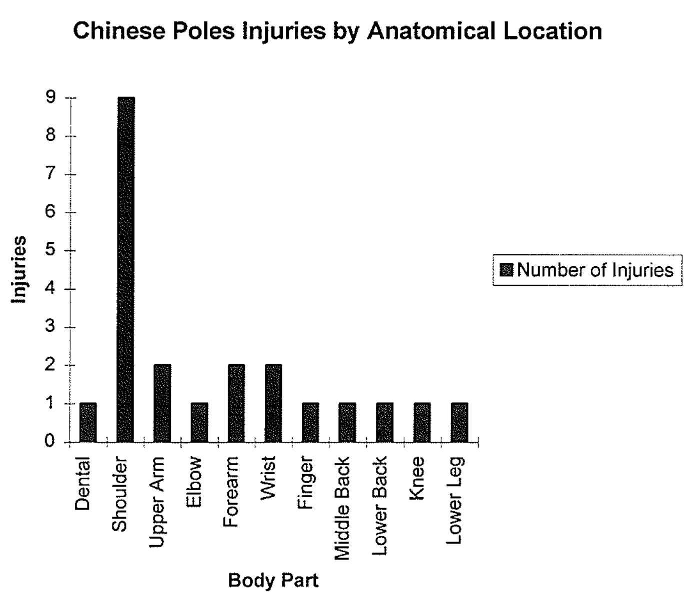

Figure 4-15. Chinese Poles Injuries by Anatomical Location. (Represented as the Actual Number of Injuries)

Seventeen of the 22 injuries were upper limb conditions (nine shoulder injuries), and the remaining five injuries included two lower limb injuries, two back injuries and one dental injury (fractured tooth) (Figure 4-15).

Of the 17 upper limb injuries, seven acute injuries and 11 injuries of gradual onset were sustained. The acute injuries included three acromioclavicular (AC) joint sprains, one of which was a recurrent injury. The other four acute injuries included two muscular strain injuries of the shoulder, a forearm strain, and an elbow sprain. The overuse injuries included various types of shoulder and forearm muscle and tendon conditions, and two skin conditions that resulted from excessive friction between the athlete's skin and the poles.

Bungee

Twenty-two injuries were attributed to bungee jumping, 13 of which were of gradual onset, and nine acute injuries. Figure 4-16 illustrates the various types of injuries that the bungeists sustained.

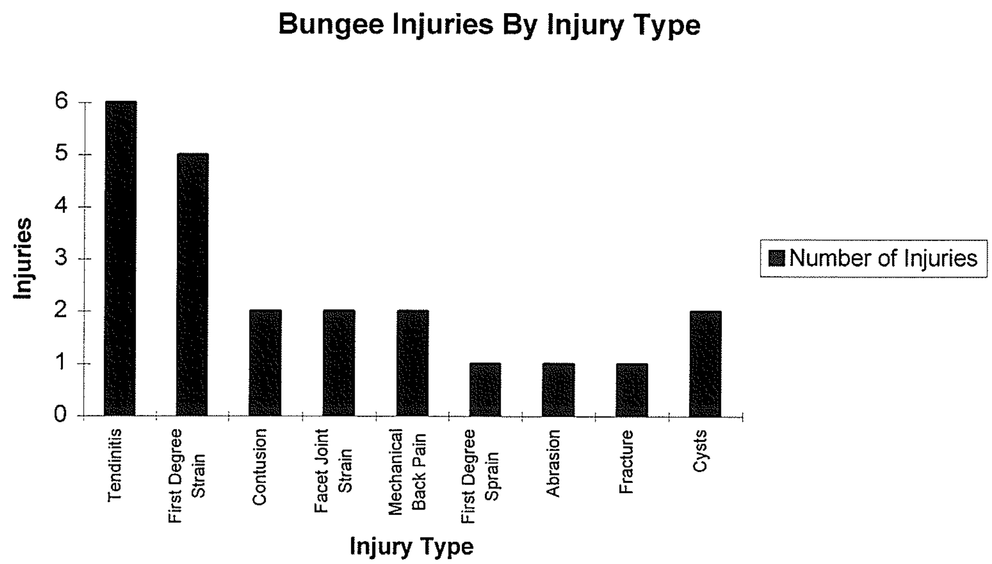

Figure 4-16. Bungee Injuries by Injury Type. (Represented as the Actual Number of Injuries)

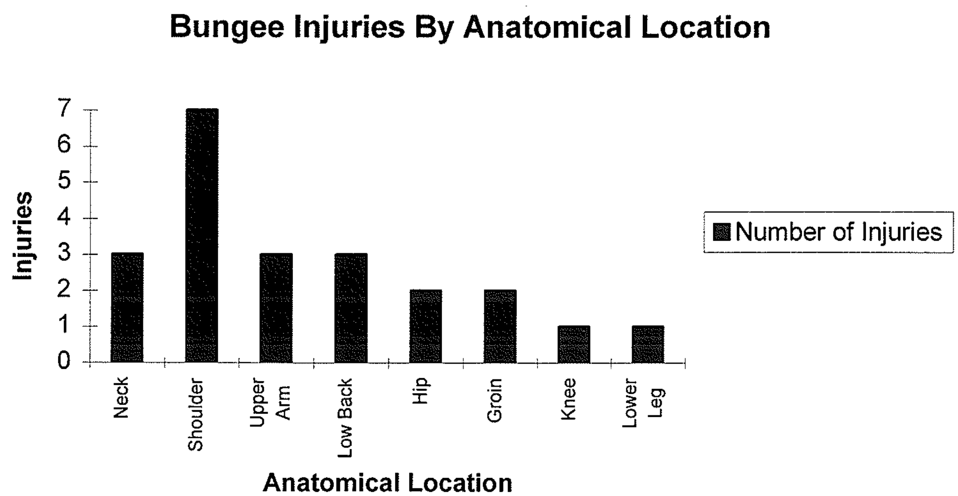

Figure 4-17. Bungee Injuries by Anatomical Location. (Represented as the Actual Number of Injuries)

Figure 4-17 represents the anatomical distribution of the twenty-two injuries that were sustained while training or performing the bungee number. Four of the nine acute injuries occurred as the result of the athlete hitting the trapeze bar with part of his/her body instead of catching the bar with the hands.

Manipulation

The three manipulators that perform this number sustained 11 injuries over the data collection period, five acute and six of gradual onset. Four muscle strains, two cases of tendinitis, epicondylitis, a nerve impingement, a facet joint syndrome and mechanical back pain were included in the injuries. Of the five acute injuries that were assessed and treated, four were muscular strains of the back, and the fifth acute injury was an inversion ankle sprain which was sustained when the performer tripped during the number. The six overuse injuries were all conditions of the neck and shoulders.

Hand-to-Hand

Seven injuries were sustained by these two athletes over the 12-month period, three of which were injuries to the porter, and four of which were injuries to the athlete who performs the balancing maneuvers of the number. The three injuries which the porter sustained were all lower leg soft tissue injuries of gradual onset, which were attributed to overuse. All three were injuries to his right leg, the weight-bearing leg in a particular balancing position in which the weight of his partner is supported while balancing on one leg. During the ninth month of show performance, the other athlete suffered an episode of thoracic spine pain which persisted for approximately two weeks, resolved, and reoccurred shortly after. After two months of diagnostic investigation, the condition was classified as syringomyelia, a rare congenital disease which results in cavitation in the spinal canal. As a result of this, this act was replaced by another hand-balancing act.

Opening, Transitions, Finale, Stilts, and Taiko

Several injuries occurred during parts of the show that are not considered main acts. For example, the opening (beginning of the show), finale (end of the show), transitions (segment of time in between each act that is required to change the stage setting/apparatus), stilts and taiko (Japanese drums which are played during the opening and the finale).

Stilt walking resulted in four injuries, two cervical strains, a thoracic strain injury, and an irritation of the patellofemoral joint.

Taiko playing resulted in three injuries, two shoulder strains and a shoulder tendinitis. Both injuries were attributed to the particular upper body mechanics that are used to play this type of drum.

Five acute injuries that necessitated assessment and treatment occurred during the opening or the finale. Among the injuries that occurred during the opening of the show were a toe fracture (athlete kicked a wall), a heel contusion (athlete hit foot into a stair), a hand contusion (athlete hit palm of hand into corner of wall), a thigh strain (occurred when an athlete jumped off a ledge), and a low back strain, which occurred when the performer attempted to lift a member of the audience. Similarly, during the finale, three injuries occurred as the performers run around the stage in a farewell salute; an inversion ankle sprain, an elbow hyperextension injury that occurred when a performer tripped and fell, and a low back sprain that occurred when a performer attempted to pull a heavy prop off the stage. Approximately 11 injuries were believed to be caused by mishaps during transitions.

Overuse Injuries

Several overuse injuries that could not definitively be attributed to one single factor, have not yet been noted. These twenty-five injuries were believed to be caused by participation in several parts of the show, which cumulatively resulted in the injuries (Figure 4-18). Thirteen of the injuries were to the lower body (Figure 4-19), 11 of which occurred in members of the troupe maison, who are required to participate in the teeterboard number, the Chinese poles number, and various other pieces of choreography that require running and jumping on stage. The other two lower leg stress injuries occurred in the same performer who had a costume that required him to wear high-heeled shoes for the duration of the show. A significant amount of walking, running and dancing was part of this character's choreography, until he developed a metatarsal stress fracture and bilateral medial tibial stress syndromes. The remaining 10 injuries consisted of four neck injuries, three low back injuries, three shoulder injuries, one upper back and one middle back injury (Figure 4-19).

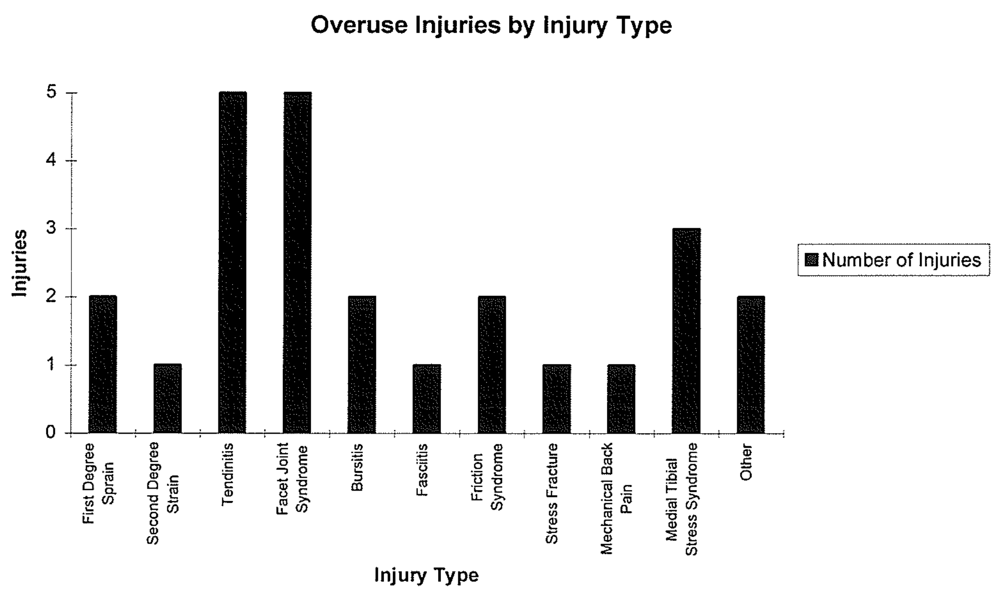

Figure 4-18. Overuse Injuries by Injury Type. (Represented in Actual Number of Injuries)

The most common types of overuse injuries that were documented were tendinitis (five), facet joint syndromes (five), and medial tibial stress syndrome (three).

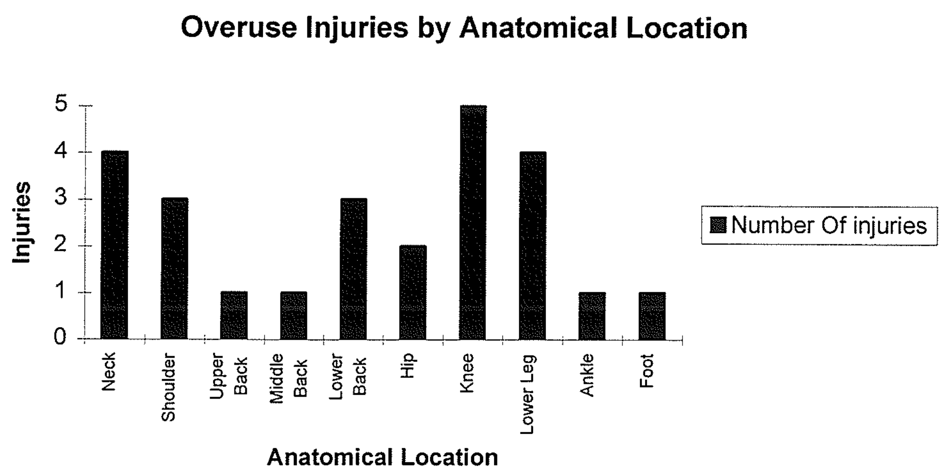

Figure 4-19. Overuse Injuries by Anatomical Location. (Represented in Actual Number of Injuries)

Overuse injuries occurred most frequently in the lower limb (13), followed by the spine and trunk (nine), and the upper limb (three) (Figure 4-19). These injuries characteristically occur to those individuals who participate in many parts in the show with insufficient rest, a situation which is discussed in greater detail in the following chapter.

The final category of injuries are those that resulted from activities not related specifically to either training, rehearsal or performance in the show Mystère, but did affect the athletes performance in the show. Twenty-three injuries of this nature were sustained, four of which occurred during conditioning that consisted of weight-training. These four injuries were believed to be caused by inappropriate lifting techniques. The remainder of the injuries were caused by various accidents that occurred outside of the theater.

Summary

This chapter has provided an overview of the descriptive statistics that were formulated from the injury report forms and the exposure charts which were accumulated during the data collection period. Statistics relating to injury rate, burden of injury, nature of injury onset and reinjury, injury location and nature of onset, injury type, and injury frequency. The main goal of the chapter was to present the results that have been compiled from this research. A discussion of the various causes and preventative measures that relate to injures in this athletic population are presented in Chapter Five.

Overall, the act affected most by injury and time loss due to injury was the teeterboard act. When considered in actual number of injuries per participant in the act, however, the trapeze artist had the highest rate of injury. The athlete who participated in the Chinese poles act had the lowest rate of injury per participant during this 12-month period. The most common types of injuries sustained by the athletes in the cast were minor strains and sprains, tendinitis and contusions. The most frequently injured anatomical locations were the ankle, shoulder, low back and lower leg. As well, each individual act displayed characteristic types and anatomical locations of injuries that related to the type of activity that is performed in the act, and the extent of the risk of injury that exists.

Chapter Five Discussion

Introduction

The following chapter includes a description of each act, and a discussion of the possible causes of injuries that occur in those athletic activities that performed in the Cirque du Soleil. As well, preventative measures that may be taken to reduce the number of injuries that occur are also discussed. The data is considered with regard to injury rate, burden of injury, nature of injury onset and reinjury (acute vs. gradual onset injury), injury location and nature of onset, injury type, injury frequency (by cast as a whole and by act), and mechanism of injury.

Injury Rate

The rate of injury was calculated by dividing the total number of injuries sustained during a specific time period by the total number of participants. (Meeusen & Borms, 1992) Research relating to gymnastics has led to injury rates between 0.12 % and 10,711 %, as previously noted in the review of literature. Table 2-1 provided an overview of the number of injuries and injury incidence that have been reported in 13 epidemiological studies on various gymnast populations. The large differences in these values (Table 2-1) may be explained by differences in some characteristics of epidemiological research. For example, the definition of injury used in the study, retrospective vs. prospective study design, the number of participants in the study, and the data collection methods, make it difficult to compare these results. In order to make direct comparisons between studies, it would be necessary that these characteristics be controlled and uniform in each study, which is difficult without a standard data collection system.

The study by Sands et al. (1993), reported injury rates of 10,711 per 100 participants (Table 2-1). This figure is likely large in comparison to other studies because of the global definition of injury that was used and the daily data collection that was conducted for this study. The definition of injury used in the study was "any damaged body part that would interfere with training." This definition was chosen because it ensured documentation of those injuries that "often can be worked around." For example, a gymnast with an injured ankle may still train on the uneven parallel bars despite the injury, and not miss training time. In this instance, no injury would be reported due to the fact that no time was lost in training. Consequently, the common injury definition of "missed training time" may not give a good indication of the actual number of injuries found in elite gymnastics (Pettrone & Ricciardelli, 1987; Weiker, 1985). During the study (Sands et al., 1993), athletes recorded an injury the first day of onset and every day thereafter until it did not interfere with training. Injury information which included the date, injured body part, event or activity that caused the injury, and the limitations to training that resulted from the injury, was stored for each athlete on each training day. Similar epidemiological studies often extract data from hospital emergency room records or doctors visits, which result in injury documentation of only more serious injuries, which may explain the lower injury rates that have been published.

Two other studies (Caine et al., 1989; Vergouwen, 1986) also reported high injury rates (from 155 to 970%) per 100 participants. These two prospective studies had small populations of high caliber gymnasts. In both studies the gymnasts were followed closely by a medical team and the gymnasts kept a training diary in which all injuries, including those which caused only mild discomfort, were recorded. The results of these two studies may be a reflection of their prospective study design combined with the day-to-day data collection methods that were utilized.

Pettrone & Ricciardelli (1987) reported the lowest injury rates in their 7-month study on recreational (.7) and competitive (5.3) gymnasts. Weiker (1985) also reported low injury rates in club gymnasts (males, 12.4, females, 9.3) over a 9-month period.

The only conclusions that can be made from these results are that the design of the study likely has a large effect on the outcome of reported injuries, (calculated by rate per 100 athletes), and that elite gymnasts appear to suffer more injuries than club or recreational gymnasts. Elite gymnasts practice more difficult and higher risk skills, and they also spend more time training, consequently, their exposure to injury is greater. It is also likely that the nature of the exposures is not similar among any of the studies.

The rate of injury calculated over the 12-month data collection period in the present study was 329 injuries/62 athletes = 531 injuries per 100 athletes per year. This is a relatively large ratio compared to a majority of the recently published literature, with the exception of the studies by Sands et al. (1993), Vergouwen (1995) and Caine et al. (1989).

The definition of injury used in this study "any condition which required treatment and or limited participation in one training session/show" was chosen because of its sensitivity, in that even minor injuries were recorded for analysis. This could be one explanation for the high rate of injury that was found in this particular subject population.

Another factor that has been considered to compare injury rates between athletic populations is the extent to which the participating athlete was exposed to injury during the study period. Several studies have reported incidence of injury per 1000 hours of exposure (Table 2-2). The injury rate per 1000 exposures in the present study was 329 injuries / 32,783 total possible exposures. This injury rate is higher than all other studies that have published rate of injury per 1000 hours of exposure (Table 2-2). It is possible that this study resulted in higher injury rates per 100 athletes, and per 1000 exposures, as well, due to; 1) the level of difficulty of the performance, 2) daily data collection by on-site therapists, 3) the sensitive definition of injury and 4) greater proportion of exposures during show performance than training.

It is important to consider the frequency of injury in each act when using the injury rate to determine the risk of injury of a particular activity. Participation in each act resulted not only in different injury rates, but also in different types of injury, different anatomical locations of injury, and different severities of injury. Therefore, descriptive analysis was completed for each part of the show to provide a clearer profile of injury risk, type, severity, and anatomical location. Table 4-1 provided a list of the number of injuries that were attributed to participation in each act in the show. The number of participants in each act of the show was also provided. From this information, it was possible to determine the average number of injuries per performer in each act (Table 4-1).

The analysis of injury rate does not indicate the severity of the injury, and therefore, as previously noted, is not necessarily an indication of the actual time lost due to injury. Performance in certain activities resulted in minor injuries that require only a few days to heal, and performance in other activities results in more severe injuries that necessitated extended periods of rest and rehabilitation. This fact is explained in greater detail when the burden of injury data (time lost due to injury) is considered for each act of the show.

Time of Injury Occurrence

The athlete who performs in the show Mystère has the highest risk of injury during show performance (51 % of all injuries occurred during show performance), specifically during the second show (28.6 % of all injuries occurred during the second show, vs. 22.4% in the first show). This fact may indicate that there is a fatigue factor related to the risk of injury to the artist who performs in a show such as this. The second highest risk of injury is present during training, which may be explained by the fact that it is commonly during training that new and more difficult skills are practiced, which place the athletes at greater risk of injury. The lowest risk of injury in this population was for those injuries of gradual onset, or injuries that were attributed to overuse.

Injury Burden

Burden of injury information provided an account of the level of participation of each athlete, and also an account of the time missed (lost) due to injury over the 12-month period (Figure 4-2). Representation of the burden of injury for each individual part of the show was given in Figure 4-3 and Figure 4-4. Figure 4-3 provided a breakdown of the burden of injury per act. This figure illustrates the burden of injury which affected the training sessions. The act that appeared to be affected most by injury during training was the teeterboard act, followed by the trapeze act. The percent of Chinese poles training exposures that were affected by injury was surprisingly low, considering the fact that most of the athletes who performed in the teeterboard act also performed in the Chinese poles act. This result, may however, be explained by two factors. First, injuries that affect teeterboard training (primarily lower limb injuries) may not interfere to a large extent with Chinese poles training (primarily upper body strength and conditioning). Therefore, the athlete may still be able to train on the Chinese poles when he/she is unable to train on the teeterboard. This situation is analogous to the gymnast who does not report a reduction in training time due to a lower limb injury, because he/she can still train on an apparatus that requires predominantly upper body work.

Another possible explanation for the low percentage of Chinese poles training exposures that were affected by injury is data entry error. There may have been a failure to document the correct number of training exposures for this act because Chinese poles training was often considered "open" training. During "open" training, no scheduled training time, duration or tasks were allotted. The athletes often trained individually or in pairs, at their own leisure. This made it difficult to keep a clear record of the amount of training that actually occurred. The same situation existed for the manipulation and the hand-to-hand numbers. Formal training was rarely scheduled because a coach was not available for these three acts, which placed the onus of training time, duration and quality on the athletes themselves.

Figure 4-4 provided a breakdown of the burden of injury per act (including the dancers, the actors and the clown) which affected show performance. The percent of exposures that were affected by injury for Chinese poles and teeterboard are similar because the same athletes perform these two acts (troupe maison). Therefore, when an injury occurred in the teeterboard act, it also affected the Chinese poles act. Such was not the case in training however, because training need not incorporate all the necessary skills that are required to participate in the act in a show. The higher percent of time lost due to injury in the teeterboard, Chinese poles, and the trapeze act can be explained by considering the actual number of injuries that occurred to members of these three acts (Table 4-1).

It is also interesting to note that approximately half of the injury exposures for the trapeze act were designated either minimal (M) or none (N) (level of participation) compared to the teeterboard and the Chinese poles act, where less than a third of the injury exposures were designated as minimal or no participations. This illustrates the difference in the nature of the three numbers, and the fact that it is easier to partially and fully participate in the teeterboard and Chinese poles acts if an athlete has an injury. Skills can be modified and the degree of difficulty can be reduced without changing the aesthetic appearance of the teeterboard or the Chinese poles act markedly. There is often the possibility of changing choreography or cues so that an injured athlete still appears in the number, but is not required to do the movements or stunts that specifically cause him/her pain. This situation accounts for the large percent of full and partial exposures that are illustrated in these two numbers. With trapeze performance, however, it is more difficult to partially participate, the athlete is either able to fly, or unable to fly. A similar situation exists with the hand-to-hand number. All of the injury exposures for these two athletes were designated either full or none, because the act cannot be modified and preserved at the same time, in the event that one of the two performers is injured. The manipulation number and dance sequences are similar to the Chinese poles and teeterboard acts. They can be modified so that those athletes with injuries can still participate to a lesser extent.

Overall, the number that suffered the least time loss due to injury was the manipulation number, followed by the hand-to-hand number and the bungee number. Athletes who performed these numbers, the nature of which is much less dangerous than the other numbers, suffered more overuse injuries.

Injury Onset and Reinjury

Table 4-2 referred to the nature of injury onset, sudden vs. gradual, for the 329 injuries that were sustained. The majority of the injuries were acute in nature (67 %) and approximately 33% of the injuries (109) were attributed to overuse syndromes of gradual onset. This proportion of gradual onset injuries is relatively similar to the distribution of acute and chronic injuries reported in various other studies that were documented in Table 2-3.

In all of the studies except Caine et al. (1989) (Table 2-3) a majority of the reported injuries were acute in nature. This may be explained by stating that, from the research, it is evident that participation in the sport of gymnastics results in more injuries that occur from a single insult than from gradual onset. This observation may be somewhat erroneous. It has been suggested that overuse injuries are difficult to document (Meeusen & Borms, 1992) and this difficulty may translate into fewer numbers of overuse than acute injuries being reported in studies. It also has been suggested that unreported overuse injuries may lead to/cause acute injuries. Overuse injuries that lead to muscular pain, fatigue and altered biomechanics may increase the risk of sustaining an acute injury. Meeusen and Borms (1992) suggested that these overuse conditions may be so "common" to the gymnast that they may not even recognize them as injuries, and therefore not seek medical treatment for the conditions, or report them as injuries upon questioning. This type of situation also exists in the subject group which is the focus of this study. This point was validated by a Russian coach who works for Cirque du Soleil, when he said "if a gymnast wakes up in the morning without pain, that means he's dead." P. Brun (Personal Communication, April 2, 1994)

The actual incidence of overuse injuries may be underestimated for another reason. Cirque du Soleil, like traditional sports at the college and professional levels, is performed in an exceedingly competitive environment, with a large and talented labor pool awaiting the opportunity to participate. Both the employed athletes and the artistic directors (coaches) are aware of this, and such knowledge propagates an element of (sometimes justified) paranoia among the athletes. The athlete who is always hurt may, at contract time, be viewed as being less desirable than a similarly talented but non-complaining peer. Thus hiding injury may appear to be the most appropriate solution in terms of job and financial security. This may contribute to the underestimated number of overuse injuries.

Injuries: Anatomical Location

Table 4-3 documented the distribution of injuries by anatomical location for the cast as a whole. The distribution of the top ten most frequently injured anatomical sites was provided in Figure 4-5.

Comparisons between this study and several other epidemiological studies regarding anatomical location of gymnastic injuries can be made (Table 5-1).

Table 5-1 Injury Sites (body part) in Various Gymnastic Studies

Body Part	Caine et al. (1989)	Dickson & Fricker (1993)		Sands et al. (1993)	Vergouwen (1986)	Present Study (1994)
	F	F	M	F	F	
Head	0.7	1.5	.40	.25	4.2	2.1
Hand	4.1	5.4	7.7	1.4		1.5
Wrist	9.5	6.1	14	8.2	8.2	3.3
Shoulder	0.7	1.2	19	15	3.5	12.8
Upper Extremity	6.1	26	54	35	1.3	24.3
Lower Extremity						42.5
Spine	15.2	20	13	12	17	27.7
Hip		4.5	1.6			4.9
Pelvis	2.7			2.8	4.3	0.6
Thigh		3.0	2.0	1.2		1.8
Knee	14.3	11	7.7	5.8	17.2	8.2
Lower Leg	15.5	1.5	2	16.7	15.5	6.1
Ankle	21.1	16	9.8	11.4	19.0	13.4
Foot	10.1	12	5.7	2.5	13.8	4
Heel		6.9	4.0	2.0		2.1

Injury site expressed in percentage (%) of the total number of injuries in various studies.

Other studies (Table 5-1) that reported injury distribution by body part documented a variety of different injury frequencies per body part, although some similarities could be noted. Four of the five studies indicated the ankle in the top three most frequently injured body parts. The shoulder and spine were also consistently ranked among the top three commonly injured body parts in all of the studies. Dickson and Fricker (1993) present the most variability in their data, likely because they represented males and females separately, and as previously discussed, the apparatus are quite different for male and female gymnasts.

Injuries: Type of Tissue Damage

Reporting injuries by injury type provides an overview of the type of tissue damage that commonly occurs in a subject group who performs a particular activity. The most common types of injuries (Figure 4-6) were first degree sprains and strains, followed by tendinitis and contusions (Figure 4-6). The majority of injuries were soft tissue injuries (87 %), 6.69 % were bony injuries, 3.34 % were neurological injuries, and 2.74 % were injuries to other tissues (teeth). The types of injuries that were sustained by participation in each individual segment of the show have been described in detail in the sections dedicated to analyzing the individual acts independently.

Just as there were similarities among anatomical location of injuries in gymnastic studies, there are also similarities among reports on injury type (Table 5-2) in other studies.

Table 5-2 Injury Types (Percentage % of Total Injuries in Study)

Reference	Caine et al. (1985)	Garrick (1985)	Lowry & LeVeau (1982)	Petrrone & Ricciardelli (1987)	Vergouwen (1986)	Present Study (1994)
Sprain	19	16.1	21.5	33.9	31.8	17.6
Strain	17.7	21.6	23.7	6.5	18.9	17.0
Fracture		5.8	4.7	25.8	1.3	6.7
Contusion	3.4	3	30.9	9.7	15	9.1
Overuse	4.1	31.3	11.8	17.7	29	33.0
Other	55.8	14.8	7.4	6.5	3.8	2.7

Injury types presented in percentage (%) terms, of the reported injury types in various gymnastics studies.

Strains, sprains and contusions were consistently ranked highest among all injury types, with the exception of the study by Pettrone & Ricciardelli (1987) who reported fractures (25.8 %) as the second most common type of injury. They provided no explanation for this high incidence of fractures, although it may be a reflection of their data collection method. Injury information was gathered by questionnaires that were distributed among gymnastic clubs. Data collection in this manner likely resulted in an under-representation of less severe injuries (strains and contusions), that did not require extended medical attention, which is the case with fractures, and more severe sprains and strains. The term "overuse" was commonly used as a category of injury type in the studies in Table 5-2. In the present study, however, this term was not used to represent an injury type, but rather a possible cause of injury. For this reason, the injury type "overuse" is not included in Figure 4-6.

Injuries: Gender, Frequency and Severity

The average number of injuries per cast member over the 12-month period was five, and each member of the cast of 62 athletes sustained at least one injury. The female cast members sustained more injuries, on average (6.4 injuries per athlete), than the male cast members (5 injuries per athlete) over the 12-month period. This may be explained by variability in the roles that females and males have in the show. Ten of the 14 females participate in acrobatic numbers and four are dancers. Several of the male performers, however, are characters or actors (clown, babies) who do not participate in stunts and acrobatic parts of the show, but are still considered as part of the cast of the show, and therefore are included in the data collection. Consequently, many of the male performers sustained very few injuries over the course of the data collection period, which likely accounts for the lower average number of injuries per male performer than per female performer.

Mechanism of Injury Review

The goal of the following section is to briefly describe each act and review the injuries that occurred as a result of participation in each act, and to provide insight regarding the causes and possible prevention of the injuries that have occurred. As previously stated, the analysis of injury mechanism data is difficult if it is not coupled with a biomechanical analysis of the activity being performed at the time of injury. Presently, a research based biomechanical analysis of the activities performed by the artists of Cirque du Soleil has not yet been conducted. Despite this, however, insight regarding the possible causes and contributing factors, as they relate to injuries incurred by these athletes, has been provided.

To maintain consistency with the results sections that were outlined, each segment of the show will be considered as an individual subgroup.

Teeterboard

Injury may result to a teeterboard jumper due to lack of skill or strength of his/her spotters. Appropriate spotting technique is necessary if the individual is to be successful at preventing injuries and reducing the severity of injuries that occur.

Variables that pertain to the risk of injury in the teeterboard number may be more clearly depicted if considered from three perspectives; one, the teeterboard jumpers; two, the spotters; and three, the apparatus.

The athlete who performs in the teeterboard number must acquire the ability to control his/her own movements as well as anticipate the movements of their jumping partner. Jumpers routinely train with a select few jumping partners, likely due to the fact that a partner of similar body weight and skill level facilitates the acquisition of controlled and safe skills. Communication between the two jumpers is also important. It is essential that each jumper be aware of their partner's actions prior to their performance in order that appropriate timing and momentum of the teeterboard be maintained.

Injuries often occur due to lack of control of one of the jumpers. For example, the jumper may lose body position or space position awareness while he/she is in the air, and be unable to land appropriately as a result. When an athlete lands inappropriately, injury risk increases for himself as well as his/her jumping partner. If, for example, the jumper lands and is unable to jump again when his/her partner returns to the board to push, the momentum of the teeterboard will be lost and the descending jumper must anticipate this break in momentum. Simultaneously, the jumper who has fallen must anticipate the rebound of his/her end of the teeterboard which occurs when his/her partner lands from their jump. It is rare that a fallen jumper has enough time to reposition him/herself on the board in a controlled position to jump again, prior to the partner returning to the board for the subsequent push. Therefore, it is possible for the fallen jumper to be injured at the time of the fall or when the board rebounds as a result of their partner landing on the teeterboard, and it is also possible for the jumping partner to be injured as a result of the loss in momentum of the teeterboard.

Athletes may lose awareness of their body position in the air for several reasons. Lack of concentration (the athlete may be distracted by light or music during the show), lack of skill (attempting to perform skills that are too advanced for his/her ability), too forceful of a push by the jumping partner (which results in unanticipated height/momentum in the air), loss of communication between the jumping partners, and psychological factors such as fear or apprehension of the individual's own ability or the ability of the spotters.

The exact role that spotting has in preventing and reducing the number of injuries in an athletic population such as this is difficult to determine from this study. As previously mentioned, Weiker (1985) found spotting vs. non-spotting to be the most significant controllable factor in determining the rate of injury in womens' gymnastics. This type of observation is possible in a sport such as gymnastics, because spotters are only present part of the time the gymnast is training, and the use of spotters during competition is against the rules of the sport. Therefore it is possible to do a comparative analysis of injuries that occur with and without the presence of spotters. This is not the case in this study, however. The use of spotters is relatively consistent in both training and during show participation. Spotters are incorporated into the choreography of the show. Although it is only possible to speculate about the role that spotting has in preventing injuries, it is likely appropriate to assume that a significantly higher number of injuries would be sustained if spotters were eliminated in this particular number in the show.

Spotters themselves are often at risk of injury. It is not uncommon for a spotter to be hit by an uncontrolled jumper who has fallen on landing. Also, spotters often sustain injuries while attempting to catch a jumper, or prevent a jumper from falling. Injuries that are sustained by spotters, and the causes of these injuries will be considered after those that are sustained by teeterboard jumpers.

The teeterboard as an apparatus also plays a role in the occurrence of injury. Due to the fact that the landing surface at the end of the teeterboard is relatively small, (two feet by two feet), there is a relatively small margin for error when attempting to perform an aerial movement and land in the original position on the teeterboard. If the jumper travels posteriorly during a movement, he/she may miss the end of the board on landing and consequently, land on the stage. If he/she travels laterally more than 6-8 inches, there will be insufficient space for the athlete to land with both feet on the teeterboard. And finally, if he/she travels forward and lands close to the central fulcrum of the teeterboard, the force that is created by the athlete's weight being applied at a distance (perpendicular) to the axis of rotation of the board (the central fulcrum), which in turn creates the upward propulsive force at the opposite end of the board, will be reduced.

Therefore, the jumper at the opposite end of the teeterboard will not receive sufficient upward force to create a successful jump, and the momentum of the jumpers will be lost.

Teeterboard Jumping Injuries

Forty-seven (of a total 329 injuries) injuries were attributed to teeterboard jumping. The most common types of injuries that occurred as a result of teeterboard jumping were muscular strains, followed by contusions and sprains (Figure 4-7). Medial tibial stress syndrome, second degree sprains and strains, and tendinitis followed in frequency. Figure 4-8 illustrated the anatomical distribution of the teeterboard jumping injuries. Of these 47 injuries, 38 were injuries to the lower extremity, and nine were injuries to other parts of the body (one head, one neck, five lower back injuries, one mid-back injury and one shoulder injury). Before reviewing injuries that occurred to the lower extremity, the 11 other injuries will be considered. The head injury (concussion) occurred when an athlete lost spatial awareness while in mid-air performing a movement, after having been pushed too hard by their jumping partner. The spotters were unable to completely break the fall. The neck injury (burner/stinger) was also attributed to an athlete losing control in the air after having been pushed too hard by their jumping partner. The athlete was caught by the spotters in an inverted position. At the point of contact, the athletes head was forced into lateral flexion, resulting in the burner/stinger.

Of the five lower back injuries that occurred, four were of the acute nature, resulting from jarring the low back when the athlete landed on the teeterboard. Athletes commonly land on the teeterboard with their legs straight. This causes a jarring mechanism/force that has been considered a contributing factor in lower back injury and pain. The speculated cause of this type of low back injury is the possibility that the impact forces that should be consumed by bending the knees on landing, instead are transmitted to the low back area, especially the L4-L5, and L5-S1 joints. The pain is usually felt bilaterally, especially if the athlete landed with equal weight distribution on both feet, with his/her legs straight, and the low back slightly extended. Impact forces sustained with the lumbar spine in this hyperextended position have been implicated as a causative factor in the pars interarticularis stress fracture in young gymnasts (Hall, 1986). Quantification of impact forces at the point of landing on the teeterboard, both forces that are sustained from a proper landing, and those forces sustained when landing mechanics are incorrect, would likely aid in clarifying these causative injurious factors.

The low back injuries that were characterized by a gradual onset of symptoms were attributed to overuse. Although it is difficult at this point to definitively state that these low back injuries were caused from repetitive microtrauma incurred with the impact of landing on the teeterboard, this was believed to be the cause of this type of injury. Despite the fact that the athletes who participated in the teeterboard number also participated in trampoline, fasttrack and "chavel" (part of the choreography of the teeterboard number, in which the athletes are required to travel around the stage performing successive stag leaps), these athletes implicated teeterboard jumping as the major contributing factor to the gradual onset of their low back pain.

The mid-back injury occurred when an athlete who was jumping on the teeterboard "buckled" (knees gave out) on landing, resulting in the thoracic spine being forced into hyperextension. The spotters that were present were successful at supporting the athlete's hips and low back, although the thoracic spine was not supported, which could be a possible explanation for the landing impact force being transmitted to the thoracic spine region. The shoulder injury occurred as a result of a fall on an outstretched hand.

The 38 injuries to the lower extremity consisted of one hip, two thigh, three knee, 11 lower leg, 11 ankle, and 10 foot/heel injuries (Figure 4-7). The hip injury, classified as a contusion, was sustained when an athlete lost his/her awareness in the air during a double twist and landed on the hip/buttock on the teeterboard. The two injuries to the thigh region, one of gradual onset and one acute, included an iliotibial band friction syndrome, which was attributed to increased hours of training on the teeterboard and dance rehearsal, and a rectus femoris strain, which occurred when the athlete attempted to jump on the teeterboard for the first time. The athlete's knees buckled from the upward force of the board, causing forced knee flexion with simultaneous eccentric contraction of the knee extensor muscles, resulting in the muscle strain.

Three knee injuries resulted from teeterboard jumping, two acute injuries, and one injury which had a gradual onset of symptoms. The first acute injury occurred when an athlete landed from a twisting somersault prior to having completed the revolution, resulting in a valgus stress being placed on the knee, which caused a medial collateral ligament sprain. The second acute knee injury, a sprain of the superior tibiofibular joint, occurred on landing a "double fly". During the double fly, the athlete travels from one end of the teeterboard to the other, while performing two backward somersaults during the flight. The superior tibiofibular joint was sprained at the point of landing on the teeterboard after the fly was completed. This is a common mechanism to sprain this joint. Arnheim (1989) explained this mechanism as a strong eccentric contraction of the biceps femoris muscle with the knee in a flexed position, which is the exact position the athlete assumes on landing from the double fly. One case of patellar tendinitis (jumper's knee) occurred when the athlete altering his/her jumping mechanics. This athlete had previously sustained a heel contusion, and in an attempt to protect this injury, changed landing mechanics from toe-heel landing to toe-landing. This likely caused an increase in stress placed on the knee extensor mechanism, which resulted in the gradual onset of bilateral patellar tendinitis.

Eleven lower leg injuries were attributed to teeterboard jumping. The injuries that were classified as gradual onset, overuse type injuries, deserve special note. Five cases of medial tibial stress syndrome, two cases of Achilles tendinitis and one case of peroneal tendinitis were attributed to overuse, or excessive amounts of teeterboard jumping. Participation in other activities (fasttrack, trampoline and chavel) in training and show performance, as previously noted, must be considered to be additional factors in the onset of lower leg stress syndromes. The athlete commonly reported pain/irritation with several or all of the activities in which he/she participated. Despite this, however, the repetitive pounding that is characteristic of teeterboard jumping is likely the most significant factor in these lower limb stress injuries.

Approximately half of these injuries (six of 11) were acute in nature. Four of the six acute lower leg injuries were muscular strain injuries (two peroneal tendon, two Achilles tendon) that occurred during improper landings on the teeterboard. Both peroneal tendon strains occurred when the athlete landed on the side of the teeterboard, with the injured leg positioned slightly off the board, which caused an inversion force at the ankle (subtalar) joint. The Achilles tendon strains occurred when the athletes landed "short" from an aerial movement. Landing "short" refers to an improper landing position, and occurs when the athlete lands on the teeterboard with his/her center of gravity farther forward than is biomechanically appropriate to achieve a stable landing (the center of gravity of the athlete's body should be directly over the feet on landing). Such a landing position will characteristically result in either straining the posterior structures of the lower leg/ankle, or compression of the anterior structures of the ankle joint, as the ankle joint is forced into extreme dorsiflexion when the athlete lands.

Eleven acute ankle injuries occurred while athletes were teeterboard jumping. The most common mechanism of ankle injury resulted from landing on an inverted ankle. Six of 11 ankle sprains occurred as a result of this injury mechanism. Four of the 11 ankle injuries occurred when the athlete landed short, causing extreme dorsiflexion at the ankle joint. One ankle injury was classified as a contusion. This contusion occurred when the athlete stepped off the teeterboard, placing the foot to the side of the board, resulting in the board hitting the medial malleolus as it rebounded off the floor.

Ten foot injuries were attributed to teeterboard jumping, nine of which were acute in nature, and one overuse injury. The most common injury was the heel contusion, or the calcaneal fat pad contusion, comprising six of 10 foot injuries. The athletes sustained these injuries as the heel contacted the teeterboard during landing. Three factors could possibly contribute to these injuries; one, insufficient padding on the teeterboard, two, insufficient padding in the shoes, and three, improper landing mechanics. A toe-heel landing is appropriate, although athletes commonly land with the forefoot and rearfoot contacting the teeterboard simultaneously. Three metatarsal arch sprains also occurred as a result of improper landings on the teeterboard. Landing with the forefoot placed off the board and the heel placed on the board, which resulted in an inversion force at the forefoot, was the speculated cause of these three arch sprains. One case of bilateral plantar fasciitis was the only foot injury of gradual onset. Factors that contribute to the onset of plantar fasciitis are varied. In this particular athlete, the onset of symptoms was attributed to the athlete's pes cavus foot structure coupled with insufficient arch support, intrinsic foot musculature weakness, and fatigue.

Other factors that could possibly contribute to these lower limb injuries include improper footwear, poor lower limb/foot mechanics, weak lower limb musculature, poor jumping mechanics, improper warm-up, previous injury, increased training time, improper padding on the teeterboard, and jumping on a stiff teeterboard. The wood used in the construction of the teeterboard has a small amount of resiliency. When the athlete lands on the teeterboard from an aerial movement, a part of the impact is consumed initially as the board "gives" or bends slightly, part of the impact is consumed as the jumping partner is catapulted into the air, and finally, the remaining impact force is consumed by the athlete's body on landing. Therefore, if the first or second factor is reduced or deleted, impact forces inevitably increase.

To summarize the possible causes of injury that have occurred as a result of teeterboard jumping, it may be appropriate to consider those injuries that are acute in nature and those of gradual onset separately. A disproportionately high percentage (76%) of the injuries were acute in nature.

The two most important factors that relate to the number of acute injuries that occur as a result of teeterboard jumping are the severity of the falls that occurred on landing, and the athletes body position upon landing. Falls on teeterboard occurred for several reasons. Athletes often claimed they fell because they "got lost" in the air, rendering them unable to successfully complete the movement in the air and position themselves appropriately for landing. Athletes also claimed to lose spatial awareness when their jumping partner pushed them too hard, resulting in unanticipated height and uncontrolled rotational forces in the air. Falls also occurred because of lack of skill or an attempt at an aerial movement without the appropriate training. Lack of concentration and fatigue were also cited as causative factors in falls. Because the jumpers regularly worked with a jumping partner, falls also occurred due to lack of communication between two jumpers. Unskilled spotters or an insufficient number of spotters, improper use of safety equipment (spotting belts), or poor apparatus has also resulted in injury. Insufficient warm-up, previous injury and returning to jumping too soon after an injury were additional factors that contributed to the number of falls that occurred. Finally, inappropriate coaching techniques were also cited as possible causative factors relating to falls.

Causative factors attributed to injuries that were of gradual onset were quite different than those factors that contributed to acute injuries. The major cause of overuse injuries was cited as repetitive microtrauma that occurred as a result of excessive teeterboard jumping. Factors that may also have contributed to these overuse injuries were considered to be improper footwear, insufficient padding on the teeterboard, a stiff teeterboard, poor jumping mechanics, poor lower limb/foot biomechanics, weak lower limb musculature, fatigue and previous injury that resulted in the athlete compensating in such a way that additional stress was placed on a structure that could not sustain the stress.

The role of footwear used by the teeterboard jumper deserves more investigation than it has received by those who participate in this number, those who coach teeterboard jumpers, and the therapists who play a role in the prevention and care of these injuries. Traditionally the teeterboard jumper has either jumped barefoot or worn a shoe referred to as a gymnastic slipper. This shoe is extremely light weight, has a thin sole, and is popular among the jumpers because it enables the athlete to "feel" the teeterboard. The shoe offers relatively little support to the ankle/foot, and because the sole is constructed of simply a thin piece of leather, there is virtually no shock absorbing capacity, no support to the medial longitudinal arch, and minimal rear-foot control. A shoe that could be designed to provide support to the ankle as well as the arch, have a shock absorbing capacity, and still be relatively lightweight may aid in the prevention of lateral ankle sprains, heel contusions, as well as lower limb stress injuries.

Teeterboard Exiting Injuries

Fifteen injuries occurred as a result of teeterboard exiting; 13 acute injuries, and two injuries of gradual onset. A graphical representation (Figure 4-9) of the types of injuries that occurred as a result of teeterboard exiting has been provided. Sprains (first degree) accounted for 7 of the 15 injuries, the remainder of the soft tissue injuries were strains (first and second degree), sprains (second degree) and tendinitis injuries (Figure 4-9). One concussion and one fracture were also sustained.

The distribution of injuries caused by teeterboard exiting included five upper extremity injuries, six lower extremity, one thorax, one neck, one head and two back injuries. Both injuries of gradual onset were to the upper extremity, the first was classified as a shoulder impingement syndrome, which occurred in an athlete who performed an exit to a handstand position on top of a 2-man column. Each time the athlete performed the exit and was caught in the handstand position, the athlete's shoulder was placed in an impingement position, which likely caused the injury. The second injury occurred in an athlete who had previously suffered a fracture-dislocation of the elbow. This athlete had recurrent episodes of residual elbow pain with increased training and performance of the handstand dismount.

The acute upper extremity injuries all occurred when the athletes fell from the column while attempting a dismount. Two wrist sprains, one wrist strain and a scaphoid fracture resulted from these falls, all of which were falls on the outstretched arm. These injuries represent cases where the exiting athlete fell and was not caught by the spotters prior to contacting the stage. Of the five acute lower extremity injuries, two occurred as a result of falls from the column, and three occurred on landings from exits. One fall resulted in a muscular contusion as the athlete missed landing on their feet and hit the buttock, and the other fall resulted in a muscular strain injury when the athlete missed the column and landed on the stage in a full knee flexion position. The four exiting injuries that occurred on landings included two inversion ankle sprains, an eversion ankle sprain, and a lower leg muscular strain. All of these injuries were sustained when landing on the crash mat. It was often difficult for the spotters to catch the athlete before he/she hit the stage, especially if the exiter fell in an awkward position, or the exiter and another member(s) of the column fall simultaneously. The spotters are trained to attempt to catch/support the athlete that has fallen to the best of their ability. The head and cervical injuries were sustained when an exiting athlete fell posteriorly from the column and the top-man on the column fell on top of the exiter. The chest injury, classified as a sterno-costal sprain, occurred when an exiter performing the dismount to a crash mat was caught by the spotters around the chest, compressing the chest region. Spotters are taught to catch the exiter around the waist to support him/her on landing, although in this case, the athlete was caught around the chest region, which resulted in compression of the ribcage. The two back injuries that occurred were low back sprains, one of which occurred at the point of contact with the landing mat, the other occurring during a fall from the column that resulted in the athlete contacting the stage in an awkward position. The characteristics of the injuries that have occurred as a result of teeterboard exiting denote the fact that the prevention of falls is essential in the prevention of injuries during this activity. Exits to the column appear to present more risk of injury than exits to the crash mat, which is logical when one considers that the nature of the landing is far more difficult, and requires extreme precision and consistency on the part of the exiter. Inherent in this part of the teeterboard number is danger and risk, and the easiest feasible way to reduce the number of injuries that occur due to falls would be to either use more safety equipment, more spotters, or reduce the difficulty of the skills that are performed. These may be the logical solutions to those concerned with the health and safety of the athletes, but they are rarely accepted as appropriate solutions to those who create the acts that please the audience.

Column Injuries

A total of nine injuries were sustained by the athletes who create the column; three neck, two low back, one middle back, one upper arm, one buttock and one ankle injury, all of which were acute in nature.

Strength and correct technique are essential if the athletes who create the column expect to repeatedly be successful at catching the exiter. The exiter is caught easily if, at the point in the air when he/she finishes the aerial movement, the column is directly under either their feet or hands. This is possible if the exiter is accurate in the distance and height that he/she travels during the exit. If it appears that the exiter is not in a correct position to land on top of the column, the athlete at the base of the column must move in the appropriate direction to catch the exiter. If the base of the column fails to move, the second and third man must attempt to lean their upper body to the estimated position of the exiter to successfully catch the exiter. This places the second and third man at an increased risk of injury because they must sustain compressive forces while in a bent or leaning position, which is a weaker body position than when the column is straight. Therefore, it is crucial that the athlete at the base of the column is both strong and experienced enough to be mobile, if movement of the column is necessitated.

Although this data collection did not reflect overuse injuries resulting from the compressive forces that the members of the column sustain when an athlete is caught, undocumented data from the 1995 show period has indicated this type of injury. Within a two month period, two members of the column underwent surgery to repair bilateral inguinal hernias, which were believed to be the result of increased abdominal pressure (Valsalva maneuver) that occurs when the weight of an exiting athlete is absorbed.

Teeterboard Spotting Injuries

As has been previously mentioned, it is the role of the spotter to protect both the teeterboard jumper and the teeterboard exiter in the event that the athlete should fall while attempting to perform an aerial movement or exit. During the act of spotting, the spotter himself is also placed at risk of injury. The reality of this statement is clear due to the nature of the 10 injuries that were sustained while an athlete was spotting another performer. The injuries were all acute in nature, five to the upper extremity, one face, two head and one neck injury. The nose fracture occurred when a spotter was hit by a jumper's uncontrolled elbow. Similarly, the two concussions occurred when the spotter was hit in the head by a jumping athlete, and the cervical strain occurred when a spotter was kicked in the head by an exiting athlete. The upper extremity injuries were sustained when the spotter attempted to catch a teeterboard jumper who was falling backward off the teeterboard. The majority of the body weight of the jumper was sustained by the spotter's hands in an attempt to catch the athlete. Spotters attempt to brace themselves appropriately by having a wide base of support and a low center of gravity, but this position is often difficult to maintain if the spotter is required to move to catch a falling jumper. Upper body injuries are common in spotters as it is the hands, especially the thumbs, that are either sprained or fractured in the attempt to catch or brace a jumper with the spotters upper body, guided by the hands. The speed, force, and direction in which a jumper will fall is often difficult for a spotter to anticipate, and every attempt is made to protect the jumper regardless of the risk it poses to the spotter.

Teeterboard jumpers often become quite comfortable with the presence of the spotters and consequently rely on spotters to catch them regardless of how they land on the teeterboard. This confidence in spotters is necessary, although it becomes dangerous when the jumpers place more responsibility on the spotter to assist their landings than is appropriate. Injuries commonly occur to spotters when teeterboard jumpers attempt skills that are too difficult for their skill level, when the teeterboard jumper has insufficient control of his/her body while performing skills, or when the spotter is not strong enough to support the weight of the jumper. These types of injuries are preventable. Teeterboard jumpers should be taught, (and often are not), proper body positions both in the air and on landing, and they should be coached in an appropriate manner so that skills that are extremely dangerous are not attempted until the athlete is ready. Additionally, an athlete should not be required to spot those athletes that are excessively large and too heavy for that particular individual to spot. This would likely reduce the number of injuries that are sustained by spotters and jumpers.

Trampoline Injuries

The nature of the injuries that were assessed and treated as a result of trampoline jumping have indicated that the athlete who performs in this discipline is more likely to sustain an acute injury than an overuse injury (13 of the 15 injuries were acute in nature). This is consistent with one other study that has been conducted on trampoline injuries (Hage, 1982). The underlying risk of injury is magnified in the present study because, in this particular trampoline number, the jumper is required to jump vertically, which is the traditional form of trampoline jumping, and they are also required to travel from one lateral trampoline to the trampoline on the other side of the apparatus. Seven of the 10 acute injuries occurred when the athlete was traveling from one side of the structure to the other. This finding may suggest that jumping trampoline on such an apparatus presents an additional danger that does not exist when jumping on a traditional trampoline. Risk of injury may simply be increased due to the fact that these athletes have much more experience jumping on the traditional trampoline, and were just learning the techniques that are required on this new apparatus. Three of these 15 injuries actually occurred when the athlete was exiting from the trampoline to a crash mat and landed incorrectly, resulting in a wrist sprain, a shoulder separation, and a low back sprain. Of the remaining 12 injuries that occurred while jumping trampoline, two were injuries of gradual onset, a cervical facet joint irritation and a lower leg tendinitis. The remaining 10 injuries all occurred when the athlete contacted the bed of the trampoline in an incorrect position. Three of these injuries occurred when the athlete traveled while they were in the air and landed on the metal frame that surrounds the bed of the trampoline, instead of landing in the center of the bed. Two inversion ankle sprains occurred as the athletes were attempting wing-to-wing fly's, one cervical facet joint sprain occurred as an athlete sustained a whiplash type mechanism as a result of an improper landing, and one low back sprain resulted from an improper landing, as well. The three acute upper body injuries, a wrist sprain, shoulder strain and a shoulder subluxation, also resulted from falls while attempting aerial stunts.

Spotting techniques and safety equipment are difficult to implement effectively on trampoline because of the nature of the apparatus. The only safety equipment used regularly are crash mats that are placed around the trampoline on the floor to protect an athlete who may fall off the trampoline. Consequently, the athlete has relatively little protection against falls that occur on the trampoline itself. It is difficult to suggest preventive measures that should be used to reduce the number of injuries that occur on this type of apparatus. Inherent in learning new acrobatic techniques on any apparatus is some risk of injury. Proper warm-up and appropriate skill progression are essential elements that are required to reduce this risk of injury. Another factor that needs to be addressed to ensure the safety of athletes is the presence of a coach that is knowledgeable about both the apparatus and the ability of the trampoline jumpers. Such an individual should be responsible to ensure the gradual progression of skills and techniques that are necessary to prevent injury, and the conditioning that is required to attain these skills. At present, these athletes train without a coach and therefore lack appropriate guidance and assistance that is afforded to those who do receive coaching.

Fasttrack Injuries

Seven injuries were attributed to performance on the fasttrack. The most common acute injury, the inversion ankle/foot sprain, (three of seven injuries) likely occurred because the fasttrack has a resilient and unstable surface. Unlike tumbling on the floor, which offers a stable surface on which to land and rebound, the fasttrack gives with the weight of the tumbler. This type of surface offers the athlete a greater capacity to attain both horizontal and vertical momentum, although the stability of the surface is lost. Such conditions, coupled with the fact that the ankle is an anatomically unstable joint, may provide an explanation for the number of inversion ankle sprains that occurred on this apparatus. One other acute injury occurred, a cervical facet joint sprain, which was attributed to insufficient warm-up prior to commencing training on the apparatus. Three injuries were believed to be caused by overuse, two upper body and one lower body injury. A combination of athletic participation in various activities in the show likely resulted in these overuse conditions. The lower body injury, bilateral patellar tendinitis, was sustained by an athlete who also tumbled on the floor and jumped teeterboard. The combination of participation in these three activities likely resulted in this overuse condition. Similarly, one of the upper body overuse injuries was sustained by an athlete who performed on the fasttrack, tumbled on the floor, and participated routinely in the bungee number. The third overuse injury was a chronic wrist injury that was attributed to increased training on the fasttrack.

Tumbling on the fasttrack may cause fewer injuries than tumbling on the floor. The ground reaction forces that the athlete sustains each time either the feet or the hands land on the fasttrack are significantly smaller than those which are sustained when tumbling on the floor, simply because the fasttrack has a more resilient surface. Such an observation is speculation however, since only two athletes who performed on the fasttrack also tumbled on the floor. Consequently, however, both of these athletes suffered overuse/stress injuries as a result of participation in these two activities. Athletes who participated in fasttrack alone did not suffer similar overuse injuries. So tumbling on the floor maybe the true causative agent in these overuse injuries.

Trapeze Injuries

Sixty-one injuries were sustained by ten trapeze artists over the 12-month data collection period (Figure 4-10). To review, the type of injuries sustained by the trapeze flyers varied a great deal, although the most common injuries sustained were minor sprains and strains, followed by tendinitis, fractures, skin abrasions from landing incorrectly in the safety net, and second degree strains (Figure 4-10). Injuries to the trapeze catchers (eight) occurred most frequently in the shoulder (four) as well, which accounted for half of the injuries (Figure 4-11).

It is possible to suggest several biomechanical factors that cause shoulder injuries in the flying trapeze artist. These mechanisms may be demonstrated if the stresses that are placed on the shoulders as a result of trapeze flying are explained and estimated. The complete aerial sequence that a trapeze flyer performs can be considered to consist of three phases; the preparation swing phase, the aerial phase, and the catch phase. During the swing phase, the athlete obtains the necessary momentum and height to perform the aerial skill. Each sequence begins with two to three long hanging swings on the trapeze bar. At the highest point in the swing, the athlete releases the trapeze bar to perform the aerial skill, which may consist of a variety of gymnastic type maneuvers, varying in difficulty. He/she completes the sequence by grasping the catcher's wrists (and simultaneously the catcher grasps the flyers wrists), in the manner previously explained. The initial stress that is placed on the athletes shoulders occurs during the preparation swing phase. The stress placed on the shoulders during the aerial phase of the skill is likely minimal. The majority of the stress is likely placed on the flyers shoulders during the catch phase. At the instant that the flyer grasps the catchers wrists, the flyers shoulders are fully flexed. If the catch is performed correctly, there is relatively minimal additional stress placed on the athletes shoulders, as the transition from the aerial phase to the swing phase is made. However, it is common for there to be a significant jarring/traction force placed on the flyers shoulders at the point of the contact with the trapeze catcher. This jarring force is often significant enough to cause an injury from only one insult. But more commonly, it is the repetitive jarring force at the shoulder joint, while the joint is in this impingement position, that leads to stress and overuse injuries.

It is critical that the transition from the aerial phase to the catch phase is smooth if this type of injury is to be prevented. For the inexperienced trapeze flyer and catcher, however, this is often quite difficult. As previously noted, if a catch is to be smooth, the flyer and catcher both have to be in correct positions at the point the catch is attempted. This makes it necessary that the aerial skill be complete (in the air) by the time the athlete attempts to make the catch. As well, the height of the flyer in relation to the height of the catcher must be correct, and the distance the flyer travels during the aerial skill must also be appropriate. Each time the flyer attempts to make a catch, these three factors inevitably dictate whether the catch will be successful and biomechanically correct. A fourth factor in the success of the catch is the position of the catcher at the time the catch is attempted. Because the center catcher in this particular number uses a swinging chair, his position at the time the athlete attempts to make the catch is variable. Timing of the flyer's sequence and the swing of the catchers chair is therefore crucial. If the two athletes fail to meet in an appropriate position at the end of the athletes aerial phase, the catch will be unsuccessful, and potentially dangerous. Timing and coordination is crucial on the part of both the flyer and the catcher. The trapeze flyer relies on verbal cues given by the catcher, for example, regarding when to begin a swing to achieve appropriate timing. If timing is inappropriate, the catch attempt will inevitably fail.

Several cases of biceps tendinitis and/or rotator cuff tendinitis were treated in the trapeze flyers which were attributed to the jarring mechanism that occurs at the point of the catch, described above. Once an athlete had sustained such an injury, recurrence of the injury was difficult to prevent. Most of the athletes were responsive to treatment, which focused on inflammatory control and strengthening, but it was difficult to prevent a subsequent irritation if the correct catching technique was not practiced. The athletes were aware of the injurious nature of improper catching techniques, and practiced appropriate biomechanics during training. During show performance, however, it was common for the flyer and the catcher to attempt to complete an aerial skill catch, by any means necessary, to avoid falling into the net. This often led to injuries that resulted from the stress/traction force of an awkward catch. Three acute myotendinous shoulder injuries were caused by improper catching techniques that resulted in the athlete attempting to make a catch from an inappropriate position.

Just as there is a correct way to catch an aerial skill, there is a correct way to land in the safety net. If an athlete is to avoid injury when landing in the net, he/she must always attempt to land supine with the body flat, so that the whole body contacts the net as a unit. Prone landing may result in excessive hyperextension of the spine as the body contacts the net, resulting in injury, and landing on the side may result in the athlete being unable to control the bounce in the net. Supine landing is not always possible, however. Consequently, missing the catch with the catcher and being unable to land in a safe position in the net was the leading cause of injury to the trapeze flyer. Biomechanically incorrect falls in the net were responsible for five low back injuries, three neck injuries, four knee injuries, several skin abrasions, a fractured phalange and seven of the eight ankle and foot injuries that occurred during trapeze flying.

The second most frequently injured body part during trapeze flying was the low back. Three low back joint sprains were attributed to the jarring forces that occur at the point of contact between the flyer and the catcher (similar to the jarring forces that occur at the shoulders during an incorrect catch). These injuries were likely sustained when the lumbar spine was in a hyperextended position at the time of the catch, and the catch did not occur smoothly. This was also considered to the causative factor in three thoracic spine injuries; hyperextension of the thoracic spine at the point of contact with the catcher, which resulted in repetitive jarring of the thoracic facet joints (in a closed packed position in extension), subsequently causing pain and irritation. The remaining five low back injuries were sustained when the athlete landed incorrectly in the safety net.

Biomechanically incorrect falls in the net were responsible for seven of the eight ankle and foot injuries that occurred during trapeze flying. One athlete suffered bilateral ankle/foot injuries, a fractured calcaneous of the left foot and a third degree right ankle sprain, when he landed at the side of the net, bounced uncontrollably, and fell to the stage. As previously stated, the stage is 14 feet below the level of the net. This particular accident led to the safety net being enlarged. Unfortunately, it is often not until a life threatening injury such as this occurs that extra safety measures are considered.

All three of the neck injuries resulted from whiplash type mechanisms that occurred when the athlete fell into the safety net incorrectly.

Four of the knee injuries were sustained by athletes falling in the net, which resulted in either a rotational force or a unilateral stress being placed on the knee joint, at the point of contact. One knee injury occurred when an athlete returned to the trapeze platform, lost his footing and struck his knee on a part of the metal frame. The final knee injury was a meniscal irritation that was the result of a previous injury.

One athlete fractured a phalange when he caught his finger in the net during a landing. Another hand injury was attributed to the use of grips, which is a common practice among those who perform as trapeze flyers. A grip can be described as leather palm protector, which is worn to reduce the amount of irritation to the palm of the hands that is caused by gripping the trapeze bar. Grips are usually secured by straps that are fastened around the athlete's wrists. This proved to be the source of irritation for one athlete who had sustained a wrist contusion, which later developed into DeQuervain's tendinitis as a result of the grips continually compressing the wrist joint.

Several skin abrasions were the result of the athlete sliding across the net during a fall. This type of injury constituted three of the four thigh/buttock injuries that necessitated treatment. The abrasive nature of the net often caused burn-like injuries to the athletes if they slid across the net during a fall. This type of injury could have been prevented had the athletes been wearing costumes that provided protection to a greater area of skin. Unfortunately, the buttocks, legs, shoulders, arms and a significant amount of the back were exposed in the trapeze costumes. This situation warrants consideration in the design of future trapeze and aerial act costumes.

Two concussions were sustained during the practice/performance of the flying trapeze number. One injury occurred when an athlete was attempting a new skill and traveled too far horizontally, causing him to hit his head on the knee of the trapeze catcher. Contact was actually made between the flyer's chin (which resulted in a laceration), and the catcher's knee. The other concussion occurred in a similar manner when a flyer misjudged the distance to the catcher and hit his head on the catcher's shoulder. Two other head injuries, an abrasion caused by the net, and a contusion which occurred when an athlete was hit in the head by a spotting belt, were also sustained. Three dental injuries occurred among the flyers, two of which were sustained when the flyer hit his mouth on the trapeze bar, the other occurring in the flyer who hit his head on the catcher's shoulder while attempting to catch.

Eight injuries were sustained by the three trapeze catchers (Figure 4-10 and Figure 4-11). Two of the catchers suffered episodes of shoulder tendinitis which were caused by a similar mechanism that resulted in shoulder pain in the trapeze flyers. Both catchers complained of pain at the instant the flyer is caught, at which time the catchers shoulders are fully flexed, and the weight of the flyer must be sustained. Both of the acute injuries occurred at the point of catching the trapeze flyer, when the catcher was forced to reach out for the flyer, in an attempt to complete the sequence. This resulted in excessive stress being placed on various parts of the body that are not normally stressed if a catch is completed correctly, which may also contribute to stress related injuries. These injuries included a shoulder strain, and a costal cartilage sprain. One catcher sustained three tooth fractures over the course of the year from being kicked in the mouth by uncontrolled flyers. To review, there are two major factors that contribute to the high incidence of injuries in this particular number. The first, incorrect catches between the flyer and the catcher, which commonly led to injuries to either athlete; and the second, uncontrolled falls in the safety net. It is evident that biomechanically correct techniques of catching and landing in the net must be practiced consistently if injuries are to be avoided.

It is also important that a group of athletes that perform a number such as this have sufficient time to prepare and rehearse skills prior to performing the act for the public. It is, as previously explained, possible to practice safe catching techniques during training. If it is obvious to the catcher and the flyer at the time of the catch that a successful catch will not be possible, neither of the two will attempt to grasp the other. During practice, the pressure to complete every catch is minimal, but as soon as an audience is present, flyers and catchers make every attempt to complete a catch, which frequently has been shown to result in injury.

Sufficient time should be allotted for those who are embarking on creating a new trapeze number to train and practice basic skills first, prior to the introduction of more difficult aerial skills. It may be possible that this particular group of trapeze artists was allocated inadequate time to prepare the number before having to perform in a show situation. This could have been a contributing factor in the high frequency of injuries that were sustained by these athletes. Such an observation is difficult to substantiate without documentation regarding injury frequency and nature in other flying trapeze acts. It is also imperative that these athletes have an experienced coach to assist in their training and progress. These athletes only had skilled instruction for a limited time prior to the opening of the show, and a coach was rarely present once the show opened.

Dance Injuries

Six dancers play a significant role in the show Mystère, primarily to add to the artistic component of the show and to enhance the transitions between the numbers. The nature of the dance is a combination of classical ballet and modern dance. The amount of time each dancer spent on stage performing varied, although each dancer was required to attend three hours of dance class per week. The Mystère dancers sustained a total of 24 injuries, 20 lower limb injuries, and four back injuriesFigure 4-13). The majority of the injuries were minor joint sprains, followed in frequency by muscular strains and second degree sprains. The remainder of the injuries included mechanical back pain, nerve impingements, and tendinitis/bursitis type of injuries (Figure 4-12). Inversion ankle sprains accounted for eight of nine ankle injuries. This incidence of ankle injury is similar to another epidemiological study conducted on musculoskeletal injuries in theatrical dance students (Rovere et al., 1983). In this study, injury to the ankle occurred more than any other injury, and accounted for one in every five visits to the physician. The spine was the second most frequently injured site, followed in frequency by the foot, knee, hip and lower leg. The foot injuries sustained by the dancers in Mystère appear to be similar in nature to the reported foot injuries treated in the study conducted by Rovere et al.,(1983) as well. Four foot injuries were assessed and treated in this 12-month study, two incidences of plantar fasciitis (one recurrent), a great-toe sprain, and a mid-foot sprain. The low back and knee were the second most frequently injured site in Mystère dancers, followed by the hip, buttock, knee and lower leg. The preponderance of lower limb injuries that were assessed and treated in the dancers can be attributed to the excessive stresses that are placed on the lower body in dancers of this caliber, as well as the demanding training and performance schedules that they follow.

Chinese Poles Injuries

Twenty-two injuries were sustained by the athletes who performed the Chinese poles number. The various types of injuries that occurred have been illustrated in Figure 4-17. The most common type of injury was classified as tendinitis, followed by sprains and strains of varying degrees (Figure 4-14). Two abrasions, two contusions and one meniscal tear also occurred. Seventeen of the 22 injuries were upper limb conditions, and the remaining five injuries included two lower limb injuries, two back injuries and one dental injury (fractured tooth) (Figure 4-15). The significantly higher number of upper limb injuries was predictable considering the biomechanical components of the Chinese poles number, which is a climbing act. It is difficult to clarify the biomechanical components of this act by simply observing the athlete's performance of the particular skills. It is, however, appropriate to suggest that the majority of the strength that is needed to successfully perform many of the skills is derived from grip, forearm and shoulder musculature.

The "fungi" is a movement in which the athlete uses both strength and coordination to perform a series of inverted hops coupled with a half turn hop to face the pole, then another half turn to return to the inverted hop position. Two muscular strain injuries of the shoulder region were sustained by athletes performing this movement on the poles, and another AC joint sprain was sustained when an athlete hit the tip of his shoulder on the pole attempting to return to the inverted position of this movement, in which the pole is held between the shoulder and both hands. A forearm injury was sustained when an athlete performed an inverted twisting slide to the stage, holding onto the pole with his left hand, which resulted in a muscular strain. And finally, an elbow injury was sustained when an athlete attempted to jump to an inverted handstand position on the pole, hyperextending the elbow attempting to grasp the pole.

Wrist, elbow, and shoulder overuse injuries were all common problems attributed to Chinese poles. Shoulder tendinitis and forearm tendinitis were the most common overuse injuries, of which five cases were treated. Two of the shoulder injuries were recurrent inflammatory conditions that the athlete attributed to increased training of the "fungi" movement. One case of elbow extensor tendinitis was treated, and two athletes sustained skin abrasions on the superior aspect of the shoulder from repetitive friction between this part of the shoulder and the pole during the inverted hop.

Various other injuries were also attributed to Chinese poles. The lower limb injuries, all of which were acute in nature, varied in cause. One athlete suffered a meniscal irritation of the knee from climbing the poles with the knees fully flexed and the hips externally rotated. An athlete also developed a contusion to the lateral aspect of the lower leg from repeatedly performing a skill which required her to catch herself in an inverted position by wrapping one leg around the pole. Each time she performed the skill, she hit the lower leg in the same location. A similar injury was sustained by an athlete who performed a skill in which the pole was caught between the legs. This athlete suffered a severe groin contusion from repeated contact between the pole and the groin. This injury, which is not reflected in the graph, occurred during the pre-production period of training and is a common injury that occurs when this skill is initially learned, therefore has been included.

Equipment malfunction played a role in causing an injury to an athlete participating on the Chinese poles. This athlete suffered a fractured metatarsal while falling off the poles attempting a skill, and landing on an uneven surface (which should have been flat) below the poles. Such an injury could easily have been avoided had an equipment check been performed prior to the athlete having begun training.

The back injuries that occurred as a result of training/performance on the Chinese poles also varied in cause. Only one injury of gradual onset occurred, which was attributed to an increase in training of the inverted hop skill. Two contusions were sustained, one occurring when an athlete fell off the pole while attempting a skill, and landed on his back on the stage. The other contusion resulted from repetitive banging of a particular area of the back during an inverted catch, similar to the contusions that have previously been discussed.

When athletes begin their initial training on the Chinese poles, they most commonly complain of forearm and shoulder pain and fatigue. It is possible to perceive fatigue in the wrist, forearm and shoulder compartments due to the fact that virtually all of the athletes body weight is supported by these muscle groups. As well, it is possible to predict fatigue of the shoulder musculature due to the fact that the shoulders likely play a major role biomechanically during climbing as well as strength movements that are performed in a handstand or inverted position, which is also an impingement position of the shoulder.

Conditioning for the upper body is essential to prevent injury in the athlete who performs on the Chinese poles. Insufficient upper body strength will inevitably lead to muscle injuries and joint irritation. Similarly, it is important to avoid overuse type conditions that can easily occur with the monotonous repetition of similar skills that is necessary on this type of apparatus. It is also important that the appropriate type of protective padding is utilized as soon as the possibility of an injury becomes apparent. Various injuries that were attributed to Chinese poles were classified as contusions, attributed to repeatedly performing a skill which caused repeated contact between the pole and a particular part of the body. These types of contusions are avoidable with the simple use of protective foam or padding which the athlete can simply incorporate into his/her costume. Many of the skills that are performed on the Chinese poles result in predictable and characteristic types of contusions or irritations to the skin as a result of friction/contact between the skin and the poles. It is therefore important that those individuals involved in training these athletes are aware of these types of injuries and ensure the appropriate use of protective measures.

Bungee Injuries

Twenty-two injuries were attributed to bungee jumping, 13 gradual onset and nine acute injuries. Figure 4-16 illustrated the various types of injuries that the bungeists sustained. The most common type of injury was classified as tendinitis, followed by first degree strains. The remainder of the injuries ranged from contusion to abrasions and cysts (Figure 4-16). Figure 4-20 represented the anatomical distribution of the injuries that were sustained as a result of bungee training and performance.

As previously mentioned, the trapeze bar is used as the start and finish point of each successive aerial maneuver that is completed in the bungee routine. When the athlete misjudges the distance he/she must travel to re-grasp the trapeze bar, either due to an overestimation or an underestimation in the amount of bounce that is needed, it is not uncommon for him/her to either hit the bar with excessive momentum, or to miss the bar altogether. Two upper body muscular strain injuries resulted when the bungeists underestimated the amount of bounce that was needed, and as a result, were required to over-stretch to make a successful catch of the trapeze bar. Two injuries similarly occurred when bungeists were attempting to bounce and sit on the trapeze bar, instead of grasping the bar with their hands. In one attempt, a bungeist sustained abrasions to the inner aspect of both arms while passing over the trapeze bar and missing the trapeze swing's ropes. In another attempt, the bungeist hit the trapeze bar with the posterior aspect of the knee prior to pulling himself to an appropriate sitting position. The other acute injury occurred when a bungeist overestimated the amount of bounce that was required and jerked her head back to avoid hitting her face on the trapeze bar, which resulted in a cervical strain.

The bungee belt itself was implicated as the causative factor in a unique condition that occurred in two of the bungee jumpers. This condition, diagnosed as groin cysts, was believed to be caused by repetitive rubbing or friction in the groin area between the bungee belt and the athlete's skin.

The remaining 12 injuries that occurred as a result of bungee jumping were injuries of gradual onset, attributed to overuse; five cases of shoulder tendinitis (two of which were recurrent injuries), two cases of cervical facet joint syndrome, two cases of mechanical back pain, and two hip injuries that resulted from excessive pressure from the bungee belt progressively causing muscular inflammatory conditions.

Overuse injuries to the shoulders, which were common among the bungeist, may be attributed to the nature of the activity the bungeist must perform during a typical bungee practice or number. Much of the bounce that is attained by the bungeist is derived from the athlete's body weight and the force of gravity pulling the jumper downward. However, in order to perform various types of aerial movements the athletes must repeatedly use upper body strength to obtain the momentum that is necessary to successfully complete the skills. This momentum is attained by the bungeist as he/she pulls on the bungee cords with each ascending segment of the bounce. Additional stress may also be placed on the shoulder joints as a result of catching and hanging from the trapeze bar.

Upper body muscular strength and endurance are essential elements of physical fitness that are required to perform such a number. Too rapid an increase in training time, over-training, or a weakness in the scapular stabilization musculature of the shoulder may be contributing factors that relate to this type of shoulder pain and injury.

Both cases of cervical facet joint syndrome were believed to be caused by the repetitive neck hyperextension that is required as the bungeist looks up while ascending to catch the trapeze bar. The three cases of mechanical back pain were attributed to pelvic muscle imbalances. The speculated cause of these muscle imbalances was the effect the bungee belt had on the movement and mechanics of the pelvis, low back and hip joints. A bungee belt needs to be developed that facilitates stabilization of the bungee jumper's pelvis without influencing the movements at the above mentioned joints. To date, such a bungee belt has yet to be constructed, although experimentation with different bungee belt designs is currently being done.

Manipulation Injuries

The three manipulators sustained 11 injuries during training and performance of this number. These performers may be susceptible to repetitive strain injuries because of the particular posture that must be maintained during both rehearsal and performance of this number. Excessive stress is placed on the neck, shoulders and back when the jugglers perform with either the ball(s) or the shape. Due to the size of the shape, it is possible to rotate the shape successfully only if it is held at a significant distance from the body. This requires the juggler to sustain certain shoulder positions for extended time periods. For example, to rotate the shape, the shoulders must be flexed to approximately 40 degrees, and slightly abducted (due to the width of the shape), throughout this part of the number. Maintenance of this particular posture places stress on the muscles of the neck, shoulders and upper back. Evidence of this stress was observed in two cases of shoulder tendinitis, one case of long head of biceps tendinitis, and the other infraspinatus tendinitis. A common complaint of these performers was persistent tightness and irritation of the cervical and upper thoracic paraspinal muscles, the trapezius and the rhomboids. In addition to the stress placed on the upper body postural muscles, the jugglers spent a significant amount of time with the neck in a hyperextended position. This proved to be the source of irritation in one juggler who developed a cervical facet joint syndrome. The other two injuries of gradual onset were elbow injuries. One performer developed an ulnar nerve irritation from holding the shape behind his head with his arms in an abducted and externally rotated position, which resulted in a traction/stretching of the ulnar nerve. The other elbow injury was assessed and treated as epicondylitis of the medial epicondyle, which was believed to be caused by repetitive work with the shape held with the forearm in a supinated position, with the elbow slightly flexed, and the shoulder flexed to approximately 40 degrees. The lower back injuries were both attributed to fatigue and overuse.

The number itself lasts for approximately 10 minutes, but countless hours of rehearsal are required to perfect these juggling acts. These performers characteristically practice 2-3 hours daily in addition to their performance in 12 weekly shows. The cumulative stress of training sessions and show performance can likely be implemented as the main causative factor in the above noted overuse injuries.

Hand-to-Hand Injuries

The two athletes who perform this particular number had been working together for approximately four years at the onset of the data collection, and therefore were well conditioned and familiar with the physical requirements of the act. Muscular strength and endurance, coordination, balance, and flexibility are required on the part of both the porter and the athlete who is being supported, if the number is to appear aesthetically pleasing to the audience. Originally, however, the act was created to be performed on a stationary, flat surface. Therefore, the two athletes had to make the transition to performing the number on the revolving dome. Several minor injuries were sustained by the two performers prior to the termination of their participation in this show which was inevitable after one of the athletes was diagnosed with syringomyelia.

Opening, Transitions, Finale, Stilts, and Taiko Injuries

Various injuries occurred during the opening of the show, finale, transitions, stilts and taiko. Walking on the stilts resulted in four injuries, all of which related to the mechanical design of the stilts and the stilts costume. The athlete walks on the stilts while wearing a headpiece that is secured to a shoulder harness. The weight of the headpiece of the costume was considered to be the causative factor in both a cervical strain and a thoracic strain injury. A third athlete suffered from an irritation of the patellofemoral joint which was believed to be caused by the attachment of the stilts to the boots, which may have been placed too far posteriorly, causing abnormal loading of the patellofemoral joint.

Two injuries were caused by playing taiko, and the particular upper body mechanics that are used to play this type of drum. The first injury that occurred as a result of playing taiko was attributed to a lateral arm swing that is used during a particular type of drumming stance. This drum is played while the individual stands with the side of the body facing the drum, and the arm is brought across to body to strike the drum. Normally, the drums are played while the individual faces the drum, and an exaggerated shoulder flexion motion is performed prior to each strike of the drum. This repeated shoulder flexion was likely the cause of the tendinitis injury that one athlete developed after a period of increased training time.

The injuries that occurred during the opening and finale were likely related to the nature of the activity of the performers during these two parts of the show. During the opening, several characters referred to as "spermato" intermingle with the audience. These characters "play" with the members of the audience, and they are required to appear energetic and agile, climbing on the seats, staircases, railings and various parts of the stage. Injuries that occurred during the transitions were attributed to similar factors as those that occurred during the opening and finale. Various activities that range from dancing and gymnastic-type skills, to rigging of equipment occurs during these transitions. The majority of the injuries were simply attributed to accidental occurrences that probably could not have been prevented.

Several injuries were, however, attributed to equipment failure or improper placement of props backstage. These types of injuries can and should be prevented if the stage management staff and the athletes that are working backstage are conscious of the potential for injury. Three ankle sprains were caused by water on the stage, which had accumulated as a result of the use of a device that makes smoke, a special effect during the show. Another ankle sprain occurred when an athlete tripped on a part of the stage that had an uneven surface. The stage that is used in this show is actually composed of four different pieces, each of which has the capacity to ascend and descend independently. In this particular incident, the athlete was unaware that two parts of the stage were not level, (which they should have been), and as a result, the athlete fell. Another athlete, a trapeze catcher, sustained severe burns to the palms of his hands when cables that are part of the trapeze rigging malfunctioned. A major risk factor in a set such as the one used in this show is the fact that a majority of the props, equipment, and apparatus function automatically, being controlled by computer input. This increases the potential for mechanical error and subsequently, for human injury.

Overuse Injuries

Several other overuse injuries could not definitively be attributed to one single factor. These twenty-five injuries were all believed to be caused by participation in several parts of the show, which cumulatively resulted in the injuries (Figure 4-18). Thirteen of the injuries were to the lower body, (Figure 4-19) 11 of which occurred in members of the troupe maison, who are required to participate in the teeterboard number, the Chinese poles number, and various other pieces of choreography that require running and jumping on stage. Overuse injuries occurred most frequently in the lower limb, followed by the spine and trunk, and the upper limb (Figure 4-24). The most common types of overuse injuries that were documented were tendinitis, facet joint syndromes, and medial tibial stress syndrome.

Overuse injuries characteristically occur to those individuals who simply participate in too many parts in the show, with insufficient rest. This problem is often compounded by the fact that when an athlete gets injured, other athletes are given additional cues to cover the roles of the injured athlete. This places added stress on those that may already be performing too much. Consequently, those that are replacing injured athletes themselves sustain injuries because of overwork. Therefore, it is essential that there be a sufficient number of performers to act as replacements when an athlete is injured, without putting additional stress on a select few athletes that are trained to perform in the various numbers in the show.

Summary

It would be unrealistic to visualize complete elimination of injury in an athletic population such as the cast of Mystère, but it is necessary to attempt to minimize both the number and severity of injuries that do occur.

In order to attempt to make further suggestions as to how injuries may be prevented, an overview of their causes may provide some insight. To maintain consistency with the previous descriptive analysis that has been done on each segment of the show, this overview will be broken down into factors that may lead to acute vs. overuse injuries. To further simplify causative factors, internal variables (factors that relate to the athletes skill/ability, body type, posture, etc.) and external variables (factors that the athlete has less control of, for example, equipment, skill of other athletes, costumes, etc.) will be considered separately.

The acute injuries that occurred during the study period have been attributed to several internal variables. For example, inadequate warm-up, poor conditioning, lack of strength, poor biomechanics/technique with which the skill is performed, lack of skill (to rapid a progression in skill difficulty), fear/anxiety (of individual's own ability, or the ability of others), lack of concentration while attempting skills, previous injury (may render the normally capable athlete incapable of performing necessary skills), and return to performance/training too soon after an injury, before the athlete is physically and psychologically ready to perform. This final point substantiates the need for physician/therapist clearance to return to activity, which is not always obtained. Formal guidelines that delineate the functional requirements that must be met by the athlete prior to return to participation should be implemented. These should include appropriate testing, for example, Cybex strength testing, and functional evaluations, as well. Ideally, each athlete should be given an individualized stretching and strengthening program that is specific to his/her weaknesses prior to injury. This is often done in the event of an injury, although adherence to the program is difficult to ensure.

External variables that have contributed to acute injury include poor timing (while performing a stunt) between two athletes which may result in a fall (many skill/stunts are performed by two or more athletes, therefore good communication is essential between those who are participating). Poor timing may be caused by a lack of communication or misinterpreted messages between two or more athletes. This may occur, for example, because the show music is too loud or the stage lighting is too dark. Equipment fault/failure (apparatus rigged incorrectly), poor spotting or insufficient safety equipment, poor use of the lounge (spotting belt), or lack of use of the lounge, poor coaching or insufficient instruction/supervision during training, and interference from costumes, props or apparatus are additional factors that may contribute to the incidence of injury. Costumes are an important consideration because the athlete must be able to move freely and perform difficult skills while wearing a variety of different costumes. As discussed in previous sections, the costumes were implicated as contributing factors in several injuries. For example, the headpieces of the stilts costumes are heavy and tall, which places excessive stress on the muscles of the neck and upper back which must be used to control that piece of the costume. The trapeze costumes provide minimal coverage to areas of skin that are susceptible to abrasions from the trapeze net. The headpieces of the teeterboard costumes often are not secured well, and consequently move while the athlete is in mid-flight, which makes it difficult for the athlete to see his/her landing. The shoes that are worn by a majority of the cast are non-supportive and they lack shock-absorption capacity, which has led to overuse/stress injuries to the lower legs and feet. The bungee belts have led to friction irritations in the hip/pelvic region, and may be a contributing factor in low back pain that is common in the bungee artists. An in-depth analysis of the affect that costumes and the apparatus used by these performers is necessary to obtain a true idea of the role that they play in injury.

Overuse injuries, or injuries of gradual onset, may be caused by internal factors such as increased training time, over-training/overwork, poor warm-up/conditioning, muscle imbalances, inflexibility, postural problems, poor structural alignment, poor skill biomechanics, previous injury (injury may cause athlete to favor other parts of the body to reduce the amount of stress on the injured body part) and fatigue. Fatigue is likely one of the most important factors in injury occurrence. Physical and mental fatigue may lead to increased numbers of overuse and acute injuries. One important aspect of most sports with regard to injuries and healing time is the off-season. The presence of an off-season in which to rehabilitate and condition is not, unfortunately, a part of a production show such as this, which runs continually. It is often difficult to convince an athlete that they need to take time off to allow healing when their pain is persistent, yet tolerable. Instead, they participate with pain until they sustain a more serious injury which renders them non-functional. The consequence of this is a longer rehabilitation period. It often takes several weeks to months to rehabilitate from a serious injury which would have healed in a much shorter amount of time had the athlete allowed healing to occur when symptoms initially began. This problem is magnified not only by the athlete pushing him/herself through injuries, but also by pressure from artistic staff to return to participation before the athlete is ready. It is important that there are a sufficient number of athletes available as replacements for those that are injured, which is rarely the case. With an insufficient number of performers, when injuries occur, extra cues are distributed among other cast members, which inevitably increases their workload, and places them under additional stress and increased risk of injury.

External factors that may contribute to overuse injuries include; effects from the costumes that are worn, the effect of the headpieces that are worn, shoes (may lack support and shock absorbing capacity), the effect of apparatus (for example, stage too hard a surface to work on, teeterboard lacking sufficient cushioning, teeterboard too stiff, trapeze net too abrasive, stilts may change lower limb walking mechanics, bungee belts may change mechanics of the pelvis) and insufficient coaching of technique and skill. It may be possible to utilize an analysis such as this to educate those that coach athletes in these particular activities, so that they are also aware of potential factors that lead to injury. The coach should play a role in detecting athletes that are at risk of injury, whether it be from improper technique, fatigue, or psychological problems.

All of these factors have been cited, to one extent or another, as possible causes of the 329 injuries that were sustained by 62 athletes that compose the cast of Mystère.

Chapter Six Summary and Conclusions

Athletes who perform the show "Mystère" were the focus of a 12-month epidemiological study conducted to determine the nature and distribution of injuries and their causative factors as they relate to Cirque du Soleil performers. Their ages ranged from 18-45 years, and they included both male and female athletes. Data collection was done on a daily basis using 'injury report forms,' and daily exposure sheets were used to determine time lost from shows due to injury. Twelve shows were performed per week, with Monday being a regular day off. This data was recorded and entered into the Microsoft Access relational database program used with an IBM-PC computer for collection and analysis. The study was conducted because research of this type had yet to be done with an athletic population of this type. The unique nature of the apparatus and the skills that are performed by these individuals warranted the inclusion of a brief section describing each apparatus and several biomechanical analyses of various skills that are performed.

Based on the results of the study, the following conclusions appear to be justified:

1. The rate of injury was found to be 531 injuries per 100 athletes, and 10 injuries per 1000 exposures.

2. Females sustained a higher number of injuries (6.4) than the males (5.0) over the data collection period.

3. Athletes who performed in the trapeze act sustained the highest number of injuries per performer (6.20).

4. Athletes who performed in the Chinese poles act sustained the lowest number of injuries per performer (2.44).

5. Fifty-one percent of all injuries occurred during show performance, 9.7% occurred during training, and 33 % occurred over a period of time (gradual onset).

6. Sixty-seven percent of all injuries were acute in nature, while 33 % were of gradual onset (overuse injuries).

7. The body part most susceptible to acute injury was the ankle, followed by the low back, neck, shoulder and the knee.

8. The body part most susceptible to gradual onset, overuse injuries was the shoulder, followed by the low back, knee, lower leg, and hip/buttock.

9. The most common injury types were first degree sprains and strains, followed by tendinitis and contusions.

10. For all of the acts, insufficient warm-up, previous injury, and return to performance too soon following an injury contributed to injury.

11. Acute injuries were attributed to several factors which included: poor conditioning, poor biomechanical techniques, lack of skill, fear/anxiety of injury, lack of concentration while performing skills, equipment failure, poor communication between two performers, poor spotting, insufficient safety equipment, and interference from props or apparatus.

12. Overuse injuries were attributed to several factors which included: increased training time (a rapid increase in training without the body having sufficient time to adjust), over-training, muscle imbalances, inflexibility, postural problems, poor skill biomechanics, previous injury, fatigue, effects from costumes, and effect of apparatus.

13. This information will provide a base of information from which future therapists and other medical staff, and current coaches and trainers can learn and expand knowledge. As Cirque du Soleil grows and develops as a company, the medical aspect of the productions have become more of a concern, and more time and money are being invested in the care of the individuals who make these types of show a reality.

Recommendations

1. Implementation of this database for ongoing tracking of injury and exposure data may be helpful to predict injury nature and patterns. The possibility of incorporating this data collection system into the medical department of each show that is created by Cirque du Soleil in the future, as well as the currently running productions, is being explored. This would facilitate tracking of injury information in each show and allow comparisons to be made between different acts and types of performances. The need for a tool to collect and analyze data on an ongoing basis is evident as Cirque du Soleil is a relatively young corporation which is expanding rapidly. Research is needed with regard to the long-term effect of performance in unique athletic creations such as the show Mystère.

2. The database may be used to develop conditioning and rehabilitation programs that are specific to the various apparatus used during Cirque du Soleil performances. As well, teaching coaches about biomechanics and injury prevention can be improved if such information is available.

3. Long-term injury tracking should be used for both financial and insurance purposes using this database for all of the shows that Cirque du Soleil creates.

4. Casting new athletes for potential employment with Cirque du Soleil should make use of information derived from the database. Each athlete invariably begins their employment with Cirque du Soleil already having had a variety of sport-related injuries. This is to be expected when the most common arena from which these athletes are recruited from gymnastics, trampoline and diving. Information regarding common injuries and anatomical locations with respect to specific activities allows detection of those individuals better suited for one type of apparatus as opposed to another.

5. Further research is necessary in the area of biomechanical analysis of the various skills that are performed by these athletes. This type of research may be used in conjunction with injury information to create injury prevention and rehabilitation programs.

6. For future data collection, injury report forms should include a category that clearly defines the cause of injury, for example, equipment failure, costumes, or skill technique. This would enable those individuals that have the power to change these factors (artistic directors and producers) to appreciate the magnitude of the effect that they have on the athletes.

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Appendix A

RESEARCH PROJECT CONSENT FORM

This consent form is part of the process of informed consent. It should give you the basic idea of what this research project is about and what your participation will involve. If you would like more information about something mentioned here, you should feel free to ask. Please take the time to read this carefully and understand any accompanying information.

The purpose of this project is to determine if it is possible for an artistic injury reporting system to be used for the show Mystere. Your participation will consist of allowing:

(i) access to pre-show examination (medical) forms,
(ii) the athletic therapist to record your level of participation in training and shows, and
(iii) having the athletic therapist fill out an injury report form if you sustain an injury.

This information will be recorded weekly , and your name will be removed from all information. This information will identify injury patterns, assess the predictability of injury and form a basis for injury prevention.

This will all be done as part of your normal medical care, so there will not be any commitment of time from you, aside from five minutes to complete this consent form.

The results of any data will be confidential, and confined to the purposes of injury reporting and prediction. Release of any information for research purposes, including publishing results and giving feedback to your production staff, will not identify you by name. If the nature of an illness or injury is such that you might be identified, it will not be released. You may benefit from this research, since it will be used to start an injury prevention program.

Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in this research project and agree to participate as a subject. In no way does this waive your legal rights, nor release the investigators, sponsors or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time without jeopardizing your health care, or your status or activity with the Cirque du Soleil. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

Please ask either athletic therapist if you have any further questions concerning matters related to this project.

____

Name of artist

____

Signature of artist (or parent/guardian if not of legal age)

____

Name of witness

____

Signature of witness

____

(Date)

If you agree to be involved in this project, please indicate if you would <u>also</u> allow us to contact you at a later date **if** more information is needed:

q YES, I will allow   q NO, I will not allow

Appendix B
Individual Injury Report Form

1. Artist's Name: ____________________ **2. Date of Injury:** ____________

3. Normal Role in Show: ❑ Member of Troupe Maison
❑ Dancer ❑ Bungeist ❑ Trapeeze Artist
❑ Hand to Hand ❑ Single Pole ❑Chinese Poles (Chinese)
❑ Actor ❑ Clown ❑ Musician

4. Injury Status:
❑ New Injury
❑ Ongoing Injury
❑ Recurrence of injury from previous Mystere show
❑ Recurrence of non/other sport, activity, show injury

5. Was **bracing or taping** used on the injured area or limb at the time of injury?
❑ No
❑ Yes
if so, what type? ____________

6. Did artist **return to perform** the same show or practice?
❑ No
❑ Yes

7. This Injury Involved:
❑ Fasttrack
❑ Fasttrack Exit
❑ Tetterboard Spotting
❑ Teeterboard Jumping
❑ Teeterboard Exiting
❑ Trapeze Flying
❑ Trapeze Exiting
❑ Trapeze Catching
❑ Opening
❑ Transition
❑ Dancing
❑ Other
❑ Chinese Poles
❑ Bungeing
❑ Pulling Bungee Trapeze
❑ Trampoline
❑ Manipulating
❑ Main a Main
❑ Stilts
❑ Finale
❑ Overuse
❑ Taiko

8. Injury Occurred During:
❑ Warm-up
❑ Training
❑ 7: 30 Show
❑ 10: 30 Show
❑ Gradual Onset
❑ Weight Training
❑ Other Conditioning
❑ Other Sport
❑ Non Sport

❑ Tuesday
❑ Wednesday
❑ Thursday
❑ Friday
❑ Saturday
❑ Sunday
❑ First Wk Po
❑ Second Wk
❑ Third Wk po

10. Mechanism of Injury (i.e. force placed on body segment):
❑ Unknown ❑Known
Remarks:, ____________________
(Subjective report of cause; e.g. unsafe action, hazardous conditions, equipment, contact etc.)
Other Assessment Notes: ____________________

Assessment: ____________________
Side (Right/Left/Both) **Body Region** (and structure) **Type of Injury** ("Diagnosis") e.g. Right shoulder A/C joint 3° sprain
Treatment Plan- Initial ("first aid"): ____________________

Treatment Plan- Subsequent: ____________________

Your Estimate of Time Loss from Injury (days): ____________ **Therapist's Name** (print): ____________
Therapist's Signature: ____________

If athlete was seen by a physician, please record:

Physician's Diagnosis: ____________ **Physician's Name** ____________

Physician's Treatment Plan: ____________________

Appendix C

Analysis of Variance: Number of injuries per performer in each act (Table 4-1)

Act	Manipulation	Chinese Poles	Hand to Hand	Bungee	Teeterboard	Trapeze	Dancers	Taiko	Stilts
Members									
1	6	5	4	7	9	14	7	1	1
2	1	4	3	6	8	12	6	1	1
3	4	3		4	5	9	5	1	1
4		3		3	6	8	4		1
5		2		1	5	4	1		
6		2		1	7	4	1		
7		1			6	3			
8		1			1	2			
9		1			6	1			
10					5	5			
11					2				
12					4				
13					1				
14					8				
15					5				
16					8				
17					1				
18					5				
19					4				
20					1				
21					3				
22					1				

N	3	9	2	6	22	10	6	3	4	65
Σ X	11	22	7	22	101	62	24	3	4	256
Mean X	3.67	2.44	3.50	3.67	4.59	6.20	4.00	1.00	1.00	1008.25
Σ X sqr.	53	70	25	112	605	556	128	3	4	1556
Σ X / N	40.33	53.78	24.50	80.67	463.68	384.40	96.00	3.00	4.00	1150.36

Between	142.11
Within	405.64
Total	547.75

	S.Sqrs	Deg Free	Mean Sqr	
Between	142.11	8.00	17.76	
Within	405.64	56.00	7.24	
Total	547.75	64.00	2.45	F Value

F Value = 2.45 is significant at P = 0.05, but not at P=0.01

Appendix D
Analysis of Variance:Number of Injuries in Trapeze Athletes vs. Cast

Trapeze	Cast
7	6
12	4
9	1
8	5
5	4
4	3
4	3
3	2
2	2
1	1
	1
	1
	4
	3
	7
	6
	4
	3
	1
	1
	9
	8
	5
	6
	5
	7
	6
	1
	6
	5
	1
	2
	4
	1
	8
	5
	8
	1
	5
	4
	1
	3
	1

		7	
		6	
		5	
		4	
		1	
		1	
		1	
		1	
		1	
		1	
		1	
		1	
n	10.00	55.00	65.00
Sum x	55.00	194.00	249.00
Mean x	5.50	3.53	953.86
Σ x sqr	409.00	1000.00	1409.00
(Sum x)sqr/n	302.50	684.29	986.79

	Sum Sqrs	Deg Free	Mean Sqr
Between	32.93	1	32.93
Within	422.21	64.00	6.60
Total	455.14	65	4.99

F=	4.99
0.05	4.00
0.01	7.08

F value=4.99, significant at 0.05 but not at 0.01

Appendix E
Analysis of Variance:Number of Injuries in Teeterboard Athletes vs. Cast

Teeterboard	Cast
9	6
8	1
5	4
6	5
5	4
7	3
6	3
1	7
6	7
5	1
7	1
4	1
1	4
8	3
5	7
8	6
1	4
5	3
4	1
1	1
	14
	17
	9
	8
	5
	4
	4
	3
	7
	1
	7
	6
	5
	4
	1
	1
	1
	1
	1
	1
	1
	1
	1

n	20.00	43.00	63.00
Sum x	102.00	175.00	277.00
Mean x	5.10	4.07	1217.92
Σ x sqr	640.00	1231.00	1871.00
(Sum x)sqr/n	520.20	712.21	1232.41

	Sum Sqrs	Deg Free	Mean Sqr
Between	14.49	1	14.49
Within	638.59	62.00	10.30
Total	653.08	63	1.41

F=	1.41
0.05	4.00
0.01	7.08

F value=1.41, insignificant at 0.05 and 0.01

Appendix F
T-test:Number of Injuries in First vs. Second Show

Subject #	First Show	Second Show	D	D sqr
1	1	6	-5	25
2	0	0	0	0
3	1	5	-4	16
4	3	6	-3	9
5	0	1	-1	1
6	1	4	-3	9
7	3	1	2	4
8	0	2	-2	4
9	3	8	-5	25
10	1	1	0	0
11	1	0	1	1
12	1	3	-2	4
13	0	0	0	0
14	1	0	1	1
15	2	2	0	0
16	3	0	3	9
17	0	0	0	0
18	0	0	0	0
19	0	1	-1	1
20	3	6	-3	9
21	0	0	0	0
22	2	2	0	0
23	3	1	2	4
24	0	0	0	0
25	1	1	0	0
26	2	1	1	1
27	1	0	1	1
28	1	0	1	1
29	5	1	4	16
30	1	4	-3	9
31	1	3	-2	4
32	0	0	0	0
33	1	0	1	1
34	1	0	1	1
35	0	0	0	0
36	0	2	-2	4
37	2	2	0	0
38	1	3	-2	4
39	0	0	0	0
40	5	3	2	4
41	4	3	1	1
42	0	0	0	0
43	0	0	0	0

44	6	3	3	9
45	0	0	0	0
46	1	1	0	0
47	1	1	0	0
48	3	2	1	1
49	2	2	0	0
50	0	0	0	0
51	0	1	-1	1
52	0	0	0	0
53	1	2	-1	1
54	0	0	0	0
55	0	1	-1	1
56	0	0	0	0
57	0	0	0	0
58	1	2	-1	1
59	1	3	-2	4
60	1	2	-1	1
61	1	1	0	0
62	1	1	0	0

Sum x	74.00	94.00	-20.00	188.00
Mean x	1.19	1.52	-0.32	
N	62			
N(Sum D)	11656			
(Sum D)sqr	400			

T=	-1.47
0.05	2.00
0.01	2.66

T value=1.47, insignificant at 0.05 and 0.01

Appendix G

Analysis of Variance:Number of Injuries Between Males and Females

Males	Females
1	1
1	2
1	2
1	3
1	4
1	6
1	7
1	8
2	8
2	8
2	9
3	9
3	10
3	12
3	
3	
3	
3	
3	
4	
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12
12
15
19

n	48.00	14.00	62.00
Sum x	240.00	89.00	329.00
Mean x	5.00	6.36	1745.82
Σ x sqr	1884.00	717.00	2601.00
(Sum x)sqr/n	1200.00	565.79	1765.79

	Sum Sqrs	Deg Free	Mean Sqr
Between	19.96	1	19.96
Within	835.21	61.00	13.69
Total	855.18	62	1.46

F=	1.46
0.05	4.00
0.01	7.08

F value =1.46, insignificant at 0.05 and 0.01