

Incidence of Injury in Relation to Limb Dominance in Arizona State University

Men's and Women's Gymnastics Teams

by

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ABSTRACT

Previous research on gymnastics injuries has examined several differences in the types of injuries and event/location where injury is most likely to occur. This research shows that male gymnasts are more likely to have more upper body injuries compared to lower body injuries whereas female gymnasts are more likely to have lower body injuries. The majority of all gymnastics injuries are sprains that are most likely to occur during the landing phase on the floor exercise during routine performance or competition. Gymnastics injuries are also more prevalent in older gymnasts, like those at the collegiate level. However, there is limited research on the effects of limb dominance on injury occurrence in both male and female gymnasts at the collegiate level.

This study was designed to examine the effect of both upper and lower body limb dominance on injury occurrence in Division I male and female gymnasts at Arizona State University during competition season.

Thirty-seven subjects were recruited from the Arizona State University Men's and Women's Gymnastics teams. Athletic trainers/coaches from each team were asked to record injury incidence during the 2013 competition season from January through April. Injury type, body location, event of occurrence, and location of injury (practice or competition) were recorded along with the gymnast's upper and lower body limb dominance (right or left).

Statistical analysis shows that there is a significant difference between male and female gymnasts in that female gymnasts are more likely to be injured than their male counterparts ($P = 0.023$). However, there were no significant findings between

limb dominance and injury incidence. Limb dominance did not show any relationship with side of injury, but a trend in the data shows that right-sided dominant athletes, both upper and lower body, were more likely to be injured overall than left-sided dominant athletes. A trend in the data also shows that injury is more likely to occur on the floor exercise than any other gymnastics event for both men and women.

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Chapter 1

INTRODUCTION

Gymnastics has recently been reported as the most popular sport that girls participate in within the United States (O’Kane, Levy, Pietila, & Caine, 2011). Due to the increase in participation along with increases in competition, training load, and difficulty or skill level of the sport, injury risk factors have begun to rise. With an increase in injury risk factors, more acute injuries are also developing (Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003). Both men and women participating in gymnastics have shown greater incidence of injury compared to athletes participating in other sports like basketball, fencing, swimming, tennis, track (indoor and outdoor), and volleyball. There is evidence that shows only about 3 percent of gymnasts remained injury-free after a single training and competition season (Lanese, Strauss, Leizman, & Rotondi, 1990).

Research has shown the majority of injuries occur within the lower limbs (Murphy, Connolly, & Beynnon, 2003) of the gymnast’s body (Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003; Lanese, Strauss, Leizman, & Rotondi, 1990; Marshall, Covassin, Dick, Nassar, & Agel, 2007; O’Kane, Levy, Pietila, & Caine, 2011; Sands, Shultz, & Newman, 1993). However, there is some mixed evidence showing wrist pain to be the most common complaint (Keller, 2009), and that male gymnasts sustain more upper body injuries due to the apparatus difference (Keller, 2009; Lanese, Strauss, Leizman, & Rotondi, 1990). There is also evidence that supports the notion that more injuries are likely to occur during performance of routines and during competition season rather than with individual skills training or pre-competition training even when the number of hours

engaged in practice or competition were accounted for (Murphy, Connolly, & Beynnon, 2003; O’Kane, Levy, Pietila, & Caine, 2011; Sands, Shultz, & Newman, 1993). Due to this evidence, this research will be conducted during the gymnasts’ competition season. With competition season held constant, Division I female gymnasts have a higher incidence of injury than Division III female gymnasts (Marshall, Covassin, Dick, Nassar, & Agel, 2007). Athletes with a higher skill level may practice and compete at a greater intensity than their lower skill level counterparts creating an increased injury risk (Murphy, Connolly, & Beynnon, 2003). Therefore, this current study will include Division I female gymnasts and highly competitive male gymnasts from Arizona State University. When it comes to gender, there is some evidence showing that 12-year-old females are more likely to be injured during the landing phase on the floor exercise compared to their male counterparts (Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003). Typically more injuries were found to be highest on the floor exercise, especially during the landing phase (Lanese, Strauss, Leizman, & Rotondi, 1990; Keller, 2009; Marshall, Covassin, Dick, Nassar, & Agel, 2007; O’Kane, Levy, Pietila, & Caine, 2011) along with dismounting (Keller, 2009; Marshall, Covassin, Dick, Nassar, & Agel, 2007). This study will examine the event and skill where injury occurs to further support or refute this evidence. Another study examined gender differences among college athletes within a variety of sports and found that out of 8 sports, gymnastics was the only sport that was different between males and females in terms of injury incidence throughout an entire academic year (Lanese, Strauss, Leizman, & Rotondi, 1990). This may be due to a difference in hours and number of events trained. Age is another factor that influences the injury rate in gymnastics. Research shows that older gymnasts tend to suffer more

injuries than youth and children 18 and under involved in competitive club gymnastics (Keller, 2009; O’Kane, Levy, Pietila, & Caine, 2011). This may be due to the number of hours practiced along with the hormonal change that occurs as the athlete ages. The difference may possibly be attributed to work ethic and the cumulative hours spent training. Older athlete have been competing at a high level for much longer than younger athletes and therefore have greater cumulative musculoskeletal stress.

Much of this research has not included men’s gymnastics. Those few studies that have, show promising evidence that females are more likely to be injured than their male counterpart (Keller, 2009; Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003; Lanese, Strauss, Leizman, & Rotondi, 1990). The majority of this research has been done on gymnasts under age 18 (Keller, 2009; Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003) except for one study in 1990 examining intercollegiate gymnastics (Lanese, Strauss, Leizman, & Rotondi, 1990). However, this research did not include any evidence that higher level male gymnasts (Division I vs. Division III) have a greater injury risk like their female counterparts. Due to the ever-changing demands of the sport, this evidence needs to be updated and examined in greater depth to determine if a gender difference continues to exist.

The published research examining whether the incidence of injury is related to the preferred, dominant limb of the gymnast is extremely limited. The closest evidence we have within the gymnastics population is the study by Sands, Shultz, and Newman (1993) indicating that the right side of the gymnast’s body underwent a greater amount of injuries than the left side for both new and continuing injuries. There is conflicting evidence of injury incidence and leg dominance within other sports. More quadriceps

injuries are likely to occur in the dominant kicking leg for Australian Football League Players (Orchard, 2001). Research examining a large number of athletes in a variety of sports, found that the individual's dominant leg had a higher likelihood of becoming injured than the non-dominant leg (Yeung, Chan, So, & Yuan, 1994). One study of left leg-dominant soccer, lacrosse, and field-hockey players found a higher incidence of left ankle sprain for both men and women (Baumhauer, Alosa, Renstrom, Trevino, & Beynnon, 1995). However, another study showed no relationship between leg dominance and ankle injury found for men and women soccer, lacrosse, or field hockey players in both male and female college athletes (Beynnon, Renstrom, Alosa, Baumhauer, & Vacek, 2001). Based on observation, gymnastics seems to greatly depend on leg dominance to perform the majority of the skills, therefore leg dominance may play a significant role in injury incidence and needs to be examined in this population.

As far as we know, there has not been any research specifically defining leg/arm dominance in gymnastics. This research will define leg dominance as the leg most commonly used for pushing off and landing skills, and arm dominance as the arm the athlete plants and turns on most often for his/her skills. Each gymnast will be able to verbally express what this side is being that leg/arm dominance is commonly referred to within this population.

The importance of this research is to identify if a gender difference exists along with a relationship between leg dominance and injury incidence to further provide athletic trainers, coaches, and gymnasts evidence for preventative rehabilitation to decrease the injury incidence rate during the competition season. Evidence may also be

provided to determine the event and skill where the injury will most likely occur to also be used for preventative rehabilitation purposes for coaching, conditioning, and physical therapy treatment.

PURPOSE OF STUDY

The primary purpose of this prospective study was to examine the relationship between limb dominance and incidence of injury in the lower and upper extremities of Arizona State University Men's and Women's Gymnastics teams during the 2013 competition season. The secondary aim of this study was to determine if a gender difference exists in relation to lower or upper extremity injury type and occurrence.

RESEARCH AIM AND HYPOTHESIS

Our primary hypothesis is that there will be a null effect when comparing the dominant limb to the non-dominant limb with incidence of injury in the lower and upper extremities for both men and women on Arizona State University's gymnastics teams during the 2013 competition season. We also hypothesize that there will be a null effect when comparing gender with lower and upper extremity injury occurrence and type.

DEFINITION OF TERMS

- Lower extremity: includes the hip, thigh, lower leg, knee, ankle and foot areas (Powell, & Barber-Foss, 2000)
- Upper extremity: includes the shoulder, upper arm, elbow, forearm, wrist, and hand areas (Powell, & Barber-Foss, 2000)
- Injury: musculoskeletal; causes participation in gymnastics to be limited or discontinued for that session or longer (Powell, & Barber-Foss, 2000; Sands, Shultz, & Newman, 1993)
- Dominant leg: the primary leg favored by the gymnast for use in performing, taking off, and landing skills based on individual preference by the athlete him/herself

- Dominant arm: the favored arm that the athlete plants or turns on when performing the majority of his/her skills
- Athlete: an active participant competing in at least 1 competition on at least 1 event during the given 2013 season

DELIMITATIONS AND LIMITATIONS

Delimitations of this study are that the population only consists of Division I male and female gymnasts currently competing for Arizona State University during the 2013 competition season. Some subjects only train certain events or may not compete and may therefore be prone to more/less injury.

The limitations to the study are that athletic trainers will also provide the injury incidence data based on a standardized definition of “injury” that has been determined from previous research. Having medical personnel, like an athletic trainer, record the injury has also been found to be a gold standard within previous research.

Chapter 2- Review of Literature

LIMB DOMINANCE

Baumhauer, Alosa, Renstrom, Trevino, and Beynnon (1995) conducted a study to identify the risk factors for ankle injuries in 145 men and women college-aged lacrosse, soccer, and field hockey players by comparing joint laxity, anatomical alignment, isokinetic ankle strength, ankle strength ratios, and leg dominance before the competitive season. Researchers found a significant difference with limb dominance where left leg-dominant athletes had a higher likelihood of ankle sprains (25 out of 100 athletes) compared to right leg-dominant athletes (8.5 out of 91.5 athletes). Limb dominance was not a primary focus of the research and was no longer discussed but shows promising evidence of increased injury rates due to the athlete's dominant side.

A further study with a similar population of lacrosse, soccer, and field hockey players was conducted to again determine if limb dominance was associated with ankle sprain injury risk. Beynnon, Renstrom, Alosa, Baumhauer, and Vacek (2001) included 118 Division I male and female college athletes participating in these sports and documented ankle injury during a competitive season. Each injury was documented by an orthopedic surgeon who graded the severity of ankle sprain upon diagnosis. Results indicate that injury rate per 1000 person-days of exposure were 1.6 and 2.2 for men and women, respectively. They also noted that female soccer players tended to have a higher injury risk than the other sports while finding no difference in injury risk between dominant and non-dominant legs for both men and women ($p=0.41$, 0.11 for women and men, respectively).

Other research on limb dominance and injury was conducted by Orchard (2001) who examined risk factors for hamstring, quadriceps, or calf muscle strains in 1,607 Australian Football League players over 7 season years. Results show that the quadriceps muscle was more likely to be injured in the athlete's dominant leg during kicking (relative risk 2.13) compared to hamstring and calf injuries that were distributed equally across both legs. This research is limited in that it was conducted solely on Australian Football League players including those with previous injury who are more likely to sustain a similar injury in the future. Based on this research there may be evidence that the athlete's dominant leg is more likely to be injured depending on the injury type, however the sample was limited to football players with the majority of players not engaging in kicking exercises on a daily basis.

Soccer is similar to gymnastics in that it relies heavily on limb dominance to perform some of the critical skills of the sport like kicking or jumping. Ekstrand and Gillquist (1982) studied the incidence of injury in hopes to identify the causes of injury in 124 Division IV male soccer players (24.6 ± 4.6 years of age) from 12 different teams for 1 year of playing while controlling for athletes exposure time (~130 hours). In their research, injury was defined as an occurrence during practice/game where the athlete misses the next practice/game. Supporting previous research, they identified injury to most commonly occur within the lower limbs of the body (88%), specifically in sprains to the ankle (59%). Of the total number of ankle sprains, athletes had 92% more injuries to their dominant ankle compared to their non-dominant ankle. Researchers suggest that more ankle sprains occur in the soccer player's dominant leg because of greater exposure to forced ankle inversion with kicking and jumping on that leg. However, the skill level

in these athletes may be different when compared with Division I soccer players who are thought to be more advanced in their sport and may potentially have a difference in injury incidence.

Supporting conclusions by Ekstrand and Gillquist (1982), Faude, Junge, Kindermann, and Dvorak (2006) prospectively studied the injury risk factors in 143 female German National League soccer players on 12 different teams. Researchers were looking to identify which player characteristics would determine injury throughout an entire season. Athletic trainers documented an injury whenever an athlete was physically unable to practice or compete for at least one day. Results indicate that significantly more injuries occurred to the athlete's dominant leg during the study period (~60%), especially in terms of ankle injury to the dominant leg (66%) compared to the non-dominant leg. This evidence gives further insight into the notion that leg dominance in both men and women may be a key factor in injury incidence that may carry over into other sports like gymnastics.

Previous research does not include gymnastics in identifying if limb dominance is a risk factor for injury, however, it provides a starting ground to identify some of the similarities in the sports where leg dominance in injury may or may not play a significant role. Based on this research there is no concrete determination if limb dominance is a significant risk factor, but certain positions in soccer and football have been examined and show signs of a greater possibility of risk in the kicking and jumping aspects of the sport.

COMPARING MEN AND WOMEN IN SPORT

Taking the research a step further, several studies have been published comparing the incidence of injury between male and female athletes in similar sports. Powell & Barber-Foss (2000) examined injuries among high school varsity athletes in men's and women's baseball/softball, basketball, and soccer. In this study certified athletic trainers documented the injury incidence, type and severity over a 3 year. Results show that in baseball/softball, there were similarities between the sports with the most frequent injury type being a sprain occurring in the forearm/wrist/hand category and the majority of injuries during games were likely to occur during base running. Differences in injury results show that softball had a lower likelihood of major injuries than baseball, the lower body was less likely injured in baseball, and baseball pitchers were more likely to be injured than softball pitchers. In terms of basketball, the similarities with injury type occurred in the ankle and foot and there was no difference in percentage of injury related to position or playing in practice vs. games. However, injury rate for female players was greater than males, and girls' teams were more likely to have major injuries (hip/thigh/leg injuries and surgeries) than the boys' teams, but not significantly. Injury rate for female soccer players was significantly greater than males by 14% with the most common injury in both genders in the ankle/foot. Overall, girls were more likely to have a higher injury rate in softball and soccer, but similar injury rate for female and male basketball players. This evidence shows a variety in results with injuries that may occur based on the sport being played. An important limitation to this study was that researchers did not account for or control for the amount of time each athlete was engaged in participation of sport.

Sallis, Jones, Sunshine, Smith, and Simon (2001) examined the gender difference for injury type among 3,767 athletes participating in basketball, cross-country, soccer, swimming, tennis, track, and water polo at an NCAA division III college over a 15-year time frame. Results indicated that female athletes sustained more injuries than their male counterparts, but the difference was insignificant. Lower body injuries were significantly more prevalent than upper body injuries among female soccer and track athletes. Swimming and water polo were the only two sports to show a significant difference in injury type with females having more injuries than males. Overall, these results show similar injury patterns among male and female athletes. Some of the limitations to this research are that the athletic trainer reporting injuries used a retrospective technique leaving room for recall error, and injury was broadly defined as anything needing treatment in the training room. A more defined and clear cut definition may be useful for determining how significant the overall injury incidence actually was.

More specifically to this research, Kirialanis, Malliou, Beneka, and Giannakopoulos (2003) compared lower body injuries between 162 Greek girl gymnasts and boy gymnasts ages 9 to 16 years old, while taking event and exercise phases into account. During these 12 months, injury was determined by an orthopedic surgeon, physiotherapist, and athletic trainer who documented injuries if the athlete had missed the next practice or game. Results indicate that 151 injuries occurred with 93 of them being acute injuries and 58 being overuse injuries with the majority being moderate cases. The floor exercise was found to be the event with the highest injury occurrence, significantly, especially for the knee/ankle during landing for both sexes. The greatest number of injuries occurred during the landing phase of floor exercise, for both girls and boys, but

the girls had significantly more landing-induced injuries than boys. These results support previous research indicating that, in gymnasts the highest incidence of injuries has occurred in the lower body, and more specifically during the landing phase. However, there is some limitation, as researchers did not consider the athletes skill level in their analyses.

Lowry and LeVeau (1982) studied the type and incidence of injury in 4,215 male and female club gymnasts in relation to their participation as a non-competitive or competitive athlete over a 1-year time period. Researchers sent questionnaires to gymnastics clubs in the Virginia, Maryland, South Carolina, North Carolina area in hopes to collect data on the athlete's level of competition, event of injury, number of injuries, and conditioning program that was implemented in the previous year. Only 9 of the 14 clubs who participated in this study had hard-copy record of this information. The results of this study show that non-competitors have a lower incidence of injury (4%) compared to competitors (70%). Female competitors are injured more often than their male counterpart with females being injured 70% of the time compared to males being injured 76% of the time. Researchers attribute these differences to the greater skill level required for competitive gymnasts, which, in turn required significantly more hours of practice among competitive gymnasts compared to the non-competitive gymnasts. Contusions were found to be the most common injury type (34.2%), and the floor exercise was the most common event for injury in females (reported by 5 out of 13 club gyms) while the parallel bars and high bar were for males (number 1 for all gyms recorded). The limitations to this study include the retrospective approach since 5 out of the 14 gymnastics clubs were unable to record previous information about injuries and had to

simply recall this information. This could skew the results and providing inaccurate data. Also, certified athletic trainers/medical personnel did not record the injuries themselves. It was up to the athlete and his/her parent to determine if injury occurred based on interpretation of the given definition. However, this study does support previous research in showing a higher incidence of injury for competitive athletes at a higher skill level on the floor exercise.

Lanese, Strauss, Leizman, and Rotondi (1990) again compared injury type and site between male and female gymnastics. However they accounted for each athlete's exposure time to injury in sport participation at the collegiate level over 1 academic year. These researchers compared 8 different sports (basketball, fencing, gymnastics, swimming, tennis, indoor track, outdoor track, and volleyball) that had both male and female teams totaling 252 male athletes and 150 female athletes. Injury records were kept by team physicians and certified athletic trainers that were present at each practice or game, and injury was defined as a medical problem causing the athlete to miss participation time in practice or game. Results indicate overall minor and inconsistent gender differences within each sport. Overall, gymnastics was found to have the highest injury rate compared with other sports with all but 1 of the 35 athletes being injured during the season, and 34% of the total injuries (only 9% of the total participants). No other sport had significant gender differences among injuries. Within gymnastics, female gymnasts had a higher rate of injury (mean of 2.73 injuries per female) than their male counterparts (mean of 2.17 injuries per male), and also sustained more injuries per hour compared to men (0.82 and 0.21 injuries per person-hours, respectively) further supporting their conclusions. Among all sports, strains and sprains were most common

(over half of all injuries), especially to the foot and ankle. A surprising result was that even though women had a greater likelihood of injury, they were participating in fewer hours than the men (365 hours and 1,025 hours, respectively). These results may have been due to the difference in events performed by the female and male gymnasts, since gymnastics is the only sport where there was some discrepancy in performance. Men typically compete in 6 events while women compete in 4, and the only two events that are the same include the vault and floor exercises. This research focuses on the significance of injury in gymnastics and the difference that exists between both genders in the same sport of gymnastics.

Previous research has shown some of the trends within gymnastics and other sports comparing gender differences to injury rate, type, and location. The evidence provides a trend showing that the majority of injury is likely to occur with female gymnasts in the lower limbs during the landing phase on the floor exercise. There is limited evidence supporting the injury incidence and type for their male counterparts.

INJURY IN WOMEN'S GYMNASTICS

The majority of research on gymnastics injuries has been conducted on female gymnasts. In a prospective study by Pettrone and Ricciardelli (1987), injury incidence, event of injury, type of injury, setting of injury, and athlete's skill level were recorded via questionnaire from 15 gymnastics clubs (n=2,558) in Virginia for an entire 7-month season. Results indicate that 12 of the 15 gymnastics clubs participating in the study sustained injury to an athlete with injury rates of 5.3 injuries per 100 competitive gymnasts and 0.7 injuries per 100 non-competitive or beginning gymnasts. The majority of acute injuries occurred during practice (80%) compared to competition (20%),

however this data included those non-competitive athletes. The event with the majority of injuries was the floor exercise with 21/51 injuries occurring on this event compared to 13 on the balance beam, 9 on the vault, 6 on the uneven bars, and 2 on the springboard.

There was no relationship between the athlete's skill level and the event in which the injury occurred. The majority of the 51 injuries were ankle sprains (15 out of 21 total sprains) while 19 of the total injuries were related to either mounting or dismounting on each event. No correlation exists between injury and event of injury or skill level of the athlete and the duration of injury in terms of absence of participation from the sport. The results of this study support previous research in relation to the event in which the injury occurred, the type of injury, the gymnastics skill during which injury occurred, and the body part injured. However, there are mixed results when examining the difference in injury occurrence during practice or competition. These results may be due to the participants in this study because the majority of gymnastics clubs participating had more non-competitive athletes compared to competitive athletes with fewer competitions during the 7 months causing the number of injuries during competition to be low. Exposure time during competition and practice may need to be considered within future research. Age is another limitation that was not controlled for in this study. Nevertheless, this research provides insight into the demographics of injury that occur among female gymnasts.

Caine, Chochrane, Caine, and Zemper (1989) took this research one step further and controlled for the exposure hours during practice for 50 competitive female club gymnasts (mean age 12.6) practicing 20-27 hours, 5-6 days per week for a 1-year study. Investigators collected injury information once every two weeks from gymnasts who kept

recorded logs of injury in diaries with specific details about each injury along with verbal dialogue about the injury from the coach or athlete. Once an injury occurred, an interview was set up between the researchers and the gymnasts who filled out an injury report based on criteria of the National Collegiate Athletic Association Injury Surveillance System, including details about the injury. Results indicate that the majority of injuries occurred in the lower body (63.7%) with an injury rate of 3.66/1000 hours of participation. Class II gymnasts had the highest injury rate (4.78) compared to Class I (highest skill level) and Class III gymnasts (4.02 and 3.11, respectively). Again the floor exercise was the most frequently cited cause for injury (35.4%). A limitation to these results is the use of a questionnaire as they are often noted to underreport injury frequency due to recall bias, low response rate, and motivation bias. Another limitation is that the sample size for the Class II group consisted of 7 gymnasts causing the resulting injury rate to appear higher than other groups, however, there is evidence of increasing injury rate with increasing skill level.

O’Kane, Levy, Pietila, Caine, and Schiff (2011) conducted a cross-sectional survey in Seattle, Washington on female club gymnasts levels 4 through 10 to update previous research on incidence and distribution of gymnastics injuries in relation to age and skill level. These researchers contacted 5 club gyms to send questionnaires asking each gymnast (n = 126) basic demographics of height, weight, age, level of competition, time engaged in the sport and years involved, along with history of acute and chronic injury within the most recent gymnastics season. The results of this research show lower extremity injuries to be most common (59.6% of all injuries) especially with the foot and ankle. They also found acute injuries to be greatest with the older gymnasts (13-17 year

olds) at a higher competitive level (level 7-10). These gymnasts with a greater incidence of acute injuries were also training for 19-25 hours each week. The floor exercise and landings also show a greater percentage of acute injury occurrence, 32.1% and 49% respectively. Even though a greater number of injuries occur during practice, there is a higher injury rate during competition. Researchers also found no association with body mass and race to influence risk of injury in this population. A limitation to this study is the recall bias. Participants were asked to think about their injuries within the previous year making the actual number of injuries and details difficult to report. The small sample size also limits these results. However, this study shows evidence that age, skill level, event/skill, and competition all influence the injury rate for female club gymnasts.

Another study on club gymnasts was conducted by Kolt and Kirkby (1999) to examine if a difference exists between 64 Australian elite and sub-elite female gymnasts for injury rate, location, and type throughout an 18-month prospective study. Elite gymnasts were about 12.5 years old and training for 29-36 hours per week and were part of national, high-performance teams. Sub-elite gymnasts around the age of 14 years old were training between 4-25 hours each week and were not considered to be training at as high of a level as the elite gymnasts. Each week the gymnasts recorded their injuries with details on the injuries and hours practiced from the previous week. Results indicate that a total of 349 injuries were sustained over the entire 18-month period indicating an injury rate of 5.45 injuries per gymnast or 3.64 injuries per gymnast per 12-month period. Out of the 24 elite gymnasts, 151 injuries were sustained with an injury rate of 6.29 per gymnast or 4.19 per gymnast per 12-month period. The 40 sub-elite gymnasts who completed the experiment had a significantly lower injury rate than the elite gymnasts

with an injury rate of 4.95 per gymnast and 3.30 per gymnast per year out of their total 198 injuries. The most common location of injury was the ankle and foot accounting for 31.2% of the total injuries with the majority of the total injuries also being sprains (29.7%) with 64.2% of injuries being acute and 35.8% being overuse. These differences may be attributed to the hours spent practicing along with the skill level of the athlete with the elite gymnasts being exposed to injury for longer periods compared to the sub-elite gymnasts practicing at a lower skill level. A limitation to this study also exists in that the injury rate did not take practice hours into account. This might skew the data and show a more accurate injury rate if accounted for in future research. The gymnasts also recorded their own injuries instead of certified athletic trainers or medical personnel.

Garrick and Requa (1980) collaborated on two studies, where the second study took place over a 1-year time frame with a wide arrange of gymnasts including 221 high school gymnasts, 24 college gymnasts, and 72 club gymnasts ranging in ages of 6 to 21 years. Gymnasts were asked to answer the researchers questions concerning overall injury risk, frequency of injury, and injury type in women's gymnastics. Again, a certified athletic trainer documented injury over this time period by using the definition of an injury as an "incident" causing the gymnast to miss any fraction of the sport in practice or competition. Throughout this mixed study, researchers documented a total of 106 injuries with a rate of 33 injuries per 100 participants during the season. They found a lower rate of 22 injuries per 100 participants per season for club gymnasts while college gymnasts had the highest injury rate of 71 injuries per 100 participants per season, which they believe may be attributed to the longer duration of the college season (30% longer) and practice times allowing these athletes to be exposed to injury more often. The floor

exercise accounted for the majority of injuries once again (53%) while the other three events shared similar contributions to overall injury incidence (12%, 11%, 9% for balance beam, vault, and uneven bars, respectively). Supporting other research, the results of this study show sprains, specifically to the lower extremities, to be the largest type of injury reported at 52% of all injuries. Limitations to this research exist with the low sample size showing limited conclusions from the research, however this research presents evidence of a trend for college athletes to be exposed to a greater risk of lower-body injury compared to club/high school gymnasts especially when performing the floor exercise.

Sands, Schultz, and Newman (1993) also conducted research on women's gymnastics injuries, however they exclusively researched 37 NCAA Division I women gymnasts at the University of Utah over a 5-year time span while collecting data before every training day using a custom-designed computer program. The date of injury, event/activity injury occurred on, and the limitations to training due to injury were recorded by each injured athlete herself beginning with the day of injury and every day after until the injury no longer interfered with practice. The data shows that 71% of the time gymnasts train with injuries and new injuries are likely to occur 9% of the time while the right side of the body was more likely to be injured accounting for 65% of the new injuries (without controlling for dominant limb). The lower limbs compared to upper extremities were also more likely to be injured. Injury during the competitive season peaked for incidence of new injury as well due to performance of full routines. The overall ratio for injury rate per 100 competitors for the overall 5-year time span is 1376 new injuries per 100 participants, as injuries tend to accumulate throughout season.

This research supports the previous research by O’Kane et al. (2011) in that injury incidence raises during competition season. There are several gaps in this literature as it was conducted on a small population only utilizing the competitive athletes on the University of Utah’s women’s gymnastics team and the exact gymnastics skill where injury occurred was not reported. These results provide evidence that collegiate gymnasts are more likely to become injured during competition season.

Similar to O’Kane et al. (2011) and Sands, Schultz, and Newman (1993), Marshall, Covassin, Dick, Nassar, and Agel (2007) found injury incidence in female gymnasts to occur more frequently during the competition season. These researchers took a slightly different approach and compared injury incidence across all collegiate women’s gymnastics teams (Division I, II, and III) using the National Collegiate Athletic Association Injury Surveillance System over a 16-year time period including 86 schools with a total of 1380 athletes. These researchers found injury during competition to be twice the amount during practice while Division I gymnasts report a higher injury rate than Division III gymnasts. Results are similar to previous research that shows the majority of injuries to occur within the lower extremities of the athlete with knee and ankle injuries ranking the highest, especially during competition as knee derangements are six times more likely to occur during competition and ankle sprains are three times as likely compared to those occurred in practice. This research also supports the notion that the majority (70.7%) of injuries occur during the landing phase of a skill/routine primarily on the vault and floor exercise. This research may be limited in its results that show the vault to be the event with the majority of injury occurrence due to the type of

vault used being the old-fashioned horse or the newer vault table, which has a completely different structure. This research utilized both vaults throughout the 16-year study.

Chapter 3- Methodology

PARTICIPANTS AND STUDY DESIGN

Based on the current rosters for both the men and women gymnastics teams at Arizona State University, we estimated a sample size of 37 participants, however subjects were informed that their participation is voluntary and they could drop out at anytime during the study. This is a prospective study design that will not be randomized due to the nature of the study. Recruitment through face-to-face meetings with the coaches of these teams was conducted to gain participation in late July 2012. All subjects were 18-23 year-old college athletes with prior experience in competitive gymnastics at an elite level. The Institutional Review Board (IRB) approved this study, and informed consent was obtained from each participant prior to their participation.

INDEPENDENT VARIABLE

Participants in this study continued to perform in practice and competition like they typically would. The training and competition routines were not altered in any form. The primary variable that was documented was the athlete's upper and lower body limb dominance. We also recorded each athlete's gender (male or female) and descriptive characteristics (age, height, and weight).

DEPENDENT VARIABLE

Throughout the 2013 competition season (January through April), injuries were recorded by athletic trainers or coaches for the competitive athletes injured during practice and competition. An injury was defined as something that causes participation in gymnastics to be limited or discontinued for that specific training session or longer. These injuries were recorded on a daily basis. Records included the type of injury (i.e.

lower body- ankle or knee), skill being performed, and the event the injury occurred on (vault, pommel horse, rings, uneven bars, parallel bars, high bar, balance beam, or floor exercise), and the place of injury (practice or competition). All study-related data was conducted at the teams' practice facilities on the Arizona State University Tempe campus or at the Aspire Kids Sports Center in Chandler, AZ.

STATISTICAL ANALYSIS

Multivariate logistic regression models were used to investigate the association between limb dominance and incidence of injury in the lower and upper extremities for both male and female gymnasts at ASU after adjustment for confounding variables (i.e., age, gender, BMI). A χ^2 -test was used to compare frequency differences across gender and limb dominance categories. The prevalence of gymnastics injuries were also estimated by gymnastics events and by side (right vs. left) of injuries across side of limb dominance (right vs. left). All P-values were two-sided, and values <0.05 were considered to indicate statistical significance. All statistical procedures were performed by using SPSS software.

Chapter 4- Results

Thirty-seven male and female college gymnasts who attended Arizona State University were invited to participate in this research to test if there is a likelihood that injuries will occur in the dominant side of the athlete and compare injury differences between male and female gymnasts. Data collection took place at Arizona State University during the teams' 2013 competition season. Coaches and athletic trainers kept a hardy copy of the data at the practice or competition facility to record injuries when they occurred. Researchers collected data at the end of each teams' competitive season for further analysis.

Descriptive statistics ($\bar{X} \pm SD$) for the study participants are presented in Table 1. As shown in Table 1, male gymnasts had greater mean height and weight measurements than did female gymnasts. There were no statistical differences in age and BMI across gender. Table 1 also shows that the prevalence of gymnastics injuries was significantly higher in female gymnasts than in male gymnasts ($P = 0.023$). There is a significant difference with more right-sided lower body dominant athletes compared to left-sided lower body athletes within this population ($P = 0.01$), but no significant difference when comparing right-sided or left-sided upper body limb dominance ($P = 0.07$).

	Gender		
Characteristics	Male	Female	<i>P</i> Value [†]
Number of participants (N = 37)	23	14	
Baseline mean Levels [‡]			
Age	20.3±1.7	19.6±1.3	0.18
Weight (kg)	59.3±6.1	48.4±3.0	<0.001
Height (m)	1.73±0.03	1.57±0.03	<0.001
Body mass index (kg/m ²) [*]	19.8±2.2	19.7±1.2	0.89
Raw baseline frequency of limb dominance			
Lower body dominance (left)	8	3	0.01
Lower body dominance (right)	15	11	
Upper body dominance (left)	5	8	
Upper body dominance (right)	18	6	
Total left (lower)	11		
Total right (lower)	26		0.07
Total right (lower)	13		
Total right (upper)	24		
Baseline percent frequency (%)			
Lower body dominance (left)	73	27	0.39
Upper body dominance (left)	39	61	0.03
Total dominance (left)	47	53	0.08
Incidence of injury out of the total number of participants (%)	13	50	0.023

Table 1. Characteristics of study participants by gender (Mean ± SD)

^{*}Body mass index (BMI): weight in kilograms divided by height in meters squared.

[†]*P* value based on F test with 1 degree of freedom for any difference between male and female college gymnasts; Fisher's exact test for frequency difference between male and female college gymnasts.

Table 2 shows the association between side of lower and upper body dominance and incidence of gymnastics injuries among college gymnasts. After adjustment for age, gender, and body mass index, the odds ratio of having injuries with left-sided lower body dominance was 0.28 (95% CI: 0.03, 2.65) as compared with gymnasts with right-sided lower body dominance. Similarly, gymnasts with left-sided upper body dominance had an odds ratio of 0.13 (95% CI: 0.01, 1.48) when compared with gymnasts with right-sided upper body dominance. Table 2 also shows that gymnasts with combined left-sided upper and lower body dominance compared to gymnasts with combined right-sided upper and lower body dominance had an odds ratio of 0.17 (95% CI: 0.02, 1.45) showing a trend in the data towards more injuries overall in right-side dominant gymnasts. Also shown in Figure 1, gymnasts with right-sided lower body dominance had a higher prevalence of incidence in gymnastics injuries as compared with gymnasts with left-sided lower body dominance (70% vs. 30%). Similar findings were observed in upper body dominance. Gymnasts with right-sided upper body dominance had almost twice the prevalence of injuries as gymnasts with left-sided upper body dominance (65% vs. 35%).

Variables	No. of Injuries	Body Dominance		P Value
		Left	Right	
Lower Body (no. of injury/N)	10	2/11	8/26	
Adjusted for age, sex, body mass index		0.28 (0.03, 2.65)	1	0.26
Upper Body (no. of injury/N)	10	3/13	7/24	
Adjusted for age, sex, body mass index		0.13 (0.01, 1.48)	1	0.10
Lower & Upper Body Combined (no. of injury/N)	10	4/17	6/20	
Adjusted for age, sex, body mass index		0.17 (0.02, 1.45)	1	0.02

Table 2. Odds ratios (95% CI) of incidence of gymnastics-related injuries by lower and upper body dominance among college gymnasts during the 2013 competition season.

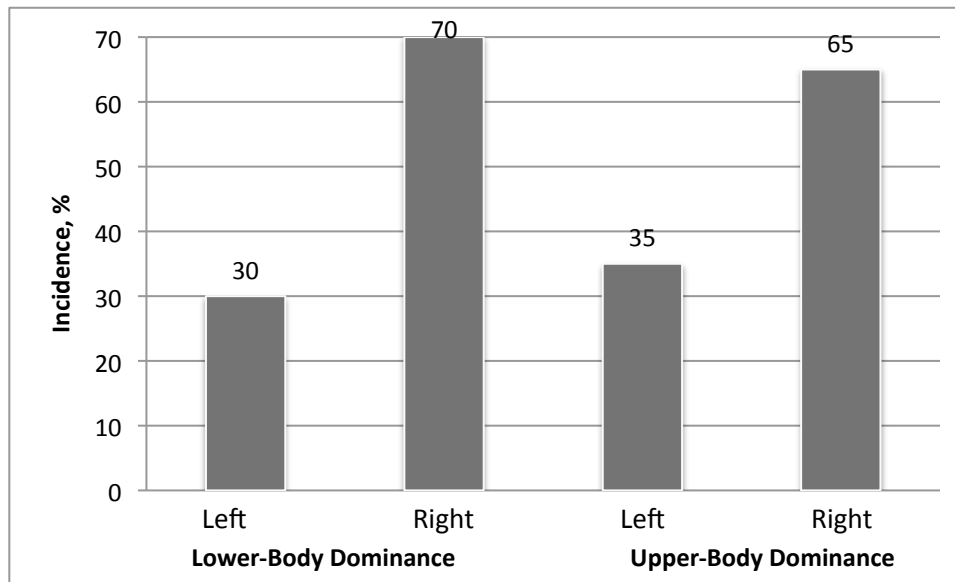


Figure1. Prevalence of gymnastics injuries by side (left vs. right) and lower and upper body dominance

Figure 2 shows the incidence of the 10 total injuries in relation to the side of limb dominance for that athlete controlling for location of injury (upper vs. lower body). No significant difference was found based on Chi-square tests for comparing the side of limb dominance and side of injury occurrence ($P = 0.058$ lower body, $P = 0.527$ upper body). In Figure 3, the event of injury occurrence is displayed. Even though most of the injuries occurred on the floor exercise (40%), there was no significant difference of injury occurrence in relation to event of injury for this sample ($P = 0.558$).

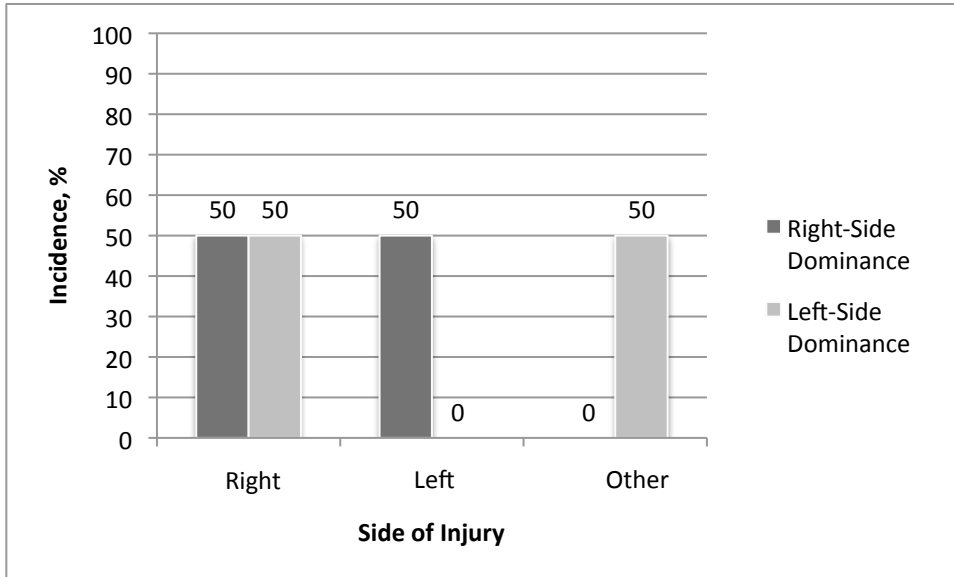


Figure 2. Incidence of side of injury (right vs. left) in relation to side of limb dominance (right vs. left)

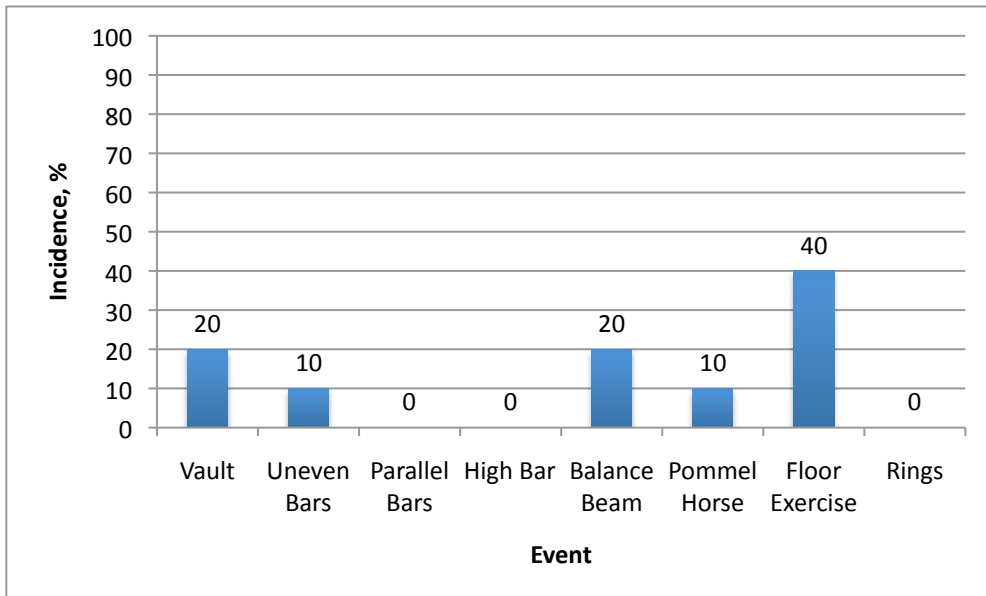


Figure 3. Injury occurrence by gymnastics event.

Chapter 5- Discussion

This study examined the relationship between lower and upper body dominance on gymnastics injuries among male and female college gymnasts. The major finding was that the odds of being injured for gymnasts with left-sided upper and lower body dominance were less than for right-sided dominant gymnasts. However, there were significantly more right-sided lower body dominant gymnasts involved in this study. When comparing the side of dominance and the side of injury, there were mixed results. Right-sided dominant gymnasts had both right and left-sided injuries equally while left-sided dominant gymnasts were split between right-sided injuries and injury involving the athlete's torso/head. However, there was no statistical significance due to small sample size. The literature review indicates that this may be the first study to examine the effects of limb dominance on injury occurrence in the sport of gymnastics.

A further analysis also shows a trend in relation to the gymnastics event where injury was most likely to occur. The floor exercise was the single most injury-prone event (4/10 injuries) when controlling for gender differences. Once again this data was not statistically significant due to the small sample size. Previous research supports these findings as Pettrone and Ricciardelli (1987) concluded that 41.2% of gymnastics injuries occurred on the floor exercise; Caine, Chochrane, Caine, and Zemper (1989) found 35.4% of all gymnastics injuries occurred on this event; and Garrick and Requa (1980) report 53% of gymnastics injuries on the floor exercise.

The other important finding is that female gymnasts had a greater number of gymnastics injuries when compared with male gymnasts. These results may be attributed to muscle mass or a strength difference between subjects. Future research controlling

these differences is suggested. However, these findings are supported by previous research. Lanese, Strauss, Leizman, and Rotondi (1990) report that collegiate female gymnasts had a higher rate of injury (273/100 persons) than their male counterparts (217/100 persons).

Although this study did not demonstrate a significant relationship between limb dominance and injury occurrence, further research is warranted. A greater sample size or longer period of data collection is advised to further support the trend in data that was found within this research. Studies examining the relationship of power in the dominant vs. non-dominant limb are also recommended to see if the more powerful limb is subject to less injury. Power of the upper or lower extremity may even be used as a greater defining variable for limb dominance in the athlete. The power difference between limbs may have been a contributing factor in the resulting gender difference between men and women. However, the information derived from this study provides gymnasts, athletes, and the general public with information regarding injury prevention in terms of limb dominance and gender. Further preventative action in areas of strength training or rehabilitative therapy may be necessary for right-sided dominant individuals, especially females, participating in sport or exercise.

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APPENDIX A
CONSENT FORM

**MINIMAL RISK
ARIZONA STATE UNIVERSITY**

CONSENT FORM

**Incidence of Injury in Relation to Limb Dominance in Arizona State University
Men's and Women's Gymnastics Teams**

INTRODUCTION

The purposes of this form are to provide you (as a prospective research study participant) information that may affect your decision as to whether or not to participate in this research and to record the consent of those who agree to be involved in the study.

RESEARCHERS

Callie Price, a Master's Student in the Exercise and Wellness Program at Arizona State University, alongside Dr. Jack Chisum as the principle investigator have invited you to participate in a research study.

STUDY PURPOSE

The purpose of the research is to examine the relationship between limb dominance (either right or left) and the number of injuries in the arms or legs of Arizona State University Men's and Women's Gymnastics teams during the 2013 competition season. The secondary aim of this study was to determine if a gender difference exists in relation to the injury type and occurrence.

DESCRIPTION OF RESEARCH STUDY

If you decide to participate in this study, you will join a study involving research where injuries during the 2013 competition season will be analyzed and compared with limb dominance and other characteristic information. The event the injury occurred on, the side of injury (right or left), and if the injury occurred in practice or competition will all be documented after each injury occurs. You will define which arm and leg is your dominant arm and leg based on your gymnastics performance, and record this information. Your name will not be used in the collection process, rather a number will be assigned to each athlete for confidentiality purposes by your athletic trainers. All competitive athletes will be included in this study, and all musculoskeletal injuries will be documented by your athletic trainer. There is not any extra participation on your behalf as the athlete, because the athletic trainer will be recording all of the information on injuries. Your participation also allows investigators to analyze your injury history over the last 2-3 years on the gymnastics teams at Arizona State University. Again, this information will remain confidential and coded by an athletic trainer prior to analysis by researchers. You can choose not to participate in the research or drop out at any time. All data will remain confidential.

If you say YES, then your participation will last until the last day of your competitive season depending on team/individual qualifications to post season at Arizona State University. Approximately 27 subjects will be participating in this study from both the men's and women's gymnastics teams at Arizona State University.

RISKS

Due to the nature of this study, there are no additional risks associated with experimentation other than the usual risks associated with your participation in gymnastics.

BENEFITS

The possible/main benefits of your participation in the research are that future injury prevention methods may be determined based on the results of this research.

NEW INFORMATION

If the researchers find new information during the study that would reasonably change your decision about participating, then they will provide this information to you.

CONFIDENTIALITY

All information obtained in this study is strictly confidential unless disclosure is required by law. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of your records, Callie Price will code your name as well as other participants' names using a numbering system. Confidentiality will be maintained by keeping the collected data out of the public eye and held privately by athletic trainers/coaches who will be responsible for data collection.

WITHDRAWAL PRIVILEGE

It is ok for you to say no. Even if you say yes now, you are free to say no later, and withdraw from the study at any time.

Your decision will not affect your relationship with Arizona State University or otherwise cause a loss of benefits to which you might otherwise be entitled.

Your participation in this study will not affect your scholarship or participation in gymnastics in any way.

COSTS AND PAYMENTS

There is no payment for your participation in the study.

COMPENSATION FOR ILLNESS AND INJURY

If you agree to participate in the study, then your consent does not waive any of your legal rights. However, no funds have been set aside to compensate you in the event of injury.

VOLUNTARY CONSENT

Any questions you have concerning the research study or your participation in the study, before or after your consent, will be answered by Callie Price. She can be contacted through email at cprice5@asu.edu or via phone 480-747-7114. Jack Chisum can also be contacted at 602-496-1872 or through email at jack.chisum@asu.edu.

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk; you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at 480-965 6788.

This form explains the nature, demands, benefits and any risk of the project. By signing this form you agree knowingly to assume any risks involved. Remember, your participation is voluntary. You may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty or loss of benefit. In signing this consent form, you are not waiving any legal claims, rights, or remedies. A copy of this consent form will be given (offered) to you.

Your signature below indicates that you consent to participate in the above study.

Subject's Signature

Printed Name

Date

INVESTIGATOR'S STATEMENT

"I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the subject/participant a copy of this signed consent document."

Signature of Investigator _____ Date _____

APPENDIX B

DATA COLLECTION FORM

Injury Report 2013 Season
January 6 through End of Season (March 30- Nationals)

Athlete #	Dominant Limb Determine upper and lower body, right or left	Side of Injury on Body Right or Left	Injury	Location Practice or Competition and event	Skill of Injury Occurrence
<i>Example: 3</i>	<i>R upper, L lower</i>	<i>Left</i>	<i>Ankle sprain</i>	<i>Practice Floor</i>	<i>Double back tuck</i>

