Sport-Related Injuries in Canadian Interuniversity Athletics: A Descriptive Epidemiologic Analysis of Knee Injuries, 2014-2017

JAMES GARDINER

A THESIS SUBMITTED TO
THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

Graduate Program in
KINESIOLOGY AND HEALTH SCIENCE

York University
Toronto, Ontario

October 2019

ABSTRACT

The purpose of this study was to identify and establish the extent of sport-related injury in Canadian university varsity athletics, focusing on knee injury and significant sport injury. Of the SRIs reported, 20% were significant in nature and 23.2% were knee injuries. A larger percentage of knee SRIs were significant compared non-knee SRIs. Those suffering a knee injury were 4.5 times more likely to suffer a significant injury than those afflicted with non-knee injuries.

Men's volleyball athletes are two times more likely to suffer a knee injury, once controlled for sport group. Once controlled for sport, men's hockey athletes are 2.3 times more likely to suffer a significant injury than any other sport (Table 4). Men's basketball has the highest rate of injury (3.32 per athlete) during this reporting period and football has the highest rate of significant knee injury at 0.27 per athlete (Table 1).

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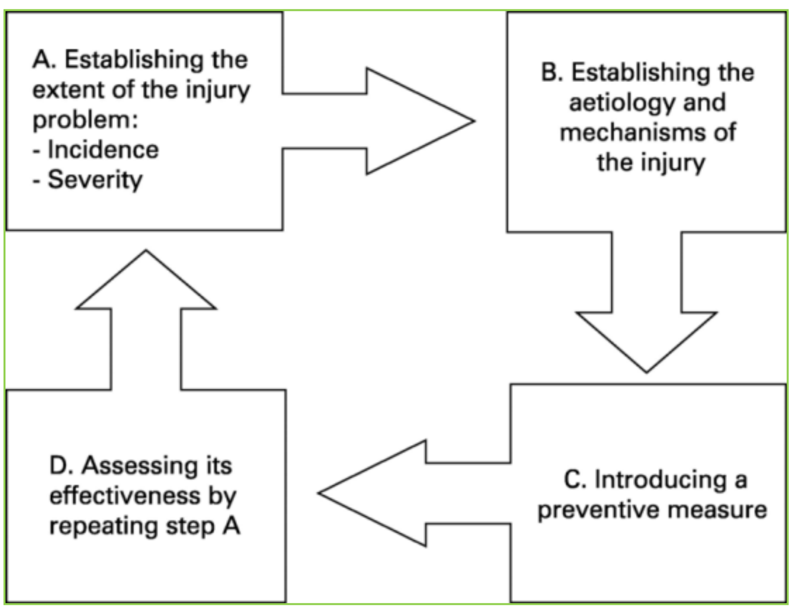
INTRODUCTION

Injury is inherent in sport. At all levels of competition in all sports there are innate risks, from the nature of the rules to the biomechanics of movement execution to the surface of play to the unpredictability of the opponent(s)- all contribute to risk of injury in sport.

University Sport Université (U Sport) serves as the governing body for Canadian interuniversity athletics competition. It represents 56 universities, 12, 000 student athletes and 7, 700 high level games and events country-wide per year (usports.ca). Injury rates and prevalence have been analyzed and studied with regularity in collegiate athletics in the United States. The National Collegiate Athletic Association (NCAA) recognizes over 460, 000 student athletes under its umbrella (www.ncaa.org/student-athletes). In Canada, however, the available published data is limited. Within this field, epidemiological studies on risks and rates of injury aim to address gaps in injury prevention, sport safety and within the literature (Hurtubise, Beech, Macpherson, 2015). Identifying the extent of a problem is the first step in a model of injury deterrence or prevention in the public health approach. This needs to be completed prior to introducing a preventive measure, and in turn, the measure needs to be tracked and evaluated critically from a clinical perspective to determine its value. Once established, this allows practitioners to adopt relevant and current best practices which can be adapted to best suit the demographic of athletes with whom they work.

Injury in sport has been identified as an issue in the data within the varsity population of York University athletics; an example of which is the minimum of twelve ACL reconstruction surgeries as a result of sport injury per year over the most recently reported academic years within this population (2016, 2017 and 2018). The injury data however, has not been analyzed at length (see “A” in Figure 1) to determine the extent of the problem in order to establish the bestsuited intervention program(s) for each individual sport. As patterns within specific sports are identified, practitioners can develop strategies to prevent injury and through efforts such as rule changes, promote athlete safety (Kay et al., 2017).

The risk of all lower body injuries may be reduced by up to 50% by regular participation in a balance training exercise program with a resistance training component, such as a neuromuscular training warm-up program. Completion of this type of warm-up program can lower the likelihood of ankle and knee injuries (Emery et al., 2015). For knee injuries specifically, numerous studies (Augustsson et al., Barron et al., Donnell-Fink et al and Grimm et al.) have demonstrated the value of training athletes in the prevention of knee injuries through various types of neuromuscular programming (see “C” in Figure 1) including: proprioceptive, plyometric, strength training and revised landing mechanics . The model below has been widely used with regard to sports injuries.



(van Tiggelen et al 2008)

Figure 1. **Four-stage sequence of prevention model** based on the Public Health Approach

The objective of conducting this study is to establish initial injury data within this demographic. Analysis of the data collected can then be used to guide practitioners in the overview and acknowledgement of the extent of injury in Canadian university athletics. Application of this knowledge may then also provide the basis for the generation of realistic and applicable injury deterrence models and potentially determine resource allotment within sports medicine environments throughout U Sport institutions.

BACKGROUND

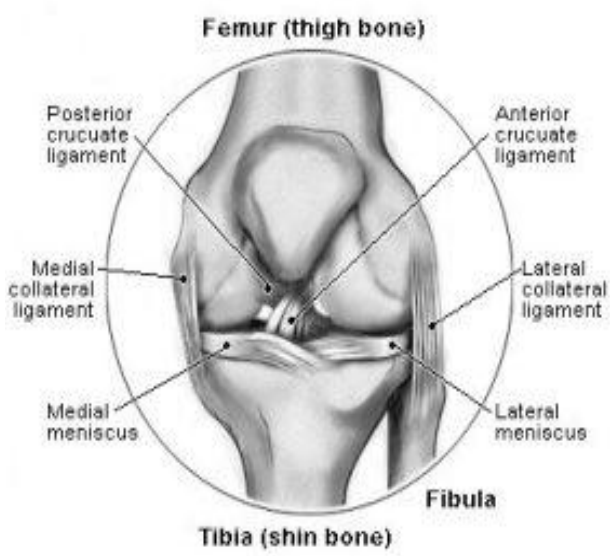
In sports, the knee is exposed to many intrinsic and extrinsic injury risks (Yang et al., 2012). This joint is commonly injured in sporting events and is the leading cause of sport-related surgeries (de Loes, Dahlstedt & Thomee, 2000). Knee injuries in sport, especially those structural in nature (damage to supportive tissue and immature bony regions), rank among the most costly sports injuries, economically, when requiring surgical intervention and rehabilitation (Joseph et al, 2013). In 2000, the economic and healthcare burden specific to knee injuries across 12 sports in those aged 14–20 years showed the mean medical costs to be $1, 114 USD per knee injury (de Loes, Dahlstedt & Thomee). Ardern et al. (2001) studied the impact of childhood injury, which included sport and other activity-based injury, and illustrated the cost of injury by the number of school days missed- nearly 2.2 million days lost per year across Canada. In 2010, the government of Canada reported that students participate in sport in greater numbers than any labour force group: "almost half of students (15 years and older) participate in sport on a regular basis" (statcan.gc.ca).

Injuries can counter the beneficial effects of sports when an athlete is unable to continue to participate because of the immediate or residual effects. In fact, injury was found to be the most common factor in withdrawal from sports among (American) high school students (Koester, 2002). The financial costs reported previously are in addition to the potentially traumatic effect that these injuries may have on the collegiate student-athletes including but not limited to: potential loss of season(s), loss of sport participation, loss of scholarship funding and the associated mental health and academic performance hindrances due to SRI (Hewett et al. 1999). Physical injury can trigger symptoms of depression as well as other problematic responses, emotional and immunological in nature (Nattiv, Puffer & Green, 1997).

Growing research is dedicated to understanding the relationship between exercise and mental health disorders as well as to chronic stress and mental health (Appaneal et al., 2009). As a result, many sports medicine personnel are now being trained in aspects of mental health and well-being. The York University sports medicine team has grown to include a network of providers for the student athlete population in this realm. Mental health concerns such as eating disorders, depression and suicide, anxiety, gambling and substance use and or abuse are among the most important in college-aged students, both athletes and non-athletes (Yang et al., 2007). Certain concerns are relatable to injury in athletes as performance anxiety, eating disorders and binge drinking may be more common in athletes than their non-athletic peers. Symptoms of depression are not uncommon in athletes either (Proctor & Boan-Lenzo, 2010). In the case of injury, a support system should be in place in order for athletes to get the assistance needed in coping with all aspects of the respective injury.

The Knee

The knee joint(s) is particularly vulnerable to injury in sports. It is a hinge-like joint made up of 4 bones (tibia, fibula, femur and patella) comprising 2 articulations and is reinforced by ligamentous structure for stability, see Figure 2.



Taken directly from: http://www.knee-pain-explained.com/kneeligaments.html

Figure 2. **Supportive structures of a healthy knee joint (Anterior view, Left knee)**

The 2 articulations are the patellofemoral: the patella (knee cap) and femur (thigh bone) and the tibiofemoral: the tibia (shin) and femur (thigh) bones. The joint is stabilized via a working combination of static ligaments, dynamic and integrated muscular forces and couplings, meniscocapsular aponeuroses, bony regions and joint load (Flandry and Hammel, 2011). From a basic functional standpoint, the tibiofemoral articulation allows transmission of body weight while the quadriceps group and patellofemoral articulation along with portions of the lower limb, act to dissipate forward momentum as the body enters the stance phase of gait (Perry and Burnfield, 2010).

Four ligaments support and maintain the mechanical stability of the knee. Two are outside the joint and two are housed within the joint. The two extra-articular (outside the joint) ligaments are named for their location, the Medial Collateral Ligament (MCL) and the Lateral Collateral Ligament (LCL). The two intra-articular (inside the joint) ligaments are the Anterior Cruciate

Ligament (ACL) and the Posterior Cruciate Ligament (PCL), named for their angle of orientation or attachment site.

Extra-articular ligaments

The MCL is the ligamentous sleeve that spans the entire medial side of the joint, from the medial aspect of the extensor mechanism to the posterior aspect of the knee (Bach et al., 1998). In sport and function, it resists forces applied from the lateral surface of the knee, preventing the medial portion of the joint from widening under stress. Injuries to this ligament typically occur in sport when the foot is planted or in contact with the ground and the knee takes an external force from the lateral side (Lohmander et al., 2004).

The LCL is a cord-like band on the lateral side of the knee joint and acts as primary stabilizer versus medial force load at the knee and as a secondary stabilizer to anterior and posterior tibial translation when the intra-articular ligaments are damaged or torn (Matsumoto et al., 2001).

Intra-articular ligaments

The PCL is one of the two intra-articular ligaments. It connects the posterior intercondylar area of the tibia to the medial condyle of the femur. This setup allows for the PCL to act as the restraint to forces pushing the tibia posteriorly relative to the femur; an example of this is falling on a bent knee (Zantop et al., 2006).

The other intra-articular ligament, the anterior cruciate ligament (ACL) is composed of numerous immature fibroblasts by 9 weeks in the gestation period and at 20 weeks development consists of marked growth with little change in form (Petersen & Tillmann, 2002). Two main bundles are already detectable by this point, but these are more parallel in orientation when compared to bundle orientation in the adult ACL. The two identifiable bundles in the fetal knee suggest early development of the knee joint is guided by the ACL (Lohmander et al., 2004). A fully formed ACL ranges from 22 to 41 mm and its width from 7 to 12mm, not very large considering its role in resisting forceful anterior tibial translation so common to ground-based sports (Grimm et al., 2014).

The ACL is attached to the lateral femoral condyle at the posterior aspect of its medial surface (Girgis, Marshall &Monajem, 1978). This attachment site is in the form of a segment of a circle, with its anterior border straight and its posterior border convex. The axis of the ACL is tilted slightly forward (non-vertical in nature), and the posterior convexity is parallel to the posterior articular margin of the lateral femoral condyle (Zantop et al., 2006). From the femoral site, the ACL runs anteriorly, medially and distally to the tibia where it has a wider and stronger attachment (Harner et al., 1999). As it passes across the joint, the ACL turns on itself in a slightly lateral spiral and this orientation is responsible for the relative tension of the ligament throughout the flexion-extension full range of motion (Zantop et al., 2006). At the tibia it is attached to a fossa in front of and lateral to the anterior tibial spine and passes beneath the transverse meniscal ligament; a few fascicles may even blend with the anterior attachment of the lateral meniscus (Girgis Marshall & Monajem, 1978).

The ACL is not a singular cord, but a collection of fascicles that fan out over a broad and flattened region. These are grouped as two parts: the anteromedial band (AMB) and the posterolateral bulk (PLB). The AMB has a more vertical orientation while the PLB has a more horizontal orientation in the frontal plane.

In any position of the knee, a portion of the ACL remains under tension and functioning (Welsh, 1980). As examples, with knee extension (straightening the leg), the PLB is tight while the AMB is moderately lax. As the knee is flexed (bent), however, the femoral attachment of the ACL assumes a more horizontal orientation which results in the AMB tightening and the PLB becoming more slackened, leaving the AMB as the restraint to anterior tibial load. Internal rotation of the tibia at this joint lengthens the ACL most noticeably at 30 degrees of flexion. It has been reported that the ACL acts as a secondary restraint to varus-valgus (lateral/medial) angulation at full extension (Markolf, Mensch & Amstutz, 1976). The twisting mechanism of injury (MOI) is resisted by the combination of capsular shearing, slanting collateral ligament action, joint surface and meniscal geometry (Matsumoto et al., 2001). Of the 4, this ligament affects athletes for the longest duration of time when injured. In fact, the ACL does not heal when torn and complicating things further following rupture, rotational axis of the knee is altered, which comprises the ground-based sport requirement of internal rotation stability (Amis, Bull & Lie, 2005) of the knee. Without stability, function is lost in sport, leaving an injured athlete with no means to change direction, accelerate and decelerate. Movement at the posterolateral component of the knee is increased by up to 413% at 15 degrees of knee flexion as a result of this instability (Kanamori et al., 2000). The tearing or rupturing of the ACL requires treatment; the standard in the field of sports medicine is reconstructive surgery (Bach, BR et al., 1998).

Without question, a maturing student athlete is complex on many levels. A maturing musculoskeletal system and one demonstrating adaptive changes to sports participation is more vulnerable to injury (Deepa and Strouse, 2016). The University-aged athlete is not skeletally mature; the bony anatomy of the knee is not fully unionized until as late as the 24^{th} year of life (Hill, 2017). Of the 4 bones, the patella is ossified earliest, at some point before puberty. The proximal end of the tibia reaches full maturity between 19 and 24 years of age, the proximal end of the fibula between 22 and 24 years, and the distal end of the femur is unionized between 20 and 24 years (Hill, 2017). Developing bone structures coupled with force transmitted through the joint in sporting activities creates the potential for long-term complications from musculoskeletal injury. As an example, physeal (growing portion of bone) injuries in the knee may produce irreversible damage to the growing cells, resulting in growth disturbance. Growth plate cartilage is less resistant to stress in younger years than in fully mature, adult articular cartilage and is also less resistant to shear and tensional forces (Caine, DiFiori, & Maffulli, 2016). In sport, when high or overload forces are applied to an extremity, failure may occur, resulting in local tissue damage, thus impacting quality of life. In terms of lower body injury, the ability to weight bear or execute activities of daily living or sporting activities (Webb and Corry 2000) are often disrupted. More skeletally mature athletes face other specified risks in sport. An example of this is that as bone stiffness increases with age its resistance to impact diminishes; significant mechanical overload, therefore, increases risk for greater damage to the bone itself and the knee's supportive structures (Deepa and Strouse, 2016). It is in these athletes that the ligamentous damage is quite typical from certain mechanisms of injury (MOI), like the plant-and-twist MOI common in ground-based sport.

One NCAA study reported that more than 10, 000 knee injuries are expected to occur in the female collegiate athlete annually; of note, girls and women in sports have a two to nine times greater risk of non-contact ACL injuries than males, or an average of 3.5 times greater risk (Voskanian, 2013).

Many knee injuries result in either a surgical intervention or considerable non-operative treatment and rehabilitation, or both (Hewett et al., 1999 & Kay et. al, 2017). With surgical intervention and the use of rehabilitation comes a burdensome economic effect. ACL reconstruction is a common outcome when significant injury to the ACL occurs in sport- the cost associated with rehabilitation, orthopaedic care and the surgery itself has been evaluated at $17, 000 USD per patient. An annual cost of over $37, 000, 000 USD has been identified within the athletic cohort alone (Noyes et al., 1999). Further to this, 10-25% of all reported SRI are to the knee joint; an estimated 250, 000 ACL-related injuries occur annually in the United States leading to somewhere between 80, 000 and 100, 000 ACL reconstruction surgeries per year (Donnell-Fink et al., 2015), totaling 1.36 to 1.7 billion USD per year. Note that this cost may vary dependent on location, but will include: hospital administration fees, operating room time, operating room personnel, post-op hospital time, education, therapy and return to play (RTP) rehabilitation relevant to the athlete's needs.

Programming within organized sports should aim to place emphasis on a proactive approach to injury deterrence in order to mitigate a large majority of these costs. A study specific to soccer identified a cost reduction of 43% in healthcare as reported in a neuromuscular training program group (−$689/1000 USD player hours; −$1741 to $234 USD); this program was a neuromuscular training program (NMT) similar to the 11+ but with additional use of wobble board, which is a therapeutic tool utilized by practitioners (Marshall et al., 2016).

The bottom line clinically, is that a reactionary approach to SRI is costly. Shifting focus to injury deterrence through the implementation of preventative measures is essential for this demographic. Allocating time to developing or modifying available measures to suit the sport or individual athlete's needs may be daunting from a clinical perspective initially; however, this will reduce risk of injury and incidence rates of injury as previously reported in the literature. The intervention of strength and proprioception has demonstrated preventive benefits when compared to stretching-based programs (Lauresen et al., 2014) in a number of field and court-based sports. Comprehensive programs based in resistance training have been found to enhance movement biomechanics, functional ability and to reduce overall injury (Faigenbaum and Myer 2010) and have been implemented in almost all high-level collegiate sports programs.

Soccer has led the way in the sports world with regards to implementing, evaluating and validating prevention programs specific to the knee and lower limb. Four recognizable neuromuscular training programs in the soccer world are: the HarmoKnee, Knee Injury Prevention Program (KIPP), FIFA 11+ and Prevent Injury and Enhance Performance (PEP). All of these have been reported to aid in reducing one or all of: the risk of knee injuries in teenage female soccer athletes, the risk of non-contact lower limb injuries, overall lower limb injuries and ACL injuries including risk of recurrence in those with previous non-contact ACL injury, respectively (Herman et al., 2012).

The HarmoKnee program is an integrative exercise program designed with the intention of educating athletes and coaches on the mechanics of soccer. The KIPP is a series of progressively challenging exercises inclusive of agility and jump training drills. The FIFA 11+ is an injury prevention program that was developed by an international group of experts for amateur players aged 14 or older. Lastly, the PEP is a prevention program consisting of a warm-up, stretching, strengthening and plyometrics built into the sport. All of these programs aim to build strength and stability in mechanics necessary for the sport and around the knee itself. An injury risk reduction of 19% to 44% for the HarmoKnee, 50% to 56% for the KIPP, 30% to 70% was reported for the 11+ Warm-up program and 78% for other unnamed NMT programs specific for all injuries, knee (ACL) and ankle injury reduction have been acknowledged (Thorberg et al., 2017, Al Attar et al., 2016). With reduction in injury risk at these levels, athletics personnel should strongly consider the implementation of these type of prevention programs specific to soccer and identify the necessary variations needed for application in all ground-based sports.

Although these programs have been validated and demonstrate success, consistency and adherence to these warm-up programs have been identified as issues in evaluating them practically (Emery et al., 2015). From a clinician standpoint, building these programs into on-field warm-up or movement preparation scenarios at practice creates opportunity for daily execution in a supervised format, which may also increase adherence and provide a more practical evaluation of their efficacy. At York University, each of the sports studied here practice multiple times a week, every week throughout the season (as well as the off-season). Educating all involved, from coaches to strength and conditioning personnel to student athletic therapists, in the value of these prevention strategies allows these on-field opportunities to become a platform for the execution of valuable NMT for athletes who may not receive it elsewhere (Van Tiggelen et al., 2008).

Programs based in neuromuscular training can build dynamic biomechanical stability around the knee through control of magnitude and rate of impact, force generation and absorption (Ferretti et al. 1992, Greska et al., 2012). Untrained individuals are pre-disposed to ligamentous knee injury due to a variety of factors, and therefore have shown to respond to neuromuscular programming at a much higher rate (Hewett et al. 1999, Faigenbaum & Myer, 2010). Injury prevention programs with a neuromuscular focus address landing mechanics in athletes by decreasing landing forces, increasing muscular strength and reducing muscular imbalances (quadriceps: hamstrings ratio being a primary target). By decreasing adduction and abduction moments at the knee, valgus and varus mechanical loads are reduced resulting in the ability to decrease potentially dangerous landing forces (Hewett et al. 1996, Flandry & Hommel, 2011). Strengthening programs that combine biomechanical and elements of NMT have been proposed by sports medicine personnel worldwide to aid in recovery from and prevention of injury. By addressing hamstring strength and the accompanying ratio relative to the quadriceps group, the knee joint can be stabilized (Augustsson et al., 2011). The hamstrings, as a group, function to compress the knee joint and restrain anterior motion of the tibia (Skelly and DeVita 1990). The hamstrings act as a decelerative agonist to the ACL in these two functions, decreasing shear forces and reducing load on the knee as the primary restraint (Hewett et al. 1999). With the use of an augmented 10-week feedback training program, altered knee and hip mechanics were identified in the performance of a dynamic stop-jump task (Greska et al 2012) - a common non-contact mechanism of injury (MOI) for knee injury.

When attempting to implement injury prevention programs a multitude of sport-relevant factors need to be taken into consideration. During preseason training, student athletes are often competing for a spot on the roster or a starting position on their team. Training camps (preseason) vary from sport to sport and each team will take on various training loads throughout. Training regimens may be more intense (two practices each day, as an example) and cause more fatigue, which has been found to be a potential cause of injury (Agel et al., 2007). Athletes may not be prepared or physically ready to meet the demands of these high-intensity training regimens when coming in from high school or from a detrained summer period. Activities in the regular season (games) may be more intense than those in the preseason (Agel et al., 2007), leading to greater force or overload potential during competition.

Another consideration within the student athlete population is that these individuals may experience increased fatigue from the cumulative exposure of training, practice, game play and academic studies (Yang et al., 2012). Of note, specific to this study, is that all ten teams have moved to a year-round training regimen in the gym for strength and conditioning as well as on-field, thus creating more exposures and risk of injury. This includes a preseason training camp which may include exhibition games, regular season (each sport has a distinct competitive schedule) and post-season training which may include exhibition games as well. The abundance in training load may add to the fatigue experienced by university athletes, and may be more applicable to newer athletes as they attempt to acclimate to varsity lifestyle in U Sport athletics from high school or elsewhere. The relationships among potential risk factors must be investigated in order to develop strategies that better protect athletes from severe injuries (Kay et al., 2017).

Although these NMI programs have been established and reported with some regularity to be an injury deterrent, adherence and compliance are common issues identified by Emery et al. 2015 in relation to both individuals and teams. Resources and availability of staff are two primary considerations when evaluating the emphasis of injury prevention within a Canadian varsity setting. As cost is a consideration in university athletics, budgets in U Sport are not that of high-level NCAA institutions; however, these programs are not costly from a strictly financial perspective.

From a clinician's standpoint, educating athletes, staff, therapists, students and coaches on the importance of these measures may, in fact, prove as valuable as the implementation and monitoring of the adherence to the measure itself. Once educated on the value and the importance of NMT programs, athletics personnel should aim to empower the athletes under their care, in their individual sports, with the ability to execute these with focus and integrity on a regular basis throughout the season (and career). The objective of this study is to identify and establish the extent of the sport related injury problem in Canadian interuniversity varsity athletics.

METHODS

York University, in Toronto, Ontario, Canada fields fifteen varsity sports and is the home to over 500 varsity athletes. The Gorman Shore Sport Injury Clinic is the primary care site for the varsity population in terms of injury evaluation and rehabilitation. All athletes are referred to the clinic, when possible, for differential diagnosis and are seen for evaluation by a student athletic therapist, certified athletic therapist, sports medicine physician or some combination of the sports medicine team personnel. York University varsity athletics run for the duration of the academic session with training camps beginning in August for football, women's rugby, men's and women's soccer while the remaining six sports begin early September. The academic session ends in mid-April. The number of regular season games played in a season within the OUA conference is as follows:

rugby- 4, football- 8, soccer- 16, volleyball- 19 women's and 18 men's, basketball- 23, hockey- 24 women's and 28 men's. Pre-season and off-season exhibition games are added by individual coaching staffs and playoff games are determined by placement within the conference regular season.

York University athletics run for the duration of the academic session with training camps beginning in August for: football, women's rugby, men's and women's soccer. The remaining six sports begin in early September.Injury data was collected from the Gorman Shore Sport Injury Clinic at York University via the injury database InjuryZone (https://sports1.injuryzone.com) from January, 2014 – December, 2017. Participants in this study were varsity athletes at the time of their sports-related injury (SRI). All participants were on active rosters of these ten varsity sports teams at York University: football, women's rugby, women's basketball, men's basketball, women's volleyball, men's volleyball, women's soccer, men’s soccer, women’s hockey and men’s hockey in the timeframe provided. All athletes signed informed consent documentation regarding the use of injury information upon joining a varsity roster at York University. Injury data was collected from January 2014 – December 2017 by a member of the York University sport medicine team in keeping with PHIPAA requirements and was anonymized for the purposes of this study, removing any identifiers. The ten varsity sports used for this study are the same as a previous study within the NCAA (Hootman et al. 2017). Each U Sport institute has their own roster of sports offered, but typically offer some (if not all) of these sports in the varsity domain.

All concussion-related injuries from these ten sports were excluded; these numbers would skew the data towards the collision sports due to the nature of the sports themselves (football, rugby and hockey). All other injuries sustained in the remaining five varsity sports and all recreational sports at York University were excluded as well. The sport playing surface was considered, but not utilized in analysis as this is team-specific within the identifiers of the study.

For the purposes of this study, a SRI is defined as any physical damage or reported complaint sustained by an athlete during competition, training or practice which required medical attention by an athletic therapist or medical doctor. The athletes were seen and treated at the Gorman Shore Sport Injury Clinic at York University. Injuries have been categorized by body part for comparison as either knee or non-knee in nature, and further sub-divided into level of injury as either significant (2^{nd} degree damage or greater) or non-significant for the purposes of analysis. The definition of significant injury was agreed upon by a panel of Certified Athletic Therapists within the sports medicine team at York University. The unanimous definition of significant injury was based upon two key factors: time lost to injury (a minimum of 15 days) and degree of injury (as determined by standard orthopaedic assessment) at the time of evaluation. Time lost to injury was determined through patient files based on subjective, objective, assessment and plan (SOAP) notes and treatment notes within individual athlete files.

Non-knee injuries include all other body parts, musculoskeletal in nature and exclude all incidents identified as concussion or possible concussion at the time of reporting or diagnosis in the clinic.

Injury rate was calculated per athlete, per sport. This calculation was performed using the number of injuries reported during this time period by rostered athletes. Archived rosters were used to capture numbers from each season.

All injuries seen for the purposes of assessment or treatment were completed by a Certified Athletic Therapist (CAT(C)), sports medicine physician or a student within the athletic therapy program at York University and entered into the injury tracking database, Presagia Sports Injury Tracker. The information provided is limited to the clinic's selective data entry process and data analysis was completed through SPSS version 24.

Data Analysis

Analyses were completed utilizing chi-square tests and via logistic regression including a bivariate and multiple logistic regression model. The chi-squared model was used to find out whether or not explanatory variables in the model are significant. The regression models were used as a predictive analysis to describe the available data and explain the relationships between the variables identified in the study. Within the regression models (Tables 3 and 4), women's volleyball was used as the reference group as it was the lowest reporting sport in terms of injury.

RESULTS

Between January 1, 2014 and December 31, 2017, 1 942 SRIs were reported; of these, 1 359 were male (70.0%) 583 female (30.0%). Sex was not used in the analysis as these teams compete specific to sex within the individual sports. Of the total injuries, 388 (20.0%) were significant in nature and 450 (23.2%) were knee injuries. The sex and sport frequency percentages are both somewhat skewed due to football's roster size being male only and more than four times the size of any of the other nine sports studied.

When looking at frequencies with respect to sport, football accounts for 40.8% of total reported SRIs with the next highest contributor being men's basketball at 10.1% (Figure 3). Other considerations when analyzing injury statistics in athletics are: length of competitive season, positional requirements, and the innate nature and rules to each sport. To keep in mind within the studied sports, women's rugby, football and men's hockey are the three collision sports.

For comparison, 20.3% of male and 19.2% of female SRIs were significant in nature.

Football reported 163 incidents, the largest number of significant SRIs, while 31.3% was the highest percentage of SRIs deemed significant within a sport - men's hockey. Injury rates range from the lowest, 0.940 per athlete in women's hockey, to the highest in men's basketball at 3.32 per athlete. Football had the highest rate of knee injury at 0.27, while women's hockey had the lowest at 0.02 (Table 1).

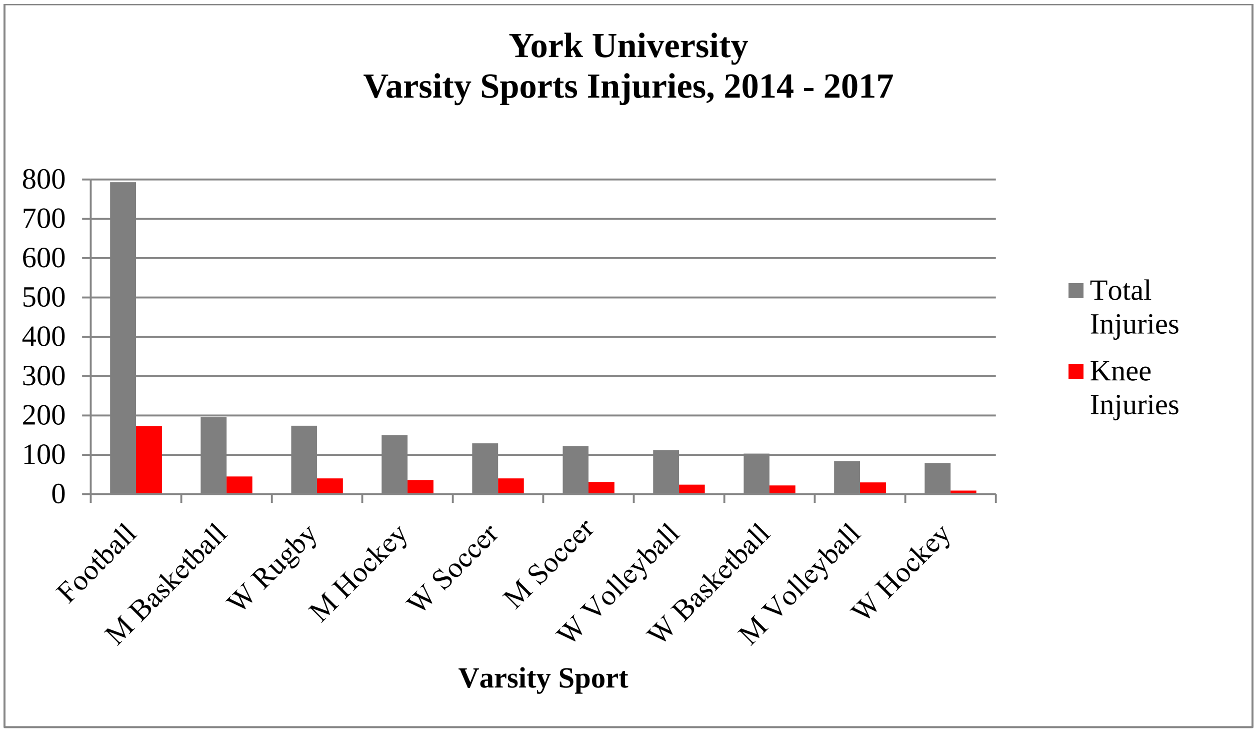
Taking sport position into consideration across the ten sports, the number of reported SRI were fairly evenly distributed amongst the offensive-only athletes (746 total SRIs, 21.6% significant in nature), defensive-only athletes (525 total SRIs, 21.3% significant in nature) and the two-way athletes (484 total SRIs, 16.9% significant in nature). With respect to knee SRIs, the numbers reported were fairly evenly distributed amongst the offensive-only athletes (178 knee SRIs, 39.5%), defensive-only athletes (116 knee SRIs, 25.8%) and the two-way athletes (122 knee SRIs, 27.1%). Offensive players were identified as those that are predominantly offensive within the nature of their position: on the offensive team in football, forwards in hockey and front line in soccer. Defensive-only athletes include: goaltenders, backline defenders and the defensive team in football and defense corps in hockey. Two-way athletes are those that play both offense and defense due to the parameters of their sport: all volleyball, rugby and basketball athletes, midfielders in soccer and any football athlete that plays on both offense and defense.

Overall, knee injuries have a much greater chance of being significant in nature versus any other joint in this population. Six of the ten sports were found to have over 40% of knee injuries reported as significant in nature within their individual sport domain. Soccer had the highest percentage, women's at 60.0% and men's at 55.5% (Table 2).

A larger percentage of knee SRIs, 41.1% (185 knee SRIs), were deemed to be significant compared to 13.6% (203) of non-knee SRIs. Football and men's basketball accounted for 48.4% of the 450 knee SRIs reported. Football accounted for the largest single-sport percentage (38.4%) of knee injuries. 315 of the 450 (70.0%) reported knee SRIs were males. Of these, 125 (39.7%) were significant in nature. 60 (44.4%) of the reported 135 female knee injuries were significant in nature.

The two multivariate logistic regression analyses were completed, the first calculating the odds of having a knee injury by sport and the second calculating the odds of having a severe injury by sport and type of injury (knee vs. non-knee). Both models were significantly better than null models with chi square values of 19.67 and 172.69 and p-values of .02 and .00, respectively. Men's volleyball was the only sport significantly associated with knee injuries with an odds ratio (OR) of 2.04 (95% CI of 1.08 – 3.84) compared to women's volleyball (Table 3). Table 4 illustrates the data generated from the regression model run for SRI significant injury versus non-significant injury. Men's hockey athletes were significantly more likely to suffer a significant injury compared to women's volleyball athletes (OR of 2.31, 95% CI of 1.23 – 4.33). Athletes with a knee injury were 4.5 times more likely to sustain a significant injury than those suffering non-knee injuries (OR: 4.55, 95% CI of 3.57 – 5.80), after controlling for sport.

Figure 3. **Reported Sport-related injuries (SRIs) by sport,** York University, 2014 –2017



M = Men’s / W = Women’s

Table 1. **Injury Rates by sport, York University, 2014 - 2017**

Varsity Sport	**Injury Rate**	**Significant Knee Injury Rate**
M Basketball	3.32	0.20
Football	2.69	0.27
W Volleyball	2.49	0.22
W Basketball	2.45	0.14
M Hockey	1.79	0.24
M Volleyball	1.64	0.04
W Rugby	1.58	0.14
M Soccer	1.16	0.13
W Soccer	1.13	0.21
W Hockey	0.94	0.02
AVERAGE	*1.96*	*0.19*

M = Men's / W = Women's

Table 2. **Knee Injuries By Sport, York University, 2014-2017**

Varsity Sport	Total Knee Injuries	Significant Knee Injuries (% within sport)
Football	173	79 (45.7)
M Basketball	45	12 (26.7)
W Rugby	40	16 (40.0)
W Soccer	40	24 (60.0)
M Hockey	36	20 (55.5)
M Soccer	31	14 (45.1)
M Volleyball	30	2 (6.6)
W Volleyball	24	10 (41.7)
W Basketball	22	6 (27.2)
W Hockey	9	2 (22.2)
TOTAL	450	185 (41.1)

M = Men’s / W = Women’s

Table 3. Logistic regression analysis of Sport Related Injuries: the association between varsity team and knee injury and non-knee injury in varsity athletes

(reference group: Women's Volleyball)

Varsity Sport	Odds Ratio (95% CI)
M Basketball	1.09 (0.62 – 1.91)
W Basketball	0.99 (0.52 – 1.91)
Football (M)	1.02 (0.63 – 1.66)
M Hockey	1.16 (0.64- 2.08)
W Hockey	0.47 (0.20 – 1.08)
Rugby (W)	1.09 (0.62 – 1.94)
M Soccer	1.25 (0.68 – 2.29)
W Soccer	1.65 (0.92 – 2.96)
M Volleyball	2.04 (1.08 – 3.84)

M = Men's / W = Women's

Table 4. **Logistic regression analysis of Sport Related Injuries: the association between varsity team and significant injury and non-significant injury in varsity athletes**

(reference group: Women's Volleyball)

Sport	Odds Ratio (95% CI)
M Basketball	0.78 (0.40 – 1.51)
W Basketball	1.20 (0.58 – 2.47)
Football (M)	1.28 (0.74 – 2.21)
M Hockey	2.31 (1.23 – 4.33)
W Hockey	0.75 (0.31 – 1.81)
Rugby (W)	1.03 (0.54 – 1.99)
M Soccer	1.40 (0.71 – 2.76)
W Soccer	1.42 (0.73 – 2.75)
M Volleyball	0.55 (0.24 – 1.28)
Knee/ Non Knee	4.55 (3.57 – 5.80)

M = Men's / W = Women's

DISCUSSION

Injury is inherent within the Canadian university varsity athletics population. The findings of 1, 942 SRIs reported over three years at this one institution identifies the extent of these serious injuries and highlights the need for athletic therapy and sports medicine staffing within this demographic. Severe injury rates will vary based on sport, event type and sex (Kay, MC et al., 2017). It is important to keep in mind the definition of significant injury when assessing the associated emotional, physical and financial costs of these injuries to student athletes. The total number of significant injuries in this study (388) identifies and highlights the need for facilities and personnel in which student athletes can report in order to receive adequate evaluation, care and treatment.

Approximately 1 in 10 injuries reported in the NCAA Injury Surveillance Program over the 6 seasons studied were considered severe, which is lower than the estimate of 14.9% in high school student-athletes (Kay et al., 2017). In comparison, this study found that 1 in 5 injuries reported (388 of 1, 942 or 19.9%) was significant in nature. This may be due to the definition used or potentially due to the nature of the reporting structure in a smaller cohort (1 university versus nationwide).

Football accounted for nearly four times as many SRIs as the next highest reporting sport, more than three times the number of knee injuries (Figure 3) and the second to highest injury rate (Table 1). The roster size in football needs to be taken into consideration as a contributing factor in all of the related findings. With more athletes there is potential for greater incidence and risk of injury, but this also mitigates elements within the regression analysis. Injury rate was determined via the calculation of SRIs over athletes, thus with a larger roster, the rate is lowered overall.

Over 23 % of the injuries reported were knee injuries and these are 4.5 times more likely to result in significant injury than non-knee injuries. A recent epidemiological paper by Kay et al. in 2017 identified knees to be the most common joint injured across 25 NCAA sports at 32.9% of total reported SRIs. A more in-depth look at injury timelines from time of injury (TOI) to RTP within this current study could prove useful for practitioners in order to identify certain aspects of budget, time and personnel allotment per injury or sport. Men's volleyball athletes are two times more likely to suffer a knee injury than any other sport and men's hockey athletes are 2.3 times more likely to sustain a significant injury than any of the other sports identified within this study. In ice hockey in Canada, a large consideration in injury reduction has focused on head injury and specific rules regarding body contact but little has been evaluated with respect to knee injuries. The value of injury prevention with regards to volleyball was demonstrated by Augustsson et al. (2011), presenting a 100% decrease in musculoskeletal injuries in the intervention group, compared to no change in injuries in the control group with a supervised and individualized resistance training program. Injury findings will vary to some degree based on the sports offered at institutions across the country, but offer insight into Canadian institutional trends.

Certain limitations have been identified in this study. In that it is a descriptive epidemiological study, this data does not take into account time on field or other sport-specific factors (ie. length of season, weather, surface) that may further aid practitioners and other personnel in relevant decision-making processes. Documented injury cases, as an example, are not adjusted for exposure risk hours or injuries incurred during training versus playing in game. Lack of certain details within the study may limit sport medicine practitioners in terms of practical application. The data utilized lacked certain elements that may be of use in clinical settings, such as time lost to injury per athlete and time and other sessional information which may help sport medicine professionals direct resources. A secondary limitation of this study is the manner in which the injury tracking program is utilized by the clinic. The data input is limited to what is submitted by the evaluating practitioner. The practitioner in this study, as noted, can range from a student athletic therapist to a sports medicine physician, leaving discrepancies in areas of injury evaluation and diagnoses. There is no cross referencing system in place in terms of validating the degree of injury, tissue involvement or other general assessment information as this is submitted on a paper form and is input directly based on what is determined by the attending practitioner. A practitioner may determine the degree of injury to be more or less significant at TOI based on certain parameters, or lack of thorough knowledge in the case of a student therapist. Multiple injury recorders may lead to a lower inter-rater reliability over the course of time.

This study provides an initial overview of injuries within ten varsity sports over a three year period and illustrates patterns of injury and prevalence within this demographic. Capturing the extent of the SRI problem will help in directing personnel to the importance of utilizing valid injury deterrence programming (Lauresen et al., 2014/ Herman, 2012) as the cost post-injury is much higher on a per athlete basis than the implementation of these NMT and other deterrence programs (Emery, CA et al., 2015). Comprehensive programs have been found to enhance movement biomechanics, functional ability and reduce overall injury (Faigenbaum and Myer 2010), most of these are easily applicable in nature. In clearly identifying the SRI problem, this study may serve as a reference point for this and other U Sport institutions to provide statistical analysis within the sports medicine field. This data should serve to identify gaps as well as potential trends in injury tracking as other institutions compile data and provide the basis from which practitioners can identify areas of need in order to implement practical deterrence programs within Canadian university sport. Within each sport there is varying evidence to support NMT programming in injury reduction. Some sports do require further investigation into cost-effectiveness and reduction rates. As an example, there is a lack of literature on interventions to reduce the risk of injury in football beyond focal studies on concussion and head trauma (Barron et al., 2014). On the other hand, there is extensive evidence (including level 1 evidence) that exercise-based interventions in the form of neuromuscular training programs are effective in reducing all soccer-related injuries (acute and overuse) across all levels of participation (Grimm et. al, 2014, 2016). There is, however, a need for more data on cost effectiveness, especially relating to the 11+ program within soccer (Marshall et. al, 2016). No matter the sport, the need for and value of progressive injury deterrence programming has been demonstrated. The Centers for Disease Control and Prevention states openly on their website rule number one is that prevention is better than a cure. The literature validating injury prevention programs may be applicable to other field-based sports as all involve similar biomechanical elements of motion: running, cutting, changing direction, acceleration and deceleration. Further investigation is needed.

Identifying the extent of the problem is the first step in a model of injury deterrence (see Figure 1) and needs to be done prior to introducing a preventive measure. Gathering meaningful and substantial data related to the extent of sport injury within this demographic provides sport medicine and varsity athletics personnel with an area of focus in which to address via practical means. Preventive measures can then be tracked and evaluated critically from a clinical perspective to determine merit and value within individual sport or varsity-wide. A applicable measure taken, as it has been stated in multiple studies, across multiple sports, that the risk of all lower body injuries may be reduced by up to 50% by regular participation in a balance training exercise program with a resistance training component, such as a NMT warm-up program (activesafe.ca).

Serving as a reference point for sport injury clinicians and management personnel within U Sport, this study may be utilized in athletics for a variety of purposes. Some points of application for the data generated include: validating sports medicine facilities and personnel by providing evidence for the need of such funding , student athlete time lost on field and the accumulation of clinical time spent. In Canadian Universities where athletics are not considered a priority, Sports medicine facilities and personnel are subject to budgetary scrutiny. With the number and significance of injuries presented in this data, providing athletes with the space and staff in which to turn in cases of injury is more than justified. Other U Sport institutions may use this study as a foundation in generating data, relevant to their athletics demographic in order to formalize space, time and personnel logistics. From a budgetary and staffing standpoint, U Sport institutions will need to acknowledge the data provided due to its descriptive nature and the number of student athletes affected over this relatively short timeframe. Epidemiological studies provide a foundation upon which practitioners can steer their focus when planning and developing programming and personnel allotment for varsity athletics. This descriptive epidemiological study serves as the foundation for future studies aimed at identifying the extent of the issue of sport injury within the varsity athletics population in Canada. In doing so, this study may serve as the catalyst for future studies in a variety of analysis in Canadian interuniversity athletics. The extent of sport injury has been has been identified here in one institution, providing practitioners with an opportunity to align specific studies in determining trends within their own institutions nationwide.

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