2021-01-28

# STICK ITT - Study to Increase Current Knowledge of Injuries in Trampoline and Tumbling

Downie, Sheila

UNIVERSITY OF CALGARY

# STICK ITT – Study to Increase Current Knowledge of Injuries in Trampoline and Tumbling

by

Sheila Downie

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN KINESIOLOGY

CALGARY, ALBERTA

JANUARY, 2021

## Abstract

Objectives: To examine incidence rates, severity, characteristics, mechanism and potential risk factors for injury in competitive Trampoline and Tumbling (T&T) athletes ages 8 to 25 years.

Methods: Competitive T&T athletes were recruited from across Canada to complete an online questionnaire (e.g., demographics, one-year injury history, injury type and location). Injury was defined as an injury that kept the athlete from T&T training and/or competing for more than one day and/or required medical attention. Univariate Poisson regression analyses were used to estimate incidence rates (IR) and incidence rate ratios (IRR), controlling for cluster by club and offset by exposure hour. Differences in rates were estimated across level of competition (sub-elite/elite), sex (male/female), age (years), T&T experience (years) and exposure (training/competition hours). Descriptive statistics (medians, ranges, proportions, 95% confidence intervals) for athlete demographics and injury characteristics are reported.

Results: A total of 132 athletes [89 female; median age=14 (range 10-24 years), 43 males; median age 15 (range 9-24)] from 25 clubs completed the survey with 65% reporting at least one T&T related injury in the previous year. A total of 135 injuries were reported (IR 2.01/1000 exposure hours 95%CI 1.69-2.39). The median time-loss was 30 days (range 0-482) and 125/135 (92.5%) of the injured athletes sought medical attention. The injury rate for elite athletes was 115 injuries/100 athletes/year (95% CI 89.4-143.1) and 92 injuries/100 athletes (95%CI 70.8-116.6) for sub-elite. The most common injury locations were the ankle [28% (24/135)] and head/face [18% (24/135)]. Ligament sprains [22% (30/135)] and concussion [17% (23/135)] were the most common injury type. Females reported significantly higher rate of injury than males [IRR 1.49 (95%CI 1.12-1.92)].

Conclusion: This study examined injury incidence in terms of exposure and found females were at greater rate of injury over their male counterparts. Athletes experience ankle, head (concussion) and overuse type injuries as they engage in competitive T&T. Additional prospective research is needed to inform the development of effective injury prevention strategies among these high-risk young athletes.

**Acknowledgements**

This thesis is the result of a group effort and would have been impossible to complete without the guidance and support of the brilliant minds in the SIPRC lab. I cannot find the words to express my gratitude to my supervisors, Dr Sarah Kenny and Dr Carolyn Emery for your outstanding mentorship, your (tested) patience and tireless guidance, and for thinking outside of the box to provide me with this opportunity. I thank my powerhouse committee members, Dr Kathryn Schneider and Dr Patricia Doyle Baker for your positive, supportive expertise and mentorship. I have learned from the best.

I would like to acknowledge and express my gratitude for the funding support that was provided by the SIPRC lab, Dr Emery, and Dr. Kenny.

Thank you to the STICK ITT support team: Kimberly Befus; without your help I would still be staring at raw data. Paul Eliason, thank you for always making time for zoom/email, your statistical brilliance and ability (talent) to explain stats so that I understand is remarkable. A huge thank you to Meghan Critchley for taking the time during your candidacy exam and vacation to Zoom with me each week. Without knowing it, you organized my weekly goals, kept me positive and thinking I can finish this, and kept my laptop on my desk as opposed to out the window. You are wise beyond your years.

Thank you to Eran Silberg, Brittney Jewan and Brett Macaulay of the Calgary Gymnastics Centre for your support, input and social media recruitment drives. Thank you to the T&T community (athletes, judges, coaches and parents) for building an outstanding T&T culture for which this thesis is aimed to inform. A heartfelt thank you to the amazing gymnasts who provided their data, (and photos/videos) to enable this research to happen.

I would like to acknowledge Tessa Van Der Veeken for the STICK ITT acronym and continued support and friendship. Also, thank you to Erinn Ogston and Catherine Tremblay for your tireless efforts in the French translation of the questionnaire.

I could not have moved forward with my education without the support, and lifetime of mentorship from my mother, father and brother, Craig. Finally, thank you to Drake, my four-legged sidekick who lay at my feet from start to finish.

## Dedication

To the person I admire the most – my brother Craig Downie

## Table of Contents

## List of Tables

## List of Figures and Illustrations

## List of Abbreviations

| Symbol | Definition |
|---|---|
| AGF | Alberta Gymnastics Federation |
| CI | Confidence Interval |
| CHREB | Calgary Health Research Ethics Board |
| DD | Degree of difficulty |
| DMT | Double Mini Trampoline |
| FIG | Federation du Internationale Gymnastics |
| GCG | Gymnastics Canada |
| IR | Incidence Rate (/1000 hours exposure) |
| IRR | Incidence Rate Ratio |
| PCSS | Post-Concussion Symptom Scale |
| PSO | Provincial Sport Organization |
| QR | Quick Response Barcode |
| REDCap | Research Electronic Data Capture |
| SIPRC | Sport Injury Prevention Research Centre |
| STICK ITT | Study To Increase Current Knowledge of Injury in Trampoline & Tumbling |
| T&T | Trampoline and Tumbling |

## Epigraph

“Sometimes I’ll start a sentence and I don’t even know where it’s going. I just hope I find it along the way”.

- Michael Scott - *The Office* - *US*

# 1 Introduction

## 1.1 Problem Statement

Competitive Trampoline and Tumbling (T&T) is a discipline of artistic gymnastics. T&T athletes require acrobatic proficiency to perform flipping and twisting somersaults at high speeds, with precision and at heights of eight meters or more (Gymnastics Canada 2020, Federation Internationale Gymnastics). Young athletes train intensely and repetitively to execute these complex skill combinations. As athletes progress through the competitive levels, increased demand is placed on acrobatic skill thereby exposing athletes to potential risk for injury.

It is well documented that sport-related injuries can often keep young athletes from progressing in sport and may have potential long-term consequences impacting health-related quality of life (e.g., osteoarthritis) (Emery, 2005). However, little is understood about the burden of injury among youth and young adult competitive T&T athletes. Therefore, epidemiological studies designed to examine the burden of sport related injury among these competitive athletes are warranted.

## 1.2 Research Purpose

The purpose of this study is to examine incidence rates, severity, characteristics, mechanisms and risk factors for injury in competitive T&T athletes aged 8 to 25 years.

## 1.3 Research Rationale

T&T is a high impact sport that is acrobatic and aerial in nature. As athletes progress through multiple competitive levels, routine components become increasingly more difficult and athletes strive to perform more flips and twists at greater speeds and heights within each routine. The potential for sport-related injury is escalated with increased training volume and repetitive, powerful motor patterns which are executed through the growth and development of these young athletes (Emery, 2005; Grapton, 2013; Esposito, 2009). Currently, there is an absence of research addressing injuries in competitive T&T. Some studies have explored T&T as an event or discipline within an artistic gymnastics' population. However, T&T athletes perform on unique platforms, which are different from those used in artistic gymnastics. Assessing the extent of sport-related injury among T&T athletes, independent of other gymnastics disciplines, is essential to develop informed injury prevention strategies that may reduce the burden of injury in this unique athlete population.

## 1.4 Study Objectives

1) To examine incidence rates, severity, characteristics and mechanism of injury in competitive T&T athletes ages 8-25 years old.

2) To explore potential risk factors for injury in competitive T&T athletes ages 8-25 years old.

## 1.5 Research Significance

It is well documented that sport-related injuries may keep young athletes from participating in sports and physical activities which can lead to long-term chronic conditions affecting fitness and overall health (Emery, 2005; Grapton, 2013; Van Rosen, 2018; Collard,

2008). Results from this research will provide a novel understanding of the burden of injury experienced among sub-elite (i.e., learning to train) and elite (i.e., training to compete, competing to win) T&T athletes aged 8-25 years. It is anticipated that findings from this study will contribute to the development of well-designed prospective epidemiological research by informing which risk factors may put athletes at higher risk of injury. It is also expected that results will lead to the development, implementation, and evaluation of effective injury prevention strategies for aesthetic aerial and acrobatic sports with the long-term goal of minimizing the overall burden of injury experienced by these athletes.

## 1.6 **Format of Thesis**

This thesis contains six chapters. Chapter 1 introduces the purpose of the STICK ITT study, research rationale and significance. Chapter 2 provides a comprehensive literature review describing background information about the sport of competitive T&T and appraising previous injury related literature conducted on competitive trampoline. Chapter 3 details the methodology of the present research, including study design, participant recruitment, data collection procedures and protocols, operational definitions, and statistical analyses. Chapter 4 reports all participant characteristics, sport participation, injury characteristics, injury estimates, and risk factor analyses. Chapter 5 discusses the results in relation to previous literature from other acrobatic sports and adolescent athlete populations. Strengths and limitations of the STICK ITT study are also described. Chapter 6 provides concluding statements and direction for future research in the field. A full list of references is provided in APA format. Appendices offer supplemental information and include recruitment and population charts, sample size

calculations, the STICK ITT questionnaire and accompanying consent forms and face validation tracking form.

# 2 Literature Review

## 2.1 Background

Within the past decade, competitive routines in trampoline and tumbling (T&T) have evolved to require higher degrees of difficulty earlier in the tiered competition levels. This means that athletes are expected to execute harder skills at an earlier age and stage in their competitive career. Elite high-performance athletes are pushing the limits of gravity in an effort to win medals and/or progress to the next level. As an acrobatic sport, the nature of T&T, and the events that comprise each competition level, potentially expose young athletes to a high risk of injury.

Understanding T&T-related injuries is important. In particular, the consequences of injuries among young athletes can include pain/discomfort, loss of physical fitness, future exercise aversion and possible financial strain for families (Emery, 2005; Von Rosen, 2018). The likelihood of reinjury is also high. Although athletes may return to sport seemingly rehabilitated, factors such as time away from sport/activity, introduction of braces and psychological barriers may predispose an individual to re-injury (Bolling et al, 2018) and the effects of long-term disability is possible (American Academy Ped, 2012; Von Rosen, 2018).

Previous related literature evaluating injury rates, characteristics and risk factors has focused on artistic gymnastics and backyard trampoline injuries. Although competitive T&T is like artistic gymnastics and other aerial/acrobatic type sports, the platform for take-off and landing is unique. Therefore, injury risk among T&T athletes should be considered independent of other sports. Studies examining injury data specific to competitive T&T is scarce, and no literature has been published to date (to the best of our knowledge) in relation to the double mini trampoline. An improved understanding of the burden and risk of injury among T&T athletes may inform the development of appropriate injury prevention strategies in this sport.

## 2.2 Trampoline and Tumbling Disciplines

Athletes may compete in one to four of the events that comprise T&T: Individual Trampoline, Synchronized Trampoline, Double Mini Trampoline and Power Tumbling.

### 2.2.1 Individual Trampoline

**Figure 2.1 Competitive Trampoline (with end decks and throw mat)**
image from www.eurotramp.com (eurotramp products)

The trampoline was invented in 1934 for use in circus performances, gymnastics practice and military fighter pilot training (Rapp, 1978; Esposito 2009; Gymnastics Canada, 2019). Over the next few decades, trampoline gained popularity for recreation and exercise. Community clubs, high schools and colleges offered classes and held competitive events. The Federation Internationale de Gynmnastique (FIG) became the international governing body for competition and the first World Championships in Trampoline was held in 1964 (Gymnastics Canada, 2019). However, throughout the 1970's, trampoline was gradually abolished from high school curriculums, collegiate competitive events and recreation parks due the high incidence of severe

injuries, specifically catastrophic spinal injuries (American Council of Sports Med, 2012, Rapp, 1978; Esposito, 2009). Statements outlining the significant risk associated with trampoline have been issued by the American Academy of Pediatrics (AAP) (2012), the Council on Sports Medicine and Fitness (2012), the American Academy of Orthopedic Surgeons (2012) and the National Collegiate Athletic Association (NCAA), with recommendations that participation be considered only under specific circumstances, such as during supervised sport training (i.e., structured coaching and competitive environments). Competitive Trampoline continued to grow with World Championships being held every 2 years. Trampoline became an event at the 1970 Canadian National Artistic Gymnastics Championships with DMT being added in 1976 and Tumbling in 1982. In 2000, individual trampoline became an official event at the Olympic games and T&T World Championships continues to occur every two years (www.olympic.ca/gymnastics, Gymnastics Canada, 2019; Esposito, 2009).

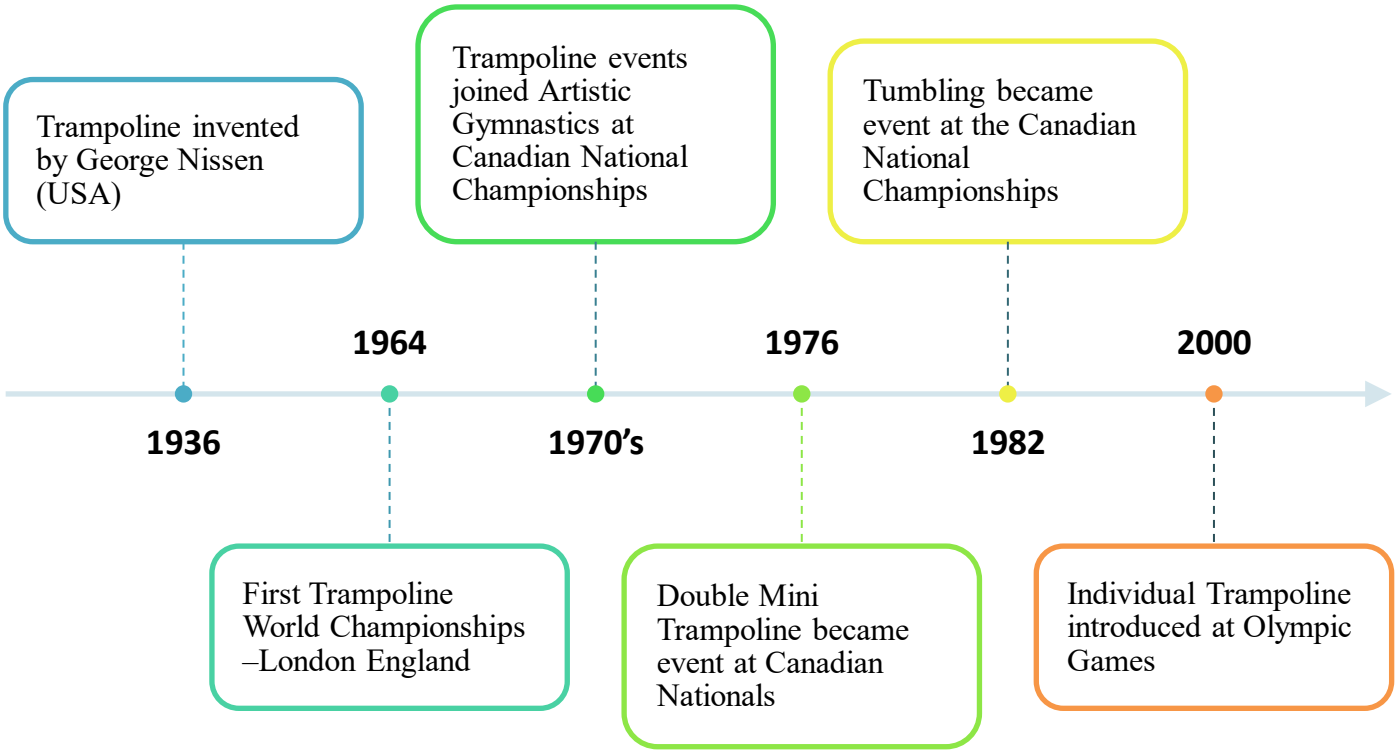


**Figure 2.2 Historical Timeline of Competitive Trampoline and Tumbling**

Competitive trampolines stand 1.15m high. The trampoline bed is 4.28m long and 2.14m wide (AGF Technical Manual, 2020). The springs are designed to provide maximal propulsion for the athlete. The beds are made of either string (Ross bed) or nylon web (Euro bed) and are marked with a red 70cm cross to emphasize the middle of the trampoline. All competitive trampolines have safety padding attached to the frame, providing padding over the springs and metal frame. Safety platforms (end decks) are secured to each end of the trampoline. End decks are level with the frame and covered with 21cm thick shock absorbing mats. On the floor, matting surrounds the trampoline and end decks. Any venue hosting a trampoline event must have a 10m high ceiling (Gymnastics Canada, 2019, Alberta Gymnastics Federation (AGF) Technical Manual, 2020).

A competitive trampoline routine consists of ten skills and is judged based on time of flight (seconds in the air), degree of skill difficulty, and the execution of each skill. The routine is terminated if the athlete fails to connect skills in succession, use the elasticity of the bed or if the athlete comes off the apparatus. Skills are assigned a degree of difficulty - a numerical value based on each skill's degrees of flip and twist. A laser under the bed of the trampoline records the time of flight. A trampoline gymnast wants to catapult as high as possible to execute a flawless routine. However, a concern in trampoline involves an improper landing in which case the athlete has the potential to rebound awkwardly, landing improperly multiple times. During training and competition, throw mats (small 1.7 x 1.0m mats) are made available for the athletes. These mats can be placed onto the trampoline for the athlete to land on to dampen the trampoline's bounce. The critical landing position is the most dangerous of improper landings. Landing on the trampoline with neck and back in either hyperflexion or hyperextension can potentially produce a critical injury and possibly long-term disability or paralysis (FIG; Esposito 2009; NCCP Level 2 Coaching Manual, 1997).

### 2.2.2 Synchronized Trampoline

In synchronized trampoline, two athletes compete side-by-side, on separate trampolines that are placed parallel to one another. The goal is to execute a routine with the same elements at the same time. There is no injury data dedicated to synchronized trampoline, however, individual trampoline studies could provide sufficient representation of this event.

### 2.2.3 Double Mini Trampoline

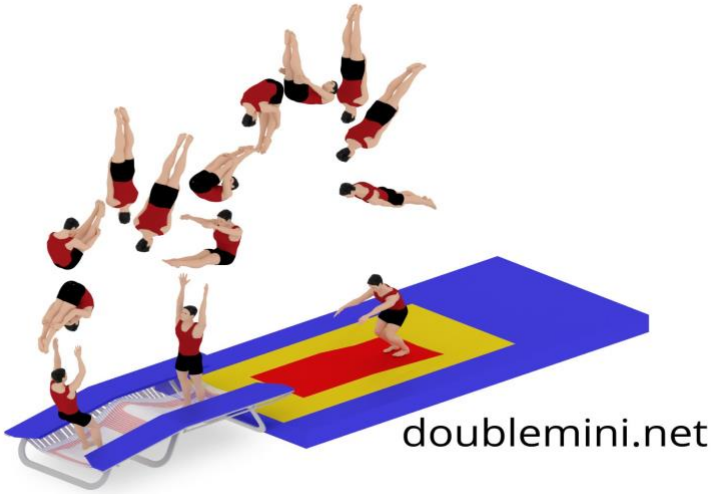


Image from www.doublemini.net by rudyout

**Figure 2.3 Double Mini Trampoline**

The Double Mini Trampoline (DMT) is 2.8m long and 0.9m wide with a slanted end and level tabletop (AGF Technical Manual, 2020). The frame and springs are covered with padding. Red zones on the trampoline bed outline where the crossbars of the frame lie below. The athlete sprints down a runway approach to the DMT and after mounting the apparatus on the slanted portion of the bed, executes two skills with the second skill dismounting onto a landing mat. Elite competitors execute double, triple and quadruple flipping and twisting skills off this mini trampoline, landing on a 30cm thick mat. Despite DMT being a competitive event internationally since 1974 (www.brentwoodtc.org), to our knowledge, there is no literature examining injury rates among athletes competing on DMT.

### 2.2.4 Power Tumbling

image from www.rossathletic.com (Ross Athletic Supply)

Figure 2.4 **Power Tumbling Runway** (Fiberglass rod frame section and foam matting)

Power tumbling is performed on a 26m long runway (1.7m wide) with routines consisting of 3 to 7 backwards bounding flips and a dismount to a landing mat. The runway is made up of fiberglass rungs (rods) strung parallel to one another along metal framed sections with a long top mat to cover the rungs. The landing (dismount) mat is 20cm thick, is level with the runway and is held in place by a thick Velcro strip (Gymnastics Canada, 2019; AGF Technical Manual, 2020). Power tumbling has been compared to the floor exercise in artistic gymnastics (Bak et al, 1994).

## 2.3 T&T Competition Participation

Across Canada, there are over 60 competitive T&T clubs listed on Provincial Sport Organization websites, and 1708 athletes were registered for the 2018-2019 competitive season (T&T Technical Committee reports) (see appendix A). Competitive T&T in Canada is stratified into levels according to ability and age. At larger sanctioned competitions, age categories are further segregated within the competitive levels. Provincial levels 1 through 4 (classified as sub-elite for this study) provide entry level competitive routines for young athletes aged 8 years old

and up. These athletes compete at invitational meets and provincially sanctioned competitions (e.g., Provincial Championships). The four national levels (level 5, 6, Junior, and Senior) require athletes to achieve a designated score based on routine execution and skill difficulty level in order to progress through each level. National level athletes are categorized as elite for this study. From National level 5 to Senior, males and females are scored under the same code of points for execution and difficulty. However, the mobilization designated scores to "mobilize" through each national level are higher for male than female athletes. Athletes must be 11 years old to compete at the national level (level 5) and a minimum age of 17 years is recommended for senior level competitions. National level athletes compete within their home province and at National Championships. Many national level athletes also qualify for international competitions such as World Age Group Championships, World Championships and the Olympic Games (see Figure 2.2)

A pre-competitive athlete designation can be assigned to those athletes who are training the necessary skills for competitive participation but whose routines may not be ready for competition. The term "pre-competitive" is used to describe those athletes that practiced T&T skills and routines but were not yet competing during the 2018-2019 competitive year. In Alberta, pre-competitive T&T athletes participate in the Alberta Trampoline and Tumbling Developmental Program. These pre-competitive athletes train to perform pre-determined skill sets, strength tests and progressive routines designed to enable the transition to competitive T&T. Judges assess the athlete's performances and athletes earn performance and participation awards. Other provinces have similar programs.

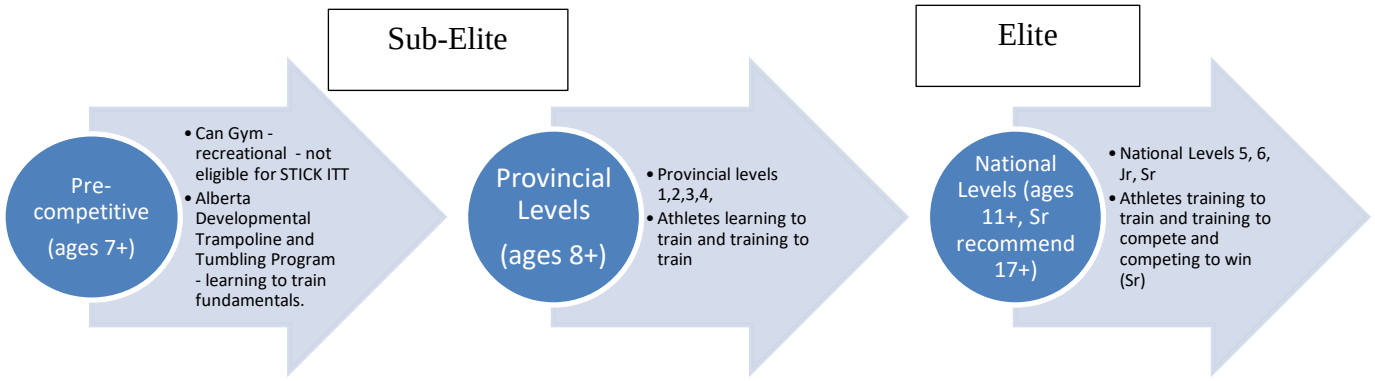


**Figure 2.5 Canadian Competitive Trampoline and Tumbling Stratum (Gymnastics Canada, 2019)**

## 2.4 T&T Competition Safety Precautions

In a competitive T&T environment, safety is addressed through extensive and mandated coach training, specific equipment (e.g., spotting harnesses, inground training trampolines, throw mats), appropriate technical progressions and strict adherence to common gym rules (e.g., one athlete on the trampoline at a time, control before height, always land with two feet on the same surface at the same time) (NCCP L2 Trampoline Coaching Manual; FIG; AGF). Coaches are required to complete the National Coaching Certification Program (NCCP) specifically targeting trampoline and gymnastics (technical and theory) levels 1-3. Many coaches then complete the NCCP Advanced Coaches Diploma (level 4 certification). This 2-year diploma consists of a series of multi-sport focused modules designed for high performance coaches. Advanced T&T specific education, the FIG Academy Program, is offered by the gymnastics international

governing body. The NCCP Level 4 and FIG Academy provide the credentials to coach athletes competing at World Championships, World Age Group Championships and the Olympic Games (www.fig.gymnastics.com; www.coach.ca-advanced -diploma).

As the competitive T&T levels progress, athletes are required to execute complex skills and combinations earlier in competitive tiered levels (Kuhn 2019, Alberta Gymnastics Federation). As such, many T&T athletes are pushing the limits of acrobatic possibilities. Despite coaches' most dedicated efforts to maintain safety, injuries are inherent to the sport given the high speeds, impacts and aerial components.

Judges score each competitive routine based on pre-determined skill difficulty, execution of each routine element and time of flight (trampoline). Following the FIG code of points, judges deduct points from the execution score in accordance to flaws in the routine. Several deductions have been established in an attempt to promote the execution of a safe routine. For example, judges will deduct points for lack of control, lack of stability, or poor position (e.g., chest down) on a landing. Deductions for horizontal displacement on the trampoline bed or tumbling floor are taken for any lateral travel during a routine. Completion of a twist, or kick out of position, should be accomplished between 180 degrees and 90 degrees to the trampoline or tumbling floor. These specifications not only ensure a minimal deduction score but keeps the athlete from landing while still flipping or twisting into the apparatus (FIG code of points, 2017-2020).

Since 1986, changes to the trampoline frame, bed and springs have been made in an effort to address safety. Competitive trampoline frames are now stiffer for better stability. Thick, tapered frame pads are now a requirement on the end decks and springs must be covered with special matting. Corner springs and braced corners now provide smooth direction of propulsion for athlete directionality. Additionally, the sharp hooks on the springs are tapered and

competition springs are tightly coiled to help decrease breakage due to high speed loading. These aforementioned changes have been accepted internationally by FIG with further modifications (i.e., thicker, layered padding in landing zones, tapered throw mats) under review (Ross, www.reboundproducts.com).

## 2.5 Trampoline and Tumbling Injury Epidemiology

Trampoline injury literature reviews reveal many studies outlining the burden of injury in children who engage in recreational/backyard trampoline. The 2012 American Academy of Pediatrics (AAP) position statement (2012); "Trampoline Safety in Childhood and Adolescence" examines prevalence and mechanism of trampoline related injuries. The AAP report does not identify any data specific to competitive or structured trampolining and, as such, several authors recognize the need for epidemiological studies investigating injury patterns, prevalence and prevention in competitive trampoline and tumbling (AAP, 2012; American Council of Sports Med, 2012; Grapton et al, 2013; Gymnastics Canada, Esposito, 2009; Nystead, 2006).

Some studies examine trampoline injury rates in relation to artistic gymnastics. Commonalities between T&T and artistic gymnastics may include aerial/acrobatic maneuvers and repetitive take offs and landings. Eduoard et al. (2017) conducted a prospective cohort study through the International Olympic Committee (IOC) injury and illness surveillance system and recorded all injuries and illness sustained to Olympic artistic, rhythmic and trampoline gymnasts over the 2008, 2012 and 2016 Olympic Games. Excluding pre-existing and/or not fully rehabilitated injury, an all injury and complaints injury and illness definition was used and all new injuries or illness, or non-injury, non-illness, were recorded daily by the National Olympic Committee's head physician and associated medical teams. Over the three Olympic games, 48

male and 47 female trampolinists registered a total of five injuries (6.25 injuries/100 male trampolinists, 4.26 injuries/100 female trampolinists). Male athletes reported head (33.3%) and foot (33.3%) injuries whereas female athletes reported hip/thigh injuries (50.0%). The type of injuries reported included sprains (66.7%), contusions (50.0%) and tendinopathy (50.0%). None of the Trampoline athletes reported time loss due to injury. This study focused upon artistic gymnasts' results or combined all three disciplines in reported numbers. A combined report of artistic, rhythmic and trampoline for injury risk and incidence may not provide injury data that is representative of the athletes participating in each discipline. Authors note that differences in physical demands, skills and rules could influence the injury risk and that the sample size and injury rates in trampoline athletes was too low to adequately power this study. The analysis of injuries/100 gymnasts does not take into account the exposure time that each discipline trains and competes. Typically, artistic gymnasts' train more hours than competitive trampoline athletes, therefore injury data should reflect the variance in exposure time. Eduard et al. note that the IOC injury and illness surveillance system is based upon a multi-sport questionnaire that may not provide adequate representation of individual sports such as gymnastics and trampoline. While injury surveillance of elite Olympic athletes is important, this study is not representative of the majority of athletes participating in competitive artistic and trampoline gymnastics.

Bolling and Leite (2012) also examined the difference in injury profiles between trampoline and artistic gymnasts. Authors analyzed injury data of competitive artistic and trampoline gymnasts that sought physical therapy treatment. Trampoline athletes (mean age 17 years old) averaged 3.0 injuries/athlete (57 injuries/19 athletes) compared to 1.9 injuries/athlete ( 27 injuries/14 athletes) among artistic gymnasts (mean age 11 years old). Authors noted a higher incidence of low back strain (26.3%) in trampoline athletes over artistic gymnasts, whereas,

artistic gymnasts sustained more injuries to the upper extremities (22.2%) than the trampoline athletes. Ankle sprains were more common in artistic gymnasts (25.9%) and muscle strain was seen more commonly in the trampolinists (no proportion given). However, the results of this study were provided in abstract form and no further information on study methods, statistical procedures, athlete exposure or competitive level was provided.

Bak et al. (1994) conducted a one-year prospective study that examined incidence, mechanism and risk of injury among tumblers, rhythmic gymnasts and elite and sub-elite artistic gymnasts ages 8 to 25 years old (n=115). Authors defined injury as any damage leading to pain, activity restriction and or requiring medical treatment in connection with gymnastics participation. Injuries were registered by the athlete and coach, and researchers regularly followed up for report completion. Both acute (sudden onset) and chronic injuries (gradual onset) were recorded and injury severity was ranked from grade 1, training with mild restriction to grade 5, injury requiring hospitalization. A total of 54 gymnasts reported injuries with 20 (10 female, 10 male) tumblers accounting for 31/98 (31.6%) of total injuries. This study examined injury in relation to exposure time and found that tumblers had a higher injury rate over artistic gymnasts (tumblers, 3.4 injuries/1000hours exposure, artistic gymnasts 1.0-1.4/1000 hours exposure). However, it was unclear how exposure time was calculated. Authors noted that among all athletes, acute injuries were more common (60/98, 61%) and occurred due to landings/dismounts (24/98, 40%). The tumblers sustained minor injuries (grade 1) in 18/31 (58%), and more severe injuries (grade 5), requiring hospitalization, in 4/31(13%). This is an older study and may not meet current epidemiological reporting standards. However, despite a lack of clarity in exposure calculations, the recognition of exposure time in comparison of injury data between artistic gymnasts and tumbling athletes is a strength of this study. Authors noted

that the tumbling athletes were older (ages 15-25 years) than artistic gymnasts (ages 8-23) and suggested that the tumbling athletes were retired artistic gymnasts that went on to specialize in tumbling. Authors also utilized a sensitive injury definition in hopes to capture all injuries from mild to severe. It is possible that the injury rate for the tumblers could be inflated due to chronic or un-rehabilitated injuries sustained during several years of training and competing in gymnastics and or tumbling. This observation may explain the 30% of tumblers who reported using prophylactic bandaging or taping to manage impediment. Based on physical characteristics and the observation that training exposure times were similar, this study provided injury data that combined artistic and rhythmic gymnasts into a single category. By combining rhythmic and artistic gymnasts, misrepresentation of injury incidence is likely because the two disciplines differ broadly (e.g., skills, landings, rules, competitive requirements). Male and female tumbling athletes were categorized homogenously with authors noting no difference between male and female tumblers in injury incidence, characteristics and mechanism. Physical characteristics, age years of experience and exposure hours were similar. However, at an elite level, male tumblers are likely to have the strength and power to perform more difficult tumbling passes. Bak's results show injury counts per 100 athletes were higher for male athletes (males 107injuries/100 gymnasts/season; females 83 injuries/100gymnasts). Although there are common acrobatic elements that artistic gymnastics and T&T share, the two disciplines vary in apparatus, training exposure and routine requirements. Injury related studies should examine T&T and artistic gymnastics independently.

Kuisis et al. (2011) examined the effect of strength on injury incidence rates among high performance trampolinists ages 10-20 years. Injury data was collected retrospectively (one year) from injury records. An injury was defined as any condition that caused time loss from

practice/competition and or required medical treatment. Of the fifteen participants, there were 13 (86.6%) injuries registered. This study found an injury incidence rate of 2.3/1000 hours of training - equivalent to one injury for every 440 hours of trampoline training. Injuries to the lower limb (heel, foot, knee) occurred in ten of the thirteen registered injuries. Due to the small sample size, no trends in injury characteristics were reported but authors suggested that the repetitive strain of trampoline training may lead to tendinopathy and excessive strain on epiphyseal plates. While the objectives of this study do not directly align with this thesis, trampoline specific injury data was presented in terms of athlete exposure hours. However, injury incidence may be inflated due to small sample size and there were only two non-injured athletes among the fifteen participants. Although an injury definition was used, it was not clear how researchers determined time loss and or medical attention in order to meet the injury criteria.

To our knowledge, there is only one previous study that examines injury data specific to competitive trampoline and tumbling athletes. Grapton et al. (2013) completed a cross-sectional study examining the possible "causal" factors anatomical location and type of injuries incurred by trampoline, tumbling and acro-sport (acrobatic gymnastics) athletes ages 12-18 years old. Over a five-year timespan, 357 injury report forms were completed and filed with the National Physician for the French Federation of Gymnastics (FFG). No definition of injury was given outside of confirmation of medical diagnosis. Each report, completed by athlete, trainer and sport medicine physician, provided information about the injury, with a goal of understanding an association between exposure (trampoline, tumbling, acrosport participation) and outcome (injury type, anatomical location and cause). Un-injured athletes were not represented for comparison and the authors noted this limitation. Selection bias is a concern as only athletes

presenting with injury are represented and with no injury definition, it is likely that only the more severe injuries were reported and diagnosed. This would lead to underestimation of injuries as less severe injuries that did not require medical attention were not registered. Also, authors note that recreation and competitive athletes were counted in participation numbers and report that 63% of the injury reports were for athlete's competing at national/international level. However, there is no information for the remaining 37% of athletes injured in trampoline/tumbling (and acro-sport) in their study. This information would be important as recreational athletes do not possess the same exposure as competitive athletes in training and could therefore cause an overestimation of some types of injuries that are more indicative of an untrained, recreational athlete. For example, an untrained athlete is more likely to fall on outstretched arm on failed skill whereas trained competitive athlete should be more comfortable aerially and navigate safely to one of the basic landing skills.

Grapton et al. (2013) found that trampoline injuries were three times more frequent (n=226) than tumbling injuries (63% vs 22%) with 63% of these injuries occurring in elite athletes. Trampoline athletes experienced lower limb injuries (111/226) 49% more frequently than upper limb injuries (42/256, 19%) with knee (19.9%), ankle (15.5%) and forearm (5.7%) showing the only significant results with respect to anatomical location. Upper body injuries were independently associated with trampoline as opposed to tumbling (forearm, OR 9.44, 95%CI 1.21-73.13) with bone damage being more frequently observed in the upper limb injuries (OR 13.3, 95%CI 2.75-64.52). This result could be indicative of the 37% sub-elite or recreational athlete reporting injuries sustained on the trampoline. The results for tumbling injuries (n=80) showed that lower limb was most frequently injured with ankle injuries being significant; (25/80, 31%) and ligament damage being most common (47.9%). Statistical results for this study were

difficult to follow and some apparent inconsistencies could have been made clear with better definitions and explanations. Confidence intervals for upper body associations were wide and imprecise. Comparisons between events and injury types was not mentioned in their objectives and authors could have utilized risk ratios to assess differences as opposed to odds ratios for associations between many insignificant variables.

Grapton et al. (2013) classified possible "causal" factors for injury as intrinsic (behavioural, psychological, fatigue, training and overtraining factors, previous injury) and extrinsic (environmental, lack of spotter, safety rules). This portion of the study was poorly defined. While it is possible that the term "causal" is a mistranslation, a cross sectional study cannot establish temporality and therefore cannot determine the cause of injury. Authors were not clear who reported the perceived cause – athlete, coach, trainer or physician of which perception of "cause" could be misinterpreted. Defining each risk category using better defined intrinsic and extrinsic variables (e.g., athlete fatigue, technical error or apparatus contact) would have shown a more thorough mechanism of injury. Causal factors were not reported on half (116/226) of the injury report forms with intrinsic or behavioural factors being noted in 84% of the trampoline injuries and 92% of the tumbling injuries (p value insignificant).

Misclassification bias is a systematic error that occurs if there are discrepancies in measurement and categorization of study variables. Authors may have tried to control for non-differential misclassification bias in utilizing medical diagnostic techniques to confirm accuracy of diagnosis of injuries. However, given the timeframe of the study (five-years-worth of reports), it is likely that more than one person was responsible for filling out the injury forms. Accuracy and completeness of health records should be considered when discussing misclassification in this study. There is no information given as to the actual information collected on the injury

report form and it is possible that form accuracy could be inconsistent. This is important to consider because the study found significant results in frequency and type of injury in some results (association of forearm and knee injuries in trampoline and high frequency of ankle injuries in tumbling).

Possible confounders for this study could include; age, training age, exposure or training hours and number of competitions and skill or competitive level and stratification for these variables should have been outlined. Authors noted greater frequency of injuries in those athletes at elite levels, however, it is unclear as to whether this is a crude number or if this variable was stratified for. In this study, age, training age and previous injury could be considered for effect modification. However, no interaction term was mentioned in the analysis and odd ratios did not appear to be adjusted.

This study could be generalized to the population of athletes who participate in competitive trampoline, tumbling and acrosport. The study looks at French athletes and mentions that the injury report data was primarily from international level competing athletes, therefore it is likely that the training environment, skills, and expectations would be similar to other countries having athletes of the same calibre.

The Grapton study provides a good overview of injury proportions and characteristics that T&T athletes experience. Authors examined 357 injury reports, over a five-year time span and data was analyzed through an exterior and governing body (physicians) with the FGG. This should have aligned the study well for blinded completion. Medical diagnostics were used to confirm injury type and significant associations were made between arm and knee injuries on trampoline and ankle injuries on tumbling. Other studies examining injury incidence (injuries/100 gymnasts, injuries/exposure time), provided rates for either trampoline or tumbling

athletes but the results of these studies focused upon artistic gymnastics. Previous literature mentions the use of double mini trampoline, however there is uncertainty if the double mini trampoline is the same single piece of equipment used in competition or two mini trampolines. There is no injury data dedicated to synchronized trampoline, however, individual trampoline studies could provide representation of this event. The STICK ITT study examined the incidence, severity, characteristics and risk of injury within a sport that is under-represented in current injury research. Previous to the STICK ITT study, concussion injuries have not been quantified in T&T. Gaining knowledge into the extent of injuries sustained in competitive T&T can provide guidelines for coaches for athlete planning and policy makers for potential rule and equipment modifications.

### 2.5.1 Injury Estimates in Competitive Trampoline and Tumbling

The Grapton study (2013) reported that trampoline athletes registered 63% (226/357) of the injuries while tumbling athletes registered 22% (80/357). Bolling and Liete (2012), found 3.0 injuries/trampoline athlete (57 injuries/19 athletes). Kuisis et al. (2011) examined the incidence reported that high performance trampoline athletes sustained one injury for every 440 hours of training (2.3 injuries/1000 training hours). Bak et al.(1994) reported an injury incidence rate of 3.4 injuries/gymnast/1000 hours for competitive tumblers and noted that when exposure time was considered, the tumblers' injury rate was that of artistic gymnasts (1.6 injuries/gymnast/1000 hours). The results of these studies suggest that injury rates in competitive T&T are high. However, Edouard et al (2017) found that over three Olympic games, a total of five injuries (6.25 injuries/100 male trampolinists, 4.26 injuries/100 female trampolinists) injuries were sustained.

### 2.5.2 Injury Characteristics

Federation Internationale Gymnastics (FIG) medical representatives, Leglise and Binder (2010), have provided a clinical reference of common injuries they have observed among T&T athletes. For example, trampoline athletes most commonly experience lumbosacral pain while tumblers most frequently sustain Achilles tendon tendinopathy and ruptures. Lower limb fractures, strains and sprains were common among both trampoline and tumbling disciplines.

Grapton et al. (2013) found that trampoline athletes experienced lower limb injuries 49% more frequently than upper limb injuries. Seven spinal injuries were reported among the trampoline athletes (n=226) with one being catastrophic. The frequency of ankle injuries frequency was significant in tumbling athletes (OR=1.89, 95%CI; 1.06-3.35) with ligament damage being the most common diagnoses. These findings align with other literature examining the characteristics of trampoline and tumbling related injuries. Kuisis et al. (2011) found lower quadrant (heel, foot, knee) comprised 83% (n=10 injuries) of trampoline related injuries. Other studies evaluating injuries within all gymnastics disciplines have found that lower extremity and trunk injuries are the most common (Bolling, 2012; Bak, 1994; Eduoard, 2017).

### 2.5.3 Mechanism of Injury

The skills required of T&T athletes demand repetitive, powerful movement patterns combined with speed, height and high impact landings. Continual mental focus is required to maintain precision and body control for execution of complex acrobatic and aerial skills. The platform on which T&T athletes perform is unique. Leglise and Binder (2010) suggest that acute trampoline injuries are related primarily to failed skills and out of control rebounds that lead to falls onto the frame or the floor. Landing on the trampoline in spinal hyperflexion or

hyperextension is the most feared injury and presents the most serious of injuries in the sport (Legise, Binder 2010; NCCP L2 Coaching Manual). It has also been hypothesized that injuries in aerial and acrobatic sports may be related to fatigue and/or psychological factors (Grapton et al., 2013).

The physical movements of competitive T&T shares similarities with artistic gymnastics and other aerial/acrobatic type sports such as landings, dismounts and flipping/acrobatic maneuvers. Therefore, a case could be made for comparing injury mechanisms across the gymnastics and T&T disciplines with possible commonalities including repetitive take offs and high impact landings, which may be consistent with the higher frequency of ankle and Achilles injuries seen in both sports (Grapton, 2013; Bolling 2013; Bak, 1994; NCCP L2,1997).

## 2.6 **Risk Factors for Injury in Trampoline and Tumbling**

Risk factors are variables that increase the likelihood of injury in sport and recreational activities and may be classified as intrinsic or extrinsic. Intrinsic risk factors are biological in nature and individual to each person such as age, sex, physical maturity and previous injury history. Intrinsic risk factors may predispose an individual to injury depending on an individual's reaction in certain situations and how events are imposed upon that athlete. Potential identifiable intrinsic risk factors for T&T athletes may include sex, age and training exposure. Increased musculature, power and aggressive approach to training may place males at a higher risk of injury (Emery, 2005). This is consistent with observed traits of male T&T athletes, specifically at the National level of competition. Table 2.1, adapted from Emery, 2003, summarized potential risk factors that may be specific to competitive T&T athletes.

Extrinsic risk factors act upon an individual from an external source such as the environment, level of competition or equipment. An athlete who is predisposed to injury through an intrinsic risk factor (e.g. previous injury) becomes increasingly susceptible to injury once an extrinsic factor is introduced (Meeuwisse, 2007; Emery 2003; Caine et al., 2008).

Risk factors may also be categorized as modifiable or non-modifiable. Non-modifiable risk factors, such as age, sex, or previous injury can possibly be lessened through external measures. For example, an athlete with a history of ankle injuries may choose to wear a brace and engage in strengthening and proprioception exercises to lessen the risk of future ankle injury (Cain et al, 2008). Modifiable risk factors may include rule changes, physical preparation and protective equipment (Emery, 2003) and serve to lower the risk of injury.

**Table 2.1 Potential Risk Factors for Injury in Competitive Trampoline and Tumbling**

**Adapted from Emery, 2003

| Intrinsic Risk Factors | Extrinsic Risk Factors |
|---|---|
| Non-modifiable<br>• Sex<br>• Age and physical maturation<br>• Previous Injury<br>• Years of T&T experience | Non-modifiable<br>• Nature of the sport (acrobatic/aerial)<br>• Skill requirements/degree of difficulty<br>• Gym environment (noise, distractions) |
| Modifiable<br>• Athlete recovery<br>• Competitive level/skills learning<br>• Fitness level (strength/endurance/flexibility)<br>• Kinesthetic awareness<br>• Psychological factors (stress/anxiety/fear)<br>• Sleep habits | Modifiable<br>• Length/duration of competitions<br>• Number of events athlete trains/competes in.<br>• Coach education<br>• Training protocols (warm up/cool down/safety training practices)<br>• Protective equipment (mats, spotting harnesses)<br>• Type of equipment (above ground vs. in-ground trampolines, matting)<br>• Equipment maintenance (softness/hardness of landing mats) |

Previous research has reported that risk of injury among athletes increases with age past 13 years old (Emery, 2005). Adolescence is a time of rapid growth and change to the musculoskeletal system. Sports such as gymnastics, competitive dance and T&T, that require repetitive and powerful movement patterns on a growing body, can potentially increase an adolescent's vulnerability to injury (Emery, 2005, Nysted et al, 2006). As T&T athletes progress through the competitive levels towards high performance, efforts to "push the limits" towards higher degrees of difficulty typically result in longer training exposure times and busier

competitive schedules. Grapton et al. (2013) noted that injuries are more likely to occur during high-volume and high-intensity training periods such as preparation for and during national and international events. High volume training and intensity combined with a lack of recovery could be considered modifiable intrinsic risk factors for T&T athletes (Emery 2005, Grapton 2013, Von Rosen 2018). Given that most young athletes striving for high performance T&T are children and adolescents, careful consideration and planning is needed related to growth and skeletal maturity. Sex and age are non-modifiable risk factors; however, training exposure can be adjusted to decrease potential risk in situations such as times of peak growth rates, stress, illness and injury (Emery, 2005).

Other T&T specific modifiable intrinsic factors to consider might include event specialization (i.e., training/competing in all 4 events), psychological issues (e.g., fear, stress) and athlete physical preparation (e.g., strength, proprioception, injury rehabilitation). Extrinsic risk factors that may be easily modified include appropriately placed and maintained matting around the apparatus', use of spotting harnesses and in-ground trampolines.

Meeuwisse's (2007) dynamic recursive model of etiology for sport injury explains that there is an interaction among risk factors and that the nature of sport injury, or potential injury is, cyclical. Applied to competitive T&T context,  For example, factors that may increase a T&T athlete's risk of injury may include age, fatigue and engaging in several hours of repetitive training such as learning a new skill. The combination of intrinsic and extrinsic risk factors creates evolving situations that require the athlete to adjust and adapt. Athlete susceptibility and their adaptation process may or may not lead to injury. If the athlete is unable to adapt to the situation, and an injury is sustained, a different set of risk factors and necessary adaptations may be required (e.g., adjusting to new ankle brace and/or effects of detraining due to time loss).

# *3* Methods

## 3.1 Study Design

A cross-sectional study design was implemented to collect research data using a one-time, online, self-report questionnaire that collected one-year injury history.

## 3.2 Study Population

The target population for this study consisted of all pre-competitive and competitive level T&T gymnasts, inclusive of ages 8 to 25 years, from 60 T&T gymnastics training centers located across Canada. This age range was chosen because Gymnastics Canada mandates that for competition eligibility, athletes must be a minimum of 8 years old and recommends that elite (senior) level athletes be over 17 years old. T&T athletes older than 25 years have typically moved onto World Class/Olympic status or have retired.

### 3.2.1 Inclusion criteria for all T&T athlete participants:

1. Participation under professional coaching supervision.
2. Participation within a structured program in preparation for competition participation.

a. Competitive (sub-elite and elite) athletes training in preparation to showcase pre-determined routines as outlined by Gymnastics Canada between September 2018 and September 2019.

b. Pre-competitive athletes participating in Trampoline and Tumbling developmental programs in preparation for competitive team membership. The inclusion of pre-competitive

athletes into the STICK ITT study allowed athletes competing at the first provincial level (of the sub-elite category) to be included in data collection.

3. Participants were 8-25 years from September 2018 – September 2019.

4. Completed informed child assent and parental consent for athletes 8-13 years; OR completed informed participant consent for athletes 14-25 years.

5. Fluent in English language.

### 3.2.2 Exclusion criteria for all T&T athletes included:

1. Athletes younger than 8 years and older than 25 years.

2. Athletes practicing at a recreational level (e.g., Cangym, drop-in programs, cross training for other sports).

3. Incomplete assent, parental or participant consent.

4. Not fluent in English language.

### 3.2.3 Sample Size Estimation

A comparison of proportions based on injury incidence (# injuries/100 participants/year) was used to calculate sample size (see Appendix A). Injury rates (#injuries/100 athletes/year) between elite and sub-elite T&T athletes have not been previously documented and is identified as a variable for evaluation in this study. Emery et al. (2006) examined sport specific injury rates among adolescent high school students and reported a rate of 40 injuries/100 participants/year. Grapton et al. (2013) reported that 63% of injured trampoline and tumbling athletes were elite level. An injury proportion of 63% among elite trampoline and tumbling athletes suggests that elite acrobats may have a higher risk of injury compared to non-elite (37%). Using an estimated

60 injuries/100 athletes/year (elite) and 40 injuries/100 athletes/year (sub-elite) garnering a difference of 20 injuries/100 athletes/year (33% lower rate of injury in sub elite vs elite), an estimated sample size of 98 participants per group (196 total) is required for 80% power to detect a difference between groups that is as small as 33%.

## 3.3 Procedures

### 3.3.1 Participant Recruitment

A total of 60 competitive Trampoline and/or Tumbling clubs are listed among Provincial Sport Organizations (PSO) across Canada (see Appendix C). A letter of intent and the STICK ITT web-based URL link was emailed to all provinces that have T&T PSO representatives (n=8) and to head coaches of the 60 T&T gymnastics training facilities at various points throughout the training season (i.e., September 2019, October 2019, January 2020, April 2020 and May 2020). Prince Edward Island, the Northwest Territories/Nunavut and the Yukon do not have any identifiable competitive T&T programs. Quebec was not included in emailed participant recruitment due to the survey only being available in the English language.

Verbal notice of the research study was delivered to coaches, judges, Gymnastics Canada Directors, and PSO Representatives at the National T&T Technical Committee Assembly held in Oshawa, Ontario in July 2019 and at the Alberta T&T Coaches retreat, which took place in Canmore, Alberta in November 2019. Personal contacts and word of mouth provided subsequent sharing of information to additional potential participants among the T&T community.

Sport-related social media sites posted study recruitment details including: the University of Calgary Sport Injury Prevention Research Centre (SIPRC), National T&T Coaches Facebook page, Gymnastics Canada Facebook page, Gymnastics Canada Twitter page and several personal

Instagram accounts belonging to athletes and coaches. See Appendix C for recruitment schedule and list of T&T training facilities contacted.

### 3.3.2 Data Collection

A web-based anonymous questionnaire was used to collect athlete demographic information and one-year injury history. REDCap (a secure web-based electronic data capture system hosted by the Clinical Research Unit and the University of Calgary) was used to build the questionnaire, collect participant responses and manage de-identified data (REDCap, version 13; Vanderbilt University, Nashville, TN).

Data collection occurred both onsite and offsite. Onsite data collection took place at two T&T competitions, held in Calgary, Alberta in January and February 2020. T&T athletes were able to complete the STICK ITT questionnaire in-person on Ipads, or through the REDCap quick response barcode (QR code) that was scanned onto personal devices. Offsite data collection took place through email and/or social media with completed questionnaires submitted online through REDCap.

### 3.3.3 Study Questionnaire

The STICK ITT questionnaire (see Appendix F) was adapted from the Alberta Sport Injury Survey for Calgary and area High Schools (Emery et al, 2006) and Volleyball Canada (Meeuwisse, et al, in progress). Participants were asked to reflect on the previous one year (September 2018-September 2019) and provide responses to questions pertaining to their sport participation and injury history. T&T specific terminology was used to reflect sport-specific content (e.g., do you find landing mats at competitions harder than the landing mats you train

on?). A grade four reading level was considered in questionnaire development such that athletes as young as 8 years old could understand.

The STICK ITT questionnaire included five sections: (1) athlete demographics (e.g., age, sex, height, weight, home province, affiliated T&T club), (2) musculoskeletal injury history, (3) concussion history, (4) perceived risk factors for injury (e.g., age, sex, experience, event specialization), and (5) sport participation [e.g., years of T&T participation, training exposure (hours/week, months/year), competition experience (n/year)].

Participants were asked to classify and describe their most serious (first) injury, second injury, third injury, or if they had sustained more than three injuries. Injury-related questions included: injury frequency (count), type (e.g., strain, sprain, fracture, gradual onset, growth plate), anatomical location, perceived mechanism of injury and medical attention sought (e.g., ambulance/emergency, doctor, physiotherapy). The severity of each injury was determined through days lost from sport. Participants were asked to report any sustained concussion(s) as a head injury, either diagnosed or undiagnosed, and recorded symptoms based on the Post-Concussion Symptoms Scale (PCSS), time loss (i.e., days, months), medical attention sought (e.g., ambulance/emergency, doctor, physiotherapy), and if return to play protocols were followed (yes/no) (Emery et al. 2006).

Potential injury risk factors and training environment were explored through the inclusion of questions related to mechanism of injury, competitive level, years of T&T competitive participation and training environment such as warm-up, cool down, physical preparation and equipment type (inground/above ground trampolines). Participants estimated the number of hours/week, and months/year that they engaged in T&T training for the 2018-2019 competitive season so that hours of participation could be calculated for injury rate estimations. Athletes

were asked about participation in sport and recreation outside of T&T (hours/week, months/year) as well as backyard trampoline use (yes/no). Questions about psychological factors including self-reported anxiety, fear and personal habits for sleep and nutrition were also included in the survey.

In order to ensure the questionnaire measured the appropriate concepts, the STICK ITT questionnaire was reviewed for face validation by two professional coaches and members of technical committees, one pediatrician, one physiotherapist and one gymnast aged 11 years. Reviewers felt that terminology was appropriate for the target age range and reading comprehension of athletes. The six reviewers reported that the survey appeared to be measuring injury type and mechanism of associated risk of injury in competitive T&T athletes. The validation tracking form that reviewers completed is enclosed in Appendix D.

### 3.3.4 Outcome Measures

The primary outcome of interest was T&T related injury. Two operational definitions of injury were utilized and adapted from Fuller et al. (2006):

1. Time loss injury – an injury that caused an athlete's inability to fully participate in T&T training/competition one or more days beyond the onset of injury.
2. Medical attention injury – an injury for which an athlete sought care from a health care professional (ambulance/emergency room, doctor or specialist and allied health care professional).

### 3.3.5 Exposure Variables

Risk factors for T&T injury included the following variables: competitive level (elite, sub-elite), sex (male/female), age (years), T&T experience (years), injury during training or competition. Additional factors such as athlete safety practices (safety falls, equipment checks), during training, physical preparation and equipment type were examined.

## 3.4 Statistical Analysis

Statistical analyses were performed with STATA statistical software (v15, College Station, TX: StataCorp LLC). Descriptive statistics [medians (ranges), and proportions (95% confidence intervals (95%CI))] of all T&T athlete characteristics were collated by competition level (sub-elite/elite). Descriptive statistics [proportions (95%CI)] examined musculoskeletal injuries and concussion by event, type, anatomical location, mechanism of injury, time loss, healthcare utilization and mechanism of injury. Injury severity was based on time loss and categorized as: minimal (0 days), mild (1-7 days), moderate (8-28 days) and severe (>28 days) (Bahr et al, 2020; Fuller, 2006).

The primary outcome of interest was T&T injury measured by incidence rate [# of injuries/100 athletes/year, and # of injuries/1000 exposure hours (95%CI)]. Exposure hours were estimated by summing athlete training and competition hours. Specifically, athlete reported training hours/week*4.33*training months/year plus athlete reported competition hours [(1 hour x # reported competitions for sub-elite) and (2 hours x # reported competitions for elite)]. Univariable Poisson regression analyses, clustering by club (offset for exposure hours) were employed to determine associations between injury outcome (yes/no) and the following primary exposure variables: competitive level (sub-elite/elite), sex (male/female), age (<15 years />=15

years), experience (<=5 years/>5 years) and participation (training/competition). Missing data from the questionnaire was excluded from the analyses. Statistical significance was set *a priori* at p<=0.05.

### 3.5 Ethical Considerations

The University of Calgary Conjoint Health Research Ethics Board (CHREB) approved the STICK ITT project on July 30, 2019 (Ethics ID#19-0290). Participants aged 8-13 years old completed an assent form and had a parent/legal guardian complete a parental consent form prior to accessing the STICK ITT questionnaire. Participants aged 14-25 years were required to complete the implied consent form before accessing the questionnaire. The questionnaire was anonymous with only the athlete's affiliate club as an identifier. No part of completing the survey was harmful and participants were given the option to discontinue if any of the questions caused concern or discomfort. Participant information was kept private and secure and only authorized personnel had access to the database. All data was deidentified and stored on a secure server within Sport Injury Prevention Research Centre. Appendix E includes samples of the consent forms used.

## 4 Results

### 4.1 Study Participants

There were a total of 1708 T&T athletes registered with Provincial Sport Organizations for the 2018-2019 competitive season (Appendix B Canadian Competitive T&T Participation). Nine percent (166/1708) of estimated eligible T&T athletes consented to participate in the study. Of the 166 surveys initiated, 33 (19.8%) surveys included consent only with no further information, leaving 133/1708 (7.8%) athletes completing, or partially completing, the

questionnaire. One participant was over the age of 25 and was excluded from analysis. In total, 132 completed, or partially completed, questionnaires were submitted and used for analysis (see Figure 4.1).

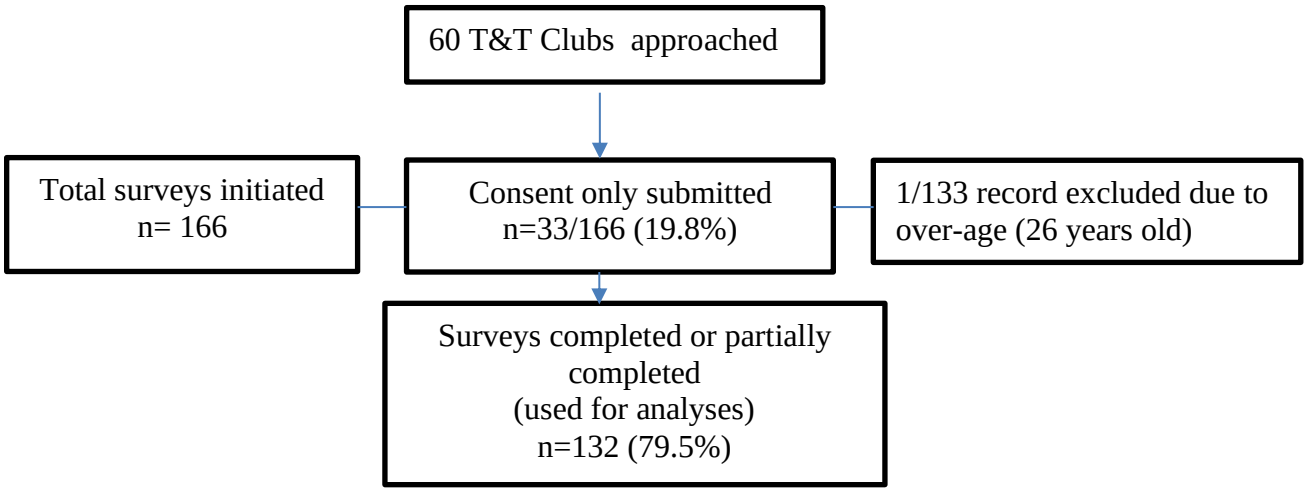


**Figure 4.1 STICK Recruitment Flow Chart**

Table 4.1 summarizes participants' sex and competitive level by provincial representation. Athletes from 25 of the 60 (41.7%) training facilities returned surveys. Alberta athletes comprised 91/132 (68.2%) of the total respondents. No questionnaires were completed by athletes in Manitoba or Nova Scotia.

In Canada, competitive T&T athletes compete in one to four events at the Provincial (sub-elite) or National level (elite) level of competition. Athletes may be sub-elite for one event and elite for another. For the purposes of this study, athletes were classified as sub-elite (n=72) or elite (n=60) based on highest competitive level on any of the four events. There were 12 participants who competed at both sub-elite and elite levels in the different events. Athletes with

overlapping categories were placed in the elite level. Athletes that may have been pre-competitive were designated to the sub-elite category. Eighty-nine (67.4%) of STICK ITT participants were female and forty-three (32.5%) were male. One participant chose "prefer not to say" for sex. Based on the self-reported height and weight of this individual, this athlete was categorized as female for the purpose of statistical analyses.

**Table 4.1 STICK ITT Survey Participants (sex, competitive level) by Province**

| Province | T&T athletes registered in Province n | Submitted Surveys n (%) | Male n (%) | Female n (%) | Prefer not to say (n) | Sub-Elite Level (Pre-Comp, Provincial 1-4) (n) | Elite Level (National Level 5,6 Jr, Sr) (n) |
|---|---|---|---|---|---|---|---|
| **British Columbia** | 190 | 5 (3.8) | 0 | 5 | 0 | 0 | 5 |
| **Alberta** | 285 | 91 (69) | 33 | 57 | 1 | 54 | 37 |
| **Saskatchewan** | 67 | 2 (1.5) | 0 | 2 | 0 | 1 | 1 |
| **Quebec** | 378 | 3 (2.3) | 2 | 1 | 0 | 0 | 3 |
| **Ontario** | 630 | 22 (16.6) | 5 | 17 | 0 | 11 | 11 |
| **New Brunswick** | 37 | 5 (3.8) | 1 | 4 | 0 | 3 | 2 |
| **Newfoundland / Labrador** | 10 | 4 (3.0) | 2 | 2 | 0 | 3 | 1 |
| **TOTAL** | 1597 | 132 | 43(32.3) | 88(66.7) | 1 (0.01) | 72(54) | 60(46) |

**No competitive T&T clubs in Yukon, Northwest Territories, PEI.

## 4.2 T&T Athlete Participant Characteristics

### 4.2.1 Athlete Physical Characteristics

The median age of all participants was 15 years (range 9-25). The median age for elite athlete participants was 17 (range; 14-25) and for sub-elite athlete participants was 13 (range; 9-24). Elite athlete participants were older, taller and heavier than the sub-elite athlete participants. See Table 4.2 for summary of participant physical characteristics.

### 4.2.2 Competitive Event Participation

Of the four T&T events (i.e., Individual Trampoline, Synchronized Trampoline, Double Mini Trampoline, Tumbling) Individual Trampoline was the most popular event with 107/132 (81.1%) of T&T athlete participants training and competing in this event. Participation in three of the four events (51/132, 38.6%) was common among T&T athletes. Sub-elite athletes participated most commonly in three events (31/72; 43.1%) whereas elite athletes participated most often in two events (20/60; 33.3%). Sub-elite athlete participants were more likely to train and compete in all four events (20/72; 27.8%) than elite athlete participants (8/60; 13.3%) and elite athlete participants more commonly specialized in one event (12/60; 20.0%) compared to sub-elite athlete participants (4/72; 5.6%).

Participants typically spent 11 months of the year training 9 to 12 hours/week. Elite T&T athlete participants reported spending more time training and competing (median=562. hours/year, range 147.9-873.0) than sub-elite athlete participants (median=431.6 hours/year, range 43.3-790.0).

### 4.2.3 Participant Non-T&T sports and recreation

In total, 38/132 (28.0%) of T&T athlete participants also engage in at least one non-T&T competitive sport. Male elite athletes most commonly participated in non-T&T competitive sport (9/21, 43%) a median of 4.0 hours/week (range 1-8). Twenty-six percent (23/89) of female athletes reported spending a median of 4 hours/week (range 1-14) participating in non-T&T competitive sport. The most common non-T&T competitive sports for participants were volleyball, track and basketball. Participation in recreational fitness and sport (e.g., biking, skiing, snowboarding) was more common than competitive sport 81/132 (61.3%). T&T athlete participants that completed this question reported spending a median of 3 hours/week (range 0-15) on recreational activities. Back-yard trampoline was reported as a popular form of recreation among 48.5% (64/132) competitive T&T athletes. Of all participants completing the question related to non-T&T sport and recreation, 35/130 (26.9%) reported a time-loss injury in non-T&T sports and recreation. See Table 4.3 for non-T&T competitive sport participation.

**Table 4.2 STICK ITT Participant Characteristics**

| Participant Characteristics | Sub-elite Male (n=22) | Sub-elite Female (n=50) | Elite Male (n=21) | Elite Female (n=39) | Overall Male (n=43) | Overall Female (n=89) |
|---|---|---|---|---|---|---|
| **Sex n(%)** | 22 (30.5) | 50 (70.4) | 21(35.4) | 39 (65.0) | 43 (32.5) | 89 (67.6) |
| **Age in years** | | | | | | |
| **Median** | 13 | 13 | 16 | 17 | 15 | 14 |
| **Range** | 9-24 | 10-24 | 14-25 | 11-24 | 9-25 | 10-24 |
| **missing** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Height in cm** | | | | | | |
| **Median** | 170.2 | 157 | 175 | 162 | 173 | 160 |
| **Range** | 127-177 | 121-176 | 162-182 | 149-172 | 127-182 | 121-176 |
| **missing** | 0 | 0 | 0 | 0 | 2 | 1 |
| **Weight in kg** | | | | | | |
| **Median** | 56 | 49 | 70 | 55 | 68 | 54 |
| **Range** | 26-77 | 29-72 | 56-81 | 41-68 | 26-81 | 29-72 |
| **missing** | 0 | 0 | 0 | 0 | 2 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Years of T&T Experience** | | | | | | |
| **Median** | 4 | 3 | 7 | 7 | 6 | 5 |
| **Range** | 0-14 | 0-8 | 3-14 | 2-14 | 0-14 | 0-14 |
| **missing** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Event Participation** | Sub-elite M n=22 | Sub-elite F n=50 | Elite M n=21 | Elite F n=39 | Overall M n=43 | Overall F n=89 |
| **Trampoline n (%)** | 22 (100) | 40 (80.0) | 17 (80.9) | 28 (72.0) | 39 (90.7) | 68 (76.4) |
| **Synchro-Trampoline n (%)** | 10 (47.5) | 22 (45.8) | 8 (38.1) | 20 (51.3) | 18 (41.8) | 42 (47.2) |
| **Double-Mini-Trampoline n(%)** | 20(90.1) | 43 (86.0) | 15 (71.4) | 27 (69.2) | 35 (81.5) | 70 (78.5) |
| **Tumbling n(%)** | 15 (71.4) | 38 (76.0) | 8 (38.1) | 21 (53.8) | 23 (53.5) | 59 (66.3) |
| **missing** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Athlete Event Participation** | Sub-elite | | Elite | | Overall | |
| **1 of 4 events n (%)** | 5 (6.9) | | 12 (20.0) | | 17 (12.8) | |
| **2 of 4 events n (%)** | 16 (22.3) | | 20 (33.3) | | 36 (27.3) | |
| **3 of 4 events n (%)** | 31 (43.1) | | 20 (33.3) | | 51 (38.6) | |
| **All 4 events n (%)** | 20 (27.8) | | 8 (13.3) | | 28 (21.2) | |
| **missing** | 0 | | 0 | | 0 | |
| **Training Exposure Hours/Week** | | | | | | |
| **median** | 9 | | 12 | | 12 | |
| **range** | 2.5-16.5 | | 3-20 | | 2.5-20 | |
| **missing** | 0 | | 0 | | 0 | |
| **Training Exposure Days/Week** | | | | | | |
| **median** | 2 | | 3 | | 3 | |
| **range** | 1-4 | | 2-7 | | 1-4 | |
| **missing** | 0 | | 0 | | 0 | |
| **Training Exposure Months/Year** | | | | | | |
| **median** | 11 | | 11 | | 11 | |
| **range** | 6-11 | | 9-11 | | 2-11 | |
| **missing** | 0 | | 0 | | 0 | |

| | | | |
|---|---|---|---|
| **Number of Competitions/year** | | | |
| **median** | 4 | 6 | 5 |
| **range** | 0-7 | 2-7 | 0-7 |
| **missing** | 0 | 0 | 0 |
| **Number of International Competitions/year** | | | |
| **median** | 0 | 0 | 0 |
| **range** | 0-3 | 0-3 | 0-3 |
| **missing** | 0 | 1 | 1 |

**Table 4.3 Non-T&T competitive sport participation, recreation and back yard trampoline**

| Non-T&T Sport/recreation | Sub-elite Male n=22 | Sub-elite Female n=50 | Elite Male n=21 | Elite Female n=39 | Overall (sub-elite + elite) |
|---|---|---|---|---|---|
| **Non-T&T competitive sport participation (%)** | 6 (27.3) | 16 (32.0) | 9 (45.0) | 7 (18.0) | 38 (29.0) |
| **missing** | 1 | 0 | 0 | 0 | 1 |
| **T&T athlete recreation/fitness participation (%)** | 13 (59.1) | 30 (61.3) | 10 (47.6) | 27 (67.5) | 81 (61.0) |
| **missing** | 0 | 0 | 0 | 0 | 0 |
| **T&T athlete backyard trampoline participation (%)** | 14 (63.6) | 28 (57.1) | 7 (33.3) | 15 (37.5) | 64 (48.5) |
| **missing** | 0 | 0 | 0 | 0 | 0 |

## 4.3 T&T Injury Rates

The outcome of interest was T&T related injury reported in the previous one year. A total of 86/132 (65.1%) T&T athlete participants reported a total of 135 T&T-related time loss injuries in the previous year. For elite athlete participants, 42/60 (70.0%) reported a total of 69 injuries and 44/72 (61.1%) sub-elite athlete participants reported 66 injuries. The injury rate in elite athletes was 115 injuries/100 athletes/year (95%CI 88.0-143.1). For sub-elite athlete participants, the injury rate was 91.6 injuries/100 athletes/year (95%CI 70.8-116.0) (see Table 4.4). Thirty-five percent (46/132) of STICK ITT participants reported no injuries in the previous year.

### 4.3.1 T&T Injury Severity and Medical Attention

#### *4.3.1.1 Time loss/ severity*

The median time loss from T&T was 30 days (range 0-482). Injuries classified as severe (>28days time loss from sport) were most prominent [62/132 (46.9%)]. The median time loss for severe injuries was 60 days (range 30-482 days). Elite athletes registered 30/61 (49.2%) severe time loss injuries and sub-elite athlete participants registered 22/72 (30.6%). All athlete participants reporting zero time-loss still sought medical attention from a health care provider for injuries (see Table 4.4). Athletes reported a median of 30 days (range 0-360) of restrictions to lifestyle and school or work attendance following an injury.

**Table 4.4 Severity of Injury by Time Loss per Injury**

| **Time Loss n(%)** | ***First Injury n=86** | **Second Injury n=39** | **Third Injury n=8** | **Total n=132** |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **Minimal**<br>**0 days time loss** | 4 (5.8)<br>0 | 3 (7.6)<br>0 | 2 (25)<br>0 | 9 (6.7)<br>0 |
| **Minor**<br>**1-7 days time loss** | 17 (20)<br>median 5<br>range 1-7 | 13 (33.3)<br>median 3<br>range 2-7 | 2 (40)<br>median 2.5<br>range 1-4 | 32 (24.0)<br>Minor Time loss |
| **Moderate**<br>**8-28 days time loss** | 12 (14)<br>median 14<br>range 9-25 | 5 (12.8)<br>median 20<br>range 14-20 | 2 (40)<br>median 21<br>range 21 | 19(14.2)<br>Moderate time loss |
| **Severe**<br>**>28 days time loss** | 52 (61.1)<br>median 60<br>range 30-482 | 12 (30)<br>median 60<br>range 30-120 | 2 (33.3)<br>median 60<br>range 30-60 | 62(46.9)<br>Severe Time Loss |

*missing n=1.

#### *4.3.1.2 Medical Attention*

Participants identified the type of medical attention sought for each injury. Several responses indicated that more than one form of health care was provided for an injury. Overall, 124/135 (92%) of the reported injuries required some form of health care. Physical therapy was the most common form of treatment (71/135 injuries; 52.5%). In total, 20/135 (15%) of the injuries required ambulance transport and/or emergency treatment and 21/135 (15.8%) required surgical intervention or follow-up by a physician specialist. Almost half (44.7%) of the study participants reported regularly visiting a health care professional such as a doctor or physiotherapist, in relation to T&T training and competition.

**Table 4.5 Athlete Reported Health Care Sought by Total Injuries**

| **Medical/Health Care** | **First Injury n=86 n(%)** | **Second Injury n=39 n(%)** | **Third Injury n=8 n(%)** | **Total n=135 n(%)** |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **No Medical Attention** | 7(14%) | 2(10%) | 2(50%) | 11(8.1%) |
| **Medical Attention** | | | | |
| **Ambulance/ER** | 20(23.2) | 0 | 0 | 20 (15.0) |
| **Doctor** | 35(40.7) | 10 (25.6) | 1(12.5) | 46 (34.0) |
| **Specialist/surgeon** | 19(22.0) | 2 (5.1) | 0 | 21 (15.8) |
| **Allied Health** | | | | |
| **Physiotherapy** | 50(58.1) | 19(48.7) | 2(1.5) | 71 (52.5) |
| **Chiropractor** | 22(25.6) | 9(23.1) | 3(37.1) | 34 (25.2) |
| **Massage Therapy** | 19(22.1) | 7(17.9) | 1(12.5) | 27 (20.0) |
| **Naturopath/Osteopath** | 5(5.8) | 3(7.6) | 0 | 8 (6.0) |

*2 none/unknown for the 2 injuries that were undetailed.
**missing n=0

### 4.3.2 Outcomes - Injury Rates

Table 4.6 summarizes injury outcomes for sub-elite, elite and all (combined elite and sub-elite) T&T athletes. The overall injury rate (IR) for T&T athlete participants, considering exposure hours reported in the previous year, was 2.11 injuries/1000 athlete exposure hours (95%CI 1.79-2.52) (including training and competition). The IR for the sub-elite athlete participants was 2.2 injuries/1000 athlete exposure hours (95%CI 1.72-2.84) and for elite athletes was 2.0 injuries/1000 athlete exposure hours (95%CI 1.59-2.59). In total, 66/135 injuries (48.8%) in sub-elite athletes had a reported time loss greater than 7 days compared to 69/135 injuries (51.1%) in elite athletes.

**Table 4.6 Injury Rates by Competitive Level**

| Outcome Variables | Sub-elite | Elite | Overall |
|---|---|---|---|
| **Number of athletes (n)** | 72 | 60 | 132 |
| **Number of injured athletes (n)** | 44 | 42 | 86 |
| **Number of injuries (n)** | 66 | 69 | 135 |
| **Seasonal prevalence (#injured athletes/#athletes) %(95%CI)** | 44/72<br>61.1%, (48.8-72.4) | 42/60<br>70.0% (56.8-81.1) | 86/132<br>65.1% (55.4-73.2) |
| **Injury rate (as total # injuries/100 athletes/yr.) % (95%CI)** | 91.6<br>(70.8-116.0) | 115.1<br>(89.4-145.5) | 102.7<br>(85.7-121.1) |
| **Injury rate (as # injuries/1000hr participation exposure hours) (95%CI)** | 2.2 (1.72-2.84) | 2.0 (1.59-2.59) | 2.13 (1.79-2.52) |
| **Athlete participation exposure hours (training & competition)** | 29,575 | 33,654 | 63,229 |
| **Injury Rate Time loss>7 days (as total # injuries w >7d time-loss/100 athletes/yr. (95%CI)** | 56.1 (43.3-68.3) | 69.6 (57.3-80.1) | 63.0 (54.2-71.1) |

## 4.4 Injury Characteristics

Participants provided additional information related to their self-reported injuries (e.g., apparatus, anatomical location, type, mechanism) for up to three injuries. Two participants reported sustaining a fourth injury (injury total 135). No descriptors (event, location, type, mechanism) were provided for these two fourth injuries. These two injuries are recorded among the unknown or other category in the descriptives of T&T injury characteristics.

### 4.4.1 Injuries by T&T Apparatus

Figure 4.2, T&T Injury Proportion by Apparatus, summarizes the proportion of all injuries that were sustained in each apparatus (event). Athlete participants reported a total of 39/135 (28.8%) injuries that were sustained on (either individual or synchronized) trampoline. The proportion of injuries sustained on trampoline was similar for sub-elite (18/66, 27.2%) and elite athlete (21/69, 30.4%) participants. The Double Mini Trampoline (DMT) accounted for 34/135 (25.6%) injuries sustained by all T&T athlete participants. In sub-elite athlete participants, the proportion of all injuries sustained in DMT (13/66, 19.7%) was lower than that for elite athlete participants (21/69, 30.4%). The highest overall proportion of injuries (47/135, 34.8%) occurred on the tumbling runway. Sub-elite athlete participants sustained similar proportions of tumbling related injuries (sub-elite 27/72, 37.5%) compared with elite athlete participants (elite 20/60, 33.3%). Considering concussions specifically, 8/20 (40%) concussions were sustained by T&T athlete participants on trampoline and 8/20 (40%) were sustained while tumbling. A small proportion of participants (12/135, 8.8%) did not specify the apparatus or event in which the injury occurred and indicated “increasing soreness over time”.

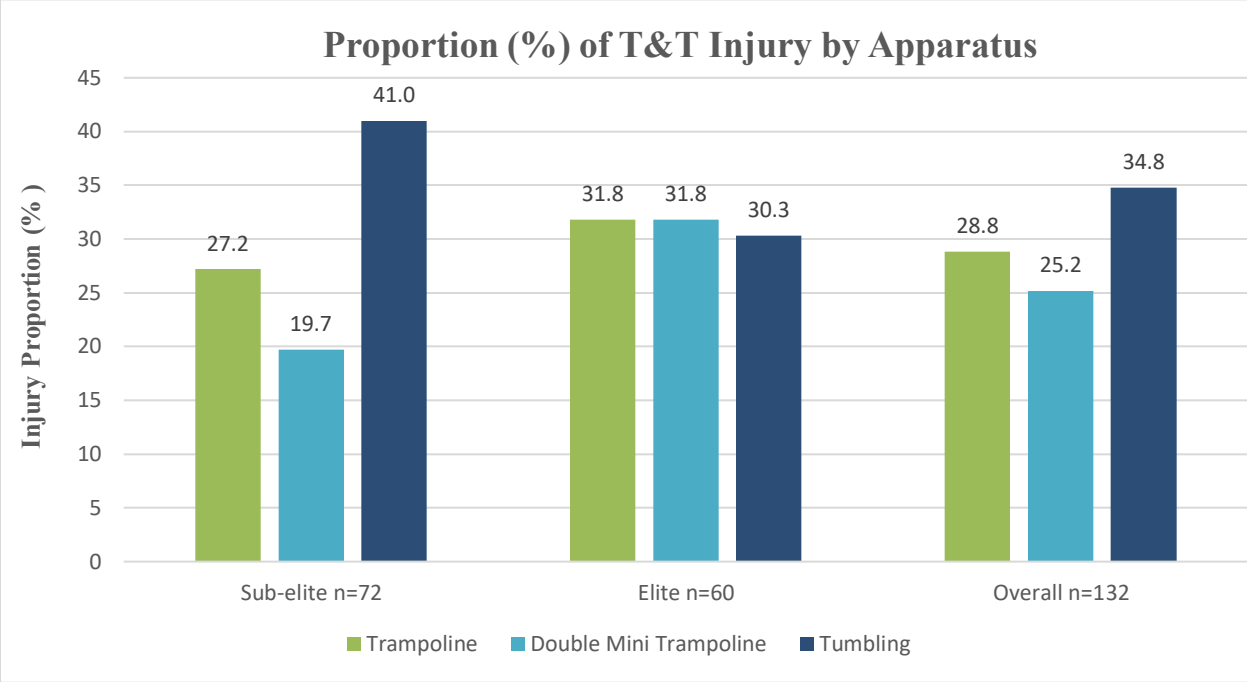


**Figure 4.2 Proportion of T&T Injury by Apparatus**

*unknown n=2

### 4.4.2 T&T Injuries Described by Anatomical Location

Participants were asked to identify the anatomical location of the injury that they considered to be their most serious in the past year, followed by the location of any additional reported injuries. The most commonly reported anatomical injury location among competitive T&T athletes was the ankle (38/135, 28.2%), followed by head/face (24/135, 17.8%), knee (16/135, 11.8%), foot/toes (15/135, 11.1%) and low back (14/133, 10.5%) (Figure 4.3). Among sub-elite athletes, the most commonly injured anatomical location was the ankle (14/66, 21.2%), head (12/66, 18.2%) knee (11/66, 16.7%) and foot/toes (10/66, 15.1%). Elite athletes reported ankles were most commonly injured (24.69, 34.8%), followed by head (12/69, 17.4%) and low back (8/69, 11.6). The most common anatomical locations injured in female athletes included the

ankle (28/99, 28.2%), head (19/99, 19.9%) and knee (11/99, 11.1%). Among male athletes, ankles (10/36, 27.8%), head (5/36, 13.9) and foot/toes (5/36, 13.9%) were most commonly injured.

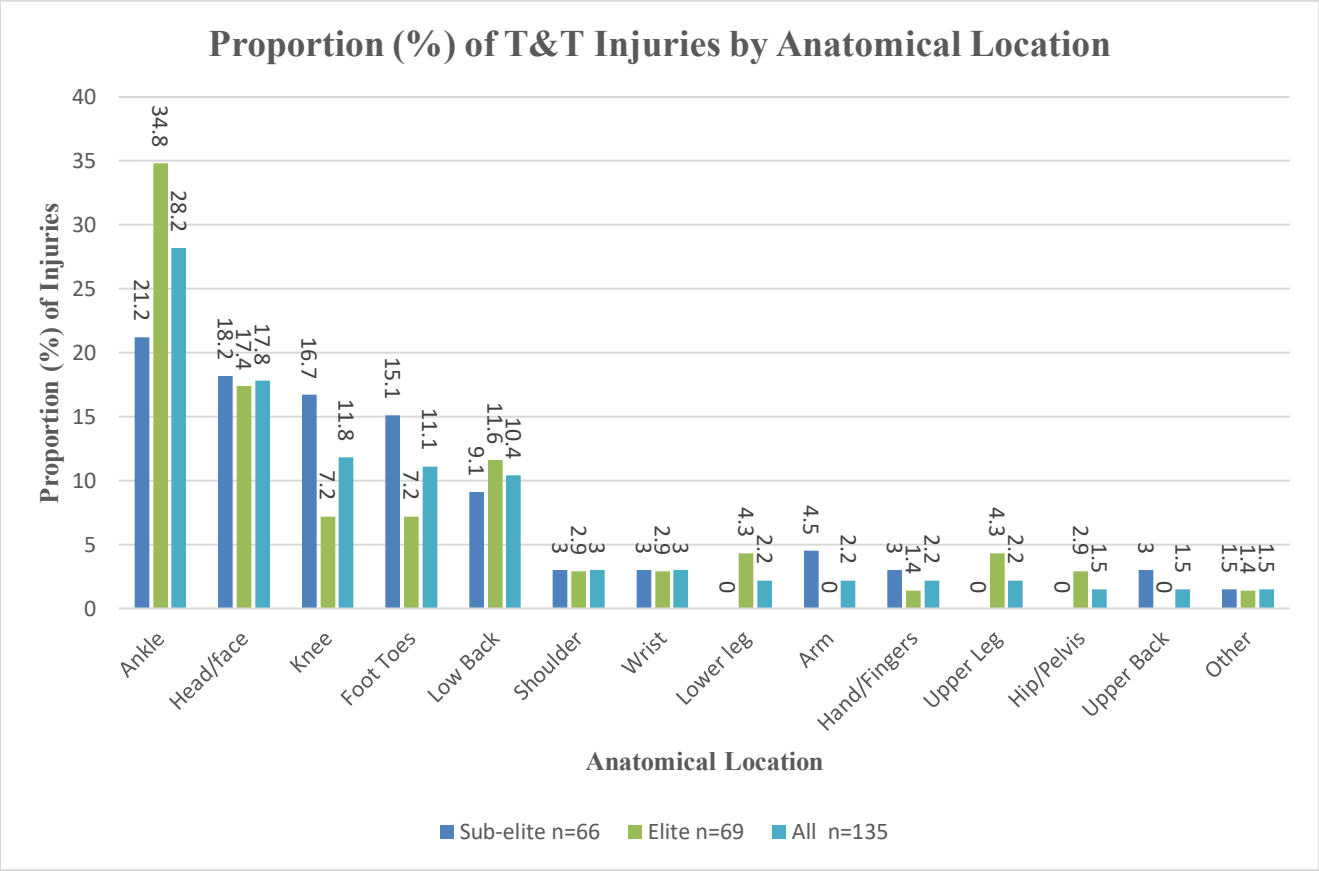


**Figure 4.3 Proportion of T&T injuries by Anatomical Location**

*Missing n=2

### 4.4.3 T&T Injuries described by injury type

Figure 4.4 illustrates the proportion of T&T injuries by injury type. Ligament sprains were the most common type of T&T injury reported by participants accounting for 30/135 (22.2%) of all injuries, followed by concussion (23/135, 17.0%), self-reported overuse injuries (22/135,

16.3%) and muscle strains (20/135, 14.8%). Elite athletes reported a greater proportion of ligament sprains (21/69, 30.4%) than sub-elite (9/66, 13.6%). The most common injuries to female athletes included ligament strains (22/99, 22.2%), injuries due to overuse (20/99, 20%) and concussion (19/99, 19.0%). The most common injuries among males included ligament strain (8/36, 27%), bone fractures (8/36, 27%) and muscle strain (7/36, 19.4%). Some athlete participants reported "other" for injury type (13/135, 9.6%) and further described the type of injury as bruises, bursitis, vertebral disc injury, meniscus injury and subluxation. Some participants did not specify the type of injury sustained for each injury reported (7/135, 5.2%) In 59/135 injuries (43.7%), participants reported that the  injury had occurred in the same body part before.

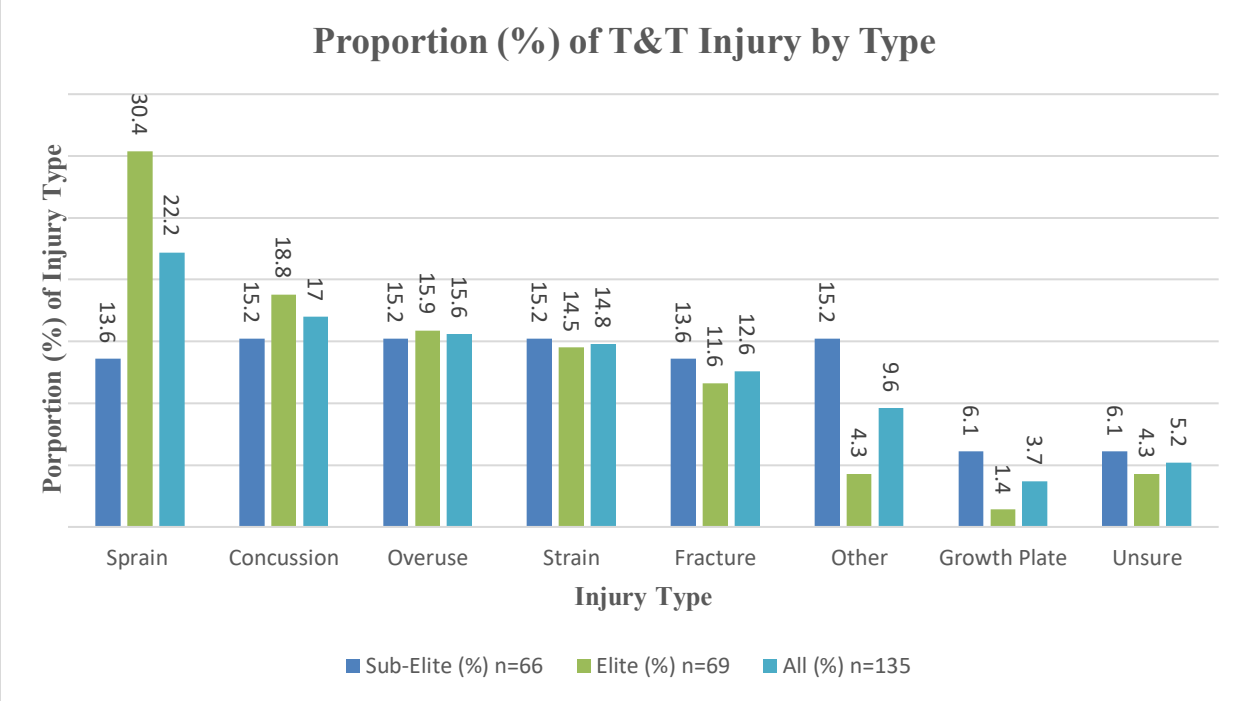


**Figure 4.4 Proportion of T&T Injury by Injury Type**

### 4.4.4 Injury by mechanism

Athletes reported that poor landings were the most common mechanism of injury (38/135, 28.1%), followed by "increased soreness over time" (31/135, 23.0%) and failed skills (24/135, 18.0%). Poor landings contributed to 15/66 (22.7%) of injuries in sub-elite athletes and 23/69 (33%) of injuries among elite athlete participants. A high proportion of sub-elite (15/66, 22.7%) and elite athlete participants (16/69, 23.1%) reported becoming "increasingly sore over time" as the mechanism of injury. Sub-elite athletes reported "failed skill" as the mechanism of 16/66 (24.2) of sustained injuries, whereas, elite athletes reported failed skill in 8/69 (12%) of injuries. Elite athletes reported injury from a falling off the apparatus more frequently (5/69, 7.2%), and sub-elite athletes reported an injury due to learning a new skill (3/66, 4.5%). Of the injuries to female athletes, the most common mechanisms of injury were poor landings (31/99, 31%) and increasing sore over time (25/99, 25%). Male athletes reported failed skills (12/36, 33%) and poor landings (7/36, 19.4%) as common mechanism of injury. Elite T&T athlete participants that reported "other mechanism" described the mount to the double mini trampoline as most problematic (8/86, 9.3%) (see Figure 4.5).

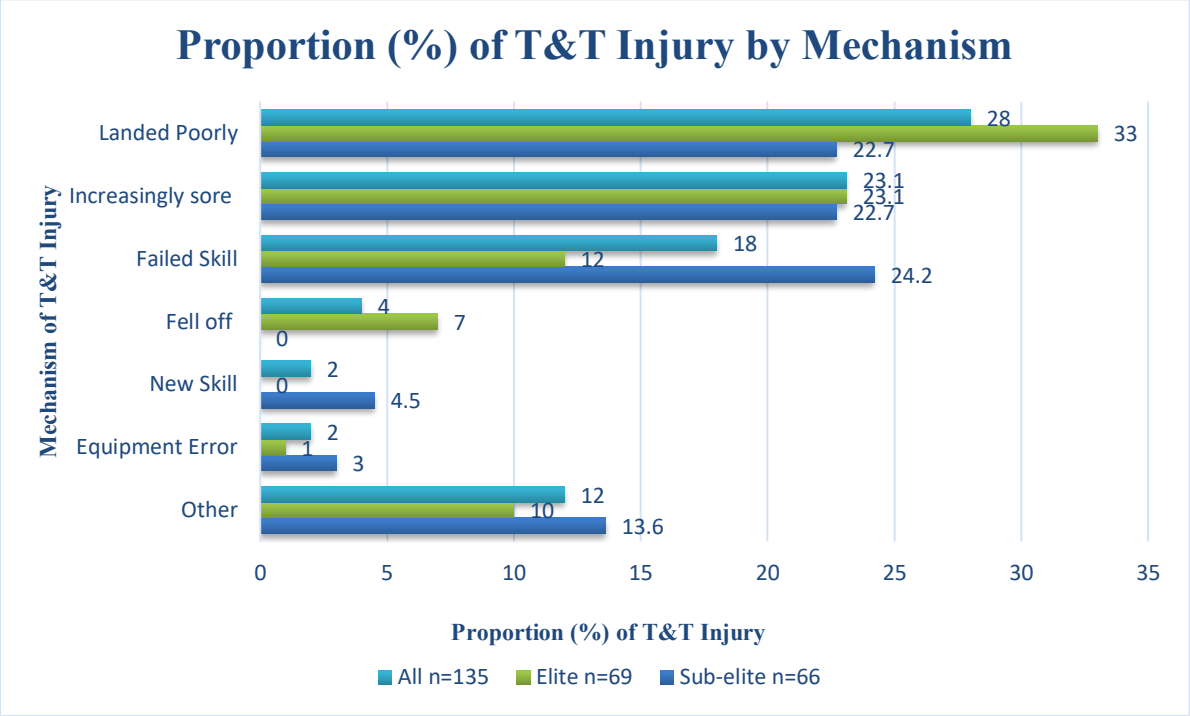


**Figure 4.5 Proportion of T&T Injuries by Mechanism**

* Missing/unknown, n=13.

### 4.4.5 Concussions in T&T Athlete Participants

A total of 23 concussions were reported in 132 T&T athlete participants [IR=17.3 concussions/100 athletes/year (95%CI 11.3-24.8)]. Considering athlete exposure hours (training and competition) the concussion IR was 0.364 concussions/1000 athlete exposure hours (95%CI 0.231-0.545). Concussion rates, time loss and medical follow-up by sub-elite and elite athlete participants are summarized in Table 4.7.

**Table 4.7 Concussion Rates Reported by T&T Athlete Participants**

| Injury rates and severity | Sub-elite | Elite | Overall (Sub-elite, Elite) |
|---|---|---|---|
| **Total number of athlete participants** | 72 | 60 | 132 |
| **Number concussions (total)** | 10 | 13 | 23 |
| **Injury Rate /100 athletes/year** | 13.9 (95%CI 6.87-24.1) | 21.3 (95%CI 11.8-33.7) | 17.3 (95%CI 11.3-24.8) |
| **Incidence Rate/1000 athlete participation hours** | 0.334 (95%CI 0.161-0.615) | 0.382 (95%CI 0.204-0.654) | 0.364 (95%CI 0.231-0.546) |
| | | | |
| **Time Loss (days)**<br>**Median**<br>**range** | <br>45<br>2-482 | <br>23<br>9-120 | <br>27.5<br>2-482 |
| **Medical Attention**<br>**Ambulance/ER**<br>**Doctor/Specialist**<br>**Allied Health (Physiotherapy, Chiropractor, Massage Therapy)** | <br>2 (10.0)<br>4 (20.0)<br>3(30.0) | <br>1 (7.6)<br>3 (23.0)<br>4 (30.7) | <br>3 (15.0)<br>7 (35.0)<br>7 (35.0) |

Although there were 23 concussions reported, only 20 concussion records provided details for perceived mechanism, symptoms, apparatus participation when injured and time loss. Figure 4.6 outlines the mechanism specific to T&T athlete participant self-reported concussion. Most concussions (12/20, 60.0%), for which a mechanism was reported, were sustained due to a whiplash effect.

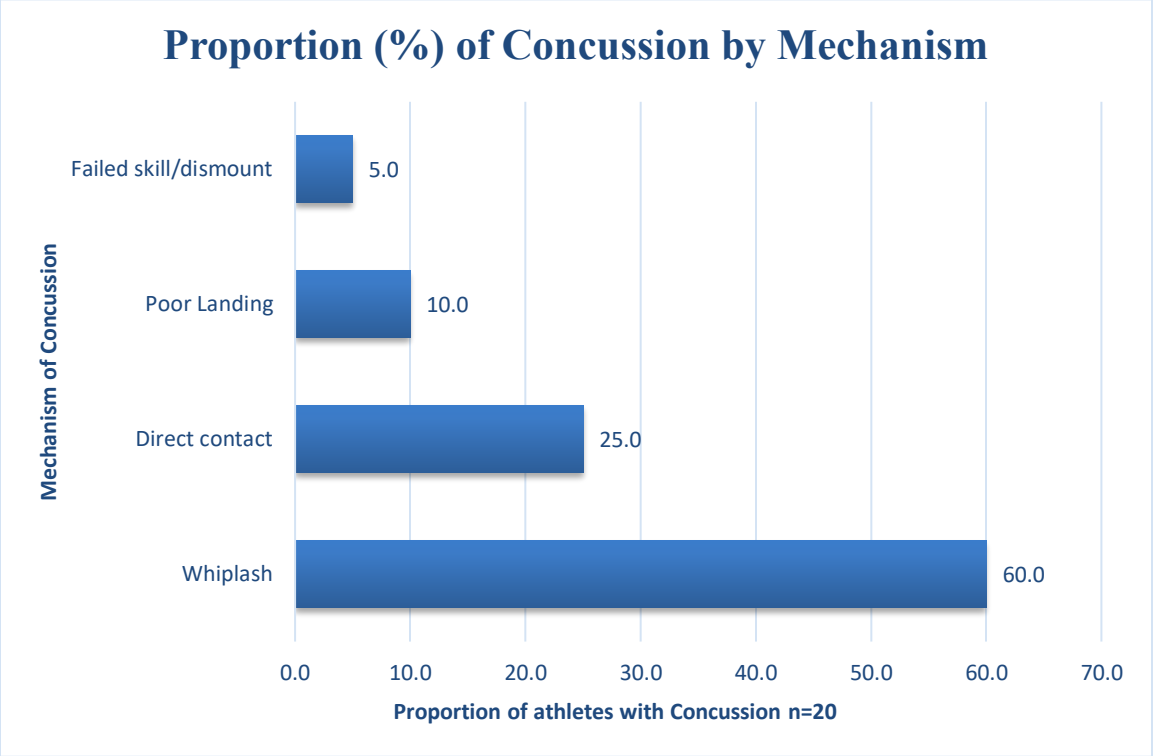


**Figure 4.6 T&T Mechanism of Concussion Injury**

*based on 20/23 concussion details including mechanism of injury

Nine of 72 sub-elite athlete participants (12.5%) reported 10 concussions and 11/60 (18.0%) elite athlete participants reported 13 concussions in the previous year of training and competing in T&T. Female participants reported 19/23 (82.6%) of the reported concussions. Concussions occurred most frequently during training (18/20, 90%). Participants were asked to identify signs and symptoms experienced at the time of concussion based on the post-concussion symptom scale. The top three symptoms reported were dizziness (16/20, 80.0%), headaches (15/20, 75.0%) and "don't feel right" (14/20, 70.0%). Other symptoms reported included fatigue (12/20, 60.0%), pressure in head (13/20, 65.0%), neck pain (13/20, 65.0%), weakness (9/20,

45.0%), poor memory (9/20, 45.0%), blurred vision (9/20, 45.0%), light/noise sensitivity (9/20,45.0%) and “feeling in a fog” (9/20, 45.0%).

There were three participants who reported more than one concussion over the course of the 2018-2019 competitive season, however, only one concussion per athlete was detailed. Two elite athlete participants were not sure if more than one concussion was sustained. The median time loss following concussion was one month (27.5 days, range 2-482 days). One athlete reported a time loss of 16 months and 12/20 (60%) athletes reported requiring medical attention for their concussion. Eight of the twenty (40%) athletes reported adhering to a return to sport protocol before re-entering back to regular training and 9/20 (45%) reported that a parent or coach provided the clearance to return to sport.

### 4.5 **Risk factors for injury**

Evaluating risk of injury by level of competition (elite vs sub-elite) was the a-priori risk factor objective for which this study was powered. In addition, sex, age, years of experience in T&T and injury during competition vs training were explored as risk factors for T&T-related injury. The incidence rate ratio (IRR) comparing IRs in elite and sub-elite athlete participants was 1.08 (95%CI 0.79-1.49) based on univariate Poisson Regression analysis, controlling for cluster by club and offset for athlete exposure hours, demonstrated no difference in injury rate by level of competition.

All exploratory variables were dichotomized into two exposure groups. Univariable analyses demonstrated no difference in injury rate by age, experience, or injury during competition vs training. However, there was a significant difference in IRs by sex with females

demonstrating higher overall injury rates than male T&T athlete participants (IRR=1.49, 95%CI 1.12-1.92). The results of univariable Poisson regression analyses are summarized in Table 4.8.

**Table 4.8 STICK ITT Risk Factors based on Univariable Poisson regression analyses**

| Potential Risk Factor | Number of athletes (n) | Number of Injuries | Athlete Participation hours | Injury Rate/ 1000 exposure hours | Injury Rate Ratio (IRR) |
|---|---|---|---|---|---|
| **Level** | | | | | |
| **Elite** | 60 | 69 | 33,654 | 2.0 (95%CI 1.40-2.79) | 1 (reference) |
| **Sub-elite** | 72 | 66 | 29,575 | 2.2 (95%CI 1.67-2.91) | 1.08 (95%CI 0.793-1.49) |
| ***Sex** | | | | | |
| **Male** | 43 | 36 | 22,131 | 1.60 (95%CI 1.11-2.29) | 1 (reference)** |
| **Female** | 89 | 99 | 41,098 | 2.39 (95%CI 1.88-3.04) | 1.49 (95%CI 1.12-1.92) |
| **Age** | | | | | |
| **15+** | 67 | 71 | 34,992 | 2.03 (95%CI 1.48-2.77) | 1 (reference) |
| **8-14** | 65 | 64 | 28,868 | 2.2 (95%CI 1.64-2.98) | 1.01 (95%CI 0.97-1.05) |
| **Years in T&T** | | | | | 1 (reference) |
| **>5 yrs.** | 61 | 65 | 34,992 | 1.89 (95%CI 1.38-2.64) | 1.03 |
| **<=5 yrs.** | 71 | 70 | 29,637 | 2.36 (95%CI 1.83-3.69) | (95%CI 0.990-1.08) |
| **Exposure Type** | | | | | |
| **Training** | 132 | 75 | 36,316 | 3.19 (95%CI 2.79-3.69) | 1 (reference) |
| **Competition** | 132 | 11 | 5,748 | 3.30 (95%CI 2.60-4.17) | 1.03 (95%CI 0.85-1.26) |

* Incidence Rate Ratio (IRR) based on Univariable Poisson regression analyses (controlling for cluster by club and offset by athlete exposure hours)

**Although exploratory, 95%CI suggests that females are at a higher risk of injury than male T&T athlete participants.

Table 4.9 outlines T&T athlete training practices such as warm up, cool down, physical preparation, safety (proper landings) exercises, use of taping and/or bracing, mental status and perception of stress and fear as reported by participants. All participants reported that warm-up was a part of T&T training and competition. Specific activities for warm-up indicated that 124/133 (93.2%) athletes ride a bike, jog and/or do dynamic stretching. Static stretching is reported as part of warm-up activities for 72/132 (54.0%) participants. A minimum 10-minute cool down (e.g., strength, conditioning) was reported by 122/132 (92.4%) T&T athlete participants. The most common forms of physical preparation entailed resistance training and ankle stability exercises and was reported as a part of warm up or cool down, or, separately as strength and conditioning. Seventy-four percent of athletes also reported that coaches lead and encouraged exercises to help them increase aerial awareness and safety landings.

In examining fatigue and sleep, 55/132 (41.7%) of athlete participants reported that they commonly felt fatigue while training, 85/132 (64.3%) reported getting six to eight hours of sleep/night and 4/132 (3.0%) of athletes reported sleeping less than five hours/night. Both fear and anxiety were reported by to be higher in competition than during training (anxiety: 87/135, 69%,  fear: 40/135, 30%).

In relation to injury management, 92/132 (69.7%) of T&T athlete participants reported using taping and bracing to enable training or competition. Of those athletes utilizing protective measures, taping (50/92, 54%) and ankle bracing (30/92, 32.6%) were most common.

The examination of potential risk related to equipment revealed that of the athletes that trained on trampoline, 60% (75/124) trained exclusively on in-ground trampolines as opposed to

free standing/above ground trampolines. Seventy-four percent (98/132) of respondents felt that the gaps between the runway and landing zone are well covered and 89/132 (67.4%) of T&T athletes responded “yes, the landing mats at competitions were harder than the landing mats used to train on”.

**Table 4.9 Athlete Practices in T&T Training and Competition**

| **Athlete practice** | **n (%)*<br>132 (100%)** | **Athlete reported detail** |
|---|---|---|
| **Warm up** | 132 (100.0) | Bike, run, dynamic stretch, static stretch |
| **Cool down**<br>**missing** | 122 (92.4)<br>1 (0.7) | Stretch, Conditioning/strength training, rolling out |
| **Physical preparation**<br>**missing** | 123 (73.2)<br>1 (0.7) | Resistance training, HITT training, ankle stability work, wrist rollers, massage/hot/cold tubs. |
| **Safety practice (e.g. crash or safety fall practice)**<br>**missing** | 97 (72.9)<br>1 (0.7) | |
| **Fatigue during training**<br>**missing** | 55 (41.7)<br>1 (0.7) | |
| **Anxiety during training**<br>**missing**<br>**Anxiety during competition**<br>**missing** | 49 (37.1)<br>2 (1.5)<br>87 (65.9)<br>1 (0.7) | Athletes self- report feeling more anxious during competition than training. |
| **Fear during training**<br>**missing**<br>**Fear during competition**<br>**missing** | 36 (27.3)<br>1 (0.7)<br>40 (30.1)<br>1 (0.7) | Athlete’s report of feeling fear during competition and training was similar. |
| **Taping/Bracing**<br>**Tape**<br>**Ankle Brace**<br>**Wrist guards/”tigerpaws”**<br>**Knee (brace/tape/band)**<br>**missing** | 92 (69.7)<br>50/92 (54.0)<br>30/92 (32.6)<br>14/92 (15.2)<br>12/92 (13.0)<br>2 (1.5) | Protective measures such as ankle braces, taping and tiger paws reported |

| | | |
|---|---|---|
| **Perceptions of risk related to equipment specifics** | | |
| **Above ground trampolines** | 33/ 124(26.6) | |
| **In ground trampolines** | 75/124 (60.3) | |
| **Both (above and in ground)** | 17/124 (12.7) | |
| **missing or does not train trampoline** | 8/132(6.0) | |
| **Mats/runways connected to trampoline** | 98/131 (74.2) | Hazards identified included gaps between mats and/or trampoline frames not covered by mats |
| **Landing mats harder at competition vs training (yes)** | 89/131 (67.4) | Athletes felt that the landing mats at competitions were harder than the mats they train with. |
| **missing** | 1(0.7) | |

*Denominator for estimating proportions (%) based on the number of T&T athlete participants with responses to that specific item (the number of missing responses is included)

# 5 Discussion

The STICK ITT study provides a novel examination of injury epidemiology for elite and sub-elite level competitive trampoline and tumbling (T&T) athletes in Canada. Numerous studies examine injuries in artistic gymnasts, but only a few include trampoline or tumbling gymnasts. The aim of this study was to establish a better understanding of injury rates, severity, characteristics and risk factors specific to the sport of competitive T&T.

## 5.1 Injury in competitive T&T

Overall, injury incidence among competitive T&T athletes is high with 132 participants reporting 135 injuries. Findings from the STICK ITT questionnaire demonstrated that the incidence rate (IR) for sub-elite athletes [2.2 injuries per 1000 participation hours (95% CI 1.72-2.84)] and elite athletes [2.0 injuries per 1000 participation hours (95% CI 1.59-2.59)] was similar. The elite category included twelve athletes that competed in both the elite (national) and the sub-elite (provincial) levels. The overlap of competitive level could have provided a gray area in the distinction between elite and sub-elite athletes. In T&T, the lower skill level could be related to a greater risk of injury in performing routines, despite the level of routine. Sub-elite athletes may not be as technically sound and aerially aware as the more experienced elite athlete. Also, drills and expectations of routine components are typically similar despite less time in the sport and lower practice time (Kolt and Kirby, 1999). The sub-elite athlete (median age 13 years) was considerably younger when compared to the elite athlete (median age 17 years) in this study and therefore immature skeletal growth and development may have contributed to greater than expected injury rate in the sub-elite level.

## 5.2 Participant Characteristics and T&T Participation

### 5.2.1 Competitive level

Of the 132 participants, 54.5% (72/132) were classified as sub-elite athletes and 45.5% (60/132) as elite athletes. Canadian T&T athletes are required to meet "mobilization" scores to progress from the provincial (sub-elite) to the national level (elite) category. It is also common for athletes to compete at a national level on one event yet still need to mobilize from the provincial (sub-elite) level to the national (elite) level on a different event. However, it is uncommon for an athlete to train and compete at a national (elite) level without being very progressed at the provincial (sub-elite) level. Athletes in the higher provincial levels (i.e. Provincial level 4) prepare for the demands of elite competition by meeting advanced routine requirements (see chapter 1 for an outline of the Canadian Competitive T&T tiers).

### 5.2.2 Participant Characteristics

T&T competition registrations consistently have more female than male participants, as reflected by the STICK ITT data. There were twice as many females as males in both elite and sub-elite categories (females n=89, males n=43). The median age for participants was 15 years old with elite athletes being older (median 17 years old) than sub-elite athletes (median 13 years old) and with a median 3 years more T&T experience than sub-elite athletes. Based on age alone, elite athletes were consistently taller and heavier than the sub-elite athletes. In contrast to artistic gymnasts, where taller and heavier athletes are at greater risk of injury (Steele, 1986), this was not seen in T&T athlete participants in this study. T&T athletes may benefit performance-wise from growth and added height and weight in order to utilize the full potential of the trampoline

and the tumbling (rod) floor. That said, a larger athlete may experience increased forces through joints when executing repetitive high impacts required in T&T (Steele, 1986).

A larger proportion of athletes participate in Trampoline (107/132, 81%) and Double Mini Trampoline (105/132, 79.5%) than Tumbling (80/132, 60%). This may be explained by the differences between the two types of events. Trampoline events offer a multitude of learning opportunities for the acrobatically inclined and younger, smaller athletes can learn new skills relatively quickly. The event of tumbling does not offer the same diversity of skills that the trampoline events do. Also, the tumbling runway can be an unforgiving surface for an athlete who struggles with power, strength and adequate technique.

A larger proportion of sub-elite athletes participated in three or four events and elite athletes tend towards specialization in one or two events. Despite training and competing on fewer events, elite athletes typically train more days/week and for longer training sessions than sub-elite athletes (elite median 12 hours/week, sub-elite median 9 hours/week). Elite athletes in Canada will usually attend two more competitions than sub-elite and are more likely to compete internationally. Also, elite (national) level athletes are required to compete in both preliminary and finals competition at each sanctioned event effectively making most competitions multi-day meets.

Most competitive T&T athlete participants reported engaging in backyard trampoline (50%) and approximately 1 in 3 athletes participated in a competitive sport outside of T&T. Volleyball was popular among the STICK ITT participants as both a competitive sport and for recreation. T&T athlete participants reported a high proportion of lower extremity injuries (e.g., ankle 28.1%, knee 11.9%) with 16% of athletes commenting “I became increasingly sore over time”. The contribution of another four to five hours reported each week from a different

jumping intensive sport may also predispose T&T athlete participants to repetitive strain injuries such as Sever's Disease or Patellar Tendonitis (Soprano, 2005).

## 5.3 Outcome Variables

### 5.3.1 Injury Incidence Rates in Sub-elite and Elite Athletes

In total, 65.1% T&T athletes reported at least one injury that resulted in time loss and or required medical treatment over the previous year. This is consistent with the proportion of athletes reporting injuries by Grapton et al. (2013) for elite Trampoline and Tumbling athletes (63.7%). It is also consistent with the overall proportion of all high school students (65.7%, ages 14-19) and junior high school students (60.9% ages 12-15) reporting sport and recreation-related injuries across multiple sports (Emery 2006; Emery, 2009).

Overall, 132 STICK ITT participants registered a total of 135 injuries over the previous year (102.7 injuries/100 athletes/year). This suggests that within a group of 10 athletes, which is a typical T&T training group size, each athlete may sustain one injury over the course of a competitive year. The high injury rate found in this study is comparable to Bak et al. (2006) who reported an injury rate of 97 injuries/100 tumbling athletes/season.

Injury incidence rates based on number of injuries reported per 100 athletes per year does not consider exposure to risk (hours of participation or athlete exposures). A more thorough picture of the injury rate among a group of athletes should consider exposure time to facilitate comparisons across study groups (Emery, 2005). The STICK ITT data was evaluated based on hours of training and competition combined to consider injury incidence rate based on number of injuries per 1000 hours of participation to optimally compare risk in sub-elite and elite athlete participants. The injury rate for elite athlete participants [115 injuries/100 athletes/year (95%CI

84.0-145.6)]) was slightly higher than for sub-elite participants [91.6 injuries/100 athletes/year (95%CI 70.8-116.6)]. However, when exposure hours are considered, the incidence rates become similar for elite athlete participants [IR=2.05 injuries/1000 athlete exposure hours (95% CI 1.59-2.59)] and sub-elite athlete participants [IR=2.21 injuries/1000 athlete exposure hours (95% CI 1.72-2.84)]. Elite athletes reported training a median of 3 more hours/week than the sub-elite group and when the higher exposure time is factored in, a more inclusive injury profile is obtained.

The overall injury incidence rate for T&T athletes was 2.13 injuries/1000 exposure hours which is lower than the injury rates seen in most team sports. In a systematic review, Caine et al. (2008) examined injury rates in child and adolescent athletes across a multitude of sports. Injury rates were predictably higher in team contact sports such as hockey (5.0-34 injuries/1000 hours) and soccer ( 3.2-5.6 injuries/ 1000 exposure hours) than in T&T. In comparing other sports that are jump intensive, basketball had a mildly higher rate of injury (3.2-4.1 injuries/1000 exposure hours) whereas volleyball registered 1.7 injuries/1000 exposure hours. Comparisons between team/field sports should be made with caution as competitive T&T is a non-contact, individual sport. Other aesthetic, acrobatic and individual sports, such as gymnastics, cheerleading and dance, may be provide more appropriate comparisons in injury data. Caine et al (2008) noted an incidence rate of 2.1–4.4 injuries/1000 hours of exposure in male and female gymnastics. Kenny et al. (2015) found a range of 0.77-4.71 injuries/1000 hours among pre-professional competitive dancers, and the American Academy of Pediatrics (2012) noted in their position statement that competitive cheer had an injury rate of 1.0/1000 hours exposure. Sports in which repetitive movement patters and time intensive practice schedules, such as dance and gymnastics, appear to be appropriately aligned with T&T in both injury rates and sport demands.

In many sports, the elite-level athletes are at a greater risk of injury which may be related to higher exposure to risk, greater complexity of athletic techniques and higher levels of intensity in sport performance (Emery, 2003, Emery et al, 2009, Grapton et al, 2013). However, in the STICK ITT study, injury rates did not reflect a significant difference between groups based on level of athlete. Elite T&T athletes are typically older, more experienced and have a greater degree of skill refinement and aerial awareness than sub-elite athletes. Possibly, these considerations may provide a protective effect against injury for elite T&T athletes. Kolt and Kirby (1999) examined injury rates in elite and sub-elite artistic gymnasts over an 18-month time frame and reported a lower injury rate in elite gymnasts (IR=2.63injuries/1000 hours exposure) than in the sub elite group (IR=4.11 injuries/1000 hours). Kolt and Kirby proposed that while the sub-elite gymnasts were highly competitive, their skill level, physical capabilities, desire to make higher ranking teams and willingness to train with modifications despite injury may contribute to the higher injury rate in sub-elite athletes.

### 5.3.2 Injury Severity

Injury severity was categorized into minimal (0 days lost), minor (1-7 days lost), moderate (8-28 days lost) and severe (>28 days lost). In sub-elite athlete participants, 51% of injuries led to more than 7 days away from the training and in the elite group, 79% of injuries led to more than 7 days away from training. The median time loss for sub-elite athletes was 27.5 days (range 9-482 days) and for elite athletes was 60 days (range 10-150 days). This suggests that the severity of injuries may have been greater for elite athletes despite similar injury rates. Modifying training and training in pain was reported among 65% of participants and 70% reported the utilization of taping and bracing to enable T&T participation while managing an

injury. The urge to modify training while injured appeared to be a common plan for competitive T&T athletes, which may be contributing to the duration of time loss. Modifying training and training through an injury is also commonly seen among dancers and is speculated to extend the duration and severity of injury (Kenny, 2017). The distribution of injuries by time loss suggests severity of injury keeps T&T athletes from their sport for longer than other sports (Emery, 2009; Caine & Maffulli, 2006). The proportion of injuries with a time loss of one week to a month was 24.2% for Alberta High School students participating in a variety of sports (Emery et al. 2009). T&T athlete injury severity is perhaps more comparable to the time-loss seen among pre-professional ballet and contemporary dancers [111-588 days, (Kenny, 2018)]. It is also possible that the large proportion of T&T related time loss injuries may be overestimated due to the retrospective nature of the survey and selection bias related to those more likely to report an injury being those who were more likely to complete the survey.

### 5.3.3 Medical Attention

Ninety-two percent (124/135) of the injuries registered by T&T participants required some type of medical treatment and 15% (20/135) necessitated either an ambulance or emergency room visit (sub-elite 15.3%, elite 14.8%). In half of the injuries reported (52.5%), athletes received treatment from a physiotherapist. The high proportion of athletes requiring medical treatment and the duration of time loss (median 1-month) demonstrates the burden of injury that T&T athletes experience.

## 5.4 **Injury Characteristics**

The high proportion of reported ankle injuries among T&T athletes is consistent with findings from numerous studies examining injury characteristics across multiple sports (Grapton 2013, Collard, 2007, Emery 2009, Bolling 2012, Bak 1994, Eduard 2017, Kenny 2017). In the STICK ITT study, 28% (1/6) of athletes suffered an ankle injury and 60% reported using tape or ankle braces as protective gear. Ligament sprains were the most common injury type (22%) and athletes were most frequently injured due to a poor landing (28.5%). Grapton et al. (2013) reported a high proportion of ankle injuries in tumblers (31.2%, p=0.005) and speculated that landings and rebounds may be the mechanism. High impact landings while the athlete may be still flipping ("landing short") or twisting (torque into the floor) are common to both artistic gymnastics and T&T. In this study 28.2% of all injuries reported by T&T athlete participants were lower extremity injuries and this is consistent with a recent systematic review where 51% (n=843) of the injuries reported were lower extremity injuries in female artistic gymnasts (Thomas, 2019). Matting, spotting belts and appropriate progression of skills can help to mitigate ankle injuries but, gravity continues to be an influential factor and further research into ankle injury prevention would benefit all acrobatic athletes.

Concussions accounted for 23/132 (17%) of all T&T injuries reported. The rate of concussion (IR) was 0.34 /1000 athlete exposure hours (95%CI 0.22-0.52). Elite athletes reported a higher rate of concussion injury [21.3/100 athletes (95%CI 6.87-24.1)] than sub-elite athletes [13.9/100 athletes (95%CI 11.8-33.7)] and the most common mechanism of concussion was whiplash due to falling backward or landing on their back. The median time loss for concussion was 27 days (range 2-482). Concussion data among gymnasts is limited and previous studies focus primarily upon musculoskeletal injury. O'Kane et al (2011) conducted a cross

sectional study evaluating injury incidence, including concussion, among competitive artistic gymnasts aged 7-17 years. Thirty percent (29/96) of the participants reported sustaining a gymnastics related concussion at least once in their gymnastics careers. This proportion could be inflated due to the concussion definition used (sustained a hit to the head) and the historical timeframe for concussion registry. However, these authors note that with the escalation of skill requirements in gymnastics, the risk of serious injuries, including head injuries, is likely. Kerr et al. (2019) examined concussion incidence in high school sport and found that cheerleaders sustained 3.2 concussion/1000 athlete exposure hours. This rate is similar to the rate seen among competitive T&T athletes (0.34/1000 athlete exposure hours). Cheerleading and T&T share similarities with respect to landings and aerial maneuvers and provides a better injury rate comparison than field or contact sports. Pfister et al (2016) conducted a systematic review of concussion in youth sports. Twelve sports were examined for concussion incidence rate of which most were team contact sports. The concussion rates seen among T&T athletes were similar to those found for soccer or lacrosse (pooled estimate 0.23, 95%CI 0.19-0.28, 0.24, 95%CI 0.21-0.28). Further research examining concussion in T&T, and other gymnastics disciplines, is warranted.

### 5.3.1 Mechanisms of Injury

T&T athlete participants were most commonly injured on the tumbling runway (35%). Tumbling routines consist typically of a series of 5-7 backward bounding flips and a flipping dismount to a landing area. Speed and power contribute to the ability to perform necessary skills and dismounts. Speed of the pass is also a judged component for competitive scoring. An interrupted tumbling pass, whereby the athlete falls backwards, does so with speed and typically

lands harshly in hyperflexion of the upper back - a dangerous position. Of all concussions for which participants reported mechanism, 40% occurred on tumbling of which whiplash “landing on back with head whiplashed back” was the most predominant reported mechanism.

Almost 30% of athletes were injured on the trampoline. The trampoline presents a unique mechanism of injury in that the athlete not only lands awkwardly once, but possibly several times in succession. Throw mats, in ground trampolines and spotting harnesses are used in an effort to avoid injuries due to falling off the apparatus, failed skills or poor landings. Participants reported very few injuries due to “falling off the apparatus” (0.0% sub elite, 2.9% elite). Failed skills were more reported by more sub-elite athletes (24.2%) than elite (11.6). This is likely due to skill level, experience and a steep degree of learning seen in younger athletes.

Sobera et al. (2015) analyzed the foot and lower leg biomechanics of competitive trampoline athletes and found that all 10 of the athletes (ages 6-14 years old) in their study presented with abnormal rear foot angles (over-pronation). These authors suggested that trampoline bouncing modifies recruitment patterns in the lower leg and the repetitive forces through the ankle experienced by a competitive trampolinist may contribute to the high proportion of chronic ankle injuries in T&T. This is possible as the trampoline forces the ankle into a pronated state and ankle and knee valgus is visible in some athletes as they push off the bed. A large proportion of STICK ITT athlete participants (25%) reported increased soreness over time as the injury mechanism of which repetitive forces through mal-aligned joints could potentiate.

Double mini trampoline consists of a run, a hurdle onto the apparatus and then two skills with the second skill (dismount) landing on a mat. The double mini trampoline could logically contribute to a large proportion of the 39/135 injuries due to poor landings. Of the 10 athletes

reporting “other” for an injury mechanism, four reported that their injury occurred during the mount onto the double mini trampoline.

## 5.5 **Risk Factors for Injury**

The primary objective for the examination of risk factors was to compare injury rates by level of competitor (elite, sub-elite). Further, sex (male, female), age (<15, >=15 years), years of experience in T&T (<=5 years, >5 years) and exposure type (injury during competition or training) were explored. Injury rates did not differ by level of competitor and these results have been previously discussed. Based on an exploratory analysis, other factors were examined, and only sex appeared to be a significant risk factor for injury in T&T athletes with females having a higher risk than males (IRR=1.49, 95% CI 1.12-1.92). The high numbers of female athletes reporting injuries in T&T may be due to the adolescent age of the athletes in combination with the level at which they were training. Adolescent athletes at the Provincial 4 to National 6 competitive levels (27-29/90, 30%) may experience an intense and demanding period of T&T progression whereby achievement of high-performance routines is required while navigating peak growth rates, hormonal changes and skeletal changes associated with puberty. The higher risk of injury found in the female T&T athletes over their male counterparts is consistent with several other studies. For example, Von Rosen et al (2018) evaluated 340 elite athletes, ages 15-19, from 16 different sports and found that females had a higher prevalence of substantial injury, a longer duration of time loss and a higher perception of pain than males. Additionally, Collard et al (2008) found a high injury rate in female gymnasts (8.5 injuries/100 athletes) and noted that females are particularly susceptible to knee (ACL) injuries due to hormonal, neuromuscular and structural difference as opposed to males. Pfeifer et al (2018) and Montalvo et al (2019) also

suggest that the risk of injury differs between sexes due to structural differences (e.g., knee valgus, joint structure, body mass index), neuromuscular control, muscle strength and hormonal changes. A systematic review evaluating the effects of menstrual cycle and knee injury in female athletes found that due to hormonal fluctuations, females were at a significantly higher risk of ACL injury than males (Hewett et al, 2007).

In this study, most athletes were adolescents, however age was not found to be a risk factor for injury in T&T athletes. The risk of injury for athletes less than 15 years old and athletes 15 and older was similar (IRR 1.11, 95%CI 0.97-1.05). This age split was based on the median age of participants and on a reasonable age of puberty ending at 15-17 for girls and 16-18 for boys. However, perhaps a better examination of maturity and risk among this group of athletes could have been observed had the age split been under 12 (child to pre-adolescent) and 13 and older (adolescent to young adult). In this study there were only 26 participants under age 13. Injury risk research in adolescence suggests that injury incidence increases with age greater than 13 (Emery, 2005).

Previous research findings show that risk is increased during competition more so than during training (Emery, 2003), but this was not the case in this study since competitive exposure was not a risk factor for injury. This may be explained by the exposure time that T&T athletes spend in training versus competition. Sub-elite athletes trained a median of 431 hours (range 43-785) of which only 4 hours/year were calculated to be spent in competition (see Chapter 3 for calculation of exposure time). Elite athletes trained a median of 571 hours and competed for a median of 7.5 hours/year. The amount of exposure that an athlete has during competition is very low in comparison to the exposure during training. For example, a sub-elite trampoline athlete

will take four to six trampoline turns including the warm-up turns and his or her 12 second performance.

Years of experience in competitive T&T (<= 5 years/>5 years) and injury occurrence while training or competition were identified as possible risk factors for injury in competitive T&T. It is possible that older, more experienced and higher level competitors have the technical skill, older training cohort (for safety mats) and better kinesthetic awareness. Potential training/competition related risk factors were explored descriptively and include modifiable risk factors such as those related to athlete practices. The proportion of T&T athletes in this study that warm up, cool down and engage in physical preparation is high (90-100%). Athletes reported running, biking, rowing and stretching for warm up and cooling down for a time frame greater than 10 minutes. Ninety-three percent of all participants reported engaging in physical preparation included in the text responses, resistance training and conditioning (90%) and foam rolling exercises (42%). T&T athletes reported training for a median of 11 months/year and 12 hours/week. While warming up, cooling down and physical preparation is imperative, a cautious approach is needed with respect to potentially over training in athletes. In this sport time-off must be incorporated into yearly training plans as a there is no defined 'off-season'. Coaches need better education to help understand the ramifications of year-round training and the necessity of recovery. Overall, increased education, better universal competition schedules and professional athlete planning would benefit the sport of T&T in injury management.

Most STICK ITT participants (75%) reported training on both above and in ground trampolines. Athletes compete on above ground trampolines only and, in Canada, equipment (e.g., trampolines, tumbling floors, mats) for sanctioned competitions is shipped to the various venues across the country. The competition equipment is used only for competitive purposes.

Most athletes (90%) reported that they felt landing mats were harder at competitions as opposed to the mats used to train on. Athletes are able to place an extra "sting" mat (2 inch foam mat) on the landing area for tumbling without deduction in competition. However, this latitude is not given on double mini trampoline due to rules about landing within the landing zone. As the most frequent mechanism of injury was landings, and the biggest skills are being executed off the double mini trampoline, it may be beneficial for athletes to have a more absorbent mat to land on.

Equipment is an extrinsic, potentially modifiable risk factor. Only a small proportion (2%) of athletes reported that the mechanism of injury was due to equipment. Changes to matting, springs, frames and trampoline beds have been made in an to attempt to make the sport safer (www.reboundproducts.com). Almost all athletes (97%) reported training practices that encourage aerial awareness and practice "crash" safety. There is little time to make a decision once an aerial skill goes wrong, however, a correct split-second decision could make a difference in an athlete's injury status. Coaching education and awareness should make safety practice mandatory and a pro-active approach towards mitigating modifiable risk factors could provide a starting point for injury prevention strategies.

These exploratory analyses examining risk factors for injury in T&T athletes showed that females may be at a higher risk of injury in competitive T&T than male athletes. The other potential risk factors explored in this study merit further research.

## 5.6 **Strengths**

This is the first study to examine in depth injury burden among competitive T&T athletes. Previous studies have focused upon injury data pertaining to artistic gymnastics. This study

provides an independent injury profile for the sport of T&T using participants from across Canada. The STICK ITT questionnaire was adapted from the Alberta Sport Injury Survey for Calgary and area High Schools (Emery et al, 2006) and Sport participation and injury burden in high school volleyball athletes [(Meeuwisse, et al (date unknown – manuscript draft)] of which was validated for content. The STICK ITT questionnaire was face validated by six reviewers. The study quantifies injury incidence rates considering exposure to risk (# injuries/1000 athlete exposure hours) contributing to a better understanding of injury risk and burden compared to prevalence of injury measures. Each athlete reported details for up to three injuries, plus concussion, thereby contributing to the depth of understanding of injury burden within T&T. The STICK ITT study provides an epidemiological perspective of injury in T&T and therefore has the potential to inform coaches, committee members, parents and future researchers about possible strategies to mitigate risk of injury and promote injury preventative measures.

## 5.7 **Limitations**

Cross sectional studies have design limitations related to the lack of temporality and has biases that include selection and measurement biases (Portney, Watkins, 2015). Regarding temporality, it is impossible to establish a link between injury and risk without fully understanding the temporality of the risk factor and injury occurrence. In this study, selection bias may have occurred as the athletes were recruited to participate online and the sample includes over-representation of Alberta gyms. For example, Quebec had minimal participation because of the requirement of English fluency. In addition, athletes that suffered recent and or serious injuries may have been more likely to complete this survey as they may have invested interest in injury prevention. Conversely, non-injured athletes may have been less motivated to

participate. Efforts were made to inform club administrators that non-injury data was also important. However, the subsequent over representation of injured athletes and under reporting of (non) injuries may cause an overestimation of injury rates.

Due to the retrospective nature of the survey, recall bias (measurement bias) is likely. The time frame of interest for the STICK ITT study was from September 2018 to September 2019 to enable data capture for a full competitive season for both Provincial (sub-elite) and for National (elite) athletes who may be attending competitions abroad over the summer months. The survey was open from October 2019 to June 2020. Due to the length of time that passed from the previous year to the date in which the survey was completed, participant recall bias could be high. When recalling details of an injury, athletes may over-estimate the burden of injury if the injury was particularly traumatic. Recall bias may also affect details of injury location, type and mechanism reported. Self-reported data lends itself to inaccurate reporting of injury location and type, which may be particularly true for the younger athletes completing the survey. Twenty-eight athletes received assistance from an adult in completing the survey. It is possible that a parent may over-estimate the severity of or be mistaken about details of their young athlete's injuries. However, given that there was no significant difference in injury incidence between the older elite athletes and the younger sub-elite athletes, this bias should be relatively low.

The original target of 196 athletes was not achieved over 9 months of data collection. Only 132 eligible participants returned surveys and a-priori sample size was short by 27 athletes each group. Onsite data collection at two events in January and February 2020 was the most successful method of recruitment and plans to attend at least 2 more competitions may have enabled reaching the target sample size. A larger sample size would not have impacted the null result found in comparing injury rates between sub-elite and elite athletes. Despite the sample

size limitation, exploratory analyses did demonstrate a difference between female and male athlete injury rates. A larger sample size may have enabled further multivariable analyses to provide a better understanding of T&T injury risk factors.

Potential modifiers and confounders such as age, sex, and years of experience were assessed. Age was found to be a confounder in the relationship between competitive level and injury, however there was no significance between level and injury ($p=0.349$). Analysis was restricted to exploratory univariate exploratory Poisson regression models. This limits the interpretation of the risk factor study findings.

Further, the generalizability of these findings based on 132 athletes participating in this cross-sectional study is limited, given the estimated target population of 1708 athletes in Canada and oversampling from Alberta athletes. This study included participants from 12 clubs (90 athletes) in Alberta and is representative of Alberta trained T&T athletes. Because of the low response rate from other provinces, generalizability across Canada is limited. However, the findings in this study are consistent with previously conducted studies (Grapton, 2013; Bak, 1994; Kolt & Kirby, 1999, Emery 2009) that analyzed artistic gymnastics, trampoline gymnastics and multi-sport injury data.

# 6 Conclusions

## 6.1 Summary of findings

The STICK ITT research is novel because it examined injury rates (including consideration of athlete exposure hours), anatomical location, type, event location and mechanism in a sport not previously studied. Risk factors were independently explored based on injury rates across levels of competitor (elite, sub-elite), sex (male, female), age (<15, >=15 years), years of experience in T&T (<=5 years, >5 years) and exposure type (injury during competition or training).

Overall, 132 participants (90 females and 43 males) provided injury data representing 135 injuries including concussion. The participants were categorized based on athlete competitive level (72 sub-elite and 60 elite). Overall, 65.1% trampoline and tumbling gymnasts were injured at least once over the previous year of training and competition. The injury incidence rate (IR) was similar for sub-elite [IR=2.21 injuries/1000 athlete exposure hours (95%CI 1.67-2.91)] and elite athletes [IR=2.05 injuries/1000 athlete exposure hours (95%CI 1.40-2.79). Sixty-four percent of athlete injuries reported time loss of greater than seven days following injury and 93% of injuries required medical treatment from a doctor or allied health professional. Ankle injuries (30%) and concussion (17%) were the most common injuries. Ligament sprains (22%), concussion (17%) and overuse/"sore over time" (16%) were the top three types of injuries. This was the first study to describe the incidence of concussion among trampoline and tumbling athletes. Considering that T&T is a non-contact, individual sport, the incidence of concussion is high (23/135, 17%). Concussion injuries kept athletes from training for a median time loss of 1 month and return to sport protocols were followed by less than half of the injured athletes (8/20, 40%).

Of all injuries reported, 35% occurred on the tumbling floor with sub-elite being injured on tumbling more than elite athletes, 29% occurred on trampoline and 25% on the Double mini trampoline. The proportion of elite athletes injured on double mini was two-fold that of sub elite. Landings were cited as most common mechanism of injury for musculoskeletal injuries and whiplash/falling back onto back was 53% of the 23 concussions occurred.

This study examined injury incidence in terms of exposure and found females were at greater risk of injury over their male counterparts. Other exploratory variables (age, level, experience and injury in competition versus training) were not found to be significant risk factors.

## 6.2 **Public Health Implications**

T&T is a sport that is enjoyed by many athletes, some with aspirations of gold medals at the Olympic Games. As athletes progress through the competitive tiers, the requirements for high degrees of difficulty and greater jump times increases. Athletes experience ankle, head (concussion) and overuse type injuries as they engage in a sport they love. Injuries place young athletes at risk of long-term disability and may lead to chronic diseases such as osteoarthritis. Time loss injuries, such as those encountered in sport, keep athletes from being active and fit and may lead to a cessation of sport entirely. Von Rosen's (2018) mixed methods research explored the adolescent athlete's perception of injury and found (pp 737, no 5):

"Injury is a threat to the identity of a young athlete". Injuries have physical, emotional and psychological implications for active people who are suddenly unable to do what makes them positive and productive in society.

## 6.3 **Recommendations for Future Research.**

Future research will inform further study examining the development of effective injury prevention strategies in the aerial, aesthetic and acrobatics sports with the long-term goal of decreasing the burden of injury in these high-risk sports thereby contributing to health and active population moving forward. A prospective cohort study following a group of T&T athletes over a span of time may inform risk factor analysis and aid in the creation of injury prevention strategies (neuromuscular warm -ups specific to acrobatic athletes). Further research examining concussion and rehabilitation from concussion is warranted. The STICK ITT study registered 23 concussions over 132 participants with 3 of those participants reporting more than one concussion. Return to sport protocols may need to be altered for athletes returning to a high impact, aerially challenging sport.

**REFERENCES**

Alberta Gymnastics Federation. Trampoline and Tumbling Technical Handbook, 2019-2020, Tumbling and Trampoline Equipment Requirements, Tumbling, Trampoline, Double-Mini-Trampoline, Appendix 1.

American Academy of Pediatrics. Cheerleading Injuries: Epidemiology and Recommendations for Prevention (2012). Pediatrics 130;966. DOI: 10.1542/peds.2012-2480 originally published online October 22, 2012;

American Academy of Pediatrics. Trampoline Safety in Childhood and Adolescence. (2012). *Pediatrics*, *130*(4), 774–779. https://doi.org/10.1542/peds.2012-2082

American Academy of Orthopedic Surgeons, (2010). Position Statement: Trampolines and trampoline safety, 1–2.

American Council of Sports Medicine and Fitness. Trampoline Safety in Childhood and Adolescence. Pediatrics. 2012;130;4;774-779

Bak, K., Kalms, S. B., Olesen, S., & Jargensen, U. (1994). Epidemiology of injuries in gymnastics. *Scandinavian Journal of Medicine & Science in Sports*, *4*(2), 148–154. https://doi.org/10.1111/j.1600-0838.1994.tb00419.x

Bergeron, M. F., Mountjoy, M., Armstrong, N., Chia, M., Côté, J., Emery, C. A., … Engebretsen, L. (2015). International Olympic Committee consensus statement on youth athletic development. *British Journal of Sports Medicine*, *49*(13), 843–851. https://doi.org/10.1136/bjsports-2015-094962

Bolling, C., & Leite, M. (2013). Difference in injury profile in Trampoline and Artistic Gymnastics. *Journal of Science and Medicine in Sport*, *15*, S127–S128. https://doi.org/10.1016/j.jsams.2012.11.307

Bolling, C., van Mechelen, W., Pasman, H. R., & Verhagen, E. (2018). Context Matters: Revisiting the First Step of the 'Sequence of Prevention' of Sports Injuries. *Sports Medicine*, *48*(10), 2227–2234. https://doi.org/10.1007/s40279-018-0953-x

Caine, D., Caine, C., & Maffulli, N. (2006). Incidence and distribution of pediatric sport-related injuries. *Clinical Journal of Sport Medicine*, *16*(6), 500–513. https://doi.org/10.1097/01.jsm.0000251181.36582.a0

Caine, D., Maffulli, N., & Caine, C. (2008). Epidemiology of Injury in Child and Adolescent Sports: Injury Rates, Risk Factors, and Prevention. *Clinics in Sports Medicine*, *27*(1), 19–50. https://doi.org/10.1016/j.csm.2007.10.008

Caine, D., Walch, T., & Sabato, T. (2016). The elite young athlete: strategies to ensure physical and emotional health. *Open Access Journal of Sports Medicine*, *Volume 7*, 99–113. https://doi.org/10.2147/oajsm.s96821

Collard DC, Verhagen EA, Chin A Paw MJ, van Mechelen W. Acute physical activity and sports injuries in children. Appl Physiol Nutr Metab. 2008 Apr;33(2):393-401. doi: 10.1139/H07-182. PMID: 18347696.

"Competition Trampolines & Equipment." *Rebound Products Inc.*, 24 May 2020, www.reboundproducts.com/.

Crossley, K. M., Patterson, B. E., Culvenor, A. G., Bruder, A. M., Mosler, A. B., & Mentiplay, B. F. (2020). Making football safer for women: A systematic review and meta-analysis of injury prevention programmes in 11 773 female football (soccer) players. *British Journal of Sports Medicine*, (2), 1–12. https://doi.org/10.1136/bjsports-2019-101587

Edouard, P., Steffen, K., Junge, A., Leglise, M., Soligard, T., & Engebretsen, L. (2018). Gymnastics injury incidence during the 2008, 2012 and 2016 Olympic Games: Analysis of prospectively collected surveillance data from 963 registered gymnasts during Olympic Games. *British Journal of Sports Medicine*, *52*(7), 475–481. https://doi.org/10.1136/bjsports-2017-097972

Emery, C.A., (2005). *Injury prevention and future research*. *Medicine and sport science* (Vol. 48). Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed7&NEWS=N&AN=16247258

Emery, C. A., Meeuwisse, W. H., & McAllister, J. R. (2006). Survey of sport participation and sport injury in Calgary and area high schools. *Clinical Journal of Sport Medicine*, *16*(1), 20–26. https://doi.org/10.1097/01.jsm.0000184638.72075.b7

Emery, C. A. (2003). Risk factors for injury in child and adolescent sport: A systematic review of the literature. *Clinical Journal of Sport Medicine*, *13*(4), 256–268. https://doi.org/10.1097/00042752-200307000-00011

Emery, C. A., & Meeuwisse, W. H. (2010). Survey Of Sport Participation, Sport Injury And Sport Safety Practices In Calgary Area High Schools. *Medicine & Science in Sports & Exercise*, *37*(Supplement), S15. https://doi.org/10.1249/00005768-200505001-00108

Emery, C. A., & Tyreman, H. (2009). Sport participation, sport injury, risk factors and sport safety practices in Calgary and area junior high schools. *Paediatrics and Child Health*, *14*(7), 439–444. https://doi.org/10.1093/pch/14.7.439

Esposito, P. W., & Esposito, L. M. (2009). The re-emergence of the trampoline as a recreational activity and competitive sport. *Current Sports Medicine Reports*, *8*(5), 273–277. https://doi.org/10.1249/JSR.0b013e3181b8f60a

Federation International De Gymnastique, Trampoline Gymnastics, https://www.fig-gymnastics.com.

Federation Internationale de Gymnastics (FIG) Trampoline Gymnastics Code of Points, 2017-2020 retrieved fromfig-gymnastics.com/rules/files/tra_2017-2020

Fuller, C. W., Molloy, M. G., Bagate, C., Bahr, R., Brooks, J. H. M., Donson, H., … Wiley, P. (2007). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Clinical Journal of Sport Medicine*, *17*(3), 177–181. https://doi.org/10.1097/JSM.0b013e31803220b3

Grapton X., Lion, A., Gauchard, G.C., Barrault, D., & Perrin, P. (2013). Specific injuries induced by the practice of trampoline, tumbling and acrobatic gymnastics. *Knee Surgery, Sports Traumatology, Arthroscopy*, *21*(2), 494–499. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed11&NEWS=N&AN=22476523

Gymnastic Canada, (1997) *Level 2 Trampoline Manual* (2nd ed*)*, Gloucester, Ont, Gymnastic Canada.

Gymnastics Canada, (2020), From here we soar, Trampoline and Tumbling History Canadian Perspective, http://gymcan.org/

Hewett, T. E., Zazulak, B. T., & Myer, G. D. (2007). Effects of the menstrual cycle on anterior cruciate ligament injury risk: A systematic review. *American Journal of Sports Medicine, 35*(4), 659–668. https://doi.org/10.1177/0363546506295699

Kenny SJ,Whittaker JL, Emery CA.Br JSports MedPublished OnlineFirst: doi:10.1136/bjsports-2015-095121

Kenny, S. J., Palacios-Derflingher, L., Shi, Q., Whittaker, J. L., & Emery, C. A. (2017). Association Between Previous Injury and Risk Factors for Future Injury in Preprofessional Ballet and Contemporary Dancers. *Clinical Journal of Sport Medicine, 2019*, 1. https://doi.org/10.1097/JSM.0000000000000513

Kenny, S. J., Palacios-Derflingher, L., Whittaker, J. L., & Emery, C. A. (2017). The Influence of Injury Definition on Injury Burden in Pre-Professional Ballet and Contemporary Dancers. *Journal of Orthopaedic & Sports Physical Therapy*, *48*(3), 1–34. https://doi.org/10.2519/jospt.2018.7542

Kerr, Z.Y, Avinash, C, Nedimyer, A.K., Arakkal, A, Pierpoint, L.A., Zuckerman, S. L. (2019) Concussion Incidence and Trends in 20 High School Sports, *Journal of the American Academy of Pediatrics*, 2019;144. https://doi:10.1542/peds.2019-2180

Kolt, G. S., & Kirkby, R. J. (1999). Epidemiology of injury in elite and subelite female gymnasts: A comparison of retrospective and prospective findings. *British Journal of Sports Medicine*, *33*(5), 312–318. https://doi.org/10.1136/bjsm.33.5.312

Kuisis, S. M., Camacho, T. C., Dafel, S. M., & Rensburg, D. C. J. Van. (2011). Kinetic Profile and Incidence of Injuries Among High Performance Trampoline Gymnasts, *11*(1996), 1001–1004.

Kuhn, M., Nunes, L., Lambert, C., Cantos, M.J., Fink, H. (2019). Federation Internationale Gymnastics Age Group Developmental and Competition Program for Trampoline Gymnastics. 3rd edition

Meeuwisse, D., Black, A.M., Schneider, K.J., Eliason, P.H., Kozak, S.M., Van den berg, C, Emery, C.A., (date unknown) Sport participation and injury burden in high school youth volleyball athletes. Manuscript draft – questionnaire referenced

Meeuwisse, W. H., Tyreman, H., Hagel, B., & Emery, C. (2007). Dynamic Model of Etiology in Sport Injury : The Recursive Nature of Risk and Causation. (2007). *Clinical Journal of Sports Medicine*, *17*(3), 215–219.

Montalvo, A. M., Schneider, D. K., Yut, L., Webster, K. E., Beynnon, B., Kocher, M. S., & Myer, G. D. (2019). "what's my risk of sustaining an ACL injury while playing sports?" A systematic review with meta-analysis. *British Journal of Sports Medicine*, *53*(16), 1003–1012. https://doi.org/10.1136/bjsports-2016-096274

Nysted, M., Drogset, J. O., & Karlsson, J. (2006). Trampoline injuries * Commentary. *British Journal of Sports Medicine*, *40*(12), 984–987. https://doi.org/10.1136/bjsm.2006.029009

O'Kane, J. W., Levy, M. R., Pietila, K. E., Caine, D. J., & Schiff, M. A. (2011). Survey of injuries in seattle area levels 4 to 10 female club gymnasts. *Clinical Journal of Sport Medicine*, *21*(6), 486–492. https://doi.org/10.1097/JSM.0b013e31822e89a8

Pfeifer, C. E., Beattie, P. F., Sacko, R. S., & Hand, A. (2018). Risk Factors Associated With Non-Contact Anterior Cruciate Ligament Injury: a Systematic Review. *International Journal of Sports Physical Therapy*, *13*(4), 575–587. https://doi.org/10.26603/ijspt20180575

Pfister, T., Pfister, K., Hagel, B., Ghali, W. A., & Ronksley, P. E. (2016). The incidence of concussion in youth sports: A systematic review and meta-analysis. *British Journal of Sports Medicine*, *50*(5), 292–297. https://doi.org/10.1136/bjsports-2015-094978

Portney, L.G., Watkins, M,P. (2015) *Foundations of Clinical Research* (3rd ed) Philadelphia, PA : F.A. Davis Company

Rapp, G. F., & Nicely, P. G. (1978). Trampoline injuries. *The American Journal of Sports Medicine*, *6*(5), 269–271. https://doi.org/10.1177/036354657800600508

Sobera, A., Sobera, M., & Kleszyk, K. (2015). Foot and Ankle Deformity in Young Acrobatic and Artistic Gymnasts. *Human Movement*, *16*(3), 130–136. https://doi.org/10.1515/humo-2015-0034

Soprano, J. V. (2005). Musculoskeletal injuries in the pediatric and adolescent athlete. *Current Sports Medicine Reports*, *4*(6), 329–334. https://doi.org/10.1097/01.CSMR.0000306295.49707.1f

Steele, V. A., & White, J. A. (1986). Injury prediction in female gymnasts. *British journal of sports medicine*, *20*(1), 31–33. https://doi.org/10.1136/bjsm.20.1.31

Thomas, R. E., & Thomas, B. C. (2018). A systematic review of injuries in gymnastics. *Physician and Sportsmedicine*, *3847*. https://doi.org/10.1080/00913847.2018.1527646

Trampoline Safety in Childhood and Adolescence. (2012). *Pediatrics*, *130*(4), 774–779. https://doi.org/10.1542/peds.2012-2082

Von Rosen, P., Kottorp, A., Fridén, C., Frohm, A., & Heijne, A. (2018). Young, talented and injured: Injury perceptions, experiences and consequences in adolescent elite athletes. *European Journal of Sport Science*, *18*(5), 731–740. https://doi.org/10.1080/17461391.2018.1440009

## APPENDIX A : SAMPLE SIZE CALCULATION

Sample Size Calculation

$\alpha = 0.05$ = acceptable type I error (two-tailed) → $Z_{1-\alpha/2} = Z_{0.975} = 1.960$
$\beta = 0.20$ = acceptable type II error for a study powered at 80% (1-β) → $Z_{1-\beta} = Z_{0.80} = 0.842$

$$n = \frac{(z1-\alpha/2)2\ (2) - \prod(1-\prod)}{\Delta\pi 22}$$

$$n = \frac{(1.96+.84)2\ (2)\ 0.5(1-0.5)}{(.2)2}$$

$$n = \frac{3.92}{0.04} = 98 \text{ participants per group (N=196)}$$

STATA – 107/group

Confirmed by STATA 15.1 (power twoproportion .60 .40, test (chi2) continuity (n=107/group, N=214)
Confirmed by https://www.stat.ubc.ca/~rollin/stats/ssize/b2.html (n=97)

## APPENDIX B : 2018-19 CANADIAN T&T COMPETITVE PARTICIPATION

2018-19 Canadian Competitive T&T – Participation

| Province | # of clubs | Provincial 1-4 level athletes | National 5-Senior level athletes | Total |
|---|---|---|---|---|
| British Columbia | 10 | 115 | 75 | 190 |
| Alberta | 12 | 204 | 81 | 285 |
| Saskatchewan | 3 | 52<br>Male 6; Female 46 | 15<br>Male 1; Female 14 | 67 |
| Manitoba | 2 | 26 | 4 | 30 |
| Ontario | 41 | 495 | 135 | 630 |
| Quebec | Not confirmed | 299 | 79 | 378 |
| New Brunswick | 4 | 30<br>Male 6; Female 26 | 7<br>Male 4; Female 3 | 37 |
| Nova Scotia | 4 | Male 17; 64 Female – level not outlined | | 81 |
| Newfoundland/ Labrador | 2 | Not confirmed | Not confirmed | 10 |
| Prince Edward Island | | No competitive T&T athletes listed | | |
| NWT/Yukon | | No competitive T&T athletes listed | | |
| | | | | **1708** |

**APPENDIX C : LIST OF TRAINING FACILITITES and RECRUITMENT SCHEDULE**

**British Columbia**

PSO – www.gymbc.org

Recruitment : via email, social media requests

Recruitment dates : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

| Training Facility | Location |
|---|---|
| **Club Aviva** | Port Coquitlam |
| **Flip City** | Langley |
| **Flip Club** | Kelowna |
| **Kamloops Gymnastics** | Kamloops |
| **Momentum Gymnastics** | Salmon Arm |
| **Okanagan Gymnastics Club** | Kelowna |
| **Prince George Gymnastics Club** | Prince George |
| **Prince Rupert Gymnastics Club** | Prince Rupert |
| **Shasta Trampoline Club** | New Westminster |
| **TAG Gymnastics** | Coquitlam |
| **Wayland Gymnastics** | Maple Ridge |
| **Whistler Gymnastics** | Whistler |
| **Total BC Facilities** | 12 |

**Alberta**

PSO - Alberta Gymnastics Federation (AGF) – www.abgym.ab.ca

Recruitment : via email, social media, word of mouth and personal contacts, Alberta Coaches retreat onsite data collection at 2 competitions

Recruitment email schedule : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

Onsite data collection : Alberta First Cup (Altadore Gymnastics Club, Calgary) January 11-12, 2020, Alberta Second Cup (Pegasus Gymnastics Club, Calgary) February 14-15, 2020.

| Training Facility | Location |
|---|---|
| **Airborne Trampoline and Tumbling** | Okotoks |
| **Airdrie Edge Gymnastics** | Airdrie |
| **Altadore Gymnastics Club** | Calgary |
| **Calgary Gymnastics Centre** | Calgary |
| **Cardston Gymnastics** | Cardston |
| **Exelta Gymnastics** | Red Deer |
| **Grande Prairie Gymniks** | Grande Prairie |
| **Ortona Gymnastics** | Edmonton |
| **Pegasus Gymnastics** | Calgary |
| **Phoenix Gymnastics** | Edmonton |
| **Thunder Country Trampoline Club** | Red Deer |
| **Westwinds Gymnastics** | Lethbridge |
| **Total Alberta Facilities** | 12 |

**Saskatchewan**

PSO – www.gymsask.com

Recruitment : via email, social media requests

Recruitment dates : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

| Training Facility | Location |
|---|---|
| **Aerials Gymnastics Club** | Prince Albert |
| **Can Am Gymnastics** | Saskatoon |
| **Gymnastics Adventure** | Regina |
| **Gymtastics** | Moose Jaw<br>*notified competitive T&T program discontinued |
| **Total Saskatchewan Facilities** | 3 |

**Manitoba**

PSO - www.gymnastics.mb.ca

Recruitment : via email, social media requests

Recruitment dates : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

| Training Facility | Location |
|---|---|
| **Flippers Gymnastics** | Winnipeg |
| **Kingswood Gymnastics** | |
| **Panthers Gymnastics** | Winnipeg |
| **Springers Gymnastics** | Winnipeg |
| **Total Manitoba Facilities** | 4 |

**Ontario**

PSO - www.gymnasticsontario.ca

Recruitment : via email, social media requests

Recruitment dates : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

| Training Facility | Location |
|---|---|
| **Airborne KW** | Cambridge |
| **Anti-gravity Acrosport** | Whitby |
| **Burlington BG's** | Burlington |
| **Discovery School of Sport and Art** | North York |
| **Dynamo Gymnastics** | Cambridge |
| **Futures Gymnastics** | Mississauga |
| **Grande River Gymmies** | Grande River |
| **Just Bounce Trampoline Club** | Toronto |
| **Kingston Aero's Trampoline Club** | Kingston |
| **London Beje Gymnastics** | London |
| **Osborne Academy Acrobats** | Pickering |
| **Oakville Gymnastics** | Oakville |
| **Quinte Bay Gymnastics** | Quinte Bay |
| **Rideau Gymnastics** | Kanata |
| **Skyriders Trampoline** | Richmond Hill |
| **Spring Action Trampoline Club** | Ottawa |
| **Tumblers Gymnastics Centre** | Orleans |
| **Total Ontario Facilities** | 18 |

**New Brunswick**

PSO - www.gym.nb.ca

Recruitment : via email, social media requests

Recruitment dates : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

| Training Facility | Location |
|---|---|
| **Beausejour Gymnos Gymnastics Club** | Moncton |
| **Kingswood Gymnastics** | Fredericton |
| **Total New Brunswick facilities** | 2 |

**Nova Scotia**

PSO – www.gymns.ca

Recruitment : via email, social media requests

Recruitment dates : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

| Training Facility | Location |
|---|---|
| **Athletics Gymnastics Academy** | Bridgewater |
| **Cobequid Spartans Gymnastics Centre** | Truro |
| **Gymnation Trampoline** | Truro |
| **Jump-2-It Trampoline** | Elmsdale |
| **Rainbow Riders Trampoline Club** | Middleton |
| **Titans Trampoline Club** | Dartmouth |
| **Total Nova Scotia Facilities** | 6 |

**Newfoundland/Labrador**

PSO - www.gymnf.ca

Recruitment : via email, social media requests

Recruitment dates : October 22, 2019, January 25, 2020, March 30, 2020, May 20, 2020

| Facility | Location |
|---|---|
| **Campia Gymnastics Club** | Mt Pearl |
| **Cygnus Gymnastics Training Centre** | St. Johns |
| **Saltos Gymnastics Club** | Cornerbrook |
| **Total Newfoundland facilities** | 3 |

**APPENDIX D : STICK ITT - FACE VALIDATION TRACKING FORM**

FACE VALIDATION TRACKING FORM

STICK ITT – Study To Increase Current Knowledge of Injuries in Trampoline and Tumbling.
*The prevalence, incidence and associated risk of injury in competitive Trampoline and Tumbling athletes aged 8-25 years old.*

MSc Student: Sheila Downie
Supervisor: Dr. Sarah Kenny

Thank you for your assistance in the face validation process for the STICK ITT study.

The purpose of this study is to examine the type, location, severity and risk of injury in Canadian competitive Trampoline and Tumbling athletes.

Please click the hyperlink to access the survey _____

Please complete the following questions as part of your review of the survey.

If you have any questions, please email Sheila Downie: Sheila.downie@

Name:
Area of Expertise:
Are the questions appropriate for achieving the study's objectives?

Would you suggest any changes to the order in which the questions are asked?

Will athletes as young as 8 years old be able to understand the questions?

Do you feel any questions or response option should be modified, removed or added?

How long did it take you to complete the survey?

What device did you use to complete the survey (i.e. phone, computer, tablet/iPad) and was the survey user friendly?

Additional comments?

Thank you very much for your time.

**APPENDIX E : STICK ITT QUESTIOINNAIRE CONSENT**

UNIVERSITY OF CALGARY
FACULTY OF KINESIOLOGY
Sport Injury Prevention Research Centre

---

## IMPLIED CONSENT

(Ages 15 to adult)

**TITLE: STICK ITT** – **S**tudy **to** **I**ncrease **C**urrent **K**nowledge of **I**njuries in **T**rampoline and **T**umbling.

*The prevalence and associated factors for injury in competitive trampoline and tumbling athletes ages 8-25 years old.*

**SPONSOR:** Sport Injury Prevention Research Centre, Faculty of Kinesiology. University of Calgary.

**INVESTIGATORS: Sheila Downie (M.Sc. Student), Dr. Sarah Kenny**

*This information sheet is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully and to understand any accompanying information.*

**BACKGROUND**

T&T is a high impact sport, and, combined with its acrobatic and aerial nature, there is a risk for injury.

An injury will keep you from practicing your sport and being active, which can change how healthy you are. Research is important to help understand how to keep injuries from

happening. It helps us understand how many injuries there are in T&T and what increases the chances of getting hurt. This research will also help us find ways to stop injuries from happening in the future.

To date, very little is known about injuries that competitive T&T athletes get. Gathering and analyzing athlete injury and training information from different T&T clubs in Alberta and surrounding provinces will be the first time that this type of study has been done.

## WHAT IS THE PURPOSE OF THE STUDY?

The purpose of this study is to understand the trends and burden of injuries that competitive T&T athletes get. Our goal is to identify certain measures that can help to decrease your chances of getting an injury before an injury actually happens.

## WHAT WOULD I HAVE TO DO?

This study entails completing an online questionnaire asking about athlete's personal information (age, height, weight, sex, resident province), club affiliation, training (hours/week), number of events train/compete in, outside T&T physical activity participation and injury occurrence over past 12 months (musculoskeletal and concussion). The questionnaire will take 15-25 minutes to complete. Participants will need to have access to internet to link to the STICK ITT questionnaire.

## WHAT ARE THE RISKS?

There are no known risks to being involved in the study and all responses are kept private. If you become stressed about any of the questions you are asked, you may leave the question blank or you may quit the questionnaire.

**WILL I BENEFIT IF I TAKE PART?**

There are no direct benefits for you to be in this study. By participating in this study, we may identify factors that increase the risk of injury in T&T, which may lead to new information about injuries and how to keep them from happening.

**DO I HAVE TO PARTICIPATE?**

You do not have to be in the study, and you can leave the study at any time by simply closing the questionnaire. There are no consequences to quitting the study.

If you agree to participate in the study, once your information is submitted, it will be de-identified. You cannot withdraw from the study after you submit your questionnaire.

**WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?**

You will not get paid for being a part of this study. You will not have to pay for anything.

**WILL MY RECORDS BE KEPT PRIVATE?**

All of the information collected throughout the study period will have the names taken off and will remain private. The information collected about you will be kept safely locked. Only the researchers responsible for this study, and the Conjoint Health Research Ethics Board will have access to this information. Using only a study identification number in the database will protect your privacy. The reported results of the study will not identify you in any way.

Authorized representatives from the University of Calgary and the Conjoint Health Research Ethics Board may look at your identifiable medical/clinical study records held at the Sport Injury Prevention Center for quality assurance purposes.

Study data will be collected and managed using Redcap electronic data capture tools hosted at the University of Calgary. Redcap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies

Data collected from your participation in this research study will be de-identified and will be held in a database for future use by other researchers. Any future use of this research data is required to undergo review by a Research Ethics Board."

**AGREEMENT TO PARTICIPATE**

Your decision to click "I agree" and complete and return this survey indicates that you have understood to your satisfaction the information regarding your child's participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time during the questionnaire. You cannot withdraw your data once the questionnaire has been submitted.

If you have further questions concerning matters related to this research, please contact:

Sheila Downie:

If you have any questions concerning your rights as a possible participant in this research, please contact the Chair of the Conjoint Health Research Ethics Board, Research Services, University of Calgary, 403-220-7990.

The University of Calgary Conjoint Health Research Ethics Board has approved this research study.

## Assent for Older Child

## (8 to 13 years old)

**TITLE: STICK ITT** – **S**tudy **to I**ncrease **C**urrent **K**nowledge of **I**njuries in **T**rampoline and **T**umbling.

*The prevalence and associated factors for injury in competitive trampoline and tumbling athletes ages 8-25 years old.*

**SPONSOR:** Sport Injury Prevention Research Centre, Faculty of Kinesiology. University of Calgary.

**INVESTIGATORS:** Sheila Downie (M.Sc. student), Dr. Sarah Kenny (supervisor)

### What is a research study?

A research study is a way to find out new information about something. Children don't need to participate in a research study if they don't want to participate.

### Why are you being asked to be part of this research study?

You are being asked to take part in this research study because we are trying to learn more about how many injuries there are in T&T and what increases the chances of

getting hurt. We are asking you to be in the study because you train and compete in T&T. About 250 children will be in this study.

**If you join the study what will you have to do?**

- You will need an email address and be able to go onto the internet so you can answer the questions we are asking.
- This study is made up of an online form that ask questions about you, your training and any injuries you have had.
- The questions will ask you to remember injuries that you got while practicing and or competing in T&T in the past year. You can ask your adult to help you remember. It will take about 15-25 minutes to fill out.
- You can email the researcher, Sheila, at any time if you have questions. Sheila.downie@ucalgary.ca

**Will any part of the study hurt?**

There are some questions that ask about injuries and where on your body you got hurt. If you feel uncomfortable answering any questions, you can skip the question or quit the study. None of your answers will be shared with parents, coaches or any friends.

**Will the study help you?** This study won't help you directly. However, by being a part of this study, we might be able to learn how T&T athletes get hurt and how we can try to keep T&T athletes from getting hurt in the future.

**Will the study help others?**

This study might find out ways that can help other children train and compete in T&T more safely someday.

**Do your parents know about this study?**

We will talk to your parents about your participation in this study as well. You can talk this over with them before you decide. Your parent or adult can help you answer the questions on the forms.

**Who will see the information collected about you?**

The information collected about you during this study will be kept safely locked up. Nobody will read it except the people doing the research. The study information about you will not be given to your parents or coaches. The researchers won't tell your friends, team mates or anyone else.

**What do you get for being in the study?**

You will not get paid or rewarded for being a part of this study. You will not have to pay for anything.

**Do you have to be in the study?**

You don't have to be in the study. No one will be upset if you don't want to do this study. If you don't want to be in this study, you just have to tell us. It's up to you. You can also take more time to think about being in the study.

**What if you have any questions?**

You can ask any questions that you may have about the study. If you have a question later that you didn't think of now, either you can email or have your adult email:

Sheila.downie@ucalgary.ca . You can also take more time to think about being in the study and also talk some more with your parents about being in the study.

**What choices do you have if you say no to this study?**

This study is extra, so if you don't want to do it nothing will change.

**Other information about the study.**

If you want to be in the study, click on the "yes, I want to be in the study" button below and then fill out the forms.

You can leave the study at any time during the questionnaire by closing the on-line forms.
If you agree be in the study and you select "submit" after you answer the questions, your information will be collected electronically and cannot be traced back to you. You will not be able to withdraw from the study after you submit your information.
If you, or, your adult, have further questions concerning matters related to this research, please contact:

Sheila Downie:

If you have any questions concerning your rights as a possible participant in this research, please contact the Chair of the Conjoint Health Research Ethics Board, Research Services, University of Calgary, 403-220-7990.
*The University of Calgary Conjoint Health Research Ethics Board has approved this research study*.

# APPENDIX F : STICK ITT QUESTIONNAIRE

## STICK ITT – Study to Improve Current Knowledge of Injury in Trampoline and Tumbling Questionnaire

Research Title: *The prevalence and associated factors of injury in competitive trampoline and tumbling athletes aged 8-25 years old.*

Investigator: Sheila Downie, MSc Student
Supervisors: Dr. Sarah Kenny, Dr. Carolyn Emery

Thank you for agreeing to participate in this study.

**BASELINE INFORMATION**

**A. This section asks for information about you and your training.**

***"Competitive T&T"*** refers to coached and structured training in preparation for T&T competition participation at invitational and/or provincially/nationally sanctioned events as outlined by Gymnastics Canada.

***"Competitive Season***" refers to competitions and training taking place from September 2018 to September 2019.

1. What is your biological sex?

   - Male
   - Female
   - Prefer not to say

2. What is your date of birth? Year/month/day
3. What is your height? _____feet_____inches
   **or** _____cm
4. What is your weight? _____pounds
   **or** _____kilograms

5. Where do you live?
   - British Columbia

- Alberta
- Saskatchewan
- Manitoba
- Ontario
- Quebec
- New Brunswick
- Nova Scotia
- Newfoundland/Labrador
- Prince Edward Island
- Yukon
- Northwest Territories

6. What club do you train at and compete for?
   Alberta
   - Altadore
   - Airdrie Edge
   - Cardston
   - Calgary Gymnastics Centre
   - Pegasus
   - Airborne Okotoks
   - Exelta – Red Deer
   - Grande Prairie
   - Lethbridge Westwinds
   - Pheonix Edmonton
   - Thunder Country
   - Ortona
   - Other_____

British Columbia

- Airborne Trampoline
- Club Aviva
- Flip City
- Kamloops Gymnastics Trampoline Centre
- Nanaimo Gymnastics School
- Okanagan Gymnastics Club
- Shasta Trampoline
- Revelstoke Acrobats
- Whistler Gymnastics
- Synergy Gymnatics
- Funtastic Gymnastics and Trampoline
- Wayland Trampoline
- TAG Gymnastics
- Other _____

Saskatchewan

- Gymnastics Adventure
- Can Am Gymnastics Club
- Prince Albert Gymnastics Club
- Other _____

Manitoba

- Flippers Gymnastics
- Kingswood Gymnastics
- Panthers Gymnastics
- Springers Gymnastics
- Other _____

Ontario

- Anti-gravity Acro-sport
- Burlington BG's
- Dynamo Gymnatics
- Futures Gymnastics
- Grande River Gymmies
- Just Bounce Trampoline Club
- Kingston Aeros Trampoline Club
- London Beje Gymnastics
- Manjak's Gymnastics
- Osborne Academy of Acrobatics
- Oakville Gymnastics Club
- Quinte Bay Gymnastics Club
- Rideau Gymnatics
- Skyriders Trampoline
- Spring Action
- Tumblers Gymnastics Centre
- Other _____

Quebec

- Acrosport Barani
- Dynamix
- Gymnitours
- Les Asmetriques
- Quebec Performance
- Trampoline Intercite
- Wimgym
- Other _____

New Brunswick

- Beausejour Gymnos Gymnastics Club
- Kingswood Gymnastics
- Other _____

Nova Scotia

- Titans Gymnastics and Trampoline
- Athletics Gymnastics Academy
- Cobequid Spartans Trampoline and Gymnastics Centre
- Gymnation Gymnastics and Trampoline
- Jump 2 It Trampoline
- Rainbow Riders Gymnastics and Trampoline
- Other_____

Newfoundland

- Saltos Gymnastics
- Other _____

7. Not including pre-competitive or recreational classes, how many years have you been doing **competitive T&T?**
    - Less than 1 year
    - first year/year 1
    - 2 years
    - 3years
    - 4 years
    - 5 years
    - 6 years
    - 7 years
    - 8 years
    - 9 years
    - 11 years
    - 12 years
    - 13 years
    - 14 years
    - 15+ years
8. What **competitive level** were you or are you in for the 2019 competitive season (September 2018 -September 2019)?
    - Provincial 1
    - Provincial 2
    - Provincial 3
    - Provincial 4

- National 5 (Novice)
- National 6 (Espoir)
- National 7 (Junior)
- National 8 (Senior)

9. Which events do you train/compete in (check 1- 4 events)
    - Individual Trampoline
    - Synchronized Trampoline
    - Double Mini Trampoline
    - Tumbling

10. How many **days**/week (include weekends) do you practice/train? _____
11. How many **hours**/week (include weekends) do you practice/train trampoline and/or tumbling? _____
12. Has the number of hours you train each week changed over the past year?
    - Yes – please specify (increased or decreased by how much?_____
    - No

13. How many **months** of the year do you typically train? _____
14. How many **competitions** did you/will you compete in for the 2019 competitive season (September 2018 – September 2019)?
    - 1-3 competitions
    - 4-6 competitions
    - 7-9 competitions
    - 10+ competitions/year
15. Do you compete internationally?
    - Yes
    - No

12. how many times over the past year did you compete internationally?

- 1-3
- 4-6
- 7+

**INJURY HISTORY**

**This section asks about any T&T related injury within the last ONE YEAR. September 2018 to September 2019**

***"Time-loss injury"*** is an injury that caused you to **miss 1 or more days** of training or competing.

1. In the past year**, how many T&T related injuries** did you have that caused you to **miss more than one day** of training/competition?
    - none
    - 1
    - 2
    - 3
    - 4
    - More than 4
2. Did your **T&T related time loss injury** occur during training or competition?
    - Training
    - Competition

3. In the past year, did you experience a T&T related injury that **required medical attention** from a health care professional? (eg: doctor, physiotherapist, certified athletic therapist, chiropractor, etc.)
    - Yes
    - No

5. Who treated your injury that required medical attention? (check all that apply)

- Ambulance Paramedic and or hospital doctors
- Family doctor
- Physiotherapist
- Massage therapist
- Chiropractor
- Osteopath or naturopath
- Medical Specialist/Surgeon
- Other_____

6. Did your **T&T related injury that needed medical attention** occur during training or competition?

- Training
- Competition

7. In which of the following **areas** did you experience **pain from a T&T-related injury** that caused you to **miss more than one day** of training and/or competition? (select all that apply)
    - Head/face
    - Foot and or toes

- Ankle
- Lower leg (between knee and ankle)
- Knee
- Upper leg (between knee and hip)
- Hip/pelvis
- Lower back
- Upper back
- Chest/ribs
- Shoulder
- Arm
- Wrist
- Hand/fingers
- Other_____

8. Please check the type of **T&T related injury** you have had in the past year that caused you to **miss more than a day of training and or competition.**

- Strain (muscle)
- Sprain (ligament – ankle or other joint)
- Fracture (bone)
- Concussion
- Stress or overuse injury (stress fracture, tendonitis)
- Growth plate injury
- I don't know
- Other – specify_____

9. With respect to this T&T related injury, were you **restricted from your normal daily activities** (school, work) for one day or more?

- Yes
- No

*10*. Due to this T&T related injury, **how long were you restricted** from normal training/competition?

_____days

_____weeks

_____months

11. Reflecting upon this T&T related injury, had/has this injury occurred in the same body part before?

- Yes
- No

12. What apparatus were you injured on when you got this injury?

- Trampoline
- Tumbling
- Double mini trampoline
- Warm up
- Cool down
- Games
- Other please specify_____--

13. How were you injured?

- Failed skill
- New skill/learning or not ready
- Gap in the mat(s)
- Landed poorly on dismount
- Direct contact with someone else or apparatus (ie trampoline frame)
- I became increasingly sore over time
- Fell off the apparatus
- Other, describe_____

14.Over the past year (September 2018-September 2019), have you ever competed or trained in pain?

- Yes
- No

15.Over the past year (September 2018 - September 2019), have you modified training/competitive routines in order to train and or compete despite injury or pain?

- Yes
- No

16.Over the past year have you worn protective equipment such as wrist guards, ankle braces or taping to support an injury in order to train and compete in T&T?

- Yes

- No

**B. <u>This section asks about T&T related concussion</u>**

1. In the **past 12 months, during T&T training or competition**, have you had a concussion, either diagnosed or hurt your head (ie. "had your bell rung"), during T&T training or competition?

    - No
    - Yes

2.Check the following **signs and symptoms** that you felt after you hurt your head: (based on the SCAT5 – 13+ concussion symptom evaluation)

- Loss of consciousness
- Dizziness
- Weakness
- Poor memory/problems concentrating
- Nausea
- Blurred vision
- Light and or noise sensitivity
- Very tired
- Headache upon exertion/physical activity
- Pressure in head
- Neck pain
- Balance Problems
- Feeling slowed down
- Feeling in a "fog"
- Don't feel right
- Difficulty concentrating
- Difficulty remembering
- Fatigue and lower energy
- Confusion
- Drowsiness
- More emotional
- Irritability
- Nervous/anxious
- Trouble falling asleep

3. In relation to this T&T injury, did your **concussion** occur **during training *<u>or</u>* during competition?**

    - Training

- Competition

4. What **event** were you training or competing **when you were concussed (hurt your head)**?

- Tumbling
- Trampoline
- Double mini trampoline
- Conditioning
- Warm up
- Games/non structured play with team mates

5. Due to your concussion (head injury), did you require **medical attention?**

- No –
- Yes
- Yes – ambulance or emergency room visit
- Yes – family doctor/clinic
- Yes – physiotherapist
- Other ____specify_____

7. How did your concussion **occur** (ie. how did you hurt your head) in T&T?

- Direct contact with something (head contacted another person, trampoline, frame, tumbling floor)
- Landed on back and head whiplashed back
- Failed skill/dismount (over or under rotation)
- Jolt to body on a harsh landing
- Other ____explain_____

8. Did your concussion symptoms keep you training/competing in T&T

- Yes
- No

9. **How long** did your concussion symptoms keep you from training and or competing in T&T?

_____days

_____weeks

_____months

10. Did you follow a **gradual back to sport protocol/return to play program** upon return to T&T after your concussion?

- Yes
- No
- I don't know

11.Who **cleared** you to return to sport after you recovered from your concussion?

- Doctor
- Physiotherapist
- Other – please specify_____

**C. <u>The following section asks about habits and safety in training and competition</u>**

1. Do you usually **warm up before** training and or competition for **at least 10 minutes**?
   - Yes
   - No

2. What do you do for **warm up**? Check all that apply
- Static stretch
- Activity (increase heart rate, bike, row, jog)
- Dynamic stretch – move muscles and joints through range of motion
- Strength exercises
- Balance (eg. Wobble board, balances, fit ball/bosu ball)
- Bounce or play on trampoline
- Games
- Other _____specify_____

3. After training, do you usually spend **at least 10 minutes on recovery or cool down**? (*Recovery/cool down being stretching, rolling out, hot/cold, spinning on bike, rehabilitative exercises)*
   - Yes
   - No

4. Does your training include **physical preparation/ strength or conditioning** at the start or end of practice? (eg. Weight training, pilates, cardiovascular training)
   - Yes
   - No
   - Other - I do my own (ie. physical preparation with a trainer or on my own)

5. Please specify the type and duration of **physical preparation** you do for training T&T (e.g. Weight training, pilates, yoga, cross fit, running, how many times/week)_____

6. Do you ensure you **eat before training**?
    - Yes – I make sure I have eaten before training/competition
    - No – I don't usually eat before training/competition

7. Do you see **health care professionals** (doctor, massage therapy, chiropractor, physiotherapist) regularly in relation to **T&T training**?
    - No
    - Yes

8. How many **hours of sleep** do you typically get each night?_____

9. Reflecting back over the past year of training T&T, do you frequently **feel fatigued** when you go to training?
    - No
    - Yes

10. Reflecting back over the past year of training, did/do you frequently **feel stressed or anxious** during training for T&T?
    - Yes
    - No
11. Reflecting back over the past year of training did you/do frequently feel fearful during training for T&T?
    - Yes
    - No
12. What **type of trampoline**(s) do you train on?
    - Above ground/free standing trampolines
    - In-ground trampolines
    - Both above and in ground trampolines
    - Not applicable - I don't train trampoline

13. Do you find tumbling and double mini trampoline **landing zone mats** (dismount areas) at competitions a **harder surface** than the landing mats you train on?
    - Yes
    - No
    - Not applicable – I do trampoline only

14. Over the past year during T&T training, have you **practiced safety falls** (i.e. how to fall safely from skills) during training?
    - Yes
    - No
    - I don't know

12.Thinking about daily training, are **mats** connected (i.e. are gaps covered) between runway and landing zone?

- Yes
- No
- I don't know

**D. <u>This section asks some questions about the sports and recreational activity you participate in OUTSIDE of T&T. This can include a sport you do in Physical Education class or a school sport.</u>**

1. Do you participate in **competitive sports outside of T&T**.

   ***"Competitive Sport"*** *being a sport that you are coached during practice and compete for points/win-loss/placement against competitors. Please list only those sports you do/have done in the past <u>year</u>.*

- No, T&T is the only sport that I do.
- Yes, I compete in other sports besides T&T

2. Which sport(s) do you compete in besides T&T_____

3. How many **months** of the year do you compete in games or competitive events at the **same time as training/competing in T&T? _____**

4. How many **hours per week** (including weekends) did you train, practice, or rehearse in **competitive** sports outside of T&T? _____

5. Do you participate in **<u>recreational</u>** sports and/or physical activity outside of T&T?

   ***"Recreational or physical activity"*** *being a sport or activity that you practice informally (no coach) and that you do for fun, with family and/or friends.*

- No, T&T is the only sport that I do.

- Yes, I play other sports and physical activity besides T&T

6. Which **sport(s)/activities do you do besides T&T**. Please list only those sports/activities that you do/have done in the past year?____specify_____

7. How many **hours per week** (including weekends) do you participate in other sports/activities outside of T&T?_____

8. Do you bounce/play on a backyard trampoline?

- Yes
- No
- sometimes

9. Over the past year, has a non-T&T injury kept you from training and/or competing in T&T for more than 1 day?

- Yes
- No

10. Did you have an adult/parent help you complete this survey?

- Yes
- No

11. If you are interested in taking part in further research about injuries and or concussion in T&T and sport, please provide your email address here._____

Thank you for completing this survey!

**APPENDIX G : STICK ITT NUMBER OF INJURIES REPORTED**

| **Injury Number**<br>**n (%)** | **Sub Elite**<br>**n=72** | **Elite**<br>**n=60** | **All**<br>**n=132** |
|---|---|---|---|
| **0 Injuries Reported** | 28 (38.9) | 18 (30.0) | 46 (34.8) |
| **1 Injury Reported** | 25 (34.7) | 22 (36.6) | 47 (35.3) |
| **2 Injuries Reported** | 17 (23.6) | 14 (23.3) | 31 (25.3) |
| **3 Injuries Reported** | 1 (1.3) | 5 (8.2) | 6 (4.5) |
| **More than 3 Injuries** | 1 (1.3) | 1 (1.6) | 2 (1.5) |
| **Total number of injuries reported** | 66 | 69 | 135 |