

Early Sport Engagement in Elite Figure Skaters

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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 AND HEALTH SCIENCES
YORK UNIVERSITY
TORONTO, ONTARIO

August 2023

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Abstract

The lack of research on athlete well-being and the impact of historical training in early specialization athletes was a catalyst for this investigation. **Chapter 1** provides background information on high-performance child athletes and presents the rationale for this study. **Chapter 2** investigates athletes' training, competition, and injury histories to understand the development of elite figure skaters. Utilizing elements of the Exposure to Sport Scale, data were collected from 23 elite figure skaters across Canada in both Junior and Senior levels of competition. Results showed high variability in our small sample size and revealed no clear path to excellence in figure skating. **Chapter 3** positions our findings relative to current literature on high-performance child athletes and discusses how National and Provincial sport organizations can utilize this study to support coaches and parents in monitoring athletes for adverse training affects.

Acknowledgements

There are many people I would like to acknowledge and thank for their support over the past few years, but first, I would like to thank my supervisor, Dr. Joe Baker. Thank you, Joe, for supporting my research these past few years and letting me find my path; you are an honorary figure skater! Thank you for all the meetings, emails, edits, and continued support and reassurance; being a BLAB Rockstar has been a fantastic experience!

Thank you to my incredible figure skating research team; I would not have any data if it weren't for you! Special thanks to Alia and Katie for your feedback on this document. Thank you to all the other Blabbies who welcomed me into the lab, your kindness and support have made me never want to leave.

A big thank you to Dr. Will Gage; I would've never figured out what I wanted to do after undergrad if it weren't for you. Thank you for your support; I owe you a plate of chocolate chip cookies!

Mom and Dad, thank you for your continued support in my never-ending journey through skating, school and beyond. If it were not for all the driving and hours spent at the rink, I would never understand the meaning of hard work and dedication or have developed a love for sport, this is all because of you. I love you both very much.

Andrei, thank you for always supporting me in all my decisions and keeping me company over FaceTime during my long hours of studying and writing. I love you.

Finally, to my little Yorkies, Tucker and Kallie, thank you for being my emotional support dogs and keeping me company during my long days and nights of studying, reading, and writing; your kisses and cuddles are always appreciated!

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Chapter 1. General Introduction

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Early Sport Engagement in Elite Figure Skaters

The current focus on optimizing sport for children coincides with broader societal changes, such as the #Metoo/Time's Up movement (*Me Too. Movement*, n.d.), publicized cases of athlete maltreatment (*Gymnastics Canada and Provincial Gymnastics Associations / Physical, Sexual and Psychological Abuse Lawsuit*, n.d.), and increasing equity and diversity in sport (*Gender Equality in Sport*, 2023). Unfortunately, many of these issues have particular relevance in the sport of figure skating. For instance, at the 2022 Olympics in Beijing, there were reports about an abusive coach, a doping scandal, and 3 distraught high-achieving skaters (*Eteri Tutberidze: Figure Skating's Abuses in Plain Sight*, 2022). In response to these complaints (among others), the International Skating Union (ISU) took action to raise the age limit from 15 to 17 for Senior competitions (e.g., World Championships and Olympics) in an effort to protect the physical, mental, and emotional well-being of young skaters (*ISU 58th Ordinary Congress*, 2022). In another example, a call to action was made by figure skaters from British Columbia to Skate Canada over physical and psychological abuse that occurred at a prominent figure skating club (Figure Skating for Change Canada [@FSforChangeCan], 2023). These recent allegations, coupled with others that are not shared on such public platforms, highlight the need for investigations into athletes and their sport experiences in pursuit of making sport as safe as possible for all.

Athletes engaging in elite sports often participate in high amounts of training and condensed competition seasons. Figure skating is no exception, although what distinguishes it from other sports is that it is generally considered an 'early specialization sport' due to its early age of peak performance (Baker, 2003; Brenner, 2016; LaPrade et al., 2016; Skate Canada, 2010; Wall et al., 2020; Wiersma, 2000). Broadly, an early approach to specialized training reflects a

desire for intensive sport engagement during childhood and youth to increase the likelihood of reaching elite status (Baker & Young, 2014). However, the current trend of specializing in a high-level sport year-round is linked to increased risk of overuse injuries, overtraining, and burnout (Brenner, 2016). The gap in research on the well-being of athletes during childhood and the lack of interventions and strategies to promote a more positive and nurturing sport environment has also been acknowledged by sport scientists (Mountjoy et al., 2015). Importantly, while elite athletes may be engaging in high amounts of training, the underlying mechanisms driving the risk factors associated with this type of specialized training are largely unknown (Mosher et al., 2023). As a result, researchers have acknowledged the need for investigations of approaches to training the elite child athlete to better inform coaches, parents, and sport governing bodies on mitigating these risks (Mosher et al., 2023; Mountjoy et al., 2008).

The High-Performance Child Athlete

Participation in sports is believed to provide children with benefits such as better social skills and physical literacy, improved self-esteem, and greater independence (Anderson-Butcher, 2019; Brenner, 2016; Fraser-Thomas et al., 2005; Mountjoy et al., 2015; Wilson et al., 2022). However, in addition to sport-specific training, young high-performance athletes (i.e., pre-pubescent athletes striving to compete at high levels of competition) often engage in strength and conditioning programs. Therefore, a coach at this level must be knowledgeable about their athletes' unique needs and the interaction of elements related to growth, maturation, and training manage risk of acute and chronic injuries (Oliver et al., 2011; Soligard et al., 2016). This relationship becomes even more important when a child engages in a sport that may encourage 'early specialization'. Skate Canada's 2010 version of the Long-Term Athlete Development Model (LTADM) encouraged athletes to start skating early to increase the likelihood of learning

more complex skills early in development (Skate Canada, 2010). The developmental focus of the LTADM was on physical and technical elements (e.g., skill development, flexibility, and strength), which reflect only part of what is required for developing a successful athlete (Anderson-Butcher, 2019; Baker et al., 2009; Oliver et al., 2011)

For the past few decades, approaches to early sports training in high-performance populations have often been guided by Ericsson and colleagues' (1993) deliberate practice framework (i.e., that 10,000 hours or 10 years are required to achieve mastery). Deliberate practice requires engaging in effortful and structured training to optimize performance. Until 2021, this framework also guided the development of elite figure skaters in Canada and was used as the basis for the LTADM created by Skate Canada coaches in 2010. The LTADM notes the importance of taking advantage of 'Windows of Optimal Trainability' such as the 5 Ss (Stamina, Strength, Speed, Skill and Suppleness) and developing these skills when the body is most responsive and capable of these adaptations (e.g., developing suppleness (flexibility) between the ages of 5-10). Ideal age ranges for athlete development are also emphasized at each stage of development to increase the chances of success in the sport (e.g., in the learn-to-train stage, females should be 7-11 years old, and males should be 8-12 years old; Skate Canada, 2010).

In 2021, Skate Canada released a new Long-Term Development (LTD) resource. This guiding framework for training figure skaters in Canada echoes the recommendations of sport scientists (Baker, 2003; Baker et al., 2009; Brenner, 2016; Güllich et al., 2022; Jayanthi et al., 2015; Kliethermes et al., 2020; LaPrade et al., 2016) by deviating from their historical framework of early specialization to one that encourages an early exposure approach to figure skating, and recognizes that each athlete progresses, learns, matures, and masters skills at different rates (Skate Canada, 2021). A robust evidence base on the value of non-specialized

approaches in youth sport is growing. A recent meta-analysis conducted by Güllich and colleagues (2022) argues multidisciplinary practice (i.e., multi-sport engagement) is a stronger predictor of sport success as it allows athletes to develop sport-specific and transferable skills while limiting overuse injuries and burnout. Specific to figure skating, coaches in a recent study by Cattle et al. (in press) also advocated for multidisciplinary practice and focus on early exposure (i.e., participating in a sport but not specializing) to skating rather than specialization with their athletes. However, despite this apparent agreement, there has been no comparisons between athletes from different levels of skill (e.g., National versus International figure skaters) or between athletes who focused on specialization and those who engaged in multidisciplinary practice. These types of comparisons are important for developing evidence-based policy and recommendations and are the focus of the current investigation.

Training Load

It is well-recognized that elite athletes frequently engage in high training volumes at a high intensity to maximize their sport improvement and performance (Baker, 2003; Carter & Micheli, 2011; Ericsson et al., 1993; Güllich et al., 2022; Jayanthi et al., 2019; Kliethermes et al., 2020; Mountjoy et al., 2008, 2015; Oliver et al., 2011; Post et al., 2017; Soligard et al., 2016; Wiersma, 2000). However, the inability to balance training load and recovery can lead to prolonged fatigue, maladaptive coping responses (e.g., self-blame and negative self-talk), and injury (Soligard et al., 2016). Therefore, it is important that an athlete and his/her/their team work to mitigate these risks through appropriate training load management (e.g., balancing training and competition loads with adequate recovery time).

Designing appropriate training for the high-performance child athlete provides extra challenges to coaches and trainers as child athletes are not ‘mini adults’. These athletes are

experiencing puberty, maturation, and growth, which can leave them at greater risk of certain types of injuries (Manna, 2014; Mountjoy et al., 2008). Coaches/Trainers should also be mindful of an athlete's holistic development (i.e., development of the 'whole person'), and provide opportunities to increase self-confidence, emotional control, motivation, and concentration during training (Oliver et al., 2011). Furthermore, female athletes may feel more pressure to meet unrealistic weight goals, which often leads to engaging in poor dieting behaviours and disordered eating, resulting in conditions such as anorexia and/or bulimia nervosa (Krentz & Warschburger, 2013; Mountjoy et al., 2008).

Typically, high performance child athletes are not only participating in sport, but other training programs (e.g., stretching, strength & conditioning) to facilitate their sport development (Oliver et al., 2011). Importantly, sport participation does not occur in a vacuum and athletes can be affected by previous training, overlapping sport-seasons (for athletes in multiple sports), and competitions (Gabbett, 2020; Mosher et al., 2023). Therefore, it is important to understand athletes' training history and competition patterns to contextualize what their current training means. Researchers note that incidents of injury often occur when an athlete's current or 'acute' workload is higher than the usual or 'chronic' workload - better known as the *acute: chronic ratio* (Gabbett, 2020; Scantlebury et al., 2020). Although approaches to periodization suggest athletes should experience higher volumes of intense training to promote performance-based adaptations, adequate recovery time also needs to be integrated into the training plan to accommodate these periods of increased load (Scantlebury et al., 2020).

Challenges with early sport training

As noted earlier, one of the main issues and concerns surrounding high amounts of training is risk of injury. For example, Jayanthi et al. (2015) noted that athletes who specialize in

one sport are more at risk for serious overuse injuries. In addition, there tend to be more injuries in athletes who participate in greater weekly training (i.e., more hours than their age) or are engaging in sports for more than 8 months of the year. As a result, some researchers recommend avoiding sport specialization completely, limiting participation to a certain number of months in a year, and/or limiting sport engagement to fewer hours than the child's age (Jayanthi et al., 2015; Manna, 2014; Mountjoy et al., 2008).

However, reducing engagement may not be possible for athletes engaging in sports such as figure skating, which require year-round training (Jayanthi et al., 2015; Skate Canada 2010, 2021). While researchers have found athletes engaging in specialized training are at a higher risk for *chronic* (i.e., overuse) injuries rather than *acute* (i.e., sudden) injuries, these risks are elevated for female athletes engaging in more technical sports (i.e., figure skating, gymnastics and dance) (Jayanthi et al., 2015, 2019; Post et al., 2017). For example, Han and colleagues (2018) noted a higher incidence of overuse injuries, particularly among Singles skaters, while skaters in other disciplines (e.g., Ice Dance and Pairs) had a higher incidence of acute upper body injuries due to the lifting requirements of their discipline. Lower extremity injuries were the most prevalent in all disciplines; for example, hip and back injuries were common and associated with the biomechanical demands of the sport (i.e., high amounts of force absorbed during the landing of a jump or repetitive action of throwing and lifting in Pairs) (Han et al., 2018).

Studies investigating figure skating-specific injuries also noted a higher incidence of injuries due to the increasing technical difficulty of the sport (i.e., the introduction of quads, which is four rotations in a jump) (Han et al., 2018; Rauer et al., 2022). More recently, a study by Rauer and colleagues (2022) investigated the correlation between increased jump revolutions and injury risk. Hypothetically, these multi-rotational jumps, specifically the quad, allow less

time for the force to dissipate; as a result, the impact becomes more significant on the body and increases risk of injury (Rauer et al., 2022). In the last 3 years, the authors observed an increase in attempts at the quad jump in the Senior Women's event, which coincided with the average age of the women in the event decreasing to 17 years of age.

The importance of proper training load is a recurring theme in developing the child athlete (Brenner, 2016; Carter & Micheli, 2011; Gabbett, 2020; Jayanthi et al., 2015, 2019). Unfortunately, there are no known standardized, global measures of training volume, intensity, or competition level. This creates issues for researchers, as focusing on the hours spent training but failing to measure the intensity of practices may lead to the inability to determine whether overtraining is the mechanism driving the association between early specialization and risk of negative outcomes (e.g., injury). Current approaches to measurement are also unable to distinguish *why* an athlete might be in a single sport (e.g., due to financial constraints or convenience for the family, etc.) and, therefore, it is not possible to separate these populations from athletes engaging in a single sport to achieve elite status.

To help address this void, the Exposure to Sport Scale (ESS) was developed to provide a reliable tool that focuses on the mechanisms driving the negative consequences of early specialization (Mosher et al., 2023). The scale accounts for *total* participation, historical and present, and is grounded in the assumption that the *total training load* for an athlete is most likely the driving mechanism that causes positive or negative sport outcomes (Mosher et al., 2023). Managing training load is an essential factor in understanding its relationship to the risks of negative consequences of early specialization. Moreover, understanding appropriate training loads across development may inform approaches to maximize training opportunities and allow athletes to have adequate time for other priorities such as schoolwork and extracurricular

activities (Mosher et al., 2022; Wall et al., 2019). Greater knowledge of these areas would promote understanding athlete development *holistically* (i.e., developing the athlete alongside the person by balancing training requirements with the psychological and social needs of the athlete at their specific stage of development; Kuhlin et al., 2020; Skate Canada, 2021; Wall et al., 2019).

Study Goal

The purpose of this thesis was to investigate athletes' historical training, competition, and injuries to gain insight into sport exposure and other aspects of development in elite figure skaters. In doing so, we hope to gain insight into the relationship between an athlete's historical training load and incidence of injury. Furthermore, we explored data regarding historical engagement in competition to understand its impact on athlete development in figure skaters. Investigating group differences (e.g., Singles vs. Ice Dance vs. Pairs or Men vs. Women) is vital to gaining insight into how groups are impacted by differences in training load.

Chapter 2 provides a manuscript describing the research study. It begins by profiling the high-performance child athlete and gives an overview of the rules and inner workings of figure skating. This chapter also describes the methods along with an exploration of the three main variables under investigation: *Training Hours, Competition, and Injuries*.

Chapter 3 provides a general discussion of the results of the study, especially regarding how they fit with other research on training and development in high performance child athletes. In addition, this chapter considers the implications of our findings to coaches, researchers, and athletes, as well as the strengths and weaknesses of this work.

Chapter 2: An Investigation of Training Exposure in Elite Figure Skaters

Note: All references cited in this chapter are provided in Chapter 4.

Abstract

Early specialization sports provide an interesting context to explore issues related to early athlete training since these athletes may be more at risk for adverse consequences of sport engagement. Figure skating is considered an early specialization sport by many researchers and policy makers due to its early age of peak performance, thereby providing a unique opportunity for exploring the relationships between sport exposure, training load and injury risk. Using the Exposure to Sport Scale (ESS), we collected comprehensive training histories on 23 elite figure skaters (8 men and 15 women) aged 16-28 (average age = 20.48, $SD \pm 2.33$), competing in Singles, Pairs, and Ice Dance. Results showed a significant difference for *total hours in figure skating* between the international-level skaters and the non-international skaters. No other significant differences were found between the groups (e.g., Men vs Women, Singles vs Pairs and Ice Dance or specializers vs non-specializers). Injuries disclosed by the skaters were mostly classified as *chronic* (overuse injuries), although a range of *acute* (sudden) injuries were also reported. The lack of group differences in our results is likely due to our sample's large variability across training hours, suggesting the pathway to success in figure skating is highly variable. Our results indicated specialization was not required to become an elite figure skater and that the incidence of injuries may be associated with a high training volume.

Investigation of Total Training Exposure in Elite Figure Skaters

It has been proposed that child athletes have unique social, emotional, and physical needs compared to their adult athlete counterparts, regardless of whether they are highly competitive or recreational performers (Mountjoy et al., 2008). This distinction is made most salient in early specialization sports such as figure skating and gymnastics, in which athletes begin their sports journeys early in life (e.g., in prepubescent years, ages 5-12) to increase the likelihood of reaching elite status (Baker & Young, 2014). Early specialization sports provide a unique context for the exploration of issues related to early athlete training since athletes in these sports may be more at risk of overuse injuries due to different bone and soft tissue growth rates and/or burnout due to higher loads of training, stress, and inadequate recovery time (Mountjoy et al., 2008). Unfortunately, there is limited knowledge of what early development looks like for athletes in these sports. Understanding the training demands of these sports may provide insight into how to mitigate or balance the negative consequences of sport participation relative to any benefits that may be accrued from early, focused training (Mosher et al., 20223).

In addition, there may be important distinctions between sports grouped under the 'early specialization' banner. For example, figure skating is generally classified as an early specialization sport due to the early age of peak performance (Baker, 2003; LaPrade et al., 2016; Skate Canada, 2010; Wall et al., 2020; Wiersma, 2000). However, the extent to which the sport, as a whole, advocates for early specialization is debatable, and coaches and figure skating organizations have developed recommendations to guide early athlete training. In 2021, Skate Canada released the Long-Term Development (LTD) resource to support optimal participation in sports by recognizing that each athlete progresses, learns, matures, and masters skills at different rates. The LTD supports athlete development in two routes: the *podium pathway*, which leads to

national and international competition opportunities, and the *star pathway*, where a skater is introduced to basic figure skating elements and where they build their skating foundation (Skate Canada, 2021). Within this new guideline, athletes can choose between either pathway depending on their sport development, long-term goals, and commitment. This repositions figure skating under the umbrella of sports requiring *early sport exposure* or *engagement* (i.e., participating in the sport but not specializing) rather than early specialization. It echoes many researchers' recommendations that specialization is unnecessary for skill acquisition and sports success (Baker, 2003; Baker et al., 2009; Güllich et al., 2022; Jayanthi et al., 2015; Kliethermes et al., 2020; Brenner, 2016; LaPrade et al., 2016).

The new LTD notes a shift in Canadian figure skating away from emphasizing early specialization to a focus on *holistically* developing each athlete. However, the international skating union (ISU) still requires athletes to meet age requirements in the Junior and Senior categories¹. For instance, according to the ISU, to compete at the Junior level for the 2022/2023 season, a skater must be between the ages of 13-19 in Singles and not yet have reached the age of 19 for women or 21 for men in the Pairs and Ice Dance disciplines (*ISU 58th Ordinary Congress. 2022*). Furthermore, after the controversy surrounding the mistreatment of three young Russian skaters at the 2022 Olympics in Beijing (Ellingworth, 2022), the International Skating Union (ISU) raised the age limit from 15 to 17 for Senior competitions (e.g., World Championships and Olympics) to protect the physical, mental, and emotional well-being of young skaters (*ISU 58th Ordinary Congress. 2022*). While individual organizations such as Skate Canada have demonstrated they are ready to move away from age categorizations and place more value on the

¹ Junior and Senior are the two highest levels of figure skating. Skaters in these categories can compete at the Provincial, National, and International levels of figure skating.

holistic athlete's development, figure skating still emphasizes the importance of early development, training, and specialization to meet the technical requirements for competition.

Sports like figure skating often must balance the objectives of early sport engagement with the type of focused training necessary for skill development. Ideally, participation in sport provides children with a positive environment that enhances their physical, psychological, and social growth, whether participating for fun or achieving elite success (Fraser-Thomas et al., 2005; Fraser-Thomas & Côté, 2009; Mountjoy et al., 2011, 2015). However, these benefits may differ for young athletes participating in sports requiring more specialized training and engaging in competitions earlier in their athletic careers. Some research suggests these athletes may face more risks due to an unhealthy sports culture and mismanagement of developmental needs (Baker et al., 2009; Callender, 2010; LaPrade et al., 2016; Mosher et al., 2022; Mountjoy et al., 2008, 2015; Wiersma, 2000). In figure skating, athletes participate in on-ice training in addition to off-ice conditioning such as jump, stretch, and dance classes (Skate Canada, 2021). As a result, long-term development in this sport requires understanding athletes' *total sport participation*.

This may be difficult to achieve. For instance, a recent study by Mosher et al. (2023) argued that there is a lack of consistent methods for measuring something as seemingly straightforward as sport specialization. This is partially due to the lack of understanding of what early specialization 'is' and what it 'means', as well as the lack of reliable tools for exploring the mechanism(s) driving adverse effects. Of the current measurement tools available, many lack elements of overall training exposure (e.g., volume, intensity, or competition level), which can be problematic given that focusing on the hours spent training but failing to measure the intensity results in the inability to diagnose whether overtraining is a risk of early specialization. At

present, a gap exists in our ability to explore the reasoning behind these patterns, which may have implications for distinguishing non-elite athlete populations from elite athletes who are engaging in a single sport to achieve elite status.

Understanding the training demands of figure skaters requires some background knowledge of the sport. A study by Story and Markula (2017) examined female Canadian figure skaters' perceptions of the structural age rules in elite figure skating. In general, the authors noted that young girls (i.e., ages 12-16) routinely outperform more mature skaters (i.e., ages 17-23). Some participants emphasized how young they were at certain milestones in their sporting career; others noted feeling 'old' by age 17, when, in any other sport, they would just be reaching their athletic potential. In addition, participants felt the pressure of the structural age limits and felt forced out of competition as they had not reached the technical requirements by a certain age (e.g., consistently landing a triple jump by the age of 18²), a required element at the Senior level of competition. Finally, participants mentioned that men were encouraged to have longer athletic careers in figure skating, whereas women, especially those in Singles skating, were considered old or 'veterans' by age 20. This age discrepancy was also observed by Rauer and colleagues (2022), who found a significant age difference between males and females, specifically, between the first and last decades of the 21st century (2000-2020) at the European championships³ where the average age increased for men but decreased for women.

A child athlete engaged in a high-performance pathway must also navigate how to balance increased training with other obligations, such as school, extracurriculars, and social engagements. Often, this navigation is supported by significant others including parents and

² Maximum age limit to remain in Junior has been increased to 19 years as of 2022/2023 season.

³ Competition for skaters who are representing countries that are a part of the European ISU (e.g., Italy, France, Switzerland, Israel, and Russia).

coaches. Wall and colleagues (2020) investigated how parents of elite figure skaters navigate the transition to higher levels of training and commitment in the sport. The authors noted that parents often adjust their child's involvement in skating to maintain balance with non-sport training (e.g., school). Furthermore, each athlete-parent dyad reported progressing through figure skating using a range of tactics (e.g., goal setting and time management) to limit risks of overtraining and burnout and increase the skater's overall sport enjoyment (Wall et al., 2020). While the end goal was common amongst participants, no athlete followed a clear/singular pathway. Instead, the parent's knowledge/decision-making facilitated the transition into elite status. In this sense, parents had a large role in facilitating their child's sport development. A separate study by the same research group examined parent-coach relationships in competitive (i.e., actively competing at a high level throughout the year) figure skating, noting three configurations of this relationship: collaborative (i.e., parent expertise is recognized and welcomed), coach-athlete centric (i.e., coach is the expert and parent in the background) and contractual (i.e., an emphasis on coaching as a business) (Wall et al., 2019). The collaborative configuration showed more holistic athlete development (i.e., development of the person alongside the athlete; socially, physically, and psychologically) and less conflict between parents and coaches. However, both studies highlight the lack of understanding regarding athlete development, as these parents and coaches navigated developmental milestones as they came, rather than having a straightforward, evidence-based approach for anticipating and managing these issues.

As implied above, in addition to the influence of parents, the coach's role in athlete development should not be overlooked. In some instances, athletes can spend more time with their coaches than their own families (Kuhlin et al., 2020). In a recent study by Cattle et al. (in press), Canadian elite figure skating coaches discussed the current standard of athlete selection in

Canada. In general, coaches reported selecting athletes who showed athletic promise at a young age while ignoring athletes who may have showed potential later in their development. This talent selection process may encourage more coaches to develop skaters early to allow them to succeed in this sport while de-selecting or ignoring the potential of ‘late bloomers’ (Cattle et al., in press). This concept of talent as something physical, fixed, and easily identified does not reflect more recent and holistic views of talent (Baker et al., 2018, 2019). Importantly, the coaches in Cattle et al. (in press) study focused on early *exposure* rather than *specialization* with their athletes, in recognition of the need to reduce early burnout and dropout. These choices reflect the recommendations by sports scientists and sports organizations (e.g., Côté et al., 2009; DiFiori et al., 2014). Moreover, the focus on early exposure over specialization may inform a better understanding of appropriate load progression for training and development (Cattle et al., in press).

The current demand of year-round training for sports that require early specialization has caused concern for multiple sport scientists (e.g., Jayanthi et al., 2015, Myer et al., 2015). There is preliminary evidence that athletes who specialize in sports may be at higher risk for serious overuse injuries. In addition, there is a trend towards higher injury incidence in athletes who participate in more weekly hours than their age (although this was also the case in athletes who diversified and engaged in a higher number of activities such as organized sport, free play, gym class, etc.; Jayanthi et al., 2015). Relatedly, a systematic review of figure skating injuries noted a higher incidence of overuse injuries, particularly among Singles skaters while skaters in other disciplines (e.g., Ice Dance and Pairs) had a higher incidence of acute upper body injuries due to the lifting requirements of their discipline (Han et al., 2018). Lower extremity injuries were the most prevalent in all disciplines; for example, hip and back injuries were common and were

mainly caused by the biomechanical demands of the sport (Han et al., 2018). The increasing technical and artistic demands of the sport (e.g., the emergence of the quad jump in Men's, Women's and Pairs events) suggests we may see a rise in some types of injuries; however, this might be mitigated with a better understanding of development and implementation of proper training plans (Han et al., 2018; Jayanthi et al., 2015; Mosher et al., 2022).

Researchers note that incidents of injury occur when an athlete's current or 'acute' workload is higher than the usual or 'chronic' workload - better known as the *acute: chronic ratio* (Gabbett, 2020; Scantlebury et al., 2020). Specific to figure skating, Rauer and colleagues (2022) noted increases in performance elements (i.e., technical improvements; more difficult jumps and spins) over the past three years, which may be due to the greater incentive to attempt more complex jumps (i.e., being awarded more points). Achieving more difficult jumping passes may increase a skater's *acute* training load, leading to more severe degenerative or overuse (*chronic*) injuries (Han et al., 2018; Rauer et al., 2022). With these observed increases in performance, it may be helpful for athletes to experience higher volumes or intensity of training to reduce fatigue and injury during heavy competition seasons. However, adequate recovery time must be implemented into the training plan to accommodate these periods of increased load (Oliver et al., 2011; Scantlebury et al., 2020).

In summary, elite figure skating is dominated by young athletes performing highly technical elements (e.g., quad jumps). Furthermore, skating culture appears to require early start ages and the need for early success to be recognized, often ignoring athletes who may show their potential later in their careers. Moreover, the limited literature on early specialization and sport exposure suggests we do not clearly understand how to develop these athletes while mitigating risks (e.g., injury). To begin to fill this gap, this study investigates athletes' training, competition,

and injury histories to gain insight into elite figure skaters' sport exposure and other aspects of their development. In doing so, we hope to gain insight into the relationship between an athlete's historical training load and whether it directly impacts injury. Furthermore, we explored data regarding historical engagement in competition to understand its impact on athlete development in figure skaters. We also investigated between group differences (e.g., Singles vs. Ice Dance and Pairs or Men vs. Women) with the potential that these differences may provide vital insight into relationships between skating discipline, training load and injury.

Methods

Participants

Participants in this study were 23 current elite figure skaters, 8 men and 15 women, aged 16-28 (average age of 20.48, $SD \pm 2.33$). These athletes were training in Canada and competing at the Junior or Senior levels of competition in one of the four main disciplines of figure skating: Men's ($n = 5$) and Women's ($n = 10$) Singles, Pairs ($n = 4$) and Ice Dance ($n = 4$). In the context of this investigation, elite figure skaters were defined as skaters with the goal of competing at national and international competitions.

Of the 23 skaters, 16 competed at the 2023 Canadian National Championships and one at the Israeli National Championships, the remaining 6 participants did not qualify to compete at national championships this year. Of the 23 skaters, 15 had international competition experience competing at events such as the Olympics, Youth Olympics, Junior and Senior World Championships, Four Continents, European Championships, the Junior and Senior Grand Prix circuit, and various other international competitions. All skaters were currently training in Canada under the guidance of Skate Canada National Certified coaches at Skate Canada sanctioned clubs.

Procedure

After receiving university ethics approval, the recruitment and data collection process occurred between February and May of 2023. The primary author contacted individuals (who were sometimes previous colleagues) above the age of 18 through email and Instagram private messages (n=130). To reach skaters under 18, clubs and coaches were sent emails (n= 15) to inform parents/guardians of Junior and Senior skaters at the club. All participants consented to involvement in the study (parental consent was collected for the single participant under the age of 18). Following expression of interest to partake in the study, the primary author followed up with the athlete history survey. Close communication (i.e., weekly check-ins) was kept between participants and the primary researcher to ensure all questions were clarified and the survey was completed promptly. In total, roughly 145 messages were sent out to skaters, 26 skaters expressed interest in participation, and 23 submitted completed data sets.

Information about athlete training, competition and injury history was collected using the Exposure to Sport Scale (ESS; Mosher et al., 2023). This scale was developed to explore the mechanisms that may influence the negative consequences of sport exposure, particularly during early phases of development (Mosher, 2022). The face validity of the ESS was shown using a Delphi approach (Vernon, 2009) and assessed researchers' opinions regarding how well the questions captured the desired information. The scale accounts for *total* participation (all sports an athlete has engaged in over their sporting career), historical and present, and is grounded in the assumption that the *total training load* for an athlete is most likely a mechanism of positive or negative sport outcomes (Mosher et al., 2022). In addition to the ESS questions, participants provided demographic information such as age, skating discipline, current level of skating, and international competition experience.

Data Analysis

The current study did not use all elements of the ESS, but focused on historical training, competition, and injuries to gain insight into elite figure skaters' development and progressive load management. Regarding statistical analyses, calculations were based on epidemiological exposure calculations of cumulative dose (White et al., 2020). For this study, we calculated historical training hours in both *Total hours in Figure Skating* and *Total Hours in All Sports* (including figure skating) using an adapted cumulative dose formula ($Weeks\ per\ year \times Days\ per\ week \times (Practices\ per\ day \times Hours\ per\ practice)$). Descriptive statistics, including means and standard deviations were calculated and inferential analyses of between-group differences (t-tests) were run to test for significance between groups. Finally, effect sizes using Cohens d_s were calculated using SPSS. Injuries were separated into two tables by discipline (i.e., Singles; Pairs and Ice Dance) due to the similarities in biomechanics. Lastly, competition was graphed to analyze possible trends in sport development.

The following groups were compared to gain insight into various training load differences: Men vs. Women, Singles vs. Pairs and Ice Dance (i.e., competing individually or with a partner; an approach used in previous studies investigating figure skating injuries, see Han et al., 2018), International Competitors vs. Non-international, and Specializers (participants who did not engage in other sports while figure skating) vs. Non-Specializers (participants who engaged in other sports while figure skating). For this study, we used Baker et al., 2009 definition of Early Specialization to classify participants as Specializers or Non-Specializers using historical training and competition data. Injuries were investigated in a similar structure to training. Participants were asked to indicate how old they were, the type of injury (e.g., broken foot, sprained ankle), whether the injury required taking time away from training and if the

injury resulted from training⁴ in order for us to identify whether training may be the cause of injuries. Finally, historical competition data was collected to assess the participant's development in figure skating.

Due to our small sample size, extensive data cleaning procedures were not used as data was inputted individually by the researcher. Since participants had some variability in their demographics (i.e., age, skating discipline, historical number of sports), the assumption of normality was tested using a histogram and concluded an unequal distribution in the sample under *both historical hours in figure skating* and *total historical hours*. Due to the exploratory nature of this study and its unequal distribution, alpha was set at $p \leq .05$. Previous explorations that have attempted to collect competition and injury histories have noted the range of difficulties with this type of data (e.g., Hopwood, 2013). As a result, competition level and frequency were considered in an exploratory fashion, with the goal of identifying any patterns as skaters progressed through the sport that might form the basis of future work. Injuries were considered relative to the frequency of the injury and classified as *chronic* (overuse) or *acute* (sudden).

Results

The findings are grouped into three main categories of analysis: *Competition, Injuries and Training*. Training was considered relative to engagement in figure skating only and in all sports. Figures 1-3 only represent athletes' ages 4-20, as a large proportion of athletes were lost outside these ages. However, statistical analyses included all data recorded by the participants.

⁴ A sample of the ESS and questions asked of the participants is provided in Appendix E.

Competition

Athlete data for Level of Competition and Competition Frequency are provided in Figures 1 and 2. This descriptive presentation was simply to guide further work by identifying possible trends (e.g., increases and fluctuations) in competition engagement across development.

The level of competition was reported based on a scale of 1-4 (e.g., 1= Recreational, 2= Provincial, 3= National and 4= International/Olympic). Figure 1 shows a gradual increase from Recreational to Provincial within the first two years of the participants starting to compete. A second and third increase in competition was observed between the ages of 12-19 when participants move to National and International levels of competition. Fluctuation in levels of competition started to occur early (age 15) and continued until the age of 20.

Competition frequency assessed the number of competitions a participant attended each year. Most participants reported competing once or twice a month between July and March. The figure highlights the considerable variability among the participants.

Injury

Injuries were separated by discipline, with Singles presented in Table 3 and Pairs / Ice Dance in Table 4. Both categories had similar frequent injuries (e.g., ankle sprain, back injury, concussions and Osgood-Schlatters). Regarding injury type, descriptively, our results indicate that Singles skaters had more acute injuries (i.e., sudden injuries), whereas Pairs and Ice Dancers reported higher incidences of chronic injuries (i.e., overuse injuries). Between both categories, lower body injuries were the most reported. Injuries reported in the ESS were indicated, by participants, to be a result of training. Out of our 23 participants, only one indicated they had never been injured during their time in skating.

Training

Training hours in figure skating are displayed in Figure 3. At first glance, similar training patterns can be observed among participants. Most started figure skating around the age of 4 and began to gradually increase their training hours between the ages of 6-11. There is a more significant increase in training at the age of 12 as participants noted their sport engagement increasing and becoming year-round (January-December). Training for most participants was noted to be 5-6 days per week with 2-3 daily practices, each lasting between 1-2 hours. The mean for the entire sample, represented on the graph using the red line, shows the predictable pattern of increasing hours of training as athletes progress (at least until the age of 17). However, there was high variability across the sample ($M(SD) = 12004.8(6624.545)$), as reflected in the individual skater's data in the figure (i.e., increasing, decreasing, and levelling off between the ages of 13-20). In particular, one outlier amassed considerably more training hours than the other participants.

Group comparisons are reported in Table 1 and Table 2. The t-tests revealed no significant differences between men and women in *Total Training Hours* or *Training Hours in Figure Skating* ($p = 0.22$ for both tests after rounding). Similarly, there were no significant differences between Singles vs. Pairs skaters and Ice Dancers in either training category ($p = 0.52$ for both tests after rounding). There were also no significant differences between groups based on specialization status (specializer versus non-specializer) under both *total hours in all sports* ($p = 0.49$) and *total hours in figure skating* ($p = 0.65$). The only significant differences were found for the skill group comparison. International athletes (i.e., those who competed in competitions outside an athlete's home country and/or competitions where they represent their country while competing) were statistically different from non-international competitors on

hours in figure skating ($p = 0.02$), and the test between the groups on total training hours approached significance ($p = 0.06$).

Effect sizes were calculated for each group comparison under both *total hours* and *total hours in figure skating* and are recorded in Table 1 and Table 2. Under both conditions, a large effect size was observed for the group comparison of Men vs. Women ($d = 0.8$) and International vs. Non- International (*total hours* $d = 0.7$, *hours in figure skating* $d = 0.8$). Oppositely, small effect sizes were observed between Singles vs. Pairs and Ice Dance ($d = 0.2$ for both) and Specializers vs. Non- Specializers (*total hours* $d = 0.3$, *hours in figure skating* $d = 0.2$) under both conditions.

Discussion

The objective of this study was to add to a limited evidence base examining training histories and sport participation/exposure in elite figure skaters to understand its impact on injury. This study also aimed to have a better understanding of other aspects of figure skaters' development such as exploring differences in competition across the participants. Despite a relatively robust literature emphasizing practice and training differences between experts and non-experts (e.g., Baker et al., 2003b; Cleary & Zimmerman, 2001; Zhang et al., 2022), results from this study were not consistent with this pattern. Instead, the patterns of historical training were highly variable, which is reflected in the lack of significant differences between the groups (with the exception of the comparison between international and non-international skaters for hours in figure skating).

On the surface, these results are somewhat hard to explain. On the one hand, they expose our sample's large variability in training hours (e.g., when comparing the group means to the standard deviations), which may be improved with larger samples although, admittedly this

would be difficult at this level of competition. On the other hand, it might simply reflect that the pathway to success in figure skating is highly variable. Further work is necessary to replicate and extend these results but there are intriguing results to justify future explorations. While not significant, meaningful effect sizes were observed between men and women, indicating a possibility of observing a significant difference in a larger sample or a different selection of skaters in Canada. The large effect sizes observed between international and non-international competitors, coupled with the significance observed in our sample, may indicate that our sample for this group comparison was strong. Furthermore, there were some interesting combinations that could be explored as interactions in future work. For instance, many ($n=8$) of the skaters who competed internationally were non-specializers, demonstrating their capacity to engage in multiple sports and still succeed in a sport usually classified as an early specialization sport.

Interestingly, participants noted in the ESS that their injuries were an occurrence of, or happened at, training, demonstrating a high possibility that a relationship exists between total training hours and injury. The data collected on injuries were mostly from Singles skaters, who reported considerably more injuries than Pairs and Ice Dancers. During growth and puberty (ages 10-16), participants noted mild injuries and common overuse injuries such as knee tendonitis, Osgoode Schlatter's disease, ankle sprain, hip and groin strain, and persistent back problems. After age 16, skaters noted more severe injuries such as concussions, muscle and ligament tears, stress fractures and a few broken toes. Competition frequency is crucial to an athlete's overall sport exposure and development (Baker et al., 2003a). In the data collected for this study, most skaters noted only competing once or twice a month between June – March; however, this varied throughout their competition history depending on the skater's categorical competition level (i.e., Junior and Senior) and the level of competition they have qualified for (i.e., Recreational,

Provincial, National, or International). For these reasons, it was challenging to identify trends or use the results to predict an athlete's success. However, *the level of competition* (i.e., Recreational, Provincial, National, or International) may be a better marker for athlete success as it shows the athlete's progression and ability to maintain a high level of competition. More interestingly, the number of training hours did not correlate with the number of yearly competitions an athlete engaged in. However, future work may wish to consider the level of competition of an athlete as more training hours would presumably increase an athlete's ability to learn and master more complex skills, allowing the athlete to progress to higher levels of competition. Importantly, there were considerable fluctuations in the level of competition. Many participants noted the impact of the COVID-19 pandemic; however, other fluctuations observed could be due to physical growth, change in categorical competition level (Junior or Senior), or injury.

Limitations

While we believe this study has important implications for researchers and coaches in this area, our design had several limitations. First, our sample had an extensive age range (16-28), which may explain the high variability in training data (e.g., it is unlikely a 16-year-old will have nearly the same amount of training hours as a 28-year-old). This sample was not based on the population and demographics of skating across Canada (i.e., male-to-female ratio or discipline ratio; Pairs, Ice Dance and Singles). Therefore, we cannot say how representative our results are for all figure skaters across Canada. As noted earlier, the sample size was also a limitation, as is common in research on elite samples. Support from National Sport Organization (NSO) and/or Provincial Sport Organizations (PSO) may allow us to reach more skaters in future work.

In terms of our collection method, it is important to note a few limitations. The first was the potential for recall bias; as some of the information from participants was from over 10 years ago, it is not easy to confirm the accuracy of their training recounts. Like all retrospective studies, our scale may be limited in its ability to collect all historical data, as participants may engage in other skill development activities (e.g., off-ice conditioning, stretch and strength classes) that are not captured in the historical data. Finally, the size and complex nature of the Exposure to Sport Scale may have been a limitation as some participants reported difficulties filling out certain survey sections (e.g., play versus training and practices per day vs. hours per practice). Future studies using the ESS may consider using a short (e.g., 10 minutes) voice or video call to encourage participants to complete the scale appropriately.

Implications and Future Directions

This study is an important step in understanding training exposure in elite figure skaters and other early specialization sports. As noted above, future work should focus on expanding this sample to further investigate interesting findings such as the relationship between multi-sport participation and international success. Ultimately, this study emphasized the variability in training, competition, and injury histories amongst this sample of elite figure skaters. This approach may provide a useful framework for NSOs in collecting important historical data on skaters to monitor their training across stages of development. Moreover, it may provide useful data to educate coaches and parents on the variability in athlete pathways (i.e., there is no single pathway to the top). Future research could also use this framework to explore similarities and differences between early specialization sports. For sports scientists, this research adds to the relatively limited literature on figure skating and provides insight into the development of athletes in sports where early training is critical to future success.

Conclusion

The path to excellence in figure skating is highly variable. Collectively, our results indicate that specialization is not required to become an elite figure skater and that the developmental pathway is varied and complex. Moreover, the incidence of injuries seems to be related to training volume. Finally, a skater's level of competition may be a better marker of success than the frequency or number of competition(s) they have been to. While this exploratory study has implications for coach education, we hope it ultimately provides progress toward more positive and holistic development of elite figure skaters.

Table 1 *Group differences in total hours in all sports*

	Total Hours M (SD)	<i>p</i> -value	Cohen's <i>d</i> _s
Men	18681.60 (15969.11)		
Women	10934.22 (2320.00)	0.22	0.8
Singles	13574.13 (9453.02)		
Pairs/Ice Dance ^a	11689.14 (3886.12)	0.52	0.2
International	14614.57 (9275.87)		
Non-International	9331.06 (2004.21)	0.05	0.7
Specializers	11339.00 (3414.37)		
Non-Specializers	13701.14 (9823.51)	0.49	0.3

^a One participant was removed from this group as they had only been a Pair skater for 2 years, prior they had been a Singles skater.

Table 2 *Group differences in total training hours in figure skating*

	Total Figure Skating M (SD)	<i>p</i> -value	Cohen's <i>d</i> _s
Men	15238.44 (10242.15)		
Women	10280.20 (2710.89)	0.22	0.8
Singles	12681.37 (7854.55)		
Pairs/Ice Dance ^a	11105.43 (3792.17)	0.52	0.2
International	13797.03 (7612.75)		
Non-International	8644.38 (1492.09) *	0.02	0.8
Specializers	11323.67 (3399.80)		
Non-Specializers	12442.68 (8162.45)	0.65	0.2

^a One participant was removed from this group as they had only been a Pair skater for 2 years, prior they had been a Singles skater. * Denotes a significant difference between groups.

Table 3 Injuries in Men's and Women's Singles

Injury	Extremity	Time away	Number of Skaters injured	Acute vs. Chronic
Ankle Sprain	Lower- Foot	No time away – 6 months	8	Acute
Back injury (Pain, Strain, Spasm, Vertebrae injury)	Upper – Torso	No time away – 3 months	6	Chronic
Osgood-Schlatter	Lower – Knee	1 week – 3 months	2	Chronic
Concussion	Upper – Head	21 weeks	2	Acute
Knee Fracture	Lower – Leg	7 months	1	Acute
Stress Fracture	No Specified	4 months	1	Chronic
Broken Leg	Lower - Leg	4 months	1	Acute
Achilles Injury	Lower – Foot	1 months	1	Chronic
Broken ankle	Lower – Foot	2.5 months	1	Acute
Broken Toe	Lower – Foot	2 weeks	1	Acute
Bruised Tailbone	Lower - Sacrum	No time away	1	Acute
Rib Subluxation	Upper – Torso	1 day	1	Acute
Foot Laceration	Lower – Foot	1 month	1	Acute
Hip Contusion	Lower – Hip	2-3 days	1	Chronic
Stretched Groin	Lower – groin	1 week	1	Acute
Ankle Cyst	Lower - foot	3 months	1	Chronic
Adductor Tear	Lower- Leg	3 months	1	Chronic
Pelvic Stress fracture	Lower - Hip	3 months	1	Acute
Meniscus tear	Lower - Knee	4 months	1	Chronic
Fibular Fracture	Lower - Leg	4 months	1	Acute
ATFL CFL tear	Lower - Foot	4 months	1	Chronic
Tibia Stress Fracture	Lower - Leg	4 months	1	Chronic

Table 4 *Injuries in Pairs and Ice Dance*

Injury	Extremity	Time away	Number of Skaters with injury	Acute vs. Chronic
Sprained Ankle	Lower – Foot	1-2 months	4	Acute
Back injury	Upper – Torso	No time off – 2 months	4	Chronic
Concussion	Upper – Head	3 weeks – 3 Months	2	Acute
Osgood-Schlatter	Lower – Knee	No Time away	1	Chronic
Knee Tendonitis	Lower – Knee	1 month	1	Chronic
Subluxated Shoulder	Upper – Shoulder	1 month	1	Acute
Lace bite	Lower – Foot	3 months	1	Chronic
Stress fracture	Not specified	1 month	1	Chronic
Periostitis (Shin Splints)	Lower - Leg	1 month	1	Chronic
Talar Dome Fracture	Lower – Foot	2 months	1	Acute
Shoulder Tear	Upper – Shoulder	No time Off	1	Acute
Bursitis	Not Specified	2 weeks	1	Chronic
Hip Flexor Strain	Lower – Hip	2 weeks	1	Acute
Tendonitis	Not Specified	No time off	1	Chronic

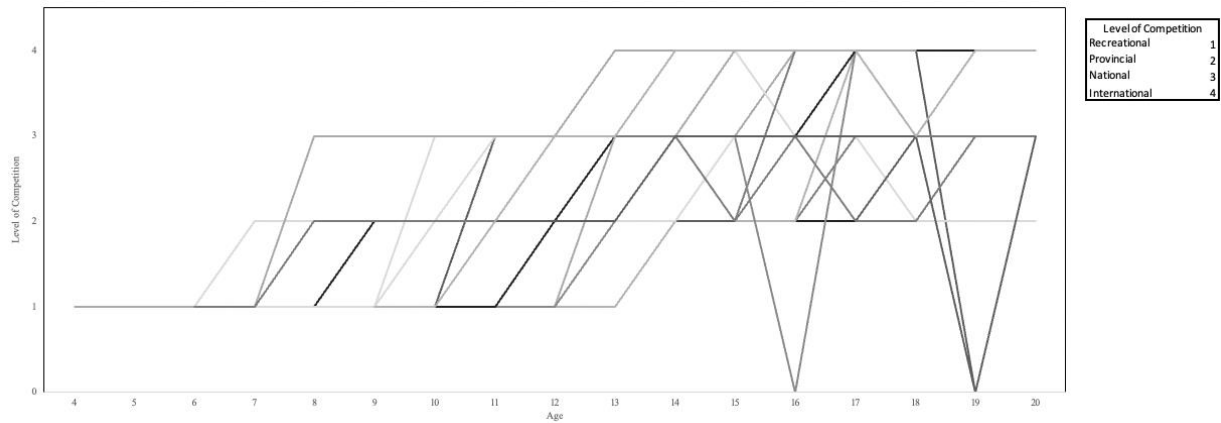
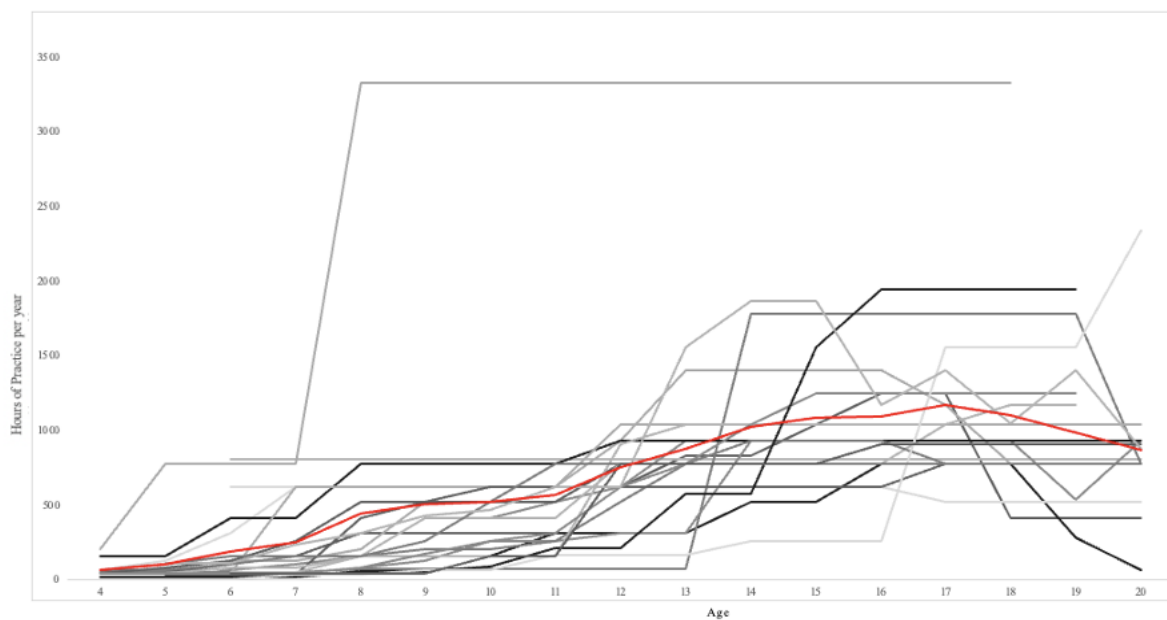
Figure 1 *Historical Level of Competition*

Figure 3 *Historical Training Hours*

Chapter 3: General Discussion

Overview

This thesis aimed to investigate athletes' training, competition, and injury histories to gain insight into the development of elite figure skaters. Using elements of the Exposure to Sport Scale, we collected comprehensive data on training, competition, and injury history for 23 elite figure skaters. While our results yielded only one significant effect (between international and non-international competitors for overall training in figure skating), the bigger story was the high degree of variability in our sample for nearly every variable, even amongst skaters at the same level, in the same discipline. In the sections that follow, key findings will be revisited and discussed in the context of the current literature on training high-performance child athletes. Finally, broad implications and future directions for this work are explored.

As observed in our study, participants seemed to follow similar training plans most participants started figure skating around the age of four and soon increased their training hours. Participants also noted their engagement in sport was year-round (January-December) and consisted of 5-6 days per week with 2-3 daily practices, each lasting between 1-2 hours. This type of training is similar to the structure suggested in the Long-Term Athlete Development Model (LTADM) produced by Skate Canada (2010). This model was grounded in the deliberate practice approach developed by Ericsson and colleagues (1993), which emphasizes the importance of an early start in sport.

As deliberate practice was the guiding framework for figure skating in Canada until 2021, we explored whether the participants in the study had followed the recommendation of specializing in one sport in order to amass a large quantity of sport-specific training hours (e.g., 10,000). Our investigation revealed that while participants engaged in an average of 12000.80 practice hours in figure skating ($SD \pm 6624.54$) and based on sport participation information

gathered from the ESS, more than half ($n = 14$) engaged in multiple sports with fewer ($n = 9$) being true specialists. Furthermore, most athletes who reached international levels of competition ($n=15$) also engaged in multiple sports, counter to the notion that sport-specific training is the only (or most beneficial) pathway to expertise. This investigation supports what many sports scientists have said regarding the need for early exposure but not specialization (Baker, 2003; Baker & Young, 2014; Brenner, 2016; Cattle et al., in press; Côté et al., 2009; Güllich et al., 2022; Jayanthi et al., 2019; LaPrade et al., 2016; Wiersma, 2000).

Training Observations

Our primary research objective explored the training exposure of elite figure skaters. Although no study to the author's knowledge has specifically investigated figure skaters, many studies have investigated the adverse effects of early sports training on high-performance child athletes' (Brenner, 2016; Carter & Micheli, 2011; Fraser-Thomas & Côté, 2009; Güllich et al., 2022; Jayanthi et al., 2015; Mountjoy et al., 2008, 2011, 2015; Oliver et al., 2011; Soligard et al., 2016). In this study, we collected historical training data from each participant, which allowed us to see how much and how often participants engage in skating and other sports. As discussed earlier, there was some similarity in training patterns among participants, which was supported by participants recounting similar training structures (days per week, practices per day and hours per practice), statistically, these participants were highly variable.

The high variability in training hours observed in our study is perhaps not surprising given our sample was drawn from four skating disciplines. Different skating disciplines have different competition requirements, which may affect the relationship between practice and skill development. For example, Pairs have overhead lifts and twists, Ice Dancers are not required to jump, and Singles skaters do not require a partner. The privatization of coaching in figure skating

is also a significant factor in training variability, as coaches operate as independent entities within a club. This means they can set their schedule for their skaters and how/when they train. Other factors impacting training hours include ice availability, the club and geographical location; our participants were spread between four provinces (Alberta, British Columbia, Ontario, and Quebec). While the high variability in this sample was interesting, and suggestive of multiple pathways to expertise, the different reasons for this variability in training hours highlights the need to replicate this study with a larger sample of skaters.

Injury

Studies have suggested there are risks associated with early specialized training, especially among high-performance child athletes, including increased injury, overtraining, dropout and burnout (Carter & Micheli, 2011; DiFiori et al., 2014; Han et al., 2018; Jayanthi et al., 2019; Malina, 2010; Matzkin & Garvey, 2019; Myer et al., 2015; Post et al., 2017; Wilson et al., 2022). Although the present study did not ask participants about burnout and overtraining directly, questions did investigate the prevalence of injury. Participants noted multiple injuries during their time in skating, which were reported by participants as resulting from their training. In total, *Acute* (sudden) injuries were slightly more common than *Chronic* (overtraining/overuse) injuries.

The injuries observed in this study were similar to previous reported research investigating injuries in figure skating (Fortin, 2003; Han et al., 2018; Rauer et al., 2022). A systematic epidemiological review conducted by Han and colleagues (2018) examined injuries in all four main disciplines of figure skating and yielded similar results to what we observed in our participants. Singles skaters had a higher prevalence of *acute* injuries, whereas Pairs and Ice Dance had a higher prevalence of *chronic* injuries. This differs somewhat from the profile noted

by Han and colleagues (2018), who observed higher incidences of upper extremity injuries in Pairs skaters due to the overhead lifting requirements of the discipline. This was not noted in our study as we only had one male Pair skater.

Our results also support Rauer et al. (2022), who investigated the prevalence of injuries in Singles skaters. Rauer et al suggest the increasing technical demands of the sport (i.e., quad jumps), require the body to absorb more force due to the increase in rotational jumps, placing skaters at a higher risk for injuries. Although the precise mechanisms of injury were not explored in this study (and remain an interesting area for further work), we observed many stress fractures and overuse injuries in our Singles skaters (n = 9) that may be linked to overtraining these more complex rotational jumps. Finally, Fortin (2003) investigated injuries in 208 athletes, at the United States Figure Skating National Championships, across all four main disciplines and three different categorical competition levels (Senior, Junior, and Novice). Their study noted a high prevalence of back, ankle and knee injuries, much like what we observed in our sample. In summary, the consistency of injuries observed across these previous studies and our own suggests the unique performance demands of the sport (e.g., absorbing force due to the repetitive nature of practicing jumps, lifts, and throws) results in a predictable pattern of *acute* and *chronic* injury.

Competition

Competition history is regularly emphasized in athlete training, as participation in competition can increase an athlete's skill development and accentuate adaptations begun in training. In the current examination, it was clear that competition frequency did not provide much helpful information when trying to understand the impact of competition on athlete development, as there was no consistency among the participants regarding the number of

competitions per year. Like training, *competition frequency* is determined by many factors, such as discipline, level of competition (e.g., Provincial, National and International), categorical level of competition (e.g., Novice, Junior and Senior) and location, among other personal and system variables. However, *level of competition* showed each participant's progression and ability to maintain their level of competition. Our data suggests that the number of competitions an athlete attends is not a strong proxy for skill, performance, or success, but the ability to remain at a high level of competition may be.

Benefits of our Methodology

The ability to investigate and understand *total* sport exposure is an important factor when trying to understand the development of a child athlete (Gabbett, 2020; Mosher et al., 2023; Oliver et al., 2011). Furthermore, valid, and reliable tools to measure early engagement in sport (especially specialization) have been lacking. Our study used the ESS, which allowed us to collect historical data from our participants across all sports they had previously participated/trained and competed in, allowing for easy classification between true specializers and multi-sport participants. Using the previously mentioned definition of early specialization, we could see whether a participant was concurrently participating and competing in other sports while engaging in figure skating or if a participant was exclusively participating in figure skating and classify them as a non – specializer or specializer. Furthermore, this scale allowed participants to detail nuances in their training and competition due to injuries, changes in coaches and events such as the COVID-19 pandemic. Finally, the scale structure allowed for easy, straightforward data analysis as we could isolate and compare specific variables of interest.

Implications and Future Directions

The results of this study provide a basis for future research, as well as recommendations for National Sport Organizations (NSO), Provincial Sport Organizations (PSO), coaches, and parents in a sport that has been under-studied in previous research. For instance, this work could inform and support future research investigating training histories in other 'early specialization' or 'late specialization' sports. The framework for this study may also be a useful tool for the NSO, Skate Canada, to investigate athletes' history. If collected, this data may provide essential information for developing figure skaters in Canada, such as typical training hours, and competition level progression. Furthermore, in Canada, there are specific 'hubs' for elite figure skating training (e.g., southern Ontario, Quebec, and British Columbia), the collection of data from athletes in these 'hubs' may indicate why we see many successful athletes emerging from these areas compared to elsewhere in Canada.

These results of this study can provide support and reassurance to coaches to allow athletes to participate in other sports knowing there is a high probability that development and achievement of success in the primary sport (i.e., skating) will not be impeded. In addition, coaches may use information from this study to decrease the risk of injury, for example, understanding that injuries can occur from fatigue, stress, and heightened anxiety, coaches may choose to address these aspects in their athletes' training. This could be done by reducing training hours when a skater feels rundown or fatigued or lessening the repetition of jumps or throws, which exert high amounts of force on the body. In tandem, these results may support parents' decisions to promote participation in multiple sports and to specialize later. For parents whose children have already specialized in skating, this study may encourage them to reduce training hours if they notice their child experiencing symptoms of burnout (i.e., fatigue, loss of

motivation and self-esteem). It is also evident from past literature and the results of our study that it is essential to have open communication between coaches and parents, as this can reduce the incidence of injuries and promote the holistic development of the athlete. Coaches and parents should work together to gradually increase training, allow adequate recovery time, and monitor the athlete for injuries during growth and puberty. The study can hopefully provide parents with a better understanding of the complex nature of figure skating.

Finally, this study is essential for sport science research as it begins to fill the gap in research around training high-performance child athletes. This exploratory study hopefully encourages other sport scientists to investigate early specialization sports (such as gymnastics and diving) to inform our understanding of specialization and youth athlete training. The common goal of these suggestions is to increase athlete well-being in sport, especially in a time of societal change with increased awareness of the need for inclusivity and respect in sport. With an increasing number of athletes sharing their stories of maltreatment and abuse during their time in sport, this study is essential to making sport safe for all.

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Appendices

Appendix A - Email to Participants

Hello (Skater name),

My Name is (research team member name) and I'm a member of the Figure Skating Research Team at York University. This newly created research group is made up of graduate students and researchers interested in helping understand coaching and athlete development in figure skating.

I invite you to participate in our current study about the development of elite figure skaters, specifically investigating training history. Participation in this study will consist of filling out an excel document, which should take no longer than 20min. This research has been approved by our university's research ethics board.

If you are interested in participating, click the link below and you will be redirected to the sign-up page. At the link you will be asked to fill out some demographic information such as your name, age, and email. Once the form is submitted, you will be contacted by our primary researcher, Nina, with the excel document. Please feel free to contact us if you have any questions.

<https://forms.office.com/r/MAx5RTNfG8>

Contact information:

Primary researcher

Nina Cattle

ninacat@yorku.ca

Appendix B - Email to Clubs and Admin

Hello (Club admin or director name),

My name is (research team member name), and I'm a member of the Figure Skating Research Team at York University. This newly created research group is comprised of graduate students and researchers interested in helping understand coaching and athlete development in figure skating. Currently, we are investigating training histories of skaters at different skill levels, and we are hoping you could encourage your athletes to participate.

We think this work will improve approaches to long-term athlete development. At the end of the study, our research team would be happy to host a webinar summarizing the results and answer questions related to training load and management.

If you could forward this email to the Junior and Senior competitive skaters at your club, it would be greatly appreciated!

Please note: This research has been approved by our university's research ethics board and we would be happy to share our informed consent/assent forms and further information about the ethics approval. If you have any questions or concerns, please let us know.

Message to be forwarded to Skaters and Parents

Hello Skaters and Parents!

My name is (research team member name) and I'm a member of the Figure Skating Research Team at York University.

I invite you to participate in our current study about the development of elite figure skaters, specifically investigating training history. Participation in this study will consist of filling out an excel document, which should take no longer than 20min. This research has been approved by our university's research ethics board.

If you are interested in participating, click the link below and you will be redirected to the sign-up page. At the link you will be asked to fill out some demographic information such as your name, age, and email. There is also a section to provide parent consent for those athletes who are under the age of 18. Once the form is submitted, you will be contacted by our primary researcher, Nina, with the excel document. Please feel free to contact us if you have any questions.

<https://forms.office.com/r/MAx5RTNfG8>

Contact information:
Primary researcher
Nina Cattle
ninacat@yorku.ca

Appendix C - Online Sign-up form and Consent

Participation form

Section 1 ...

Athlete Information

1. Name *

2. Skating Club *

3. Age *

4. Email *

5. **1. Invitation to Participate** You are invited to participate in this research study which looks to understand the development of elite figure skaters through total training load.

2. Purpose of this Study The goal of this study is to gain greater insight into the *total* training load of an elite figure skater. Using the Sport Exposure Scale to measure duration, frequency, and intensity of training, we hope to identify differences between groups and examine the relationship between training load and incidence of injury.

3. Inclusion Criteria Junior and Senior competitive figure skaters.

4. Exclusion Criteria Individuals who are not currently competing at the junior or senior competitive level.

5. Study Procedures If you agree to participate, you will be sent an excel form to fill in. This information includes historical practices and competition and current practices and competition.

6. Possible Risks and Harms There are no known or anticipated risks or discomforts associated with participating in this study.

7. Expected Benefits Information obtained from this project will be used to understand how training load can effect the development of an elite figure skater and the correlation between training load an injury.

8. Compensation There is no compensation for participation in this study.

9. Voluntary Participation Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time.

10. Confidentiality In the interest of privacy and confidentiality, all of your responses will be kept confidential. As such, only the research team will have access to your personal information and you will remain anonymous throughout the course of the research.

13. Publication You will remain anonymous throughout the course of the research and reporting of the findings in presentations at various conferences and publications in various scientific journals and magazines. If you would like to receive a copy of any potential study results, please contact the student investigator, Nina Cattle (ninacat@my.yorku.ca).

*

I consent to participate in "The Development of Elite Figure Skaters: Using The Sport Exposure Scale to Understand Athlete Development" conducted by (Dr. Joseph Baker, MSc-student Nina Cattle). I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form

Parent consent for participants under the age of 18 to participate in "The Development of Elite Figure Skaters: Using The Sport Exposure Scale to Understand Athlete Development" conducted by (Dr. Joseph Baker, MSc-student Nina Cattle). I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form

Appendix D - Follow up email to participants after signing up

Hi (Insert Participant Name),

Thank you for participating in my study!

I've attached an excel document for you to fill out; this should take no longer than 20-25min. Please save the document with your first name (example, Exposure to Sport Scale – Nina).

If you have any questions, feel free to contact me.

Best,

Nina Cattle

BA (Specialized hon.), MSc Student
School of Kinesiology & Health Science, Faculty of Health
York University

Appendix E – Sample of the Exposure to Sport Scale

*Samples are from different participants to protect anonymity

Step 1: Demographic Information

What is your age?		25
What country do you train in?		Canada
What dicipline do you compete in?		Singles- Women
What is your current level of competition?		Sneior
Have you competed internationally? If so what competitions?	Yes,	Four Continets
Do you represent a different level of competition internationally?		No
Did you compete at the 2023 Canadian National Championships?		No

Step 2: Historical Training

At what age did you begin your participation in organized sports (including or other than Figure Skating)? 4

Sport 1						
Age	Sport	Which Months	Days per Week	Practices per Day	Hours per Practice	Notes Explaining Variation
4	figure skating	Sep-Apr	2	1	1	
5	figure skating	Sep-Apr	2	1	1	
6	figure skating	Sep-Apr	3	1	1	
7	figure skating	Sep-Aug	3	1	1	I started doing little competitions
8	figure skating	Sep-Aug	3	1	1	
9	figure skating	Sep-Aug	4	1	1	
10	figure skating	Sep-Aug	4	1	1	
11	figure skating	Sep-Aug	5	1	1	Started doing pairs (2 disciplines)
12	figure skating	Sep-Aug	5	2	1	
13	figure skating	Sep-Aug	5	3	1	When to a Sport-Étude program at school
14	figure skating	Sep-Aug	6	3	1	
15	figure skating	Sep-Aug	6	3	1	
16	figure skating	Sep-Aug	6	3	1	
17	figure skating	Sep-Aug	5	3	1	Move to montreal for pairs only
18	figure skating	Sep-Aug	5	3	1	
19	figure skating	Sep-Aug	5	3	1	
20	figure skating	Sep-Aug	5	3	1	
21	figure skating	Sep-Aug	5	3	1	
22	figure skating	Sep-Aug	5	3	1	
23	figure skating	Sep-Aug	5	3	1	

Step 3: Historical Competition

At what age did you being competing in organized sports? (Including or other than Figure skating)? 6

Sport 1				
Age	Sport	Competition Months	Level of competition	Competition Frequency
6	Skating	Nov-Feb	Recreational	Less than once per month
7	Skating	Nov-Feb	Recreational	Less than once per month
8	Skating	Nov-Feb	Recreational	Less than once per month
9	Skating	Oct-Mar	Sectional	1-2 times per month
10	Skating	Oct-Mar	Sectional	1-2 times per month
11	Skating	Aug-May	Sectional	1-2 times per month
12	Skating	Aug-May	National	twice per moth
13	Skating	Aug-May	National	twice per moth
14	Skating	Aug-May	National	twice per moth
15	Skating	Aug-May	International	twice per moth
16	Skating	Aug-May	International	twice per moth
17	Skating	Aug-May	International	twice per moth

Step 4: Historical Injuries

Sport 1				
Age	Sport	Injury type	Time away from training	Did this injury occur as a result of training?
15	Figure Skating	Adductor Tear/ Pelvis stress fracture	3 Months	Yes
18	Figure Skating	Minicus Tear	3 Months	Yes
20	Figure Skating	Fibular Fracture	4 Months	Yes
20	Figure Skating	ATFL CFL Tear	4 Months	Yes
20	Figure Skating	Tibia Stress Fracture	4 Months	Yes

Step 5: Current Training

For the Past 7 Days									
Sport	Which Days	Structured practices per day	Hours per Practice	Total Hours of Structure Practce		Is this a typical week?	If Atypica	Intensity of practice (%)	
Figure Skating	Mon-Sat	3	1		16	Yes	N/A	80%	

Step 6: Current Competition

For the Past 7 Days						
Sport	Competition Level	Number of Competitions this Week	Competition Day(s)	Average Time Activley Competing	Competition Length (Days)	Intensity (%)
Figure Skating	Senior	N/A	N/A	N/A	N/A	N/A

Step 7: Current Play

For the Past 7 days				
Sport	Which Days Did you	Hours Played Per Day	Total Hours of Play	Intensity (%)
Frizbee	Saturday	2	2	60%

Step 8: Current Injuries

For the past 7 Days			
Sport	Are you currently injured	Time away from training due to injury	Did this occur as a result of training
Figure Skating	No	0	No