INJURY AND ITS ASSOCIATION WITH TRAINING IN FEMALE YOUTH FIGURE SKATERS

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ABSTRACT

INJURY AND ITS ASSOCIATION WITH TRAINING

IN FEMALE YOUTH FIGURE SKATERS

Figure skating is considered to be a physically and psychologically demanding sport. It has been estimated that 50% – 78% of figure skating injuries could be prevented. It is suggested that off-ice training may reduce injury risk. The primary aim of this project was to identify incidence and occurrence of injury in female competitive and recreational solo figure skaters. The secondary aim was to identify the role of off-ice training and its association with injury and level of skating. The third aim was to investigate associations between injury, age and maturity.

Competitive (n=14) and STARSkate (n=17) Saskatchewan female solo figure skaters, age range 10-18 reported their injury and training data in retrospective questionnaires for a period of 9 months. The injury rate per 100 hours of training was 0.26 for competitive figure skaters (CFSs) and 0.44 for StarSkate figure skaters (SSFSs). The injured skaters were significantly older, more mature and heavier than non-injured figure skaters ($p<0.05$) and had been involved in figure skating for 8 or more years. There were 21 figure skating-related injuries (57% overuse and 43% acute) reported by SSFSs (8 overuse and 4 acute) and CFSs (4 overuse and 5 acute).

There were no significant associations between the number of overuse injuries sustained and the level of skating, (χ^2 = 0.003, $p>0.05$) and no significant associations between the number of acute injuries sustained by the CFS and SSFS groups (χ^2 = 0.053, $p>0.05$). There were no significant associations found between the number of injuries sustained by the CFS and SSFS groups that followed or did not follow Skate Canada Long-term Athlete Development Model off-ice training recommendations (15 minutes off-ice training for every on-ice hour) (χ^2 = 2.801, $p>0.05$).

SSFSs sustained more overuse injuries (8) than CFSs (4) and participated in significantly less hours of off-ice training and spent less time stretching. The overuse injury rates for 100 hours of off-ice training were 1.75 for SSFSs and 0.41 for CFSs. These findings suggest that more off-ice training in CFSs could have possibly served as an overuse injury prevention component in the cohort of this study.

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LIST OF ABBREVIATIONS AND DEFINITIONS

BMI - Body Mass Index

CFSs – Competitive Figure Skaters

FS – Figure Skating

LTAD Long-term Athlete Development

LTADM Long-Term Athlete Development Model

PHV - Peak Height Velocity

SSFSs – STARSkate Figure Skaters

STARSkate Skills - Test - Achievement - Recognition

- offers opportunities for skaters to develop fundamental figure skating skills in the areas of ice dance, skating skills, free skate and interpretive skating. Skaters can test their skills through Skate Canada national standardized testing system (Skating for life, 2004).

U of S – University of Saskatchewan

Acute injury - occurred during a determined time period that caused tissue damage (Dubravcic-Simunjak et al., 2003).

Cool down – was consider as after on-ice session

Injury - was defined as "any event that (1) requires medical professional and/or (2) results in a restriction in training or performance" (Hobson, 2002).

Overuse injury - occurred due to micro-traumatic tissue damage in which the original cause of the injury could not be proved (Dubravcic-Simunjak et al., 2003).

Warm-up – was considered as off-ice warm up before on-ice session

Chapter 1

1.1 Introduction

Ideally, a figure skater should have the strength of a football player, the balance of a tightrope walker, the endurance of a marathon runner, the precision of a basketball player, the agility of a gymnast, the cool nerves of a golfer, and the grace and musical interpretation of a dancer (LeMasters, 1972). Figure skating is considered to be a physically and psychologically demanding sport. Elite figure skaters train up to 30 hours a week with training taking place both on and off the ice (Lipetz & Kruse, 2000). Starkes, Deakin, Allard, Hodges and Hayes (1996) indicated that elite figure skaters began training as early as 5 years of age.

According to Ericsson, Krampe and Tesch-Römer (1993), early specialization is important for future success. The earlier one starts with a strict training regime the quicker one will attain the desired level of skills. Training that leads to superior level of performance coincides with crucial periods of biological and cognitive development, i.e. childhood. Three of the last four female Olympic gold medalists were adolescents - Tara Lipinski in Nagano 1998 (15 years of age), Sarah Hughes in Salt Lake City 2002 (16 years of age), Shizuka Arakawa in Turin 2006 (24 years of age),Yu-Na Kim in Vancouver in 2010 (19 years of age) (US figure skating, 2010; International Skating Union: Past results, 2010). Although, increased training can lead to an increased risk of injury, it is suggested that off-ice training may reduce this risk.

With many indoor rinks open year round, figure skaters now often train throughout the whole year (Dubravcic-Simunjak, Pecina, Kuipers, Moran & Haspl, 2003; Vertinsky & Bale, 2004; Yu & Smith, 2003). More ice time availability often leads to off-ice training being set aside. Off-ice training should be an essential part of every figure skater's training plan to not only enhance the on-ice performance, but more importantly to serve as an injury prevention program. This is supported by the work of Smith and Ludington (1989) who reported that some of the injuries sustained by pair skaters and ice dancers appeared to be preventable by greater muscle strength and flexibility.

Smith (2000) and Lipetz and Kruse (2000) estimated that 50% – 78% of figure skating injuries were preventable. Some of the components of injury prevention include: (i) a properly fitted boot, (ii) an age- and skill-appropriate training schedule (containing an adequate amount of rest and cross-training), and (iii) an off-ice strength, flexibility and proprioceptive program (Porter, Young, Niedfeldt & Gottschlich, 2007). To my knowledge, no other published study has examined the injury precautions figure skaters take, nor investigated the relationship between the amount of off-ice training and incidence of injury.

Adolescent male and female figure skaters not only differ in training amounts and executed elements, but in types of injuries as well (Dubravcic-Simunjak et al., 2003). For instance, idiopathic scoliosis has been seen more often in female athletes than males; it is suggested this is because delayed menarche, often seen in this group, is a risk factor for scoliosis (Omey, Micheli & Gerbino, 2000). Today, figure skating is predominantly a female sport (Vertinsky & Bale, 2004). As of October 20th, 2010 females made up 74% of the membership in U.S. Figure Skating (US figure skating 2010-11 fact sheet, n.d.). For this reason I decided to only investigate adolescent female figure skaters.

Comprehensive research about training amounts, injuries and prevention in adolescent female figure skaters should provide valuable information for coaches, sport scientists, doctors, parents, and administrators for when they plan the training schedules. The purpose of this study is to investigate the amount of on-ice and off-ice training the Canadian Saskatchewan youth female figure skaters perform as well as document the incidence and occurrence of injuries along with the injury precaution being taken. It is hypothesized that level of competition and the amount of off-ice training will be associated with injury incidence.

1.2 Literature Review

1.2.1 Sport Participation and Fitness

Participation in sport and physical activity during childhood is well known for its positive effects in preventing many adult diseases (Auvinen, Tammelin, Taimela, Zitting, Mutanen & Karppinen, 2008). Regular physical activity has physical and psychological benefits, including enhanced quality of life. Exercise is beneficial to both disease-free individuals and for individuals with certain diseases (O'Toole & Douglas, 1994). As stated by Ward (2009), physical activity is crucial for the health and well-being of children. Children's regular participation in physical activity is important for promoting optimal physical, social, and psychological development as well as preventing excess weight gain and avoiding the antecedents of chronic health problems. Several chronic health conditions such as diabetes, hypertension, and hyperlipidemia can develop when excess body fat is accumulated.

A ten-year longitudinal study conducted on 630 adolescents suggests that the likelihood for a physically active lifestyle in young adulthood appears to be increased when children join organized youth sports at an early age and continue through adolescence (Kjønniksen, Anderssen & Wold, 2008). Similarly, Erlandson, Sherar, Mosewich, Kowalski, Bailey and Baxter-Jones (in press) suggested that future adult physical activity might be improved through promoting physical activity in childhood and adolescence. According to Papacharisis and Goudas (2005), youth learn valuable life skills and attitudes in physical (e.g. the correct posture), behavioural (effective communication) or cognitive (decision making) domains though sport participation. Responsibility, persistence, risk taking, self-control and courage are examples of characteristics that can also be learned through sport participation (Papacharisis & Goudas, 2005). Such life skills and characteristics are essential to promote healthy development and to prepare young people for their changing social circumstances. Thus there are many future health benefits associated with youth sports participation. One such sport is figure skating.

1.2.2 Figure Skating and Training

The history of figure skating dates back over 500 years. For centuries, skaters used bone or wood to move faster on the ice in Scandinavia, England and North America; iron skates were developed by the Dutch around the 14th century. Skating served as both amusement and transportation in the Netherlands. Historic paintings depict people of all classes enjoying skating together in canals during the 15th and 16th centuries. Traditionally, gentlemen in London and other big cities practiced a distinguished style of gliding on ponds and lakes in urban parks in the 17th and 18th centuries. This 'gentle art' style of skating later turned into figure skating and became a popular court entertainment for men across Europe, thanks to the elegant and noble manners demonstrated. Enclosed structures over natural ice were built in the late 1850's. Skating authors are ambiguous as to why so few women skated in the past. Some writers suggest it would have been considered immoral or too liberal, others say that women's clothing made skating impractical. Today, figure skating is predominantly performed by girls and women using indoor rinks, often available all year long (US figure skating, 2010; Vertinsky & Bale, 2004).

Figure skating is a demanding sport that combines athleticism, power, strength, endurance, flexibility, gracefulness, and artistry on the ice (Porter et al., 2007). Figure skating improves physical fitness, cardiopulmonary endurance, flexibility and strength. Other benefits include creativity, self-confidence, expression and discipline (Yu & Smith, 2003). Figure skating has become a popular sport, especially in North America. The United States Figure Skating Association reported 196, 000 members in 645 clubs nationwide (Porter et al., 2007); Skate

Canada reported 191, 000 in 1448 clubs (Kovacs, Birmingham, Forwell & Litchfield, 2004); Bradley (2006) reported that membership in United States Figure Skating more than doubled in the past 15 years. Skate Canada Saskatchewan indicated in 2008/2009 they had 1484 members (males & females) in STARSkate (recreational skating) and 116 (males & females) in Competitive Skate registered (Skate Canada Saskatchewan director, personal communication, January 21st, 2010).

As discussed by Baker (2003), early specialization is a requirement for expert-level performance in sports where peak performance occurs at a younger age (e.g. figure skating, gymnastics). According to Ericsson et al. (1993) proficiency is tied to time spent practicing and training and must also overlap with crucial periods of biological and cognitive childhood development. Early specialization means that children limit their childhood sport participation to a single sport with a deliberate focus on training and development in that sport (Baker, 2003). Although many health benefits have been associated with youth sports participation, children who start highly specialized and intensive training at an early age may be putting themselves at risk for detrimental growth. As stated by Auvinen et al. (2008), the growing musculoskeletal system might be harmed by some sport and exercise activities at an early age and it is suggested that exercise may have a detrimental effect if taken to the extremes (Sabatini, 2001).

Since early specialization is now common place, coaching styles have had to keep pace with these changes. Periodization is a process that every coach should be familiar with. Coaches need to plan training programs which consider the healthy development of an athlete while enabling athletes to be prepared for highest level of competitions. The yearly training program (the macrocycle) should consist of four mesocycles (off-season, preseason, competitive season, and recovery). Each mesocycle is unique by its training volume, intensity and activities. The length of the separate mesocycles will be dependent on the individual athlete but the recovery mesocycle is recommended to be at least one month. Mesocycles are further divided into microcycles, usually a one week time period (Moeller, Rifat & Snyder, 2004).

Porter et al. (2007) stated that competitive adolescent figure skaters usually train 4 to 6 hours per day, 6 times per week, for 10 to 11 months of the year. The repetitive training puts an enormous amount of stress on the athletes' bodies. According to Lipetz and Kruse (2000), the composition of elite figure skaters' training is approximately 15 to 30 hours practicing on the ice and 5 to 15 hours a week off the ice. This includes strength training, plyometrics, ballet, and aerobic conditioning. Since 1990, compulsory figures are no longer a part of the competitions and an increase of free skating practice time has been observed. The technical and physiological demands of the free skating programs have grown rapidly since then. Physicians caring for figure skaters have seen an increase in injuries with these changes (Bradley, 2006).

Skaters strive to perfect various elements included in their routines. They are judged on the technical difficulty and quality of execution of the performed elements. The elements vary across to the disciplines (e.g. solo ladies, solo men, pairs, ice dancing, and synchronized skating). A solo skater has to include a variety of jumps, spins, spirals and step sequences into a program lasting several minutes infused with artistic expression. The advanced elements and the desired consistency can be achieved only by long-term, persistent training (Dubravcic-Simunjak et al., 2003; Lipetz & Kruse, 2000). The increased training hours and the specifics behind the training may impact injury risk. Figure skaters spend the ice time by practicing the elements included in their programs. This limitation of variety in the training process can lead to an overload of the same muscle groups and subsequently to muscle imbalances caused by one-legged load (Dubravcic-Simunjak et al., 2003).

Pair skaters (skating as a couple) also perform multirevolution jumps and spins as well as high-risk maneuvers such as overhead lifts and throw jumps. Ice dancers skate as a couple highlighting such skating characteristics as deep edges, speed and precise skating technique. Synchronized skating is a fast-growing discipline and teams usually consist of 16 members, both female and male figure skaters (Kruse & Burke, 2005). These disciplines each have unique training and program requirements, and as a result, experience a unique set of injuries as well (Dubravcic-Simunjak et al., 2003; Lipetz & Kruse, 2000).

1.2.3 Growth, Maturation and Development

The decreasing age of specialization in female athletes has caused growing concerns about the potential for harmful effects on the growth, maturation and development of athletes (Baxter-Jones & Maffulli, 2002). Growth, maturation and development occur concurrently and interact (Baxter-Jones, Eisenmann & Sherar, 2005). Growth is an increase in the size of the body as a whole and its parts (Baxter-Jones et al., 2005; Malina, 2000). Changes in body proportions are seen during the growth period as a result of different parts of the body growing at different rates. Different body proportions and other somatic changes could influence the risk of injury (Malina, 2000). According to Baxter-Jones et al. (2005), maturation is a progress towards the biologically mature state and its timing and tempo vary considerably between individuals. Development can be psychosocial or behavioral and is culturally specific.

Growth is an important factor to consider when working with adolescent athletes. Grouping children by their chronological age is a common trend in sports. Children of the same chronological age are not necessarily at the same biological age and they can vary considerably in body size and physiological maturation (Logan-Krogstad, 2006). In order to control for confounding effects of maturation, which is a continuous process throughout childhood and adolescence, an assessment of biological age must be included in pediatric exercise science study designs. The most common methods used are assessments of skeletal age, secondary sex characteristics, status of menarche, and/or somatic characteristics (Baxter-Jones et al., 2005).

1.2.3.1 Adolescence

Adolescence, a period of transition from childhood to adulthood, includes changes in biological, personal and social domains. It is characterized by an increase in the intensity of growth, particularly statural growth. This growth spurt is in part related to pubertal development. In girls the timing of puberty varies considerably. It can start as early as 8 or 9 years of age and continues through to 17 or 18 years of age, and may continue into early 20s in some cases. The time and rate at which the structural and functional changes occur differ between individuals. This phase is defined with changes in the nervous and endocrine systems that initiate and coordinate the sexual, physiologic, and somatic changes. Growth and maturation of the primary (ovaries, vagina and uterus) and secondary (breast and pubic hair) sex characteristics lead to menarche and reproductive function. Changes in size, proportions, physique and body composition are also parts of all the changes happening in adolescence (Malina, 1994a).

According to Malina (1975), a growth spurt during adolescence is characterized by a sharp acceleration in both height and weight. The broadening of the hips relative to the shoulders is characteristic of female adolescence. It also involves primary development in endomorphy (softness and roundness of contour throughout the body as in individual who tends toward fatness and obesity), slight increase in mesomorphy (predominance of muscle, bone, and connective tissue as seen in a muscular individual) and a reduction in ectomorphy (linearity and fragility, poor muscle development as seen in an extremely thin individual).

Depending on the indicators of maturity status, children are grouped into maturity categories as early, average or late maturing. Children in whom the maturity indicators are in advance of chronological age would be defined as early-maturing (for instance, a child having a chronological age of 10 and skeletal age of 12). Late-maturing children are those in whom the maturity indicators lag relative to their chronological age. The broad middle range of normal variation includes average-maturing children. The normal range in growth studies is usually plus or minus one year of an individual's chronological age. Generally, early-maturing children are taller and heavier for their age from early childhood through adolescence into young adulthood. They also have more weight for their height than late-maturing children. Endomorphy is related to early maturation in girls while lateness of maturity is associated with a linearity of physique (Malina, 1975).

1.2.3.2 Figure Skating-specific Considerations Related to Growth in the Young Female Athlete

Leanness and linearity are desirable characteristics in figure skaters for biomechanical efficiency and the creation of aesthetic lines. Compared to the general, non-athletic population, successful female figure skaters tend to be shorter, lighter, leaner, and ecto-mesomorphic (Niinimaa, 1982). Skaters as a group also tend to be later maturing than non-athletes and athletes in non-aesthetic sports based on data on the age of menarche (Monsma & Malina, 2005). Later maturation is characteristic of competitive figure skaters, mainly pair skaters (Vadocz, Siegel & Malina, 2002). The results of Monsma and Malina's study on 161 competitive female figure skaters from 2005 suggested that test skaters (skaters who did not compete at national or sub-national level) were heavier and had a larger body mass index (BMI) than pre-elite skaters (novice competitors who competed in at least one national qualifying event). Pre-elite skaters were less endomorphic than test skaters. Elite skaters (junior and senior competitors who had competed in at least one national qualifying event) were more mesomorphic than pre-elite skaters. What is unknown is whether there is a link between maturity status and the occurrence of injury.

As described by Strickland and Metzl (2003), figure skaters must maintain 'the axis of rotation', an individualized sense of equilibrium, as well as achieve adequate rotation and height when jumping. With the increased development of fat tissue in the breast and around the hips as a result of normal growth and development in young women, maintaining spins and jumps becomes difficult, predisposing the figure skaters to possible injury. Yu and Smith (2003) indicated that physiological changes such as the change in the body's center of mass and loss of flexibility may affect skaters' ability to perform skills to the same levels as before puberty (multiple revolution jumps, full splits, Bielmann spins). Adolescence is often very frustrating time for female skaters and they need to be supported and encouraged. According to U.S. figure skating 2010-11 fact sheet (n.d.), there is a decline in female membership from 40% (ages 0-12) to 11% (ages 13-18). Physical changes experienced by maturing girls can influence their performance and willingness to be physically active (Erlandson et al., in press).

As described by Smith (2000), rotation becomes more difficult due to changes in rotational velocity caused by different body proportions, and there may be a decrease in jump height in cases of major weight gain. It has been suggested that figure skaters might limit their caloric intake trying to avoid these growth related issues; however interfering in the natural course of normal growth and development is problematic. As female athletes enter adolescence, clinicians need to be aware of the increased incidence of eating disorders (Yu & Smith, 2003). In consequence of all the body shape changes that happen during adolescence (i.e. hip-widening, weight-increase), young figure skaters are striving to learn physically demanding double and triple jumps as early as possible in their athletic careers. That puts an enormous impact on their growing bodies (Kruse & Burke, 2005).

Physique is a significant contributor to success particularly in aesthetics sports. The performance score may be influenced by skaters' physique as perceived by the judges in subjectively evaluated sports such as figure skating (Baxter-Jones & Malina, 2001; Monsma & Malina, 2005). According to Moeller et al. (2004), both male and female figure skaters consumed only about 80% of the calories that a sedentary person would consume. The goal of maintaining a lean body type demanded by the sport is particularly influencial of female skaters' eating habits. Female pair skaters must be especially light in order to successfully complete throw jumps and lifts. Inadequate caloric intake, hydration, and inappropriate food choices are the most common eating habit issues.

A study of synchronized skaters showed that they were below the 2200 to 2500 kcal/d levels recommended for female athletes exercising more than 10 to 20 hours per week. It was also found that a high percentage of the skaters (89%) wanted to weigh less than their current weight during the time of the study. Therefore, nutritionists are advised to educate (female) athletes about healthy eating practices both for the sake of their athletic potential as well as overall physical health (Ziegler, Kannan, Jonnalagadda, Krishnakumar, Taksali & Nelson, 2005). Since figure skaters are being judged not only on their athletic ability, but on aesthetic quality as well, the risk of eating disorders is increased. Losing weight interferes with healthy body processes such as menstruation and bone development; possibly influencing the injury risk. For some competitive female athletes, problems such as low self-esteem, a tendency toward perfectionism, and family stress place them at risk for various forms of eating disorders (Moeller et al. 2004). According to Sabatini (2001), the comments of parents, coaches and judges concerning the athletes' appearance have a profound influence and are a form of a child abuse in their extreme form.

Restrictive diets lead to an imbalance between the amount of energy consumed and the amount of energy expended during exercise. This energy deficit is the primary cause of the female athlete triad. The female athlete triad is common in sports like figure skating, gymnastics and ballet which emphasize "thinness" (Lipetz & Kruse, 2000; Sabatini, 2001). It is a syndrome of three interrelated conditions**:** Energy Deficit/Disordered Eating, Menstrual Disturbances/Amenorrhea and Bone Loss/Osteoporosis (Female Athlete Triad Coalition: An international consortium, 2008-2010).

Increased bone mineral density has been observed in figure skaters due to figure skating being a weight-bearing or high-impact activity. As hypothesized by experts, the high-impact loading of the trunk and lower body skeleton with jump landings protects young female figure skaters from developing osteoporosis in later life (Smith, 2000). Low estrogen levels and poor nutrition in figure skaters, especially low calcium intake (Delistraty, Reisman & Snipes, 1992; Oleson, Busconi, & Baran, 2002) can lead to an increased risk of osteoporosis, the third aspect of the triad.

1.2.3.3 Growth and Selection into Sports

In some sports, stature may be a self-selective factor. Short stature is preferred in gymnastics whereas tall stature is favourable in high jump, basketball and volleyball (Monsma & Malina, 2005; Strickland & Metzl, 2003). On average, young female athletes involved in a variety of sports have heights and body masses that equal or exceed reference medians from childhood through adolescence. The only sports that consistently present a profile of short stature are gymnastics and figure skating. Gymnasts, figure skaters, and ballet dancers also show lighter body masses (Bar-Or, 1994; Strickland & Metzl, 2003). Malina (1994b) suggested that regular training has no effect on statural growth in female gymnasts, swimmers, rowers and track athletes. It was pointed out that gymnasts are already shorter and swimmers already taller than average during childhood and maintain the position during adolescence as well.

Shorter than average heights seen in gymnasts and figure skaters are exceptions among athletes (Strickland & Metzl, 2003). The selection criteria of the sports and drop-out rates probably play their roles. Therefore, conclusions that morphological and maturational differences are caused by training, should be made with caution (Bar-Or, 1994). Unlike height, body weight can be influenced by regular training. Caloric restriction for girls often occurs in sports such as gymnastics, ballet, figure skating, and diving. The athlete's physique and body composition, as perceived by the judges, may influence the performance score in subjectively evaluated sports, such as gymnastics, figure skating and diving (Strickland & Metzl, 2003).

Later maturation is common in elite figure skaters, artistic gymnasts and divers (Porter et al., 2007). This is consistent with the findings reported by Malina and Bouchard (1991) who also reported that young females in gymnastics, figure skating, track and ballet had tendency to have late biological maturation and had later onset of menarche compared to the general female (i.e. non-competitive athlete) population.

Ages at menarche in non-athletic samples of European ancestry are approximately 13.0 ± 1.0 years. Early menarche occurs before the age of twelve, average menarche between 12.0-13.9 years and late menarche at the age of fourteen or later (Vadocz et al., 2002). Late menarche (occurring after the age of 15 years) was common among divers, figure skaters, gymnasts and volleyball players in reports from the late 1970s and early 1980s (Bar-Or, 1994). As noted by Omey et al. (2000), late menarche is a risk factor in females for scoliosis to occur. The hypoestrogenism caused by late menarche is believed to delay maturation of the osseous centers in the spine and puts females at risk for vertebral instability and curvature.

Late menarche has often been shown to occur in female athletes who are intensively training from a young age. Other factors that have been associated with physical activity and delayed menarche are: (i) a low percentage of body fat, (ii) insufficient calorie intake, (iii) onset of training prior to menarche, (iv) hormonal changes associated with chronic exercise and (v) emotional stress of training and competition. In certain sports, possible relationship may exist between the selection of girls with certain body characteristics (a linear physique, long legs, and narrow hips) who are often late maturing and those girls who drop-out due to early maturation (Bar-Or, 1994). As emphasized by Vadocz et al. (2002), a multi-factorial approach needs to be considered when trying to detect the reasons for a delayed menarche (nutrition, heredity, under-representation of early maturing girls in figure skating due to a selection, medical reasons, and many others). In summary it would appear that the young elite female figure skater may be more at risk to injury because of the aesthetic demands of the sport and associations with the training environment required to maintain such high demands.

1.2.4 Sport Injuries

Veigel and Pleacher (2008) reported that an estimated 45 million children and adolescents are involved in organized athletics in the United States and sport is the primary cause of injury in youth. The majority of injuries are acute injuries which include mild strains, sprains, and contusions. The impacts of injuries can range from a decrease in participation to withdrawal from sport, and can increase the risk of gaining excessive body fat and lowering fitness level. Higher self-esteem and community involvement are examples of the many benefits of sport. Therefore, injury prevention needs to be the main concern when working with children involved in sport to provide them with a safe and rewarding sport experience. Many of the youth sport-related injuries can be prevented through educational programs, rule changes (towards a safer sport environment), safety equipment, and specific conditioning programs.

A wide variety of definitions of injury have been used throughout the literature, thereby making it difficult to compare the incidence on injuries across studies (Gilchrist, Saluja & Marshall, 2007; Kjaer & Larsson, 1990; Sharma, Luscombe & Maffulli, 2003). As discussed by O'Toole and Douglas (1994), musculoskeletal injuries represent most of the injuries that result from participation in sports. Frequently, such injuries are: muscle strains, tendonitis and stress fractures. Progressing too fast and not allowing enough time for recovery and adaptation are examples of errors in training that overuse injuries have been attributed to. Occasionally, traumatic injuries such as fractures and torn ligaments occur (O'Toole & Douglas, 1994).

According to Gilchrist et al. (2007), injury risk factors are classified as either intrinsic (gender, age, previous injury, physical fitness etc.) or extrinsic (training parameters, environmental conditions, equipment etc.). Some factors can be modified to reduce the injury risk. Pre-season conditioning programs can improve athlete fitness and reduce injury risks, even in children (Sharma, et al. 2003). Sharma et al. (2003) stated that adolescents are vulnerable to injuries because of imbalance in strength and flexibility around the period of peak linear growth. There is a decrease in flexibility due to relative bone lengthening during growth spurts. Smith, Stroud and McQueen (1991) emphasize the importance of stretching to athletic adolescents mainly during critical period of rapid development. In their study, of 46 junior elite figure skaters, those with tight quadriceps were most likely to have anterior knee pain. Skaters with Osgood-Schlatter disease, jumper's knee or isolated patellofemoral pain had significantly less quadriceps flexibility. The pain decreased or diminished when skater increased their thigh muscle flexibility.

Arheim (1995) stated that coaches must be aware of the injuries in their particular sport, including knowledge of what produces them, and what needs to be done to avoid them. Paying attention to cross training and gradual change in training schedules, the training environment and footwear are essential (Gilchrist et al., 2007). The coach is responsible for preventing injuries by making sure that the athlete has been involved in a preventative injury conditioning program and that the sports equipment being used is properly fitted. Smith and Ludington (1989) reported that some of the injuries sustained in pair skaters and ice dancers appeared to be preventable by greater muscle strength and flexibility. According to Arheim (1995), the first 3 to 4 weeks of the season are considered the most dangerous period in any sport due to athletes lacking flexibility, strength and cardiovascular conditioning. Some of them also put on weight during the off season time. Extra weight places stress on the joints, therefore the likelihood of overuse problems increases.

The understanding of skill techniques is essential knowledge for every coach as poor technique can lead to overuse injuries. The coach should be using video analysis to reassure a proper technique is maintained. This can reduce the chance of injury among athletes. Sports programs often use support personnel (i.e., orthopedist, nutritionist, biomechanist, strength and conditioning coach, sport psychologist, physical therapist, and exercise physiologist) when dealing with athletes' health and safety (Arheim, 1995).

As reviewed by Logan-Krogstad (2006), the majority of injuries in ballet and aerobic dance, which are similar aesthetic sports to figures skating are located in the lower extremities and are overuse in nature. A prospective study of 35 female and 5 male pre-professional ballet dancers reported injury rates of 0.47 injuries per 100 hours of training in dancers aged 14-18 (Luke, Kinney, D'Hemecourt, Baum, Owen, & Micheli, 2002). Logan-Krogstad (2006) reported that most injuries in highland dancers occur on the lower leg, specifically to the knee, shin/calf, ankles and feet.

Harringe, Renström and Werner (2007) conducted a one-season prospective study in top-level teamgym on 26 females (mean age 18) and 16 males (mean age 21.8). They reported an injury rate of 0.22 per 100 hours of gymnastic training. Sixty-two percent of injuries were incurred to the lower extremity, and ankle sprains were the most common injury. Kirialanis, Malliou, Beneka, Gourgoulis, Giofstidou and Godolias (2002) reported 61.5% injuries as acute injuries and 38.5% as overuse syndromes in elite adolescent male and female artistic gymnasts observed weekly over a period of one year. Harringe et al. (2007) and Kirialanis et al. (2002) reported that higher injury rates occur in the landing phase of gymnastics skills and, thereby recommending that special attention be given to the landing phase.

1.2.4.1 Figure Skating Injuries and their Prevention

Typically musculo-skeletal figure skating injuries occur in the foot, ankle, knee, leg, hip, or lower back (Porter et al., 2007). A study by Dubravcic-Simunjak et al. (2003) reported higher rates of acute injuries among pair skaters and ice dancers as compared to solo figure skaters. These injuries were more severe due to falls during overhead lifts and the triple and quadruple throw jumps which are performed in pair skating. Pair skaters had the highest rates of injury, while the synchronized skaters had the highest risk of collision. Acute injuries were mostly seen in pairs because of the lifts and throw jumps, increased speed, momentum, and force in falls (Dubravcic-Simunjak et al., 2003; Smith & Ludington, 1989).

Wrist injuries and elbow injuries are a common result of falling and also present the possibility of a fracture (Moeller et al., 2004). Upper extremity injuries are more frequent in pair skaters because of repetitive lifting (rotator cuff injuries), and the female partners fall from greater heights in throw jumps (Porter et al., 2007). Skaters involved in pair skating, ice dancing and synchronized skating have a higher risk of concussion, lacerations and contusions compared to single skaters. Unfortunately, multiple skaters are commonly injured in a single collision event in synchronized skating (Kruse & Burke, 2005). In contrast, overuse injuries are mostly seen in solo skaters (Porter et al., 2007).

Overuse syndromes represent more than 50% of injuries in a study of 469 elite junior figure skaters (Dubravcic-Simunjak et al., 2003). Stress fractures were reported as the most frequent overuse injury in female solo skaters in the study. The authors also indicated that the overuse injuries were found in both the landing and take-off leg, suggesting the impact on the landing leg and jump repetition during each practice session as the possible causes. Oleson et al. (2002) suggested that stress fractures in adolescent figure skaters were caused due to excessive force placed on a normal skeleton and not because of low bone mass density.

Porter et al. (2007) stated that stress fractures commonly occur in the 1st and 2nd metatarsals and are more often seen in skaters' take-off leg for toe-pick jumps. This statement needs more clarification as toe pick jumps differ according to the foot that is used for toe-pick take off (Flip and Lutz versus Toeloop). Stress fractures are also seen in tibia, fibula, and navicular bones usually caused by repetitive forces placed on the bones and not due to a low bone density. Figure skaters generally have higher bone density than non-figure skaters at the same age (Porter et al., 2007).

Slemenda and Johnston (1993) compared young female figure skaters (age 10-23) to non-athletic control subjects. They found that even though the skaters were significantly more likely to have oligo- and amenorrhea, they had similar skeletal densities at upper body sites (spine, arms, and ribs) and significantly greater densities in the pelvis and legs. They proposed that intense weight-bearing activities unique to figure skating may diminish the negative effects of menstrual irregularities on bone mass.

Lack of calcium and vitamin D intake in figure skaters (Oleson et al., 2002) may serve as the basis for stress fracture. Despite the inadequate nutritional intake that often occurs, figure skaters have significantly higher bone mineral density of the spine and lower extremities than non-skaters (Kruse & Burke, 2005). These results suggest that figure skating provides sufficient weight-bearing activity to enhance bone mass. According to Iwamoto, Yoshihiro, Tsuyoshi and Matsumoto (2009), to maintain bone health females need to be encouraged to participate in sport activities across their life span. The research suggested that the most important strategy for preventing fractures later in life is to maximize peak bone mass, therefore interventions may be needed before menarche.

Smith suggested that most overuse syndromes in figure skaters could be prevented by proper preparation and training (Aleshinsky, Podolsky, McQueen, Smith, & Handel, 1988). If there is not a sufficient time for the body to recover from previous sessions, overuse injuries may occur. Overstressing a limb repeatedly can result in stress fracture, tendinitis, shin splints, and knee pain. Figure skaters should be involved in both strength and flexibility training program.

Careful coaching involves a gradual increase in training hours and intensity (Aleshinsky et al., 1988).

Smith (2000) and Lipetz and Kruse (2000) estimated that 50% – 78% figure skating injuries could be prevented. One of their suggestions to effectively prevent injuries among skater is to have a properly fitted boot that is not overly stiff (an option of using a hinged-style boot) and awareness that up to 20% of skating boots are defective. Other crucial parts of the training process include an adequate training schedule that is appropriate for the skater's skill and age, sufficient amount of rest and cross-training. Regular participation in an off-ice training program consisting of flexibility, strength and proprioceptive training components is also a key in injury prevention, especially at the time of peak height velocity. Having a sufficiently nutritious diet is essential, particularly when undergoing hard training and growing at the same time. Proper warm-up and cool down periods can also serve in injury prevention and should become a part of skaters' training sessions (Porter et al., 2007).

1.2.4.2 Figure Skating Boot

The skating boot's design has changed greatly over the past two decades. Skaters replace boots when the ankle support breaks down (usually a pair of skates per season). New skates and blades cost well over $1000. This is one of the reasons why coaches and skaters have requested that boot-making manufactures enhance support to facilitate slower break down. Consequently, the boots have become increasingly stiff. Unfortunately, it has resulted in a lot of stiff-boot related injuries (Kruse & Burke, 2005).

Porter et al. (2007) pointed out the fact that triple Axels have been performed by women during competitions. Men include quadruple jumps in their routines. The boots became stiffer to overcome the pressure placed on them when performing the multiple revolutionary jumps. The stiffness of the boots is hypothesized to contribute to weaker ankles in competitive figure skaters. In a study of elite junior figure skaters, ankle sprains were reported as the most frequent acute injury (Dubravcic-Simunjak et al., 2003). Due to the increased stiffness of the boot and higher number of hours skaters spend on the ice, poor ankle proprioception, inversion, and eversion strengths have become serious concerns. Improving ankle strength is a necessary part of off-ice training (Kruse & Burke, 2005).The high heel and the rigidity of the boot limit the skaters' plantar flexion during take-offs as well as when absorbing the landing. The limitation of the ankle and knee motion as a result of the boot rigidity may cause low back pain (Porter et al., 2007).

Figure skaters are the only athletes performing jumps in high-heeled shoes. Due to the height of the boot heels, skaters' ankles are in constant slight plantarflexion in the skates (Bruening & Richards, 2006; Porter et al., 2007). Smith and Ludington (1989) found some injuries directly related to the skating boot and called for a change in the boot design in their study. A hinged-style boot was developed to increase the flexibility at the ankle while still maintaining sufficient support (Porter et al., 2007). Skaters are often hesitant to wear them because of esthetic reasons. They are also concerned about trying a new type of boot after being accustomed to a certain design during their skating career (Bruening & Richards, 2006).

The skating boot often causes pressure points on the foot and ankle. Skaters might suffer from malleolar bursitis in one or both malleoli (Bradley, 2006; Kruse & Burke, 2005). This compression effect is normally tolerated, but it can easily become worse even with small irritation or boot changes. Punching the boot out to better fit the foot in the problem-causing areas will often relieve the pain. A proper skate fit helps to prevent up and down motion of the heel, which can lead to calluses and bursa inflammation (Kruse & Burke, 2005).

The contributing factors to ‘Lace bite’ (a compression of crossing laces) are uneven lacing technique and ineffective boot tongue padding (Bradley, 2006; Kruse & Burke, 2005). The tongue should be in a neutral (central) position to prevent anterior compression injuries. Fifth metatarsal and the tarsal navicular are other areas that also oftentimes undergo irritation. Jumping and position of the foot in the boot are the principal causes of metatarsal stress fracture. Corns and calluses on the toes trouble skaters very often. The solution would be to check for a boot fit and have the skate punched out or modified if needed (Kruse & Burke, 2005).

High thickness boot can overpower a lighter, smaller skater (Bradley, 2006). More flexible boots allowing greater dorsiflexion during landing are now available on the market. Ankle strength is a key element for those types of boots (Kruse & Burke, 2005). Most elite athletes now wear custom-made boots to help prevent boot-related injuries. Boots should be lightweight, have a broad forefoot, a well-fitted heel, and a well-padded tongue. The end of the competitive season is the best time for new boots to be broken in (Kruse & Burke, 2005). For ankle bursitis prevention, Bradley (2006) emphasizes the importance of a well-fitted boot, correct foot alignment in the boot and proper placement of the blade.

1.2.4.3 An Age-appropriate and Skill-appropriate Training Schedule

As mentioned by Baker, Cobley and Fraser-Thomas (2009), the positive relationship between time spent practicing and level of achievement was identified in behavioural science. As observed by Simon and Chase (1973), it takes 10 years to master the level of knowledge necessary to become an expert in chess. This “10 year rule” has been evident in several other domains including sport. According to 2009 Skate Canada’s Guide to Long-Term Athlete Development (LTAD), it takes 10 years or more and over 10,000 hours of training to reach international excellence. These 10,000 hours of training must be effective and take advantage of sensitive periods of athlete development (Bridel, 2008). As proposed by Wiersma (2000), early specialization means that children limit their participation to a single sport on a year-round basis with a specific focus on training and development in that particular sport.

It is argued by Ericsson et al. (1993) that a superior level of performance is not achieved by the accumulation of deliberate practice hours alone. Training must also overlap with crucial periods of biological and cognitive childhood development. Sports like dancing, gymnastics, figure skating, and ballet are examples of early specialization sports since these aesthetic sports have earlier 'peak' ages, particularly among female athletes. One key factor for success among athletes is to train the right components at the right stage of development. The LTAD focuses on athlete training and skill development, as well as on the essential role of coaches in the process (Bridel, 2008). Training needs to be well-planned because overtraining increases the risk of injury without improving performance (Gilchrist et al., 2007).

Children's ability to acquire sport-specific skills is enhanced when skills are developed through the school system. Possibly due to Canadian provincial government cutbacks and a shift in core subject matters in school curricula, competency in fundamental movement skills (i.e., run, jump, throw, swim) and basic motor skills (i.e., ABC's: agility, balance, coordination, speed) at an early age have decreased (Bridel, 2008). The Long-Term Athlete Development Model (LTADM) is a guide to assist with decision-making that considers athlete development. The LTADM provides a reference point for coaches, support team members, and administrators when developing annual and long-term training plans. The LTADM defines optimal training, competition, and recovery programs based on knowledge gained from the field of exercise science. It concentrates more on biological rather than chronological age, and tailors sport development programs around basic principles of growth and maturation, especially during the critical early years of development. Besides highlighting opportunities in training athletes when bodies will respond the greatest to different training stimuli, the LTADM also emphasizes the intellectual, emotional, and social development of the athlete. Sport can play a positive role in child, youth, and adolescent development as well as in the creation of healthy, functional, and productive individuals (Bridel, 2008).

Many prepubescent athletes are capable of doing a large number of jumps, however, they often get injured while going through puberty. It was proposed that future studies should focus on determining the exact number of jumps to be performed each day in order to prevent injuries. The age and development of the skater needs to be taken into account. Type of jump, level of mastery, strength, on-ice and off-ice training hours, training session length and recovery time are other factors which have to be considered (Kruse & Burke, 2005). USA Baseball recommendations to limit the number of pitches that youth pitchers throw are promising in terms of overuse injuries prevention (Gilchrist et al., 2007; Sharma et al., 2003).

1.2.4.4 An Off-ice Program Including Flexibility, Strength and Proprioceptive Training

Many elite skaters sustain injuries to the groin, hip flexor, adductor complex, and internal and external oblique. These injuries have mainly been attributed to a heavy focus on triple and quadruple revolution jumps (Kruse & Burke, 2005). According to Bruening and Richards (2006) elite skaters practice more than fifty jumps per day. Similarly, Kruse and Burke (2005) stated that skaters perform up to sixty jumps per day. Tight and asymmetrical musculature of hip flexors, combined with weak or unbalanced core musculature and hip stabilizers raise the likeliness or overuse injuries. Before starting training for more demanding double, triple, and quadruple jumps, the coach needs to ensure that the skater has sufficient strength as well as evaluate a potential hip strength asymmetry (Kruse & Burke, 2005).

The landing knee is subjected to great landing forces and skaters who jump on a regular basis often experience anterior knee pain. There are several reasons for the knee pain, some of which include weakness in the hip and/or quadriceps and inadequate flexibility of the hip and thigh muscles (Kruse & Burke, 2005). Inflexibility seems to be the major contributor to injury rate in the studies on figure skaters done by McQueen and collective (Aleshinsky et al., 1988). The most common area is quadriceps inflexibility which causes an increased load placed on the structures about the knee. This leads to overload syndrome such as Osgood Schlatter's disease and jumper's knee. They found a direct correlation between lack of flexibility and symptoms present in the junior figure skaters. Smith's finding indicated direct relationship between hamstring and quadriceps muscle tightness and knee pain. When skaters underwent a flexibility program, the symptoms diminished or disappeared (Aleshinsky et al., 1988).

Smith (2000) suggested that an off-ice training program incorporating flexibility of the lower extremity muscles could decrease knee overuse symptoms, especially in growing athletes. An appropriate warm-up period and flexibility exercises are believed to play a role in preventing overuse injuries (Smith & Micheli, 1982). Arbour (2006) stressed the importance of an off-ice warm-up routine as it helps to increase body temperature which results in higher muscle extensibility and efficient contractions. Warm ups enable skaters to have increased body awareness and decreased risk of muscles and tendons injuries during on-ice practice. LeMasters (1972) stated that adequate warm-up, proper training methods and good ice conditions decrease the incidence of skating injuries.

Gilchrist et al. (2007) stated that "warming up should consist of a slowly increasing a participant's heart rate and body temperature and moving though the expected range of motion of the activity". Insufficient evidence exists to recommend pre-exercise stretching as a means to prevent injuries. Sharma et al. (2003) states that studies in adults show no reduction in incidence of injury with stretching prior to exercise, although it needs to be determined if it is the case in children as well. Reviews of military risk factor studies show that participants who are the least and the most flexible are at an increased risk of injury during physical training. Stretching may be harmful if one is already very flexible (Gilchrist et al., 2007).

According to Kruse and Burke (2005), figure skaters who participate in off-ice programs are stronger, have better-developed aerobic and anaerobic energy systems, jump higher, have more consistent jump landings, have tighter and faster spins, and feel more confident on the ice. These athletes may have decreased injury rates. Mannix, Healy and Farber (1996) concluded in their study done on 15 figure skaters during a 10 week intervention that on-ice training alone did not increase aerobic power or supramaximal endurance, whereas when combined with off-ice cycle ergometer training, those parameters improved.

Van Handel suggested in 1988 during a roundtable discussion of figure skating sport science experts that fatigue appeared to reduce jumping ability and it had important implications for execution of skill elements 'late' in a competitive program (Aleshinsky et.al, 1988). As suggested by McQueen, a strengthening and conditioning program is essential in figure skating for two reasons – it maximizes performance and it reduces injuries. Figure skaters' participating in strength and conditioning program was believed to be influenced by coaches' feelings of its necessity and by skaters' conviction of their improved performance by the strength and conditioning program (Aleshinsky et.al, 1988).

Dubravcic-Simunjak et al. (2003) stated that most overuse injuries can be prevented by training programs that improve flexibility, muscle balance, jumping and skating technique. To avoid overuse injuries, one needs to follow correct biomechanics and apply a gradual process of increased training time and intensity as well as develop a muscle strength and flexibility. The correct application of biomechanics in skating and jumping technique as well as off-ice training programs not only improve a skater's performance on the ice but also, perhaps more importantly, decrease the likelihood of overuse injuries.

Off-ice programs have to include strength and flexibility exercises in order to ensure a muscle's balance. Methodical off-ice training should be part of every skater's training plan in order to prevent injuries that are caused by physical imbalance of a one-legged load (Dubravcic-Simunjak et al., 2003). All on-ice sessions should include minimum of 15 minutes off-ice (In Pursuit of Personal Excellence: Skate Canada's Guide to Long-Term Athlete Development. (2010). The study by Nikolic, Baltzer, Krämer and Liebau (1998) suggest that methodical off-ice training could be useful in preventing injuries resulting from physical imbalance. Dubravcic-Simunjak et al. (2003) also recommend reducing training load during the period of asynchronous development of bone and soft tissues because growth spurts and loss of flexibility leads to significant risk of injury.

Muscular strength and power gained in resistance off-ice training can increase the height of jumps. A meaningful relationship between of maximal knee extension force and jump height for single and double Axel has been shown. Plyometrics is another essential part of an off-ice training. Plyometrics training should be supervised (mainly when trying for the first time) and performed by advanced athletes and followed with sufficient recovery time (Moeller et al. 2004).

Skaters rotate faster but do not jump any higher when performing the increasingly difficult triple and quadruple jumps. Flight times for single, double, and triple jumps are very similar due to nearly the same vertical velocities at take-off (King, Arnold, & Smith, 1994). Only few of the biomechanical studies on figure skating have looked into the flight-time of jumps. King, Smith, Higginson, Muncasy and Scheirman (2004) reported that the decreasing moment of inertia about a skater's longitudinal axis (with only minor differences in jump height or time in the air) is the main difference in completing single to double and double to triple Axel. However, Albert and Miller (1996) suggested that the flight-times for double Axels were longer than those for single Axels. The determination of a minimum flight-time required for the completion of jumps would help to incorporate adaptations into the training process to protect figure skaters from repeated falls and greatly improve the process of learning new jumps.

It was shown by Podolsky, Kaufman, Cahalan, Aleshinsky, and Chao (1990) that the strength of knee and shoulder muscles were correlated with height of single and double Axel jumps. Consequently, they highlighted the importance of strength training. This fact is also supported by Ham, Knez, and Young (2007) who stated that a vertical jump performance can be improved substantially through proper jump-specific strength and power training. As mentioned by Kruse and Burke (2005), an athlete's ability to perform the more difficult jumps was positively correlated with the athlete's upper body strength and ability to pull arms in against centrifugal forces. Inability to attain tight air position leads to failure to land multiple revolution jumps. Strong arms contribute to the vertical velocity and are critical to the rotational component of the jump. To keep the arms and legs close to the axis of rotation to counteract centrifugal force, upper body, lower body, and core strength are required.

A randomized controlled trial of neuromuscular versus basic off-ice training programs on 44 young healthy figure skaters during a four week period (3 times a week for approximately 20-25 minutes) suggests that off-ice neuromuscular training can significantly improve postural control in figure skaters, whereas basic exercise training does not (Kovacs et al., 2004). Therefore, figure skating off-ice training should include exercises that challenge the neuromuscular system to improve postural control. Proprioception is the most important aspect of coordinated movements (Page, 2006). To maintain proper posture at the three key areas of proprioception (neck, low back and foot) is a crucial part of sensorimotor training. For that reason quality is stressed over quantity when practising (Page, 2006).

1.2.5 Literature Review Summary

Participating in sports brings many physical and psychological benefits (Auvinen et al., 2008; Kjønniksen et al., 2008; O'Toole & Douglas, 1994; Ward, 2009) but it is also associated with negative outcomes such as injury. Veigel and Pleacher (2008) stated that injuries can be associated with a decrease in participation or even withdrawal from sport, thus increasing the risk of gaining excessive body fat and lowering of fitness levels. Therefore, injury prevention needs to be the main concern when working with children involved in sport to provide them with a safe and rewarding sport experience. Many sport-related injuries among youth can be prevented through educational programs, rule changes (towards a safer sport environment), safety equipment, and specific conditioning programs.

Porter et al. (2007) stated that competitive adolescent figure skaters usually train 4 to 6 hours per day, 6 times per week, for 10 to 11 months of the year. Repetitive training puts an enormous amount of stress on athletes' bodies. Since 1990, compulsory figures are no longer a part of the competitions and an increase in free skating practice time has been observed (Lipetz and Kruse, 2000). Increased training hours and specifics aspects of training have raised concern due to their potential impact on injury risk.

Growth is an important factor to consider when working with adolescent athletes. Grouping children by their chronological age is a common trend in sports. Children of the same chronological age are not necessarily at the same biological age and they can differ in their levels of biological maturation by several years (Malina & Bouchard, 1991). This is a concern as children passing through their pubertal growth spurt could be more vulnerable to injury. In order to control for confounding effects of maturation, an assessment of biological age must be included in pediatric exercise study designs. There are several figure skating-specific considerations related to growth in the young female athlete. Later maturation, nutrition, physique and female athlete triad are just a few.

Typical musculo-skeletal figure skating injuries occur in the foot, ankle, knee, leg, hip, or lower back (Porter et al., 2007). A study done by Dubravcic-Simunjak et al. (2003) revealed that acute injuries occurred more often in pairs skating and ice dancing whereas overuse injuries were mostly seen in solo skaters (Porter et al., 2007). Stress fracture was reported as the most frequent overuse injury in female solo skaters in a study by Dubravcic-Simunjak et al. (2003).

Some of the suggestions to effectively prevent skaters from sustaining injuries are: a properly fitted boot that is not overly stiff; an adequate training schedule that is appropriate for a skater's skill and age; a sufficient amount of rest and cross-training. Regular participation in an off-ice program including flexibility, strength and proprioceptive training is also a key in injury prevention, especially at the time of peak height velocity. Having a sufficiently nutritious diet is also crucial. Proper warm-up and cool down periods can also serve in injury prevention and should be a part of skaters' training sessions (Porter et al., 2007).

1.3 Statement of the problem and hypotheses

1.3.1 Statement of the problem

There is a lack of published studies on injuries in figure skating, especially in adolescent figure skaters. No study has reported training amount and injuries in STARSkate figure skaters and looked into the relationship between the off-ice training and injury. Adolescent female figure skaters are a very unique group that needs further investigation in terms of growth and development, amount of training and their associations with injury.

The main focus of this project was to identify incidence and occurrence of injury in female solo figure skaters and investigate differences between levels of skaters. The secondary purpose was to identify the role of off-ice training and its association with injury and level of skating. The third purpose was to investigate associations between injury, age and maturity. The female figure skaters were grouped according to the category they participated in (STARSkaters and competitive skaters). These two groups typically follow different training volumes and level of performed elements.

1.3.2 Hypotheses

Hypotheses 1: There will be an association between overuse injuries sustained by competitive and STARSkate female solo figure skaters.

Hypotheses 2: There will be an association between acute injuries sustained by competitive and STARSkate female solo figure skaters.

Hypotheses 3: There will be an association between female solo figure skaters' participation in the Long-term Athlete Development Model recommended amount of off-ice training programs and the number of sustained injuries.

Chapter 2

METHODS

2.1 Research Design

A quantitative, non-experimental descriptive study design was used for this project. Data was collected retrospectively through written questionnaires. A survey design was chosen to attract the largest number of figure skaters across the province of Saskatchewan (Creswell, 2003). The independent variables under review were the amounts of training (both on and off the ice), age (both chronological and biological), body size and level of skating. The dependant variable was the incidence of injury.

The survey contained a general information questionnaire, retrospective questionnaire and an injury questionnaire asking figure skaters about their training and injuries for a 9 month period in the 2009/2010 figure skating season. For the purpose of this investigation, an injury was defined as "any event that (1) requires medical professional and/or (2) results in a restriction in training or performance" (Hobson, 2002). This study used the same definitions for acute and overuse injuries as in Dubravcic-Simunjak et al. (2003): acute injuries occur during a determined time period that causes tissue damage. Overuse injuries occur due to micro-traumatic tissue damage in which the original cause of the injury cannot be proved.

2.2 Participants

The Skate Canada Saskatchewan director provided the initial contact with the potential participants in this study. An informative e-mail about the study was sent out to the competitive skaters and to all Skate Canada Saskatchewan registered coaches to inform their STARSkate figure skaters about the study. Those skaters who decided to volunteer for this study replied back to the researcher with their mailing address as an agreement to take part in the study. The letter of invitation, the consent form, the assent form, and the questionnaires with completion instructions and a prepaid envelope were sent out to those interested skaters.

The targeted participants for this study were Saskatchewan female figure skaters between the ages of 10 and 18 who were members of Skate Canada. Upon correspondence with the Skate Canada Saskatchewan director (November 29th, 2010), it was stated that there were 1363 males and females involved in STARSkate program and 97 males and females in Competitive Skate in 2009/2010 figure skating season. Those were all skaters registered and it was not possible to identify an exact number between the age range of 10 and 18 years.

The participating figure skaters were split into two groups – a recreational stream (STARSkaters - SSFSs) and a competitive stream (CFSs). Prior to the study, a signed assent form was obtained from the participants and a consent form from their parent/guardian if the skater was under the age of 18. The certificate of ethical approval for this project was obtained from the Behavioural Research Ethics Board (Beh-REB) at the University of Saskatchewan (Appendix E).

Forty-four figure skaters expressed interest in taking part in the study. The filled questionnaires and agreement to participate (signed assent and consent forms) were received from 31 figure skaters. The response rate was 70.5% of the figure skaters who expressed an interest in being part of the study. Some of the statistical analyses were completed using a smaller number of figure skaters due to missing data in the questionnaires or due to inexact reporting (for example one skater was on and off training due to an injury so the data for training amounts could not be used).

Two participants identified themselves as both CFS and SSFS. They were identified as CFSs for the purpose of data analyses. Prediction of peak height velocity (PHV) was completed using the University of Saskatchewan (U of S) College of Kinesiology Research & Service website, the Prediction of Age of Peak Height Velocity (U of S College of Kinesiology, n.d.). Participants whose values after the calculation of PHV were -0.5 and above were included in the post PHV group. According to Mirwald, Baxter-Jones, Bailey & Beunen (2002), the maturity offset can be estimated with an error of ±1 year 95% of the time.

2.3 Procedures

The study consisted of four questionnaires: the general information questionnaire, the retrospective questionnaire, the measurement questionnaire, and the injury questionnaire. The retrospective and injury questionnaire identified training amounts and injuries sustained within 9 months of the 2009/2010 figure skating season (July 2009 – March 2010). The questionnaires had an identification number to ensure confidentiality. Participants self-identified themselves in the questionnaires (the level of skating).

Those skaters that decided to take part in the study were sent the following documents: filling instructions (Appendix A), a letter of introduction (Appendix B), two assent forms and two parental consent forms to keep copies for their own records (Appendix C), the general information questionnaire, the retrospective questionnaire and measurement questionnaire, injury questionnaire (Appendix D), and a stamped envelope. The researcher provided her mailing address, her e-mail address as well as phone numbers in case participants had any questions. The researcher also contacted the participants by phone to check if they had any questions or problems with filling the questionnaires out.

The general and injury questionnaires were modified from Hobson (2002) and Logan-Krogstad (2006) studies on injuries in rhythmic gymnastics and highland dancing, respectively. The measurement questionnaire was adapted from the U of S College of Kinesiology measurement questionnaire (2005) and contained instructions on how to take the measurements (standing and sitting height, weight). All questionnaires were reviewed by experts from the U of S Kinesiology department including a PhD student and two figure skating coaches. Three randomly selected skaters were asked to fill the questionnaires in and point out any questions or expression that they did not understand. After suggestions were made, the questionnaires were adjusted to be written in a comprehensible way for younger skaters. The same version was used for both STARSkate and Competitive skaters.

The general information questionnaire was divided into two parts: sport-related information and personal information. Questions in the first part, for example, asked figure skaters about the number of years of their involvement in figure skating, the level they were at, if they participate in other disciplines except solo, if they use a hinged-type of boot, whether they keep a training log, if their coach uses a harness when learning a new jump etc. The second part (personal information) asked about date of birth, first menstrual period, amenorrhea, diet and any injuries sustained prior to July 2009.

The retrospective questionnaire asked about the transition period in 2009 (the period between the 2008/2009 and the 2009/2010 figure skating season), 2009 summer figure skating, about training amounts both on and off the ice during September 2009-March 2010, typical training week, warm-up, off-ice training content and medical information. The measurement questionnaire contained the skater's as well as skater's parents standing height, skater's sitting height and weight. Skaters were requested to fill in detail the injury questionnaire for any injuries sustained during the period of July 2009 – March 2010. The injury questionnaire included questions about the body part injured, location of the injury, nature of the injury, timing of the injury, cause of the injury, disposition and treatment.

2. 4 Measures

2.4.1 Peak Height Velocity Measurements

(Chronological age and standing height, sitting height, weight)

As stressed by Mirwald et al. (2002), it is important to control for the effects of maturation during adolescence in context of research investigations and youth sport classification. There is a large range of variability between individuals of the same chronological age in somatic and biological growth especially around the adolescent growth spurt. Limitations are present in available methodologies. Skeletal age assessment is costly, requires specialized equipment and exposes the individual to radiation. The assessment of secondary sex characteristics is considered personally intrusive by adolescent children and their parents. Not only is the application period limited to adolescence but secondary sex characteristics do not reflect the timing of growth. The most commonly used indicator of maturity in longitudinal studies of adolescence is age of peak height velocity. This somatic method requires serial measurements for a number of years surrounding the occurrence of peak velocity and therefore cannot be used as a one-off measurement.

Mirwald et al. (2002) established a noninvasive and practical method to assess maturity status during adolescence. Gender-specific equation predicts age from peak height velocity by using four anthropometric variables (height, sitting height, body mass, and chronological age). This measure of maturity offset can be estimated within an error of +/- 1 year 95% of the time.

Any negative maturity offset prediction should classify the individual as pre-PHV and any positive prediction as a post-PHV.

The participant's date of birth, the measures of height, sitting height and weight were obtained in the measurement questionnaire as well as the date when the measurements were taken. The participants' parents provided their standing height measurements. The instructions on how to provide these measurements were sent out to the participants.

2.5 Data Analysis

Reporting data from the questionnaires was anonymous and confidential. Independent t-tests were used to identify if there were any differences between the competitive and STARSkate group of figure skaters in: age, estimated age at PHV, age of menarche, height, weight, training hours (both on and off the ice) and years involved in figure skating. The injury rate was calculated by dividing the total number of injuries sustained by the total number of on-ice hours trained, then multiplying by 100. This was done for: 1) all the figure skaters and 2) the figure skaters in each group. The injury rate was also calculated for overuse injuries and off-ice training hours.

Non-parametric statistics were used to analyze the data due to non-random selection of the samples that were drawn from the figure skating population only. The alpha level was 0.05 for all the analyses. Cross tabulations were used to analyze the three hypotheses to determine if there were any associations among the figure skaters groups (CFSs and SSFSs) for the types of injuries and between injuries and off-ice training.

The average weekly training hours were reported for the time period of September 2009-March 2010 due to the fact that most of SSFSs start the season in September while CFSs generally attend summer skating schools during July and August. Total training hours were calculated as the total amount of hours trained from July 2009 till March 2010. Participants were asked to report any time missed due to illness, family vacation or Christmas break. In case they wrote down Christmas break and did not specify the exact time missed, it was considered as a two-week training break for the calculation of the average of training amounts (the clubs usually have two-week Christmas break).

Chapter 3

RESULTS

3.1 General Information

Table 3.1 shows the means and the standard deviations for chronological age, age of menarche, predicted age at PHV, weight and height of the SSFSs and CFSs. There were no significant differences ($p>0.05$) found between SSFSs and CFSs in chronological or biological age (age of menarche, predicted age at PHV). There were also no significant differences between SSFSs and CFSs in weight or height ($p>0.05$). Skaters' data were then grouped by occurrence of injury. Table 3.2 presents the means and the standard deviations for the above five variables for figure skaters who sustained a figure skating-related injury. There were significant differences ($p<0.05$) found in age and weight between the injured and non-injured figure skaters.

Table 3.3 shows the means and the standard deviations for training hours per week, number of years in figure skating and total number of training hours. It was found that CFSs trained significantly ($p<0.05$) more hours per week on-ice and off-ice combined and they spent significantly ($p<0.05$) more hours performing off-ice training than SSFSs. There was no significant difference found in the amount of on-ice training between SSFSs and CFSs ($p>0.05$). Table 3.4 shows the means and standard deviations for the above-mentioned variable for figure skaters who sustained a figure skating-related injury. There were significant differences ($p<0.05$) found in the number of years involved in figure skating between the injured and non-injured figure skaters.

Table 3.1 Physical and maturational characteristics of the figure skaters (mean ± SD) and (range)

	STARSkate figure skaters (n = 17)	**Competitive figure skaters (n = 14)**
Age (yr.)	13.2 ± 2.8 (9.7 – 18.8)	13.4 ± 2.3 (10.9 – 17.9)
Age of Menarche (yr.)	12.6 ± 1.7 (n=8) (11.0 – 16.0)	12.2 ± 0.4 (n=9) (12.0 – 13.0)
Predicted age at PHV (yr.)	12.2 ± 0.6 (n=15) (11.1 – 13.3)	12.2 ± 0.5 (n=12) (11.1 – 12.9)
Weight (kg)	50.4 ± 14.1 (28.8 – 79.4)	46.5 ± 13.6 (27.5 – 67.1)
Height (cm)	155.5 ± 14.2 (127.0 – 180.3)	155.9 ± 13.0 (137.0 – 175.3)

Table 3.2 Physical and maturational characteristics of the combined figure skaters grouped by injury occurrence (mean ± SD) and (range)

	Non-injured figure skaters (n = 18)	**Injured figure skaters (n = 13)**
Age (yr.)	12.5 ± 2.1* (9.7-17.5)	14.4 ± 2.7* (10.1-18.8)
Age of Menarche (yr.)	11.7 ± 0.7 (n=7) (11-13)	12.8 ± 1.3 (n=10) (12-16)
Predicted age at PHV (yr.)	12.1 ± 0.6 (n=16) (11.1-12.9)	12.4 ± 0.6 (n=11) (11.5-13.3)
Weight (kg)	44.3 ± 14.6* (27.5-79.4)	54.7 ± 10.1* (36.7-73.5)
Height (cm)	152.3 ± 14.5 (127 -180.3)	160.4 ± 10.6 (142.2-175.9)

* represents a significant difference between the groups at $p<0.05$

Table 3.3 Sport-related information of the figure skaters (mean ± SD) and (range)

	STARSkate figure skaters (n = 17)	Competitive figure skaters (n = 13)
Training altogether (hrs/wk)	7.0 ± 2.0* (4.1 – 10.0)	10.6 ± 4.7* (4.8 – 21.5)
On-ice training (hrs/wk)	6.0 ± 1.8 (3.4 – 9.0)	8.2 ± 4.7 (2.9 – 17.4)
Off-ice training (hrs/wk)	1.0 ± 1.1* (0 – 4.0)	2.4 ± 2.0* (0 – 7.0)
Number of years in FS	7.3 ± 3.1 (2.0 – 14.0)	8.3 ± 2.4 (3.0 – 13.0)
Total On-ice (36 weeks)	153.9 ± 43.0* (88.0 – 234.0)	203.5 ± 106.1* (61.5 – 417.0)
Total Off-ice (36 weeks)	25.2 ± 28.7* (0 – 104)	60.0 ± 54.0* (0 – 189)

* represents a significant difference between the groups at $p<0.05$

Table 3.4 Sport-related information of the injured figure skaters (mean ± SD)

	Non-injured figure skaters (n = 18)	Injured figure skaters (n = 12)
Training altogether (hrs/wk)	9.2 ± 4.6 (4.3 – 21.5)	7.6 ± 2.2 (4.1 – 10.4)
On-ice training (hrs/wk)	7.6 ± 3.7 (3.4 – 17.4)	6.1 ± 1.7 (2.9 – 9.0)
Off-ice training (hrs/wk)	1.6 ± 2.0 (0 – 7.0)	1.6 ± 1.3 (0 – 4)
Number of years in FS	6.8 ± 2.6* (2 – 13)	9.0 ± 2.6* (5 – 14)
Total On-ice (36 weeks)	220.4 ± 118.7 (88.0 – 504.0)	181.1 ± 66.3 (104 – 356)
Total Off-ice (36 weeks)	50.7 ± 62.1 (0 – 221)	44.4 ±36.1 (0 – 104)

* represents a significant difference between the groups at $p<0.05$

3.2 Injury Incidence

The number of figure skating-related injuries sustained by all figure skaters was 21 (0.68 injury / skater). The number of figure skating-related injuries sustained by SSFSs was 12 (0.71 injury / skater). Nine SSFSs had no injury (53%), five SSFSs had one injury (29%), two SSFSs had two injuries (12%) and one SSFS had three injuries (6%). The number of figure skating-related injuries sustained by CFSs was 9 as shown in table 3.5 (0.64 injury / skater). Nine CFSs had no injury (64%), three CFSs had one injury (21%), one CFS had two injuries (7%) and one CFS had four injuries (7%) as shown in table 3.7. There were reported 8 non-figure skating-related injuries (table 3.6).

The injury rate for all of the figure skaters was 0.34 injuries per 100 hours of on-ice training. The injury rate for each group was 0.26 for CFSs and 0.44 for SSFSs per 100 hours of on-ice training respectively. The overuse injury rates for 100 hours of off-ice training were 1.75 for SSFSs and 0.41 for CFSs.

Table 3.5 Acute and overuse figure skating-related injuries

	Acute	Overuse	Total
SSFSs (n=17)	4 (33%)	8 (67%)	12
CFSs (n=14)	5 (56%)	4 (44%)	9
	43%	57%	21

Table 3.6 Acute and overuse non-figure skating-related injuries

	Acute	Overuse	Total
SSFSs (n=17)	2 (100%)	0	2
CFSs (n=14)	5 (83%)	1 (17%)	6
	87.5%	12.5 %	8

Note: Participants identified in the injury questionnaire if they got injured outside of figure skating.

Table 3.7 Figure skating and non-figure skating-related acute and overuse injuries

	FS acute	**FS overuse**	**N-FS acute**	**N-FS overuse**	**Total**
CFS		1	3		4
CFS	3	1			4
CFS	1	1			2
CFS	1		1		2
CFS			1		1
CFS				1	1
CFS		1			1
SSFS		3			3
SSFS		2			2
SSFS	2				2
SSFS	1		1		2
SSFS		1			1
SSFS		1			1
SSFS			1		1
SSFS		1			1
SSFS	1				1
7 CFSs + 9 SSFSs = 16 skaters	**9**	**12**	**7**	**1**	**29**

3.3 Injury Occurrence on the Body

As shown in figure 3.1, the most injuries occurred in the lower back (28.6 %) and the knee (28.6 %). More injuries were reported in the lower extremities including the lower back (76%) than in the rest of the body (24%). Figure 3.2 illustrates eight non-figure skating related injuries with the ankle being the most injured site (37.5%).

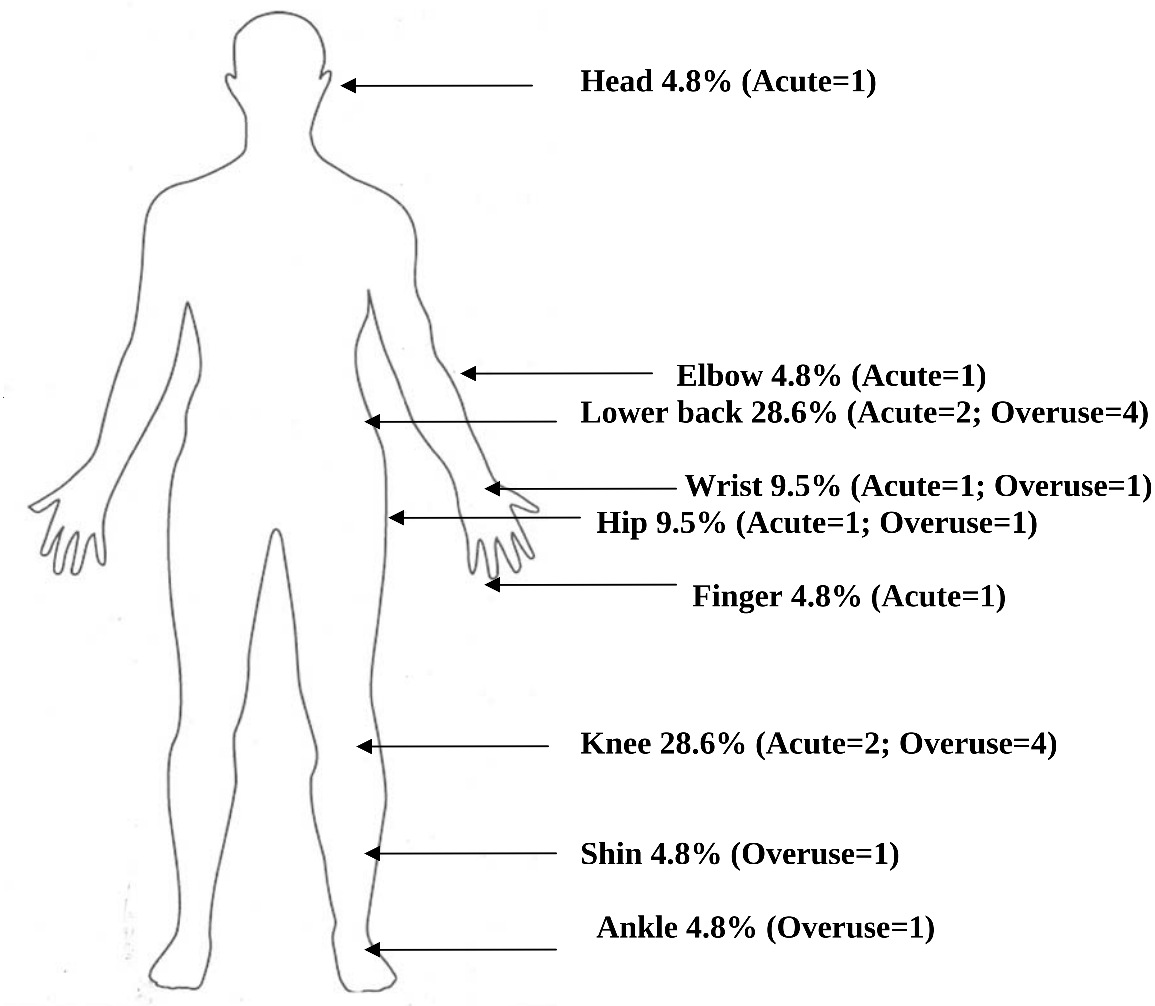

Figure 3.1 Distribution of figure skating related injuries in SSFSs and CFSs

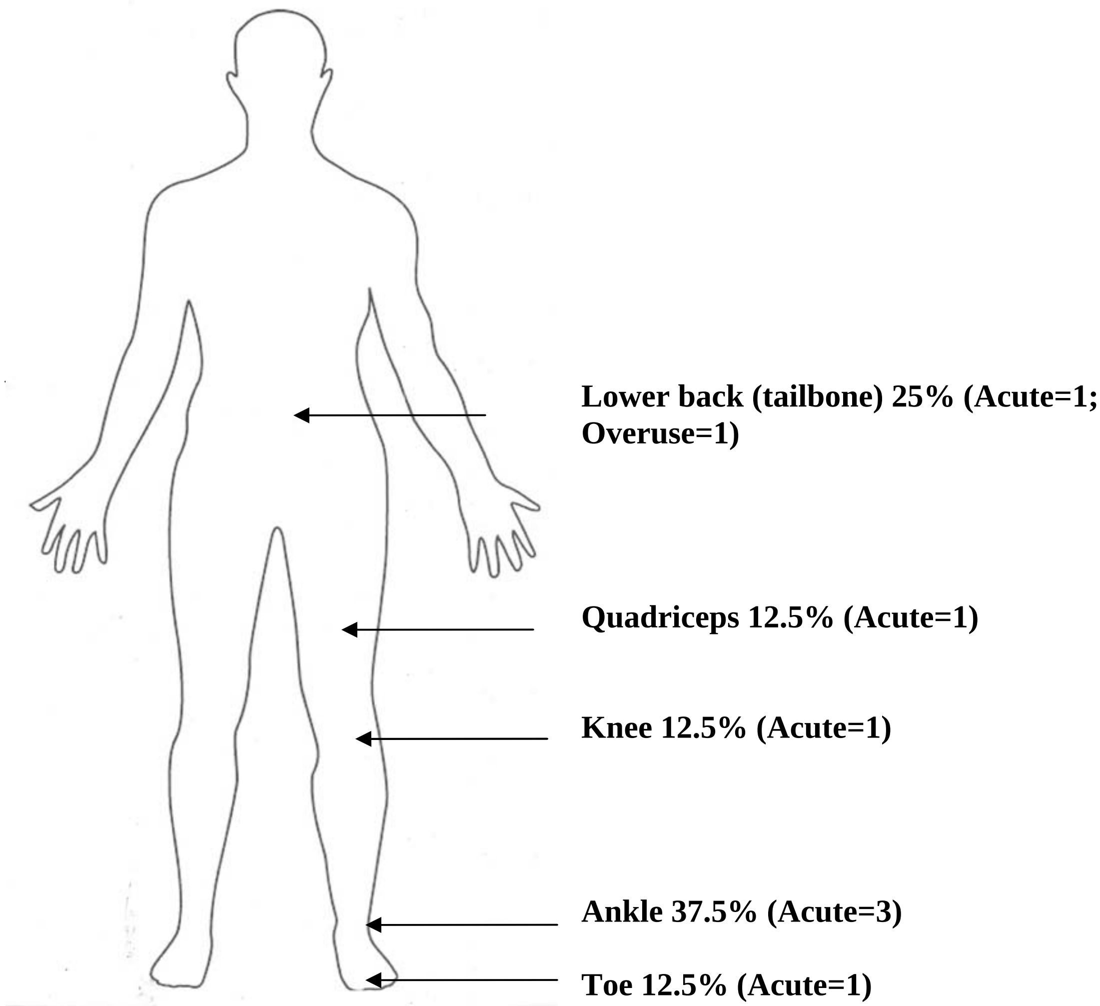

Figure 3.2 Distribution of non-figure skating related injuries in SSFSs and CFSs

3.4 Hypothesis 1

There were no significant associations between the number of overuse injuries sustained by the CFS and SSFS groups ($\chi^2 = 0.003$, $p>0.05$) as shown in table 3.8.

Table 3.8 Association between the number of overuse injuries reported by CFS and SSFS from July 2009 till March 2010

	Injured		
	No		Yes
CFS	10		4
SSFS	12		5
	Value	df	Significance (2-sided)
Pearson Chi-square	0.003	1	0.959

Note: Two injuries were reported as re-injuries by one participant and those were included as overuse injuries for the analyses considering the nature of the injury ("a reinjured ankle sprain and frequently sore knees").

3.5 Hypothesis 2

There were no significant associations between the number of acute injuries sustained by the SSFS and CFS groups ($\chi^2 = 0.053$, $p>0.05$) as shown in table 3.9.

Table 3.9 Association between the number of acute injuries sustained by SSFS and CFS from July 2009 till March 2010

	Injured	
	No	Yes
SSFS	12	4
CFS	11	3

	Value	df	Significance (2-sided)
Pearson Chi-square	0.053	1	0.818

Note: One injury was reported as a re-injury by the participant and was included as an acute injury for the analyses considering the nature of the injury (a fall on the knee).

3.6 Hypothesis 3

There was no significant association found between the number of injuries sustained by the SSFS and CFS groups that follow or do not follow Skate Canada off-ice training recommendations of a minimum of 15 minutes off-ice training for every on-ice hour ($\chi^2 = 2.801$, $p>0.05$) as shown in table 3.10 (In Pursuit of Personal Excellence: Skate Canada's Guide to Long-Term Athlete Development, 2010).

Table 3.10 Association between the numbers of injuries sustained by the SSFS and CFS groups that follow or do not follow Skate Canada off-ice training recommendations

	Injured	
	No	Yes
Do not follow	13	5
Follow	5	7

	Value	df	Significance (2-sided)
Pearson Chi-square	2.801	1	0.094

3.7 Injury and Maturity

There was a significant association between the number of injuries sustained by the pre and post PHV figure skaters ($\chi^2 = 4.949$, $p<0.05$) as shown in table 3.11. More injury was associated with post PHV figure skaters.

Table 3.11 Association between the numbers of injuries sustained by the pre and post PHV figure skaters

		Pre PHV	Post PHV
Injured	No	8	10
Injured	Yes	1	12

	Value	df	Significance (2-sided)
Pearson Chi-square	4.949	1	0.026

There was a significant association between the number of injuries sustained by the figure skaters who reached menarche and those who did not ($\chi^2 = 4.409$, $p<0.05$) as shown in table 3.12. Injury was associated with figure skaters who had attained menarche.

Table 3.12 Association between the number of injuries sustained by the figure skaters who reached menarche and those who did not

		Reached Menarche No	Reached Menarche Yes
Injured	No	11	7
Injured	Yes	3	10

	Value	df	Significance (2-sided)
Pearson Chi-square	4.409	1	0.036

3.8 Injury and Sport Involvement

There was a significant association between years in the sport and injury ($\chi^2 = 5.000$, $p<0.05$) as shown in table 3.13. Figure skaters who were involved in FS for 8 year had more associated injury.

Table 3.13 Association between years in the sport and injury

		In FS less than 8 years	In FS 8 years and more
Injured	No	12	6
Injured	Yes	3	9

	Value	df	Significance (2-sided)
Pearson Chi-square	5.000	1	0.025

3.9 Skating Information

The majority of competitive figure skaters (CFSs) and STARSkate figure skaters (SSFSs) were involved in a solo discipline and none of the CFSs and only 6% of SSFSs used a hinged boot (table 3.14). A harness was used by 78% of CFSs and 38% of SSFSs when learning a new jump and 64% and 34 %, respectively, had their coach regulating the maximum jumps per day. Medical attention when injured was not sought by 8% of CFSs and 12% of SSFSs. Table 3.15 shows that the CFSs performed more complex jumps on average than those performed by the SSFSs.

Table 3.14 Sport-related information

	CFSs (n=14)		SSFSs (n=17)	
	Yes	**No**	**Yes**	**No**
Participation in another FS discipline SSFSs (n=16)	7%	93%	0%	100%
Participation in other sports on regular basis SSFSs (n=16)	64%	36%	75%	25%
Hinged-type boot	0%	100%	6%	94%
Keep a training log	43%	57%	6%	94%
Currently on a diet CFSs (n=13)	0%	100%	0%	100%
Landing Leg CFSs (n=13)	**Left** 23%	**Right** 77%	**Left** 24%	**Right** 76%

Table 3.15 The mean of attempted jumps on a regular on-ice session

	Single jumps	Double jumps	Triple jumps
CFSs (n=12)	25	36	5
SSFSs (n=13)	49	15	0

3.9.1 Off-ice Training

As reported in question 29 in the retrospective questionnaire, of the 77% of figure skaters who performed off-ice training 65% would like to perform more. The reasons for not attending more off-ice sessions by both figure skaters who do off-ice training already (n=23) as well as those who do not (n=7) were mainly: no gym at the rink (n=8); no offer though the skating club (n=8); time demands (n=6); and no coach to run the off-ice training (n=4). Off-ice training was reported as beneficial by 80 % of figure skaters and 70% believed that off-ice training was equally as important as on-ice training.

3.9.2 Stretching

An average weekly stretching time of CFSs and SSFS is reported in table 3.16. Types of stretching (static, dynamic, etc.) were not distinguished. No stretching was reported by 7% of CFSs and 24% of SSFSs, all were from the age group of 10-12. On average, CFSs stretched more that SSFSs and in general stretching time increased with age. Figure 3.3 shows that 29% of CFSs and 53% of SSFSs spent 30 min. and less on weekly stretching.

Table 3.16 An average weekly stretching time (in minutes)

	Age group 10 – 12	Age group 13 – 15	Age group 16-19
CFSs	41	108	75
SSFSs	24	57	89

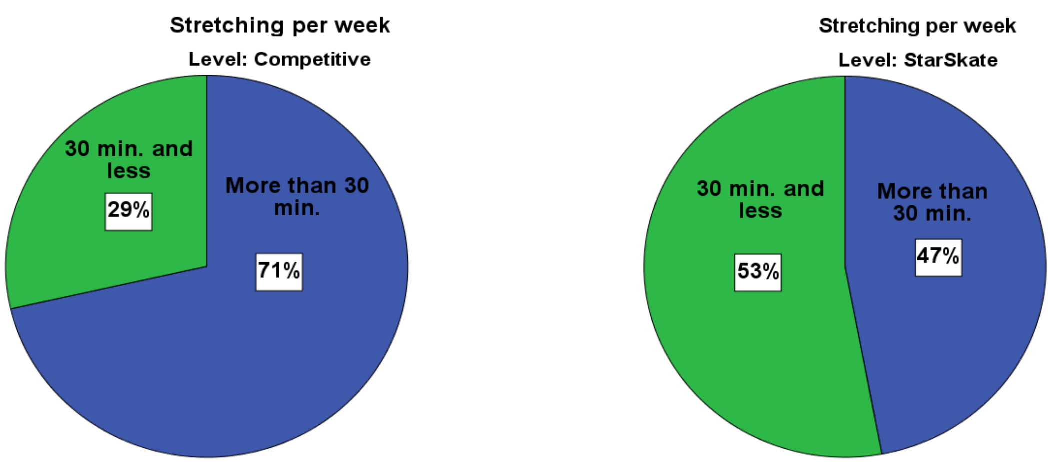

Figure 3.3 Time spent on stretching per week

3.9.3 Warm up and Cool down

Half of CFSs (50%) and over half (53%) of SSFSs spent 30 minutes or less on warm up per week. Seven skaters (4 CFSs and 3 SSFSs) did not warm up. Nineteen skaters did not cool down (8 CFSs and 11 SSFSs). Time spent on warm-up and cool down is reported in the figures 3.4 and 3.5.

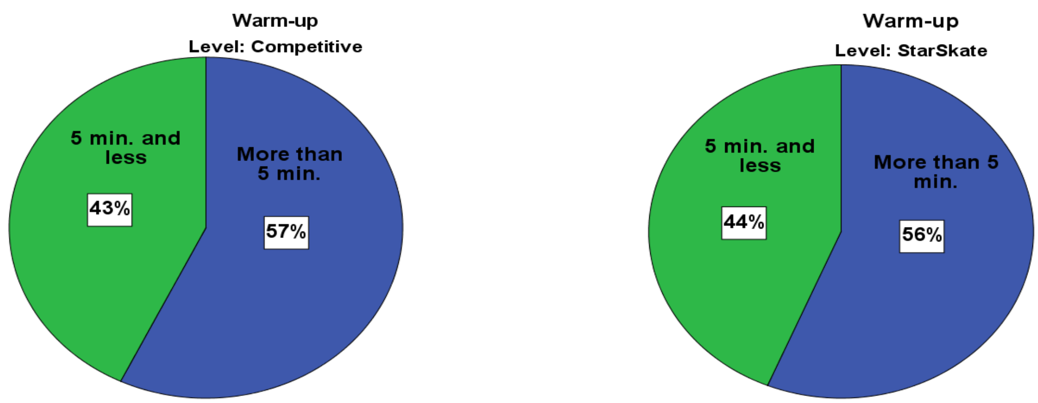

Figure 3.4 Time spent on warm-up

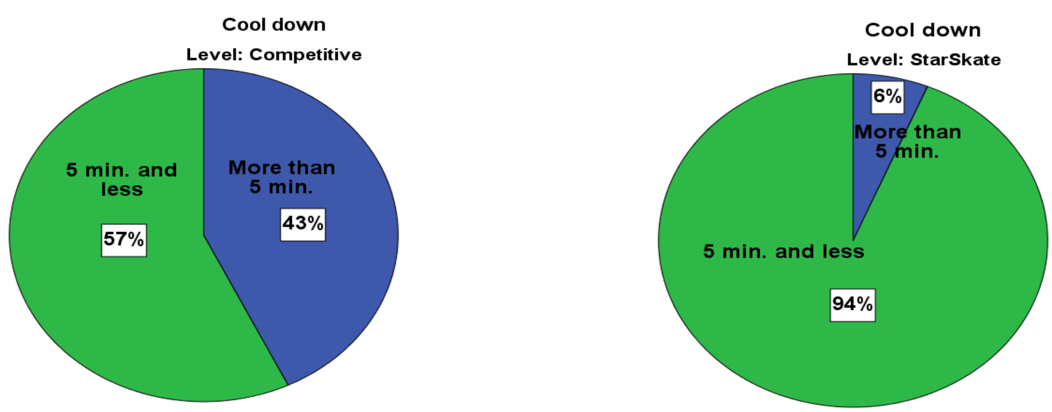

Figure 3.5 Time spent on cool-down

Chapter 4

DISCUSSION

The primary aim of this project was to identify incidence and occurrence of injury in female competitive and recreational solo figure skaters. The secondary aim was to identify the role of off-ice training and its association with injury and level of skating. The third aim was to investigate associations between injury, age and maturity.

In the present study, 17 StarSkate Figure Skaters (SSFSs) and 14 Competitive Figure Skaters (CFSs) did not differ significantly in chronological or biological age (age of menarche, predicted age at PHV) neither in weight nor height ($p>0.05$). The injured figure skaters were significantly ($p<0.05$) older and heavier than the non-injured figure skaters. CFSs trained significantly ($p<0.05$) more hours per week on-ice and off the ice combined; as well as they spent significantly ($p<0.05$) more hours doing off-ice training than SSFSs. No significant difference was found between SSFSs and CFSs ($p>0.05$) for the amount of on-ice training. More injury was associated with post peak height velocity (PHV); more mature figure skaters who have already attained menarche and were involved in figure skating for 8 or more years.

The injury rate in 31 adolescent female solo figure skaters was calculated to be 0.34 injuries per 100 hours of on-ice training. The injury rate for each skaters group was 0.26 for CFSs and 0.44 for SSFSs per 100 hours of on-ice training. The number of figure skating-related injuries sustained by SSFSs was 12 (0.71 injury / SSFS) and 9 in CFSs (0.64 injury / CFS) in this 9-month retrospective study. From the total of 21 figure skating related injuries, 57% were overuse and 43% acute. Hypothesis 1 was rejected as there were no significant associations between overuse injuries and the level of skating. Hypothesis 2 was rejected as there were no significant associations between acute injuries and the level of skating. CFSs had 4 overuse and 5 acute injuries compared to SSFSs who reported 8 overuse injuries and 4 acute injuries. Hypothesis 3 was rejected as there were no significant associations between figure skaters participating in recommended minimum of 15 minutes off-ice training for every on-ice hour and injuries.

There are challenges when comparing studies reporting injury rates due to the different injury definitions and study designs (Bronner, Ojofeitimi, & Spriggs, 2003; Kjaer & Larsson, 1992). To qualify as injury in the study by Kjaer and Larsson (1992), the injury had to lead to time being lost from practice or competition. An injury was defined as “any event that (1) requires medical professional and/or (2) results in a restriction in training or performance” in this study (Hobson, 2002). Every figure skating discipline has different program requirements and this needs to be taken into account when comparing figure skating studies. Our findings of injury rate per skater (0.71 injury / SSFS and 0.64 injury / CFS) might not be comparable with a rate of 1.4 in senior pair women in the Smith and Ludington (1989) study since pair women skaters are exposed to different figure skating elements (throw jumps, lifts, death spirals). In the Kjaer and Larsson (1992) study, eight Danish elite skaters (three males and five females) with the mean age 17 (range 14-20) were followed prospectively for a one year period and the injury rate reported was 0.14 injuries per 100 hours of training. The injury rate 0.26 per 100 hours of on-ice training in our study in CFSs is slightly higher.

This study’s injury rate findings of 0.34 injuries per 100 hours of on-ice training (CFSs and SSFSs combined) are also slightly higher to those of Harringe et al. (2007) who reported an injury rate of 0.22 per 100 hours of gymnastic training but get closer when considering the injury rate of CFSs only (0.26 per 100 hours of on-ice training). They conducted a one season prospective study in top-level teamgym on 26 females (mean age 18) and 16 males (mean age

21.8). The injury incidence for only the injured dancers was 2.59 injuries per 100 hours of training in competitive highland dancers and 4.51 injuries per 100 hours in recreational dancers (Logan-Krogstad, 2006). The present study also indicated a higher injury incidence in recreational figure skaters (0.44 for SSFSs per 100 hours of on-ice training) compared to CFSs (0.26 for per 100 hours of on-ice training). The reported injury incidence in a prospective study of 35 female and 5 male pre-professional ballet dancers aged 14-18 was 0.47 injuries per 100 hours of training thus also indicated higher incidence than this study (Luke, et al. 2002).

Warm up may be a factor in reducing injuries (Arbour, 2006). The low incidence of injury in the Kjaer and Larsson (1992) study of Danish figure skaters might have been attributed to the large amount of time spent on warming up and stretching activities. Danish skaters trained 29 ± 4 (range 15-41) hours per week including 60-95 minutes on warm-up activities. Despite the amount of training, injury incidence was low compared with other sporting events. Half of CFSs (50%) and over half of SSFSs (53%) spent 30 minutes or less on warm up per week as found in our study. Seven skaters (4 CFSs and 3 SSFSs) did not warm up at all.

The total amount of training hours per week for SSFSs and CFSs in our study was 7.0 ± 2.0 and 10.6 ± 4.7 respectively. The higher incidence of injuries in SSFSs (0.44 in SSFSs compared to 0.26 in CFSs per 100 hours of on-ice training) could be contributed to the less amount of time spent on warm-up and stretching activities. Over half of SSFSs (53%) spent 30 minutes or less on stretching per week whereas this was noted for only 29% CCFSs. Four SSFSs (24%) did not stretch at all. Small amount of time spent on warming up and stretching was also noticed by Smith and Micheli (1982) study. Skaters practiced four to six hours a day, six days a week and 48 to 51 weeks a year in their study however none of them did more than 5 minutes of warm-up before practicing jumps or spins. Most of the skaters warmed up only 1 or 2 minutes.

Brock and Striowski (1986) reported that skaters spent on average 27.2 hours a week on the ice (10.7 hours for figures work and 16.5 hours for freestyle) but only 11.9 minutes per week stretching and warming up.

Fortin and Roberts (2003) investigated 208 figure skaters who participated at United States national figure skating competition via a standard medical history form. The ankle was the most frequently injured site and most of the injuries observed were overuse injuries which is consistent with the findings of Dubravcik-Simunjak et al. (2003). There were 4 ankle injuries reported by the skaters in our study and 3 out of these four were sustained outside of figure skating. Porter et al. (2007) discussed that competitive figure skaters are at an increased risk for ankle sprains when away from on-ice training due to the support of stiff boots that weaken the muscles surrounding the ankle. We can only speculate that the ankle sprains sustained by 3 skaters outside of figure skating were influenced by their use of stiff boots which resulted in them having weaker ankles. Skaters should include ankle stabilization and proprioceptive training into their off-ice training to avoid ankle sprain injuries (Porter et al., 2007).

Lipetz and Kruse (2000) inferred that off-ice training programs can decrease stress fractures, overuse injuries, ankle injuries and increase ankle proprioception as shown by data obtained from figure skating sports science camps. As stated by Porter et al. (2007), acute musculoskeletal injuries and chronic overuse injuries that primarily occur in the foot, ankle, knee, leg, hip and lower back are a common problem in figure skating. Smith and Micheli (1982) study reported that out of 33 injuries reported in girls (not divided by category) low back pain was predominant (15%), followed by malleolar swelling (12%) and medial shin pain (9%). The present study also showed the highest number of injuries in the lower back (28.6%), knee (28.6%), wrist (9.5%) and hip (9.5%). Fourteen (12.7%) out of 107 single female skaters (a median age 16 years) reported low back pain in the study by Dubravcik-Simunjak et al. (2003). Low back and knee injuries accounted for 57.2% of all figure skating-related injuries and were the most frequently injured sites in skaters investigated in the present study.

The Smith and Ludington prospective study from 1989 looking at 48 pair skaters and ice dancers showed a high incidence of injuries over a 9 month period. Out of 33 serious injuries reported, 25 were to the lower extremity and the remaining 8 involved the head, upper extremities and trunk. The study confirmed previous findings that most injuries occur in the lower extremity and that many injuries are related to the skating boot. The majority of the injuries in ballet and aerobic dance, similar aesthetic sports to figures skating, are found in the lower extremities and are overuse in nature. Logan-Krogstad (2006) found that most injuries in highland dancers are to the lower leg, with the knee, shin/calf, ankles and feet as the major sites. Harringe et al. (2007) reported 62% of gymnastics injuries are located in the lower extremity with ankle sprain being the most common injury. These findings agree with our study where we found more injuries in the lower extremities including the lower back (76%) as compared to the rest of the body (24%).

In a study by Dubravcik-Simunjak et al. (2003), elite junior figure skaters were examined by questionnaires during four consecutive Junior World Figure Skating Championships and the Croatia Cup to determine the frequency of injuries. Overuse injuries were reported by 72.7% of single female skaters, 14.6% reported acute injuries and 12.7% low back pain. Overuse syndromes represented more than 50% of injuries in young single female and male figure skaters that occurred during their junior skating career (Dubravcik-Simunjak et al., 2003). The study of 19 high-level competitors consisting of 14 figure skaters in ladies event, 3 in men and 2 in pairs with a mean age of 13.8 revealed that most injuries were from overuse (Smith & Micheli, 1982).

More overuse injuries (57%) were reported in the present study as well when considering CFSs and SSFSs injuries combined. Our findings, 56% of acute and 44% overuse injuries in CFSs, are identical to Kjaer and Larsson's study (1992). More acute injuries found in CFSs are also consistent with the results of the study by Brock and Striowski (1986) in which sixty Canadian national level figure skaters were examined by questionnaire over a one-year period. Fifty percent of the reported injuries were acute and 43% were overuse.

To design a preventive program to lower the injury rate was an important aim of the Smith and Ludington (1989) study. Nevertheless, only 4 out of 33 serious injuries in pairs or ice dancers were possibly preventable by changes in flexibility, strength, of biomechanical techniques. This might be different in solo skaters for whom more overuse injuries, as confirmed in our study (57% of overuse injuries in SSFSs and CFSs combined), are reported whereas pair and ice dancers are prone to more acute injuries (Dubravcik-Simunjak et al., 2003; Porter et.al., 2007). Brock and Striowski (1986) suggested that future studies concentrate on overuse syndromes for two reasons: in theory, overuse syndromes are preventable and they also kept the skaters off the ice in their study longer then acute injuries did.

Smith and Micheli (1982) observed that the non-injured group's average age was 12.2 years (range 11-14) and the injured group's average age was 14.4 years (11-19). The group did not differ significantly in number of years of serious skating (the term serious skating was not further specified). We present very similar findings of the average ages of the non-injured group 12.5 (range 9.7-17.5) and the injured group 14.4 (range 10.1-18.8). The injured skaters in our study were significantly older and heavier than the non-injured skaters. Injury was also associated to post PHV skaters who have already attained menarche and were involved in figure skating for 8 or more years. Smith and Ludington (1989) found out in their study that the incidence of injury in pairs was not related to age, height or weight. The absence of injury among the novice pair skaters could be explained by the slower speed at which the relatively less difficult maneuvers are performed. It seems that younger skaters are less likely to sustain skating injuries (our study shows the same pattern of younger skaters sustaining less injuries) but we need to consider the long-term effects of the repetitive microtrauma present in figure skating mainly from jumping.

Smith and Micheli (1982) expressed concern about the repetitive microtrauma which may cause overuse injuries, including vertebral and growth plate fractures. A vertebra fracture was reported by one of the skaters in the present study. As discussed by Smith and Micheli (1982), growing children can lose flexibility easily because the bones grow rapidly and the soft tissues must elongate secondly. The average weekly stretching time of skaters in our study was the lowest in the critical age group 10-12 years old with 24 minutes in SSFSs and 41 minutes in CFSs.

Smith and Micheli (1982) also pointed out the high incidence of low back pain (one third of the investigated female figure skaters) and almost no exercises to stretch the lower back were done in the skaters' stretching classes. Studies have suggested that the lower back injuries are related to the figure skating boot whose rigidity limits the ankle and knee full range of motion to absorb the landing force (Lipetz & Kruse, 2000; Smith, 1997). Only one skater in our study used the hinged style of boot that has been shown to decrease peak heel force (Bruening & Richards, 2006). Smith (1997) encouraged the development of core strength and stability with an understanding of appropriate body alignment in the air and at landing.

As discussed by Smith and Micheli in 1982, the muscoleskeletal system of a young skater might not be mature enough to withstand the stresses of training 6 hours a day, 50 weeks a year.

Children attempting triple jumps, commonly performed at the novice level, without gaining sufficient height first may incur substantial rotational forces in the lower extremity. Bradley (2006) stated that immense forces are applied to the skater's foot during both take-offs and landings. It was proposed that the risk of overuse injuries could be reduced by monitoring the number of attempts of jumps within the training session (Bradley, 2006). Previous studies have indicated that skaters attempt more than 50 jumps daily (Bruening & Richards 2006; Kruse & Burke, 2005). CFSs attempted on average 25 single, 36 double and 5 triple jumps while SSFSs attempted 49 single, 15 double and no triple jumps per session in our study. Harringe et al. (2007) and Kirialanis et al. (2002) notice that higher injury rates occur in the landing phase of gymnastics skills and call for special attention to the landing phase. Almost 63% of SSFSs learn new jumps without the use of harness (a training aid operated by the coach that protects skaters from falls and allows them to experience a successful landing). No jump regulation in terms of the coach setting up a maximum number of jumps the skaters is allowed to attempt per day was seen in 67% of SSFSs. This often results into uncontrolled jumping and potentially increases the risk of an injury.

It was shown by Podolsky et al. (1990) that strength of knee and shoulder muscles correlates with height of single and double Axel jumps. Consequently, they highlighted the importance of strength training. This is also supported by Ham et al. (2007) who state that a vertical jump performance can be improved substantially through proper jump-specific strength and power training. As pointed out by King (2005), different arm motions in particular jumps are used and therefore skaters should not limit themselves to a single joint exercise neither rely only on bilateral symmetrical resistance training exercises. To keep the arms and legs close to the axis of rotation to counteract the centrifugal force, upper body, lower body, and core strength are all required (Kruse & Burke, 2005).

As indicated by Bronner et al. (2003), the primary injury prevention in dancers includes surveillance of exposures and injuries, screening to identify intrinsic risk factors, education on proper warm up, errors in training and alignment, use of protective equipment, footwear and cross training. Examples of injury preventive measures in figure skating as listed by Porter et al. (2007) are: wearing a properly fitted boot and following a skill and age appropriate training schedule, maintaining proper flexibility, participating in off-ice strength and proprioceptive training programs. LeMasters (1972) suggested that to decrease skating injuries one needs to pay attention to proper training methods, good ice conditions and adequate warm up. Prevention of injury rarely receives the same attention as treatment of injury. Only 3 out of 48 skaters attended a one day symposium on injury prevention and training methods that was offered to the skaters (Smith & Ludington, 1989).

To prevent injuries, Lipetz and Kruse (2000) stressed the importance of flexibility, core strength, explosive power and cardiovascular fitness in a figure skating conditioning program, with an emphasis on symmetry of flexibility and musculature. Smith et al. (1991) stressed the importance of thigh muscle flexibility in adolescent athletes who are involved in sports requiring jumping. Most of the 46 elite junior skaters (20 males and 26 females) in the Smith et al. (1991) study had flexibility deficit with thirty skaters having tight quadriceps and eleven having tight hamstrings. Fourteen out of forty-six skaters had anterior knee pain at the initial examination which decreased or got eliminated in nine skaters after increasing their thigh muscle flexibility. No significant association was found between the amount of recommended off-ice training and injuries in the present study but it should be noted that SSFSs sustained more overuse injuries (8) than CFSs (4) and did significantly less weekly off-ice training and spent less time stretching. The overuse injury rates for 100 hours of off-ice training were 1.75 for SSFSs and 0.41 for CFSs. These findings suggest that more off-ice training in CFSs could have possibly served as an overuse injury prevention component in the cohort of this study.

The current study's main strength is that a unique population of adolescent female figure skaters involved in STARSkate and competitive streams was investigated across the Canadian province of Saskatchewan. The importance of evaluating STARSkate figure skaters can be documented by the registration numbers (there were 1363 StarSkaters registered in 2009/2010 figure skating season versus 97 competitive skaters; personal communication with Skate Canada Saskatchewan director, November 29th, 2010). Peak height velocity measurements were included, which is an important consideration when working with adolescent athletes. The training hours' data collection allowed us to calculate the injury rate per 100 hours of training and examine if there was any association between off-ice training and injury rates. The questionnaires used open-ended questions so that skaters had freedom to expand on their answers if needed. The researcher followed up with the participants by calling them to make sure any necessary clarification was obtained.

Some of the challenges of the study included recruiting a large sample of participants and having skaters who signed up for the study send their envelope back to the researcher. Even after following-up with the skaters and being reassured that the pre-paid envelope would be mailed back, many were not received. Skaters had to self-identify themselves in the questionnaire and self-report their injuries. Accuracy of recall information is a known limitation in retrospective studies. It has been shown that more injuries were reported in a prospective study design and therefore the injury number might have been underreported (Kjaer and Larsson, 1992; Logan-

Krogstad, 2006). This study was retrospective in nature mainly because of the difference in STARSkate and competitive skaters season (STARSkaters usually skate from September till March whereas competitive skaters often skate all year long and the study started in March). Only solo female skaters were included since they represent the highest percentage of skaters although it is essential to collect male figure skaters data in the future as well.

Future studies should be prospective in design including preparatory period (critical first 4 weeks of the season) and cover all categories. Keeping a training log could assist in gaining prospective data in terms of injuries, training amounts and contents and jump attempts with a success rate. The researcher should attempt to collect data on his/her own if feasible (potentially during major competitions) as some envelopes got lost in the mail and some data was missing. Ideally, any future recruitment of figure skaters will be supported by motivated coaches who will encourage their skaters to participate since all information is confidential and the results will only help the figure skating community.

A possible follow-up to this study would be to look at STARSkate and competitive figure skaters across Canada to see whether the injury and training patterns are different between provinces. A longitudinal study looking at the injury patterns of figure skaters during the peak height velocity would be able to show whether more injuries are occurring during this period of rapid growth. It would also be interesting to compare the type and amount of off-ice training and injury precautions taken by successful athletes qualifying for national and international competitions to those of aspiring athletes. Further, a fitness testing component in the next figure skating injury study could reveal any potential relationship between athletes' fitness level and likelihood of getting injured. A comparison of available injury data reports during the old versus new judging system might be beneficial for officials to work on improving the program's requirements. Figure skaters need to be exposed to a variety of elements especially at a younger age. Having a skater only working on those elements included in the program over the whole season limits the skater for the upcoming seasons when the program requirements change.

Chapter 5

CONCLUSION

This study presents injury data and training amounts in Saskatchewanian adolescent solo female figure skaters. The injury rates per 100 hours of on-ice training, the number of acute and overuse injuries in both STARSkaters (SSFSs) and competitive figure skaters (CFSs), injury sites, training amounts, and injury prevention measures are all discussed. The findings are similar to other figure skating, ballet, gymnastics, and dance studies. Figure skaters sustain few injuries considering the number of hours of training. Skaters reported more injuries as they got older but some of the overuse injuries could have been potentially avoided by maintaining proper strength and flexibility during the years of peak height velocity. Smith et al. (1991) study has shown that regular stretching during adolescence has helped to reduce knee pain. It is rather alarming that some of skaters participating in this study do not stretch, warm-up, or cool down at all. Athletes, coaches, medical professionals, and officials should follow injury prevention recommendations available to ensure athletes a positive sport experience and lifelong participation in sports.

Club officials, coaches, and parents should provide skaters with a warm-up area (other than a dressing room or a car). Warming up needs to be an essential component for every athlete especially in Saskatchewan where winter temperatures sometimes drop to minus 40 degrees Celsius. Athletes need to be educated about the importance of injury prevention and coaches should ensure their athletes follow these recommendations. Structured off-ice classes that are safe and effective are crucial for skaters to learn warm-up, stretching, and strengthening exercises plus any other additional movements enhancing skaters overall performance on the ice.

Off-ice classes offered through the club and held at the rink would maximize the skaters' time efficiency.

Preferably, younger figure skaters should stay under coach supervision for most of the on-ice sessions to ensure that a proper technique is developed. Figure skaters are often left unsupervised after their fifteen minute lesson and they attempt excessive numbers of jumps that can have harmful effects. Coaches should also be encouraged to seek training aids that can prevent skaters from injuries (e.g. harness or video analysis system).

There are many aspects to consider when working with adolescent female figure skaters in terms of injury prevention (training with a sufficient recovery period, diet, equipment, environment, previous injury, growth and development, etc.). Preventing an athlete from getting injured is the ultimate goal for all concerned. Sufficient treatment in case of injury becomes crucial in order to avoid under-recovery. A long-term athlete development model has been developed by specialists to serve as a guideline when developing athletes. Coaches must look for ways to help skaters achieve their goals in a safe and healthy manner and never forget that every athlete is a unique individual that requires a particular approach to their training.

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APPENDIX A

Participant Instruction Sheet

University of Saskatchewan Figure Skating Research Project

<u>Instructions - please read first</u>

This envelope includes:

1. **Letter of Introduction** (please read)

2. **Parental Consent Form 2x** - PARENT(S) - please read and sign parental consent forms if the skater is under 18 years of age, keep one for your record and send one back to the researcher

3. **Assent Form 2x** - SKATER - please read and sign assent forms, keep one for your record and send one back to the researcher

4. **General and Retrospective questionnaires** (fill in; try to be as precise as possible in your answers)

5. **Measurement questionnaire** (fill in – parents' height as well)

6. **Injury questionnaire(s)** (fill in if sustained an injury – a separate form for each injury)

7. **Prepaid return envelope** (use it to send the required documents back)

8. **Check list** - see below (to check that everything is included before sending it back to the researcher)

<u>Checklist</u>

Please send the following back in the prepaid envelope as soon as possible:

- ☐ **A signed parental consent form** (signed by the parent(s) if the skater is under 18 years of age; keep one for our own record)
- ☐ **A signed assent form** (signed by the skater; keep one for our own record)
- ☐ **Filled General information questionnaire and filled Retrospective questionnaire**
- ☐ **Filled Measurement questionnaire**
- ☐ **Filled potential Injury questionnaire(s)**

APPENDIX B

Letter of Invitation to Participate in a Research Study

Letter of invitation to participate in a research study

You are invited to participate in a research study *"Injury and its relationship to training in youth female figure skaters"* that is to be the researcher's Master's thesis. The researcher is a graduate student at the University of Saskatchewan, Saskatoon. If you are interested in learning more about this study, please contact Lenka Seniglova and more details will be provided.

Researcher:
Lenka Seniglova, University of Saskatchewan, College of Kinesiology
Cell phone number: 1-306-881-5315
Home phone number: 1-306-651-1715
U of S phone number: 1-306-966-1093
E-mail address: les637@mail.usask.ca
Mailing address: College of Kinesiology, University of Saskatchewan, 87 Campus Drive, Saskatoon, SK, S7N 5B2

As a former international figure skating competitor representing the Czech Republic during the European and World Figure Skating Championships in 2001, I have experienced figure skating injuries and am familiar with the training requirements. I realize the demands that figure skating places on the athletes' bodies. Through this research, I will investigate the possible connections between training amounts and compositions in relation to figure skating injuries.

Injury data collection will help coaches, sport scientists, and doctors to have this valuable information available as there is a lack of published studies on injuries in figure skating. The connection between training and injuries in figure skating that will be revealed by this research can be used by Skate Canada Saskatchewan in figure skater development in the future. Filling out the questionnaires for this project will help you to learn how to monitor both the training amounts you do and potential injuries in case you have not started your training log yet.

Both Skate Canada Saskatchewan and Skate Canada Saskatchewan High Performance Coach, Sylvie Wandzura supports the study. They are interested in the results and encourage figure skaters to take part in the study. Your participation is voluntary, you can withdraw from the study at any time and all data collected will be strictly confidential. This research study was approved by the Research Ethical Board on January 25th, 2010.

Thank you very much for your interest in participating in this study.

Kind regards, Lenka Seniglova

APPENDIX C

Assent Form and Parental Consent Form

ASSENT FORM

You are invited to participate in a research project entitled *"Injury and its relationship to training in youth female figure skaters"*. You do not have to take part in the study, the decision is yours. Please read this form carefully, and feel free to contact the researcher to ask any questions if you have any.

Researcher: Lenka Seniglova, U of S office telephone number (306) 966 1093, Cell phone number: (306) 881-5315; Home phone number: (306) 651-1715; E-mail address: les637@mail.usask.ca; College of Kinesiology, University of Saskatchewan, 87 Campus Drive, Saskatoon, SK, S7N 5B2 Canada

Purpose and Procedure: This project will collect information about your injuries and training as it relates to your participation in figure skating. You will be asked to fill in a questionnaire that asks questions about age and involvement in figure skating; you will also be asked questions about the amount of training you do and any incidence of injury you experienced in the last figure skating season. I will call you to check if you have any questions about filling the questionnaire out. The questionnaire will take around 15 minutes to fill in.

You will be asked to fill in your height, seated height (height measured while seated) and weight as a part of one of the questionnaires. Instructions on how to provide these measures will be sent out to you. You will need your parent(s) help you with these measurements. It will take approximately 15 minutes.

Data collected during this study will be used for my thesis. The results of the study could be also presented at national conferences. Your name will not be mentioned when presenting the study results.

Potential Benefits: Keeping a training log is a great way for you to learn how to keep an eye on your training amounts as well as injuries. Completing the questionnaires will help you to establish this habit.

This study will provide valuable information for other skaters, coaches, doctors, club executives as well as Skate Canada Saskatchewan. Especially as there is a lack of research involving figure skaters.

Potential Risks: There is no risk being involved when participating in this project.
Storage of Data: The data will be securely stored at the University of Saskatchewan for a minimum of five years upon the completion of the study and will be appropriately destroyed when no longer required.

Anonymity: Your personal details or data will be kept private and will not be given to your parents, coach(es), other skaters or Skate Canada Saskatchewan. Your data will be analyzed anonymously.

Right to Withdraw: Your participation is voluntary, and you can answer only those questions that you are comfortable with. There is no guarantee that you will personally benefit from your involvement. The information that is shared will be held in strict confidence and discussed only with the research team. You may withdraw from the research project for any reason, at any time, without penalty of any sort and it will not cause anyone to be upset or angry. If you withdraw from the research project at any time, any data that you have contributed will be destroyed at your request.

Questions: If you have any questions concerning the research project, please feel free to ask at any point; you are also free to contact the researcher at the numbers provided if you have other questions. You will be informed of any new information that may affect your decision to participate. This research project has been approved by the University of Saskatchewan Behavioural Research Ethics Board on January 25th, 2010. Any questions regarding your rights as a participant may be addressed to that committee through the Ethics Office (966-2084). Out of town participants may call collect.

Follow-Up or Debriefing: An e-mail with summary of the study results will be sent out to you (or your parents) at the end of the study. I will be happy to answer any additional questions you might have.

Agreement to Participate: I have read and understood the description provided; I have had an opportunity to ask questions and my questions have been answered. I agree to participate in the research project and I understand that I may withdraw at any time. A copy of this Assent Form has been given to me for my records.

_____________________________ _____________________________

(Name of Participant) (Date)

_____________________________ _____________________________

(Signature of Participant) (Signature of Researcher)

PARENTAL CONSENT FORM

Your daughter is invited to participate in a research project entitled *"Injury and its relationship to training in youth female figure skaters"*. Please read this form carefully, and feel free to ask questions you might have.

Researcher's Supervisor: Adam Baxter-Jones, Ph.D., Telephone: (306) 966-1078, Facsimile: (306) 966-6464, Cellular: (306) 230-8145, e-mail: baxter.jones@usask.ca, College of Kinesiology, University of Saskatchewan, 87 Campus Drive, Saskatoon, SK, S7N 5B2 Canada

Researcher: Lenka Seniglova, U of S office telephone number (306) 966 1093, Cell phone number: (306) 881-5315; Home phone number: (306) 651-1715; E-mail address: les637@mail.usask.ca; College of Kinesiology, University of Saskatchewan, 87 Campus Drive, Saskatoon, SK, S7N 5B2 Canada

Purpose and Procedure: The main focus of this project is to identify the prevalence, severity and frequency of injury in female figure skaters and investigate differences between levels of skaters. The role of training and its relationship with injury and level of skating will also be identified. Your daughter is requested to fill in general information, retrospective, injury and measurement questionnaires. The general information, retrospective, injury and measurement questionnaires, assent form and parental consent form will be requested to be sent back to the researcher if your daughter decides to take part in this study. The researcher will call the participants to check if there are any questions about filling out the questionnaires. Your daughter's time commitment will be approximately 20 minutes for the general information questionnaire and for the retrospective questionnaire (both filled only once). All envelopes will be prepaid. You (the parents) and your daughter will be asked to fill in the height, sitting height and weight as a part of one of the questionnaires. Instructions on how to provide these measures will be sent out to you (the measurements will take around 15 minutes).

Data collected during this study will be used for the researcher's thesis and for 1 or more published articles. The results of the study could be also presented during an academic conference. Complete anonymity for the participants will be ensured in all cases.

Potential Benefits: Keeping a training log is a great way for young skaters to learn how to monitor their training amounts as well as injuries. This study will help coaches, sport scientists and doctors to have this injury information available as there is a lack of published studies on injuries in figure skating. The barriers for participating in more off-ice training will be identified and provide a valuable source of information for administrators, coaches and clubs executives. The results of this study will address several important issues in injury prevention and the training of youth figure skaters that the Skate Canada Saskatchewan High Performance Section could use in figure skaters' development planning in the future. These benefits are not necessarily guaranteed.

Potential Risks: There is no risk involved by participating in this project.

Storage of Data: The data will be securely stored at the University of Saskatchewan for a minimum of five years upon the completion of the study and will be appropriately destroyed when no longer required.

Confidentiality: Your daughter will be assured complete confidentiality and anonymity. Personal details and data will not be given to the participants' coach(es) or Skate Canada Saskatchewan. Only aggregate results will be reported. The questionnaires will be sent back to the researcher under identification numbers and no names will be included when working with the data or providing the results.

Right to Withdraw: Your daughter's participation is voluntary, and she can answer only those questions that she is comfortable with. There is no guarantee that she will personally benefit from her involvement. The information that is shared will be held in strict confidence and discussed only with the research team. You may withdraw her from the research project for any reason, at any time, without penalty of any sort and it will not influence your daughter's participation in figure skating events. If you withdraw from the research project at any time, any data that you have contributed will be destroyed at your request.

Questions: If you have any questions concerning the research project, please feel free to ask at any point; you are also free to contact the researchers at the numbers provided if you have other questions. This research project has been approved on ethical grounds by the University of Saskatchewan Behavioural Research Ethics Board on January 25th, 2010. Any questions regarding your rights as a participant may be addressed to that committee through the Ethics Office (966-2084). Out of town participants may call collect.

Follow-Up or Debriefing: An e-mail with summary of the study results will be sent out to the participants at the conclusion of the study. The researcher will be happy to answer any additional questions.

Consent to Participate: I have read and understood the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project, understanding that I may withdraw my consent at any time. A copy of this Consent Form has been given to me for my records.

______________________________ ______________________________
(Name of Participant's parent) (Date)

______________________________ ______________________________
(Signature of Participant's parent (Signature of Researcher)
if the skater is under 18 years of age)

APPENDIX D

General Information Questionnaire, Retrospective Questionnaire,

Measurement Questionnaire and Injury Questionnaire

University of Saskatchewan Figure Skating Research Project

General Information

Sport-related Information

1. Number of years in figure skating ________

2. The highest complete free skate test passed ______________

3. Number of years at this current level ________

4. You are currently involved in:

☐Star Skate ☐Competitive Skate ☐Both ☐Other: __________

5. Are you a member of any of the following teams in 2009-2010? If yes, please specify:
☐ Competitive Development Team ☐ SaskFirst Team ☐ High Performance Team

6. Do you participate in any other discipline than solo ladies? ☐ Yes ☐ No
If yes, please specify: ☐ Pairs ☐ Dance Team ☐ Synchronized skating

7. Do you participate in other sports on regular basis besides figure skating? ☐ Yes ☐ No

If yes, please list: ____

8. Do you use a hinged-type of boot? ☐ Yes ☐ No

9. Do you (or you coach) keep a training log? ☐ Yes ☐ No
If yes, do you include the following information?
a) The amount of hours you train ☐ Only on-ice ☐ Only off-ice ☐ Both
b) The number of jumps you attempt during every skating day ☐ Yes ☐ No
c) Your success rate when jumping ☐ Yes ☐ No
d) Your health (injury, illness) ☐ Yes ☐ No

10. Does your coach use a harness when you are learning a new jump?
☐ Yes ☐ No ☐ Sometimes

11. Does your coach regulate the maximum number of jumps you can do per day?
☐ Yes ☐ No ☐ Sometimes

12. Which is your landing leg? ☐ Left ☐ Right

Personal Information

13. Date of birth ______________
(Month/Day/Year)

14. Have you had your first menstrual period? □ Yes □ No

If yes, a) at what age did you reach it? ___________
b) Have you had amenorrhea (the absence of menstrual cycles for a length of time equal to the total time of the three previous menstrual cycles)? □ Yes □ No

15. Are you currently on a diet? □ Yes □ No
If yes, please specify ________________________________

16. List any injuries sustained prior to July 2009 (please fill in the injury questionnaire provided for any injuries sustained during and / or after July 2009 till March 2010):

a) Injuries sustained during figure skating or off-ice training (prior to July 2009):

____

b) Injuries sustained outside of figure skating (prior to July 2009):

____

17. Do you seek medical attention when injured? □ Always □ Sometimes □ Never

University of Saskatchewan Figure Skating Research Project

Retrospective Questionnaire

Transition period

(the period between the 2008/2009 and the 2009/2010 figure skating season)

18. How long was your transition period last year (in 2009)? E.g. 3 months or 3 weeks

____

19. What type of training did you do during this transition period? Check off all options that apply to your situation.

☐ None ☐ On-ice only ☐ Off-ice only ☐ Both on-ice and off-ice

☐ Cross-training (please indicate what type): ___________________________________

☐ Other (Please specify): ____

20. Were you involved in other sports than figure skating during this transition period?

☐ Yes ☐ No

If yes, please specify____

2009 summer figure skating

21. Did you figure skate during the period from July 2009 - August 2009? ☐ Yes ☐ No

If yes, please answer the following:

Indicate the time period of your summer skating ___________________________

How many hours, on average, did you skate per week? _____________________

How many hours, on average, did you do off-ice training per week?____________

Did you go to competition and/or tests? ☐ Yes (How many? ________) ☐ No

Did you get injured? ☐ Yes ☐ No

If yes, please fill in the injury questionnaire (a separate form for each injury).

If no, when did you start your figure skating season 2009/2010? _____________________

Time period of September 2009 till March 2010

22. Please indicate the number of hours for on-ice and off–ice training you did for the months listed. Think of the off-ice training as a figure skating related training. Also, how many competitions and/or tests did you go to? Write down any training time that was missed (e.g. due to Christmas break etc.)

	On-ice training Number of hours per week (on average)	Off-ice training Number of hours per week (on average)	Number of competitions and/or test you went to	Indicate any training time missed (e.g. Christmas break etc.)
September 2009				
October 2009				
November 2009				
December 2009				
January 2010				
February 2010				
March 2010				

23. Did you get injured from September 2009 till March 2010? ☐ Yes ☐ No

If yes, please fill in the injury questionnaire (a separate form for each injury).

24. How many hours of sleep did you get each night on average in the time period from September 2009 till March 2010? E.g. 8 hours/night ____________________________

Typical training week

25. Think of your typical skating week with no competition during the weekend in the last skating season (July 2009 – March 2010). How much time did you spend on the following (in minutes)? Write zero (0) for those that you did not participate in.

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
On-ice training							
Warm up before on-ice session							
Cool down after on-ice session							
Stretching /flexibility							

26. Describe your typical off-ice warm up before your on-ice session in the last skating season (July 2009 – March 2010). If you did not do any, please leave blank.

Duration (in minutes): Location:

The order and type of exercises you did:

27. Estimate how many of the following jumps you attempt on a regular on-ice session:

	Axel	Salchow	Loop	Toe loop	Flip	Lutz
Single						
Double						
Triple						

OFF-ICE training (think of the off-ice training as figure skating related training):

28. Please describe your off-ice training during the last skating season (July 2009 – March 2010). Write zero (0) for those that you did not participate in.

	Duration (in minutes)	Frequency (indicate if per week or per month)
Cardiovascular conditioning (e.g. running)		
Strengthening (e.g. core strength exercises)		
Dance (e.g. ballet, hip hop)		
Jumping (off-ice jumps)		
Gymnastics (e.g. balance)		
Relaxation (breathing exercises, muscle relaxation)		
Other - specify:		

Off-ice training (figure skating specific)

29. Over the last 9 months (July 2009 – March 2010), were you interested in attending more off-ice sessions? ☐ Yes ☐ No

If yes, what were the possible reasons that you did not attend more off-ice sessions? Check off all options that apply to your situation.

☐ No gym at the rink ☐ The skating club does not offer any off-ice training ☐ Cost

☐ No coach or instructor available to run the off-ice training

☐ Time demands, I already have too much on-ice training to do extra off-ice training

☐ Other (Please specify): ____

30. In your opinion, off-ice training is:

☐ More important than on-ice ☐ Less important than on-ice ☐ Equally important

☐ Have not thought about it

31. Do you think that off-ice training could be beneficial to you? ☐ Yes ☐ No

If yes, please list reasons why you think so:

____

Medical information

32. Have you been ill since July 2009 till March 2010? ☐ Yes ☐ No

If yes, indicate the time period ______________________________

How many days of skating did you miss due to illness since July 2009 till March 2010? ________

33. If your answer is yes to the following questions, please indicate the frequency (e.g. 2/month):
Since July 2009,

a)…have you gone for sport-related medical check-ups? ☐ Yes _______________ ☐ No
b)…have you seen a physiotherapist? ☐ Yes _______________ ☐ No
c)…have you seen chiropractic? ☐ Yes _______________ ☐ No
d)…have you gone for a massage? ☐ Yes _______________ ☐ No

University of Saskatchewan Figure Skating Research Project

Measurement Questionnaire

Skater's Date of Birth: ____________ Today's Date: ___________
(Month/Day/Year) (Month/Day/Year)

1. Equipment Required:
To perform the measures of growth you require a marker, a tape measure, a breakfast cereal box, a stool or chair and a flat surface such as the edge of a door or a wall.

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2. Standing Height

A. Stand your daughter along a flat surface with her heels and head touching the surface.

B. Place a cereal box on her head

C. With her looking straight ahead place a mark on the flat surface using the underside of the box

D. Measure the distance from the floor to the mark on the flat surface and record the distance.

Height _________ cm Or __________ inches

<u>Parents' height:</u>

Standing height of the skater's mother:

Height _________ cm Or __________ inches

Standing height of the skater's father:

Height _________ cm Or __________ inches

3. Sitting Height

A. Sit your daughter on a stool or chair. She should be sitting upright with the base of her spine flat against the flat surface, her legs together and hands by her side.

B. Place a cereal box on her head

C. With her looking straight ahead place a mark on the flat surface using the underside of the box

D. Measure the distance from the floor to the mark on the flat surface and record the distance.

Sitting Height on stool

_________ cm Or _________ inches

E. Measure the height of the stool or chair:

_________ cm Or _________ inches

F. Sitting Height = Sitting Height on stool – height of stool.

4. Weight

A. Weigh your daughter on your bathroom scale with minimal clothing and with shoes removed

B. Check the scale is reading zero

C. Ask your daughter to stand on the centre of scales, without support and with her weight distributed evenly on both feet

Weight ____________ kg Or ____________ lb

University of Saskatchewan Figure Skating Research Project

Injury Questionnaire: July 2009 –March 2010

An injury is any event that (1) requires medical attention and/or (2) there is a restriction in training or performance. Please fill in a separate form for each injury.

1.Body Part:

Head	Spine (bone)	Trunk (soft tissue)	Arm	Pelvis	Leg	Foot
□ Head	□ Neck	□ Upper Back	□ Upper	□ Hip Bone	□ Quadriceps	□ Ankle
□ Face	□ Upper	□ Lower Back	□ Elbow	□ Hip Joint	□ Hamstring	□ Achilles
□ Dental	□ Lower	□ Abdomen	□ Forearm	□ Groin	□ Knee	□ Toe(s)
	□ Sacral/ SI		□ Wrist		□ Shin	□ Sole/Arch
			□ Hand/Finger		□ Calf	□ Heel

2. Location of Injury:

□ Left □ Right

3. Nature of Injury:

□ Acute (developed suddenly) □ Overuse (developed over time; the original cause of injury cannot be proven) □ Reinjured

4. Injury Classification:

□ Fracture □ Dislocation □ Concussion □ Strain □ Stress Fracture

□ Swelling □ Scrape/Cut □ Sprain □ Tendonitis □ Other: _____________

5. Time period:

Indicate the month when the injury happened (occurred): _______________________________

6. Sustain Injury:

a) □ Off-ice when practicing:

□ Weights □ Stretching □ Yoga □ Cardiovascular Conditioning

□ Dance, ballet □ Jumping (plyometrics) □ Athletics □ Gymnastics □Other: _____________

b) □ On – ice when practicing:

□ Footwork □ Jumps: please underline relevant (single, double, triple)

□ Spins □ Spiral sequence □ Dance □ Skating Skills □ Freeskate (Short program, Long program)

□ Stroking, Field movements □ Other: _____________

c) □ Injured outside of figure skating

7. Timing of Injury: (Check off all options that apply to your situation)

□ Off-ice warm up □ First half of the practice □ when having session with a coach □ Cool down

□ On ice warm up □ Second half of the practice □ when practicing on my own □ Other: _____________

8. Cause of Injury:

□ Ice rink condition (ice, temperature) □ Fear □ Overtraining □ Fatigue □ Skate □ Fall

□ Insufficient warm up □ Collision with another skaters □ Attempting skill beyond ability □ Other: __________

9. Disposition:

□ Missed Remainder of Training/Comp. □ Missed ___ Training Days

□ Hospitalised _____Nights □ Training Modified for ___ days

10. Treatment: Did you receive medical attention? □ Yes □ No

APPENDIX E

Ethical Approval

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics Board (Beh-REB)

Certificate of Approval
Study Amendment

PRINCIPAL INVESTIGATOR	DEPARTMENT	Beh #
Adam Baxter-Jones	Kinesiology	09-269

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT
University of Saskatchewan

STUDENT RESEARCHER(S)
Lenka Seniglova

SPONSORING AGENCIES
UNIVERSITY OF SASKATCHEWAN

TITLE
Injury and its Relationship to Training in Youth Female Figure Skaters

APPROVAL OF	APPROVED ON	CURRENT EXPIRY DATE
Revised recruitment protocol	05-Mar-2010	24-Jan-2011

Full Board Meeting ☐ Date of Full Board Meeting:

Delegated Review ☒

CERTIFICATION
The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair for Research Ethics Board consideration in advance of its implementation.

ONGOING REVIEW REQUIREMENTS
In order to receive annual renewal, a status report must be submitted to the REB Chair for Board consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions: http://www.usask.ca/research/ethics_review/

John Rigby, Chair
University of Saskatchewan
Behavioural Research Ethics Board

Please send all correspondence to:

Research Ethics Office
University of Saskatchewan
Box 5000 RPO University, 1602-110 Gymnasium Place
Saskatoon SK S7N 4J8