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THE EFFECT OF WINTER VERSUS SUMMER RUNNING ON LOWER EXTREMITY MUSCULOSKELETAL INJURY RATE IN RECREATIONAL RUNNERS

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ABSTRACT

THE EFFECT OF WINTER VERSUS SUMMER RUNNING ON LOWER EXTREMITY MUSCULOSKELETAL INJURY RATE IN RECREATIONAL RUNNERS

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The effects of cryotherapy on body tissues suggest that cold exposure can decrease performance measures, including proprioception, strength, and agility. Since a decrease in proprioception and strength have been linked with an increase of injury rates, this suggests that exposure to cold conditions may increase injury rates. The main purpose of this study was to determine if there is a difference in musculoskeletal injury rates in the winter compared to the summer months in recreational runners. The participants were surveyed on their injury history for the past year. The results of this study showed that the injury rate for musculoskeletal injuries was higher in the winter months. While the numbers themselves were not significantly different, when scaled to the number of exposures, the results show that there were more injuries per exposure in the winter months than the summer months. The winter conditions of cold, icy, and hard surfaces likely account for these differences. The knee was the most common body part injured, while tendonitis was the most common type of injury sustained.

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CHAPTER 1

Introduction

Overview of the Problem

The cardiovascular benefits of running regularly have been well documented in the literature (Fletcher et al., 1996; Gent et al., 2007; Koplan et al., 1982; Lane et al., 1987; Williams 1997). These cardiovascular benefits are dose responsive to the amount of running performed (Williams 1997). However, there have been numerous epidemiological studies that have also shown an increase in musculoskeletal injury rates with physical activity, particularly with running (Almeida et al., 1999; Koplan, 1982; Lane et al., 1987). This rate of musculoskeletal injury while running changes with differing environmental conditions (Gabbett et al., 2007; Orchard & Powell, 2003), but few studies have examined the effect of winter weather conditions – freezing temperatures, snow, ice, and a frozen ground – on musculoskeletal injury rates in runners.

Previous research found mixed results regarding injuries in cooler temperatures. One study by Orchard & Powell (2003) found that cooler temperatures are associated with less ankle and knee sprains, and less anterior cruciate ligament (ACL) tears in National Football League players. This association between cooler temperatures and a decrease in injury rates has been found in other studies as well (Gabbett et al., 2007; Orchard & Powell, 2003). However, the average temperatures in these studies were above freezing, which means the ground was not frozen. When assessing ankle fracture rate in a winter with an average temperature of 1-2 ° C compared to the summer, Morris & Lovell found an increased rate of fracture in the winter months (Morris & Lovell, 2013). Studies found a correlation between the increase in injury rates for rugby, soccer, and football players with harder surfaces, which happens when the ground freezes during winter (Gabbett et al., 2007; Orchard & Powell). The studies that focused on environmental conditions and injury rates found that colder temperatures are associated with fewer injuries, but a harder surface is correlated with more injuries. None of these studies examined the effects of environmental conditions in runners. Both colder temperatures and harder surfaces can occur in the winter months, so this combination should be addressed to determine whether winter conditions are correlated with an increase or a decrease in musculoskeletal injury rates in runners.

Since there are few studies of the effect of cold weather on athletic performance, we can review the effects of cryotherapy on the body, since there is likely a similar response in the body to freezing temperatures as to cryotherapy. There have been numerous studies completed that examine the effects of cryotherapy on the body. Researchers have shown that there was peripheral cooling during acute exposures to cold (Patton & Vogel, 1984), which can mimic effects of cryotherapy on the body. In the field of sports medicine, cryotherapy has commonly been used to treat pain by decreasing tissue temperatures, inflammation, stiffness, muscle spasm, metabolism, circulation, and nerve conduction velocity (Algafly & George, 2007; Costello et al., 2010). Negative side effects of cryotherapy are uncommon, but many researchers have examined the effects of cryotherapy on various aspects of athletic performance, such as strength, agility, proprioception, joint position sense, joint laxity, and overall lower-limb function (Algafly & George, 2007; Costello et al., 2010; Evans et al., 1995; Hopkins & Adolph, 2003; Ingersoll et al., 1992; Knight & Londeree, 1980; Oliveira et al., 2010; Patterson et al., 2008; Ruiz et al., 1993; Uchio et al., 2003). Despite the numerous studies regarding the effects of cryotherapy on these performance measures, questions still remain on its effects.

Overall, there have been inconsistencies on the effects of cryotherapy on the body's ability to perform certain athletic measures. These discrepancies were likely due to the differing methods of cryotherapy used on the participants; those who endured more intense cryotherapy, such as a cold whirlpool, for longer duration had more significant affects than those with less intense methods, such as cold sprays (Costello et al., 2010). Patterson et al. (2008) found a decrease in power, speed, agility, and range of motion immediately following a cold whirlpool treatment. Additional studies have shown a decrease in concentric and eccentric strength (Ruiz et al., 1993), agility (Evans et al., 1995), joint position sense (Costello et al., 2010; Oliveira et al., 2010; Uchio et al., 2003), and range of motion (Hopkins & Adolph, 2003). However, there have been studies that show no change in sensory perception and overall lower limb function following cold therapy (Hopkins & Adolph, 2003; Ingersoll et al., 1992). Generally, cryotherapy has a negative effect on these performance measures, which may also be seen during cold weather exercise.

Statement of the Problem

A negative correlation between the ability to complete certain performance measures and the rate of musculoskeletal injury has been shown (Hewett et al.,1999; Payne et al., 1997). For instance, when there was a lack of agility and mobility in ankles, there have been higher rates of ankle injuries (Payne et al., 1997). Conversely, there was a decrease of knee injury rates when a neuromuscular training program was implemented (Hewett et al., 1999). Therefore, if there was a decrease in these performance measures that was seen with cold treatments, there will likely be a decrease in these measures when exercising in the cold. Since there was a higher rate of injury when these performance measures are decreased, a higher rate of injury may occur during winter weather conditions.

Purpose of the Research

The main purpose of this study was to determine if there was a difference in lower extremity musculoskeletal injury rates in the winter when compared to the summer for recreational runners. Because there was a decrease in neuromuscular function with cryotherapy, which can lead to increased incident of injury, I proposed that there will be an increase in injury rates in the winter. An additional purpose of this study was to examine if there was a significant difference between winter and summer injury rates for each body part and each type of injury.

Need for Study

Little research has been performed comparing running in summer conditions to running in winter conditions. As popularity of winter running increases, there was an increased need for research on this topic. There has been limited research on running in winter conditions and how running in these conditions affects injury rates. This study aimed to explore this further.

Hypothesis

The main hypothesis for this study was that there will be a higher rate of injury in the winter months when compared to the summer months. The secondary hypotheses of this study was that in both the summer and the winter, the knee will be the most injured part of the body and that a muscle strain will be the most common type of injury.

Assumptions, Limitations, and Delimitations of the Study

Assumptions

The assumptions of this study included that each subject answered each question honestly and accurately. This assumed that each subject could recall every injury that occurred in the past year, when the injury took place, the type and location of each injury, the number of days each injury kept them from running, whether the injury occurred during training or a race, and the correct average number of miles each subject ran while training. This study also assumed that, even though some were self-diagnoses, the injury diagnosis was accurate. An additional assumption was that the survey was a reliable and valid questionnaire for recording musculoskeletal injury rates.

Limitations

A limitation of this study was that the population may not be representative of the total population and the results can only be applied to populations of the same age range and to those living in a similar climate. Another limitation of this study was that it did not account for miles run on a treadmill or indoors. An additional limitation is that this study did not directly assess the surfaces being run on by each participant nor did it assess the gear that each participant was wearing while running.

Delimitations

A delimitation of this study was that the subjects reported subjective data regarding their musculoskeletal injuries, but these injuries were not necessarily verified by a physician.

Operational Definitions

An *injury* was defined as a musculoskeletal injury that occurred during running exercise, resulted in loss of time from exercise, or resulted in the consultation of a physician. Skin abrasions, such as blisters or cuts, were not included.

Injury rate was defined as the number of injuries sustained divided by the product of the number of exposures, which in this study was 1 mile run, and the amount of time, which in this study was in number of weeks in that season. This was a measure of the likelihood that an athlete will sustain an injury.

A *strain* was defined as an injury to a muscle or tendon where an acute trauma of overstretching causes the muscle fibers to tear.

A *sprain* was defined as an injury to a ligament that supports a joint and is usually caused by twisting or by stretching the fibers.

A *fracture* was defined as a broken bone caused by an acute trauma.

A *stress fracture* was defined as a break of a bone caused by repeated mechanical stress over time.

A *dislocation* was defined as the displacement of a bone at a joint.

A *tear* was defined as the rupture of a structure, including a tendon, cartilage, labrum, or meniscus.

Tendonitis was defined as the inflammation of a tendon, usually caused by overuse or repeated mechanical stress.

Winter was defined as the 22 weeks from November through March.

Summer was defined as the 30 weeks from April through October.

Methods

Participants

Permission to perform the study was granted by Northern Michigan University's International Review Board. Subjects were recruited from either a local running race or club and volunteered to join the study. They were briefed on the purpose, nature, and potential risks involved with the study. Written consent from each participant was obtained. Inclusion criteria required that each participant be a recreational runner who consistently ran outside in both the winter and summer seasons. Exclusion criteria prevented those who were unable to consistently exercise in the cold weather from being a part of this study.

Experimental Design

This was an epidemiological study to determine the injury rates of runners in both cold and warm temperatures. The independent variable of this research was the weather condition: winter or summer running. The dependent variables were the number of musculoskeletal injuries, the type of musculoskeletal injury, and days missed due to injury while running.

Survey

There were 49 participants that completed this study. Each participant was asked to fill out a survey regarding their injuries from the previous year of running which was broken into two seasons: summer and winter. For this study, summer was defined as April – October and winter was defined as November – March. The survey included questions regarding the training levels of each runner, including the average number of miles run per week, number of races performed in the previous year, and number of years of regular running training. The age, sex, and self-reported height and weight of each participant were recorded. The participants were then asked to recall the injuries sustained from the previous year of training and to distinguish whether the injury occurred in the winter or the summer months. The participants were asked only to include injuries that occurred while running, and they were given definitions of common injuries. They were asked the type of injury (strain, sprain, etc.), the anatomical location of the injury, the number of days the injury prevented the participant from running, and whether the injury occurred during a race or a training session.

Data Collection

The data collection occurred at local running races and clubs during the winter months. There was a spot at the registration table of each race for the participants to participate in the study. Once the participants completed the informed consent for the study, they were asked to complete the questionnaire regarding his or her injuries. When the surveys were completed, the results were entered into a Microsoft Excel spreadsheet and transferred to SPSS so that statistical analysis of the data collected could be performed.

Data Analysis

The data were analyzed using IBM® SPSS® Statistics Version 21 by determining the incidence of an injury by determining the number of new injuries over the past year compared to the number of chances, or miles run, of developing an injury over the past year. This was done by dividing the total number of injuries sustained in a specific season by the total number of miles run per season. For example, one participant sustained 1 injury in the winter and ran an average of 25 miles for 22 weeks in the winter, which equals a total number of 550 miles in the season. The calculation of $1/550 = 0.0018$, which is the rate of injury per miles of exposure. The injury rates of all the participants were compared between the winter and summer months by performing a paired samples t-test on the data. Two Chi-squared tests were then performed to determine if there was a significant difference between the number of winter and summer injuries for (1) each body part and (2) each type of injury. The odds and risk ratios were then calculated.

Results

Descriptive Statistics

All 49 participants successfully completed the survey. The average age of the participants was 42.02 ± 12.91 years; the average height was 68.39 ± 4.62 inches; the average weight was 157.16 ±24.22 pounds; the average number of years training was 14.54 ± 12.16. The descriptive information on the participants' running habits is listed in Table 1. In the winter, there were 25 injured and 24 participants not inured; in the summer, there were 23 participants injured and 26 were not. In total there were 67 injuries. The breakdown of the anatomical location of these injuries is listed in Table 2. The breakdown of the type of injuries is listed in Table 3. The average number of days missed from a winter injury was 10 days with a range of 0-150 days while the average from a summer injury was 13.5 days with a range of 0-84 days. In the winter, 30 injuries occurred while training and 9 occurred during a race. In the summer, 17 injuries occurred while training and 8 occurred during a race.

Variable	Winter	Summer
Miles per Week	29.64 (15.23)	42.9 (16)
Total Miles	652.14 (334.98)	1288.16 (498.99)
Number of Races	1.96 (1.32)	6.85 (4.28)

Table 1. Descriptive characteristics of participants running habits, mean (standard deviation).

Body Part of Injury	Winter	Summer	Total
Head	0	0	0
Neck	0	0	0
Shoulder	2	0	2
Arm	0	0	0
Elbow	0	0	0
Forearm	1	0	1
Wrist	1	0	1
Hand	0	0	0
Upper torso	0	1	1
Lower abdomen	1	0	1
Upper back	0	0	0
Mid-back	0	0	0
Low back	1	0	1
Hip	5	2	7
Thigh	3	4	7
Knee	11	6	17
Lower leg	4	2	6
Ankle	6	6	12
Foot	4	6	10
Toe	1	0	1
Total	40	27	67

Table 2. The number of injuries per anatomical location in the winter and summer.

Figure 1. The percentage of injuries per anatomical location in the winter months.

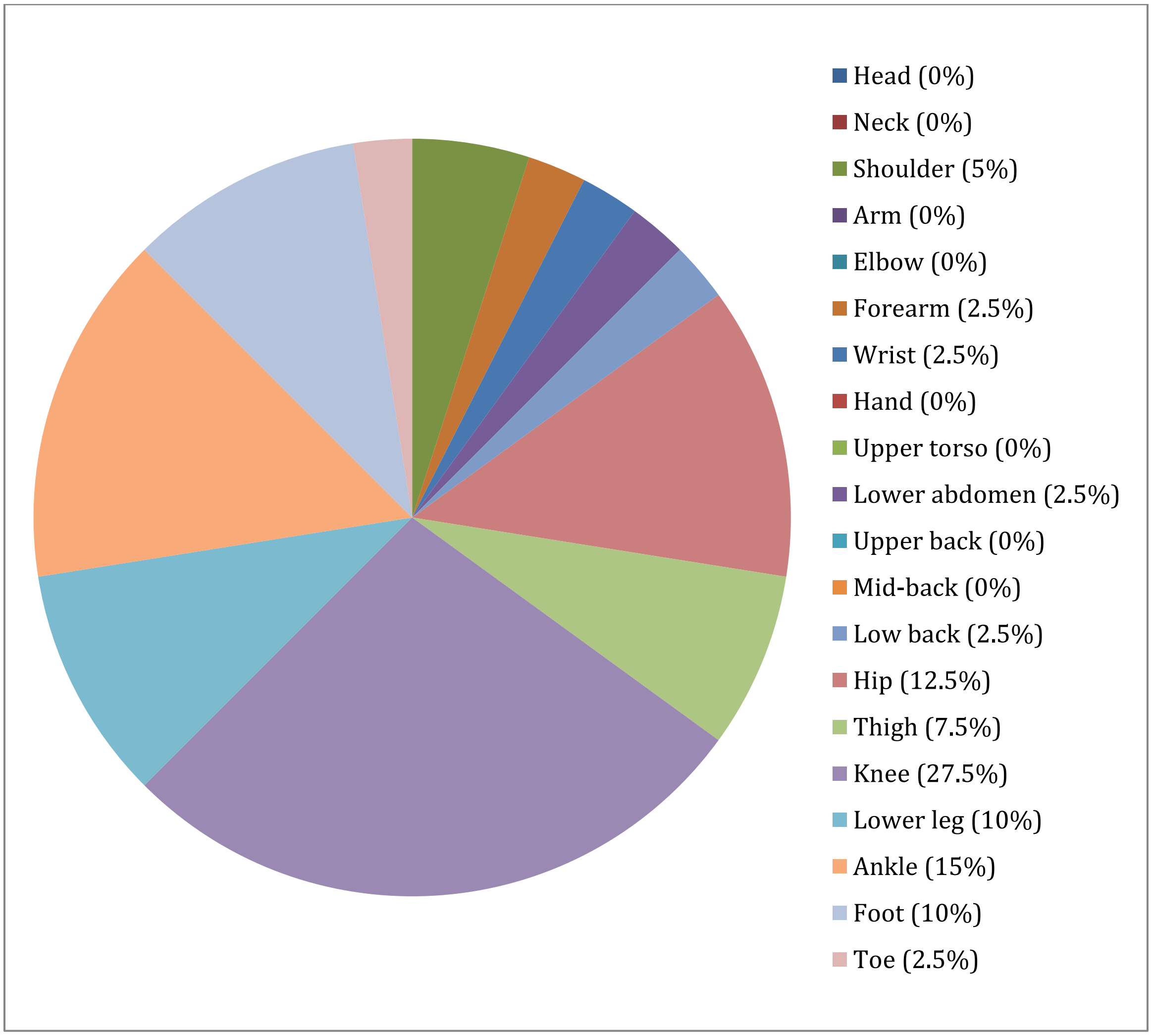
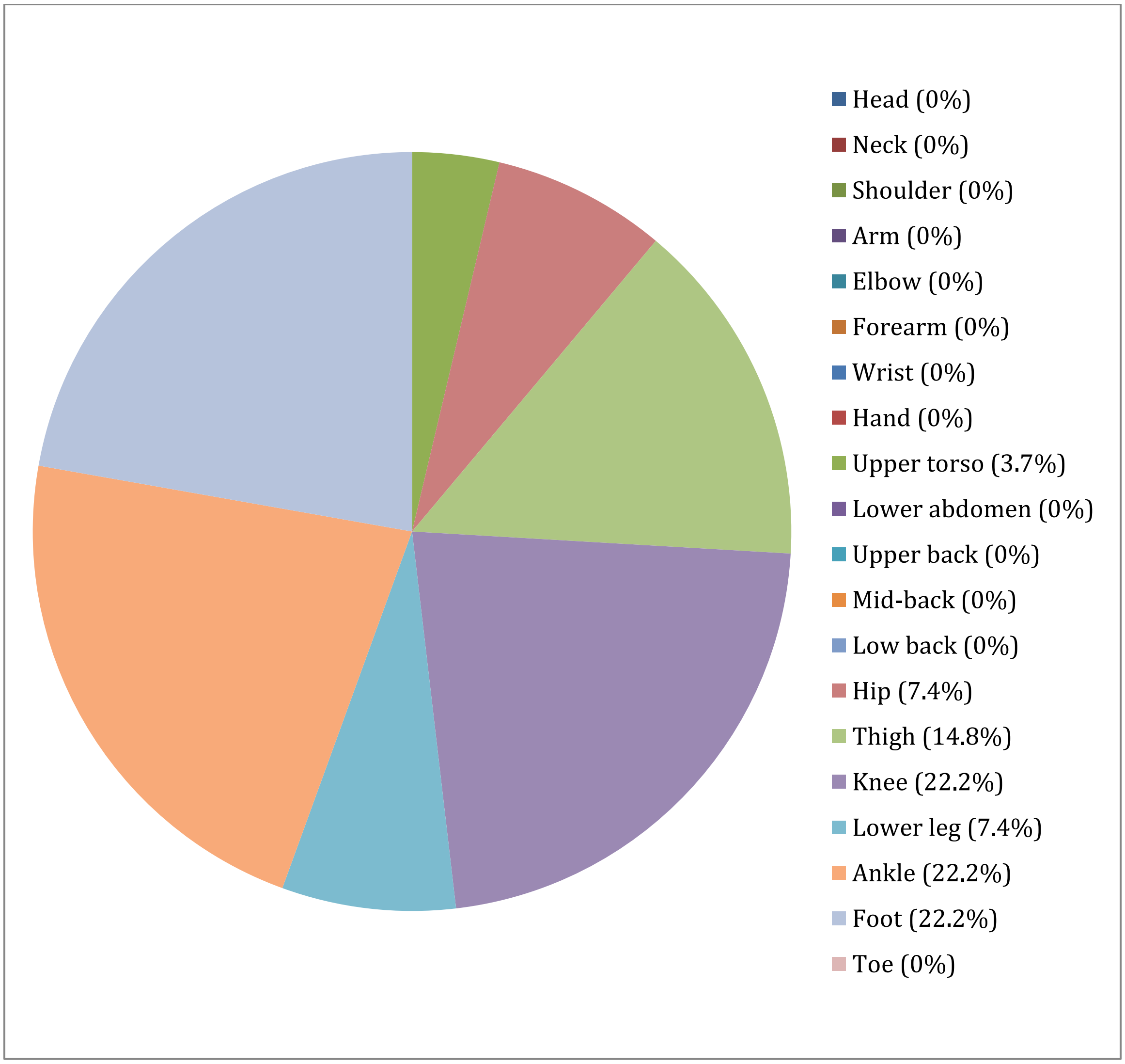


Figure 2. The percentage of injuries per anatomical location in the summer months.



Type of Injury	Winter	Summer	Total
Strain	16	9	24
Sprain	3	0	3
Fracture	0	1	1
Stress fracture	0	0	0
Dislocation	0	0	0
Tear	2	0	2
Tendonitis	14	15	29
Other	5	2	7

Table 3. Frequency of the type of injury in the winter and the summer.

Rate of Injury

The number of injuries in the winter when compared to the summer was not significantly different (P = 0.156). The amount of miles run in the winter compared to the summer was significantly different (P = < 0.0001). When the number of injuries was scaled to account for the number of exposures, or miles run, the rate of injury was statistically significantly different (P = 0.029) with more injuries occurring in the winter months. When the injury rate was calculated to account for total miles run per season, the injury rate was also statistically significantly different (P = < 0.0001).

The Chi-squared test results determined that each type of injury occurred with equal probability (P = 0.993). The Chi-squared test to determine whether each anatomical body part was injured with equal probability was not significantly different (P = 0.082). The odds ratio comparing winter and summer injuries was 1.177; the risk ratio was 1.087.

Discussion

These results show that the injury rate for musculoskeletal injuries is higher in the winter months. Although the number itself was not significantly different, when scaled to the number of exposures, the result is that there are more injuries per exposure in the winter months than the summer months. This increase in injury rates in the winter months is likely due to the environmental conditions. Winter in the northern mid-west creates cold, snowy, and icy conditions, which most likely accounts for the increase in injury rates. Since the odds ratio is greater than 1, the risk of a participant being injured in the winter is slightly higher than in the summer. However, this ratio does not account for participants who were injured more than once, which occurred 15 times in the winter and 3 times in the summer.

As hypothesized, the knee was the most common body part injured, followed by the ankle and the foot. This is consistent with previous studies on musculoskeletal injury rates; however, the rate of injury to the knee was not statistically significantly different than from any other body part (Gent et al., 2007; van Middelkoop et al., 2008). Muscle strains were hypothesized to be the most common type of injury; however, they were the second most common. Tendonitis was the most common type of injury, but was not statistically significantly different from the rate of all other types of injuries.

Most of the injuries occurred during training. However, 23% of winter injuries occurred during a race while 47% of summer injuries occurred during a race. This shows the importance of medical staff at both winter and summer races to ensure the safety and health of all participants (Koplan et al., 1982).

Much more research on musculoskeletal injury rates in below freezing temperatures should be performed. Most of the current literature on athletes in these conditions has focused on “cold injuries” instead of musculoskeletal injuries. However, more focus should be put on musculoskeletal injuries since 51% of participants in this study reported being injured in the past winter. This research should examine the specific reasons for the increase in musculoskeletal injuries, whether it is the cold, the icy conditions, the hard surfaces, a combination of these factors, or if other factors are involved. Further research should also look at whether the use of winter running gear aids, including YakTrak Ice Grippers or Ice Trekkers Spikes Traction, in the decrease of injury rates so that runners can be better informed on possibly preventing or minimizing risk of winter injuries.

Perspective

The results of this study showed that the injury rate for musculoskeletal injuries was higher in the winter months. While the numbers themselves were not significantly different, when scaled to the number of exposures, the results show that there were more injuries per exposure in the winter months than the summer months. The winter conditions of cold, icy, and hard surfaces likely account for these differences. The knee was the most common body part injured, while tendonitis was the most common type of injury sustained, as found in previous literature (Gent et al., 2007; van Middelkoop et al., 2008).

This research demonstrates the importance of safety while running the in the winter months in the northern United States. This information is useful for runners who want to know the risks of running outdoors in these conditions. These findings are also important for physicians, physical therapists, athletic trainers, and other health care professionals that may help in the prevention or rehabilitation of musculoskeletal injuries. Future research should examine the rate of musculoskeletal injuries endured while exercising in the harsh conditions of Northern winters, including the exact mechanisms of injury or the potential benefit of winter running aids, such as YakTrak's.

CHAPTER 2

Literature Review

The purpose of this study was to determine whether there was a difference in injury rates when running in the winter versus the summer months. In order to gain a complete understanding of previous research on this topic, the literature review was divided into five sections: (1) musculoskeletal injury rate with running, (2) effect of environmental conditions on injury rates, (3) effects of cryotherapy, (4) performance measures and injury rates, and (5) summary of the literature.

Musculoskeletal Injury Rates with Running

Much of previous research in musculoskeletal injury rates has focused on running. There have been many positive effects of running described in the literature, such as a decreased risk of cardiovascular disease and other chronic illnesses, and weight loss (Gent et al., 2007; Koplan et al., 1982; Lane et al., 1987). An additional benefit of beginning a running program was that 81% of males and 75% of females quit smoking once they started to run (Koplan et al., 1982). Despite the benefit of decreased risk of cardiovascular diseases, there was an increase in musculoskeletal injuries associated with running, according to various research groups (Gent et al., 2007; Koplan et al., 1982; Lane et al., 1987; Van Middelkoop et al., 2008; Rauh et al., 2006).

In a current literature review of injury incidence rates during running, Gent et al. (2007) found a range of 19.4% to 79.3% of lower extremity injuries. When non-lower-extremity injuries were studied, there was an injury incident rate of 26.0% to 92.4%. There was a strong positive correlation between the mileage run per week and the incidence of injury. Interestingly, there was only limited evidence that an increase in the number of days running was positively correlated with an increase in injuries (Gent et al., 2007; Koplan et al., 1982). There has been evidence that being older and a female, and having a higher quadriceps angle (Q-angle), especially one greater than 20°, are significant risk factors for injury (Gent et al., 2007, Rauh et al., 2006). However, the biggest predictor of an injury was a history of previous injuries (Gent et al., 2007, Rauh et al., 2006). Koplan et al. (1982) found that one-third of participants in a 10K race reported various types of musculoskeletal injuries, but only about one-seventh of total participants sought out medical consultation for their injury. This indicated that only about 14% of race participants were injured severely enough to seek medical attention (Koplan et al., 1982).

In general, the most common anatomical location for injuries noted in the literature was the knee (Gent et al., 2007; van Middelkoop et al., 2008). In the year preceding a marathon, 30.7% of the total injuries occurred at the knee, according to a study by van Middelkoop et al. (2008). Furthermore, the next most commonly injured body parts in the year leading up to the marathon were: the calf (23.3%), foot (14.6%), Achilles' tendon (13.6%), shin (12.6%), and thigh (12.3%) (van Middelkoop et al., 2008). During a marathon, 33.9% of the injuries sustained were to the calf, and 27.1% were to the knee (van Middelkoop et al., 2008). In the year leading up to the race, only 5.3% of injuries occurred at the toes, but this injury increased to 13.6% during the marathon (van

Middelkoop et al., 2008). In a study examining only high-school-aged distance runners, the shin was the most common body part injured at the beginning of the season with an incidence rate of 36%, followed by the knee at 25% (Rauh et al., 2006). When examining U.S. Marine Corps recruits, the ankle/foot region accounted for 34.3% of injuries with 28.1% of the injuries coming from the knee (Almeida et al., 1999). This discrepancy in the literature may be attributed to the classification of injury locations, since Almedia et al. (1999) combined the foot and ankle into one category. While there have been a large number of body parts potentially injured while running, running has still been linked to improved overall health (Lane et al., 1987).

One study by Lane et al. (1987) compared 98 long-distance runners aged 50 to 72 years of age to 365 non-runners on overall health status. By using a modified Health Assessment Questionnaire Disability Index, they determined that runners had less physical disability and more functional capacity than their age-matched counterparts. Overall, the runners sought out medical services less often, but one third of their visits to a physician were for injuries caused by running. However, the rate of musculoskeletal disability developed slower for the runners than for the control group. This development occurred in both upper and lower extremities, which suggested that even though runners experienced more musculoskeletal injuries, their overall musculoskeletal function was better.

Effect of Environmental Conditions on Injury Rates

Cold Temperatures

As outlined by the National Athletic Trainers' Association position statement on environmental cold injuries (2008), there are certain injuries that can only be sustained when exposed to cold environments, called cold injuries, which include hypothermia, frostbite, chilblain (pernio), and immersion (trench) foot (Cappaert et al., 2008). Hypothermia, the decrease in core body temperature below 35° C, is classified as mild, moderate, or severe depending on the amount of core temperature drop below average. It has a range of symptoms from shivering, pallor, and decreased blood pressure to impaired mental function, loss of consciousness, bradycardia, and cardiac arrest depending on the severity of the hypothermia and core body temperature loss (Cappaert et al., 2008).

Frostbite is defined as the freezing of body tissues and had three stages of worsening severity: frostnip, mild frostbite, and severe frostbite (Cappaert et al., 2008). This injury occurs because blood is shunted away from peripheral tissues and sent to the body's core to maintain the core temperature as a survival mechanism (Cappaert et al., 2008). Frostnip is the first stage of frostbite where superficial skin is frozen and the tissues are not permanently damaged (Cappaert et al., 2008). The second stage is mild frostbite where skin and subcutaneous tissues are frozen (Cappaert et al., 2008). The final stage is deep frostbite where tissues below the skin and adjacent tissues freeze, which can include the freezing of muscle, tendon, and bone (Cappaert et al., 2008).

Chilblain, or pernio, is an exaggerated inflammatory response to exposure in cold environments (Cappaert et al., 2008). This injury typically occurs with hours or days of cold exposure (Cappaert et al., 2008). It is defined by prolonged constriction of the skin's blood vessels, which results in decreased oxygen to the tissues, vessel wall inflammation, and possible edema in the dermis (Cappaert et al., 2008). It most commonly occurs at the hands and feet and can occur with or without frostbite present (Cappaert et al., 2008). Similar to chilblain, immersion foot usually happens with lengthy exposure to cold temperatures (Cappaert et al., 2008). This injury is associated with a loss of sensation, burning, tingling, and pain in the affected extremity (Cappaert et al., 2008). It most commonly occurs with prolonged contact with wet footwear (Cappaert et al., 2008).

While these injuries may be severe, they have not been as common as they once were (DeGroot et al., 2003). A study following the U.S. Army's rate of cold weather injuries showed a decrease in the number of cases that resulted in hospitalization from about 30 cases per 100,000 soldiers in 1980 to almost zero in 1999 (DeGroot et al., 2003). Frostbite was the most common injury reported, accounting for 43.8% of all cases of cold weather injuries. These drops in cold weather injury rates were, in part, attributed to following proper guidelines, which lead to better preventative practices. With prevention in mind, the National Athletic Trainers' Association has 48 points in their recommendations for the prevention and recognition and treatment of cold weather injuries. Important preventative suggestions include a pre-participation exam to identify at-risk participants; educating participants on cold injuries, proper hydration, proper diet, and proper clothing for cold and dry or wet conditions; and proper aid stations that allow for rewarming if necessary (Cappaert et al., 2008).

A study by Burtscher et al. (2012) supported these guidelines on proper clothing during running in the cold. They found that exercising at 70% VO_{2max} for one hour was enough to maintain core temperatures so protective clothing was not necessary. However, after one hour of exercise at 70% VO_{2max} or during low-intensity exercise below 70% VO_{2max} protective clothing was necessary to keep core temperatures at comfortable levels.

These researchers suggested using gloves, a polyester cap, a lightweight windbreaker jacket, and pants to maintain core body temperatures.

Although cold weather injury of the type mentioned above can be severe for athletes exercising in the cold, musculoskeletal injuries are a primary concern too and the focus of the current study. Notably, there has been limited literature on the incidence of injury rates in the cold when running; however, information related to other forms of exercise exists. One study examined the injury rates of Australian rugby players and found no difference in injury rates in warm and cold temperatures during competition (Gabbett et al., 2007). One possible reason for no difference between temperatures was that the coldest temperature recorded during the study was only 5° C (41° F). Therefore, the temperatures documented were higher than is commonly observed during winters in the northern United States. They did find, however, that when temperatures fluctuated, ground conditions changed, which may have affected injury rates, discussed in the next section.

Another study that investigated unstable environmental temperature conditions was completed by Orchard & Powell (2003). They looked at the injury rate of athletes in the National Football League. Their study found that playing football on grass in cool temperatures, defined as below 21 °C, decreased the risk of knee injury by 31% and ankle injury by 32% when compared to playing in hot temperatures, or anything above 21 °C. The combination of playing on grass in a cool and dry environment decreased the rate of knee injuries by 25% and ankle injuries by 31%; while playing on grass in a cool and wet environment decreased the injury rate by 42% in the knee and 36% in the ankle. However, because this study classified "cool" temperatures as those below 21°C, it is not comparable to winter temperatures that are below freezing (0°C), often seen in northern climates of the United States. Another limitation to this study was that injuries were reported at the beginning of a football season, when warmer temperatures were more likely to occur.

A third study, by Morris & Lovell (2013), examined the seasonal variance of ankle fractures in the general population. Over the course of two years, in which the winter average temperature was 1-2 °C, the number of diagnosed ankle fractures was studied (Morris & Lovell 2013). The researchers found that there was a higher rate of ankle fractures in the winter months. The researchers speculated that this was due to the icy conditions found in the winter months. These results are consistent with the hypothesis that more musculoskeletal injuries will occur in the winter months in this study. Another factor that may affect outdoor running injuries is the difference in surface conditions, discussed below.

Hard Surfaces

Surface conditions are different in the summer compared to the winter months. Specifically, the surface is harder in the winter months when the ground freezes. Studies by Gabbett et al. (2007) and by Orchard & Powell (2003) assessed the injury rates with different environmental conditions. Gabbett et al. (2007) found that harder ground conditions, which occur after limited rainfall, were associated with a higher rate of injury. Orchard & Powell (2003) also determined that wet conditions on grass fields decreased the rate of injury when compared to the control, but so did dry conditions. The control surface was turf, not a grass, field, which may account for the decrease in injury risk in both wet and dry surfaces when compared to the control. These studies illustrated that surface conditions significantly influenced injury rates, with hard ground conditions associated with an increased rate of injury.

The aforementioned variations in surface conditions may have also affect running technique and kinematics. For instance, a study by Hardin et al. (2004) found that with a harder surface, increased ankle, knee, and hip flexion velocities occurred in conjunction with change in posture. Consequently, the study participants improved their metabolic cost of running. There was also an increase in vertical ground reaction force upon contact with a harder surface, which suggested that the participants changed their normal running mechanics and underwent additional impact shock in order to minimize metabolic cost. Ultimately, the rise in impact forces associated with a hard surface increases the stress put on the musculoskeletal system, which could potentially increase injury rate (Hardin et al., 2004).

Effects of Cryotherapy on the Body

Effects on Body Tissues

Cryotherapy has often been used as a form of treatment for musculoskeletal injuries to reduce pain, soreness, and inflammation. While the cryotherapy affects the skin and subcutaneous tissue quickly, the deeper muscle tissues' temperature might increase initially, but eventually decrease, with the cooling effects lasting for several hours in the muscle tissues (Swenson et al., 1996). However, these cooling effects might be reversed with exercise immediately after cryotherapy (Myrer et al., 2000; Ruiz et al., 1993). Researchers also found that exercise following cryotherapy increased the return to normal concentric strength, with no effect on return to eccentric strength (Ruiz et al., 1993).

Therefore, those who exercised following the use of an ice bag for 25 minutes were able to recover their concentric strength faster if they exercised following the intervention than if they were simply resting (Ruiz et al., 1993). This delay in eccentric strength might effect a person while running downhill, which might cause an increase in injuries.

Aside from using exercise post cold treatment to possibly restore strength rapidly, decreases in tissue temperatures result in a reduced metabolic rate in the affected area, which resulted in a decreased inflammatory response (Ruiz et al., 1993, Swenson et al., 1996). Similarly, the decrease in tissue temperatures resulted in a decreased vascular response due to vasoconstriction (Swenson et al., 1996). This decrease in blood flow occurred most rapidly at the beginning of the cooling treatment, but these effects generally did not last (Swenson et al., 1996). Any decrement in inflammation with cold treatment has been known to have an analgesic effect on the injured area.

This reduction of pain also occurred because of the decrease in nerve conduction velocity with cryotherapy, which could actually cease nerve conduction (Algafly & George, 2007; Swenson et al., 1996). Algafly & George (2007) found that a cold application of 10°C for about 26 minutes resulted in a 33% reduction in nerve conduction velocity. Within these same parameters, there was a significant increase in both pain threshold and pain tolerance following ice application. The relative difference in pain threshold in the treated side from the control side was 89%; the difference in pain tolerance was 76% when compared bilaterally. These numbers showed that cryotherapy was an effective and economical analgesic treatment.

Since a decrease in nerve conduction velocity with cryotherapy has been shown, it might be possible that this would affect sensation at the area undergoing treatment. However, there has been little in the literature to support this theory. Ingersoll et al. (1992) examined three different measures of sensation following ankle immersion into either a 1°C cold treatment or a 40°C hot treatment. The sensation tests used measured the three categories of sensation: superficial, deep, and combined. They found no significant difference between any of the three tests (the hot, the cold, and the control groups). Therefore, this group of researchers concluded that cryotherapy had no effect on sensation. Similarly, Rubley et al. (2003) determined that there was no change in accuracy and precision in hand movements after a 15-minute ice bath immersion of the arm. They did find a significant decrease in the sensation of pressure post-treatment, but there was no overall effect on proprioception (Rubley et al., 2003). These studies suggest that there was no change in sensation during warm or cold exposure. However, the treatments might not have been applied for a long enough period of time or were not cold enough for sensation to be altered. Overall, exposure to cold decreased tissue temperature and reduced pain by the vasoconstriction of blood vessels and the decrease of nerve conduction in the exposed area.

Effects on Performance Measures

Although the above mentioned studies showed no effect of cold on either sensation or proprioception, other studies have examined how cryotherapy affects certain performance measures, specifically agility, strength, power, range of motion, proprioception, and joint position sense. Agility is the ability to perform coordinated movements over a specific period of time and has been shown to be an indicator of functional performance (Evans et al., 1995). Following a 20-minute ice immersion of just one ankle, Evans et al. found no significant difference in performing three different agility tests when compared to a control. However, Patterson et al. (2008) found there to be a decrease in agility at 2 and 7 minutes following a 20-minute ice immersion of both lower legs from below the knee. Then, at 12 minutes to 32 minutes, there was no difference versus the control group. These differences were likely attributed to the fact that Evans et al. (1995) only had their participants put one ankle into the cold immersion bath, while Patterson et al. (2008) had their participants put both legs below the knees into the cold tub.

Patterson et al. (2008) also found other decrements following lower leg immersion into an ice bath. There was a decrease in ankle active range of motion with dorsiflexion at 7 and 12 minutes. However, there was no difference in dorsiflexion range of motion at 2 minutes and after 17 minutes. There was also no difference with the other ankle motions tested: plantar flexion, inversion, or eversion. Forty yard dash times for speed were significantly increased at 2, 7, 12, and 22 minutes following cryotherapy, but this increase was not seen at 17, 27, and 32 minutes post cold whirlpool immersion. Both peak and average power, measured by a counter movement vertical jump test, were lowered following cold immersion. These finding suggest that range of motion, speed, and power might all be negatively affected by exposure to the cold, which may affect injury rates.

In a similar study, Ruiz et al. (1993) examined the effects of an ice bag on concentric and eccentric strength of the quadriceps muscle group. They found that immediately following the 25 minutes of cryotherapy, there was a significant decrease in both concentric and eccentric muscle strength. There was no change in concentric strength at either 20-minutes or 40-minutes post-intervention, however there was a still a decrease in eccentric strength at both 20- and 40-minutes after icing. These findings were consistent with the idea that exposure to cold temperatures negatively effects performance measures, in this case eccentric and concentric muscle strength.

Multiple studies have examined the effects of cryotherapy on joint position sense with mixed results (Costello et al., 2010; Oliveira et al., 2010; Uchio et al., 2003). Joint position sense is the ability of a person to perceive and reproduce joint location and is an important component of proprioception, which has been correlated to better performance in running (Costello et al., 2010; Oliveira et al., 2010). Some studies found that joint position sense was reduced immediately following a cryotherapy intervention. One study found that, regardless of if the ice treatment was placed over the quadriceps muscle group or directly over the knee, there was a significant decrease in both the absolute and relative angular error in determining joint position sense (Oliveira et al., 2010). Another study by Uchio et al. (2003) found a significant decrease in the side-to-side difference of the joint position. However, a study by Costello et al. (2010) found there was no difference in knee joint position sense following a cold whirl pool immersion treatment. Studies that have delved into the topic of overall lower chain function following a cryotherapy treatment have not found a difference when compared to pre-test measures (Atnip & McCrory, 2004; Hopkins & Adolph 2003). There might be discrepancies within the literature on the effects of cryotherapy on joint position sense because of the differing specific cold modality used, time of exposure, and individual differences in the response to cold exposure. However, cryotherapy appeared to negatively effect a person's proprioception, which might increase the risk of injury.

Performance Measures and Injury Rates

A variety of studies have examined how performance measures (strength, flexibility, proprioception) can affect injury rates. One study by Payne et al. (1997) inspected the effects of ankle strength, flexibility, and proprioception on the incidence of ankle injuries in basketball players. They did not find ankle joint muscle strength or heel cord flexibility to be predictors for ankle injury. However, they did find that decreased proprioception, especially decreased left inversion proprioception, was a risk factor for ankle injuries.

Another study examined the influence of core stability on lower extremity injury rates (Leetun et al., 2004). They found hip external rotators and hip abductor muscle weakness to be the biggest predictor of injury. Excessive femoral adduction and internal rotation have been linked to increased knee injuries, particularly patellofemoral pain. Another risk factor for injuries is a decrease in core muscle capacity. The ability to both generate and maintain force in the lumbo-pelvic-hip complex was negatively correlated to injury (Leetun et al., 2004). The study by Payne et al. (1997) and Leetun et al. (2004) suggested that increased strength and proprioception could lead to decreased injury rates.

Summary of the Literature

The current literature regarding injury rates on runners in the winter and summer has multiple components. The overall health of individuals who frequently run have been better than their non-exercising counterparts, and more people have been using running as a form of exercise (Gent et al., 2007; Koplan et al., 1982; Lane et al., 1987). As the popularity of running increased, so did the frequency of musculoskeletal injuries associated with both training and racing for runners (Gent et al., 2007; Koplan et al., 1982; Lane et al., 1987; van Middelkoop et al., 2008; Rauh et al., 2006). The majority of injuries occurred in the lower extremities. The most common body part injured is the knee, followed by the foot and ankle (Gent et al., 2007; van Middelkoop et al., 2008; Rauh et al., 2006).

There seemed to be a trend toward more people running, including an increased rate of training during potentially harsh winter conditions. Individuals who run in cold temperatures are more at risk for cold injuries, such as hypothermia and frostbite (Cappaert et al., 2008). Although previous research has determined that cooler temperatures were associated with fewer injuries, no research has been completed on musculoskeletal injuries on runners who were exercising near or below freezing temperatures (Gabbett et al., 2007; Orchard & Powell, 2003). However, current research has also determined that hard surfaces are associated with more injuries, which is observed when the ground freezes during the winter months (Gabbett et al., 2007; Orchard & Powell, 2003). There was an increase in the incidence of ankle fractures in the winter months when compared to the summer months when assessing the general population (Morris & Lovell 2013). Therefore, there is a need for research to assess the injury rates of musculoskeletal injury rates in athletes during winter-like conditions.

While there is a lack of research on outdoor cold conditions, there have been many studies that examine the effects of cryotherapy on the body. Researchers have found that there was an immediate decrease in the skin and subcutaneous tissue temperatures, with a subsequent decrease in the muscle tissue temperature (Swenson et al., 1996). The muscle tissue temperature drop lasted for several hours even once the treatment was removed. However, research has shown that muscular rewarming occurred more quickly when an individual exercised following cryotherapy (Myrer et al., 2000; Ruiz et al., 1993). This suggested that exercising in cold temperatures might have different effects on the body versus exercising immediately after a cold treatment.

There have been mixed results in the literature regarding cryotherapy and performance measures. In general, proprioception, strength, and agility have all been found to decrease following cold interventions (Evans et al., 1995; Costello et al., 2010; Oliveira et al., 2010; Patterson et al., 2008; Ruiz et al., 1993). A decrease in proprioception and strength has also been linked to an increase in injury rates (Leeton et al., 2004; Payne et al., 1997). Therefore, if a cold environment had a negative effect on performance measures, and a decrease in performance measures was linked to a higher injury rate, I hypothesized that cold environments would lead to an increase in musculoskeletal injury rates. The main purpose of this study was to determine if there was a significant difference in musculoskeletal injury rates in the winter compared to the summer.

CHAPTER 3

Summary & Conclusions

Summary

While there are many known cardiovascular benefits associated with routine running, there is a higher risk of musculoskeletal injury with the more mileage a person runs (Gent et al., 2007; Koplan et al., 1982; Lane et al., 1987; Van Middelkoop et al., 2008; Rauh et al., 2006). Another potential increase in risk of musculoskeletal injury is winter weather conditions, including cold, icy, and hard surface conditions; however, more research on this topic should be examined (Gabbett et al., 2007; Morris & Lovell 2013; Orchard & Powell, 2003). The effects of cryotherapy on body tissues suggest that cold exposure can decrease performance measures, including proprioception, strength, and agility (Evans et al., 1995; Costello et al., 2010; Oliveira et al., 2010; Patterson et al., 2008; Ruiz et al., 1993). Since a decrease in proprioception and strength have been linked with an increase of injury rates, this suggests that exposure to cold conditions may increase injury rates (Leeton et al., 2004; Payne et al., 1997).

The main purpose of this study was to determine if there is a difference in musculoskeletal injury rates in the winter compared to the summer months in recreational runners. The hypothesis is that there will be a higher rate of musculoskeletal injury in the winter months. A secondary purpose of this study is to examine if there is a difference in the injury rates for each body part and each type of injury, in which I hypothesize the knee will be the most injured body part and a muscle strain will be the most common type of injury.

Conclusions

The results of this study showed that the injury rate for musculoskeletal injuries was higher in the winter months. While the numbers themselves were not significantly different, when scaled to the number of exposures, the results show that there were more injuries per exposure in the winter months than the summer months. The winter conditions of cold, icy, and hard surfaces likely account for these differences. The knee was the most common body part injured, while tendonitis was the most common type of injury sustained (Gent et al., 2007; van Middelkoop et al., 2008).

Future research should further examine the rate of musculoskeletal injuries endured while exercising in the harsh conditions of northern American winters. It would also be beneficial to examine the exact mechanisms that increase the rate of injury in the winter months. This research should also determine the effects of winter weather running aids, such as YakTrak Ice Grippers or Ice Trekkers Spikes Traction, on the rate of musculoskeletal injuries.

Appendix A

Survey

The effect of winter versus summer running on lower extremity musculoskeletal injury rates in recreational runners.

Name:

Age:

Sex:

Height:

Weight:

How many years have you been training regularly by running?

How many miles/week do you average in the winter (November-March)?

How many races have you done this winter?

How many miles/week do you average in the summer (April-October)?

How many races have you done this past summer?

In this section, you will be asked about your injury history from the past year. Please only include injuries that were sustained while running. Please do not include skin abrasions, such as blisters or cuts.

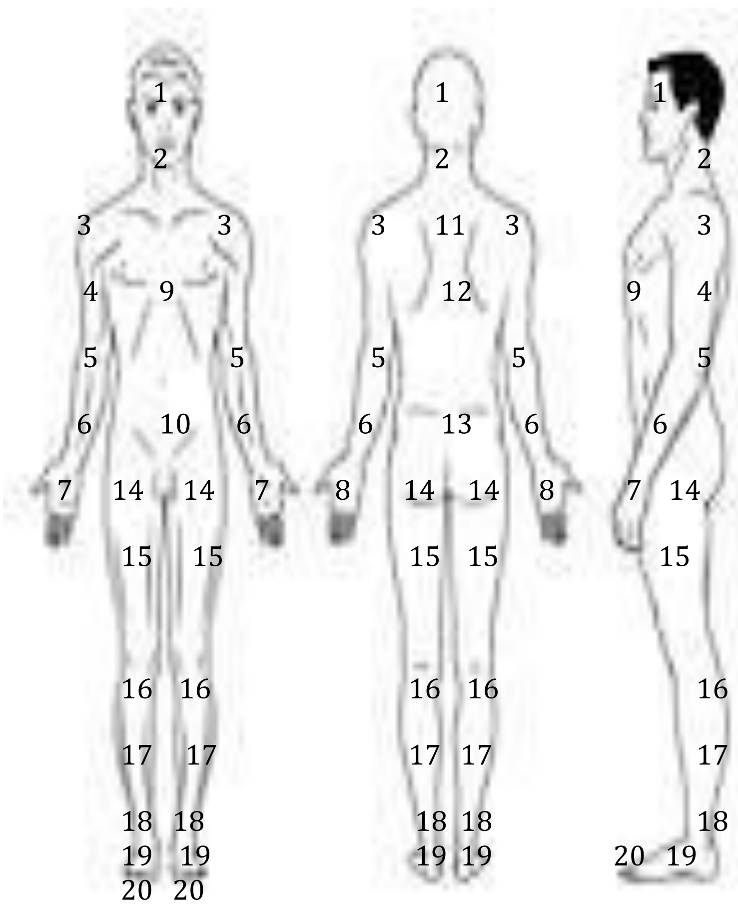
Common types of injuries:

> Strain: an injury to a muscle or tendon where an acute trauma of overstretching causes the muscle fibers to tear.
>
> Sprain: an injury to a ligament that supports a joint, usually caused by twisting or stretching the fibers.
>
> Fracture: a broken bone caused by an acute trauma.
>
> Stress fracture: a break of a bone caused by repeated mechanical stress over time.
>
> Dislocation: the displacement of a bone at a joint.

Tear: the rupture of a structure, including a tendon, cartilage, labrum, or meniscus.

Tendonitis: the inflammation of a tendon, usually caused by overuse or repeated mechanical stress.

Anatomical location:



1 – head
2 – neck
3 – shoulder
4 – arm
5 – elbow
6 – forearm
7 – wrist
8 – hand
9 – upper torso
10 – lower abdomen
11 – upper back
12 – mid-back
13 – low back
14 – hip
15 – thigh
16 – knee
17 – lower leg
18 – ankle
19 – foot
20 – toe

Please list any injuries from the previous winter:

Type of Injury	Anatomical Location (see picture above)	Days kept from running	Did this injury occur during training or a race?

Please list any injuries from the previous summer:

Type of Injury	Anatomical Location (see picture above)	Days kept from running	Occur during training or a race?

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