Effect of Protocol and Mouthguard on VO_2 max in Female Hockey Players using the Skating Treadmill

By

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Table of Contents

Table of Contents

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Abstract

Athletes competing in contact sports commonly wear intra-oral dental mouthguards. Data are sparse concerning the influence of a mouthguard on breathing during exercise. We compared V_E and VO_2 during submaximal and maximal exercise on a skating treadmill (TM) while wearing an intra-oral dental mouthguard. Female varsity hockey players (n = 12) performed two skating tests on a TM with and without a mouthguard (WIPSS Jaw-Joint Protector™). The players wore the mouthguard during hockey practices prior to collection of ventilation data on the treadmill. Also, the players completed a questionnaire that examined their perceptions of the mouthguard in terms of ventilation, comfort and performance. A 10-point rating scale was used for this evaluation. Two performance tests on the skating treadmill examined the effect of the mouthguard on submaximal and maximal aerobic exercise. The subjects skated for 4 min at 2 submaximal velocities (14 and 16 $km \cdot h^{-1}$) separated by 5 min of passive recovery. A VO_2 max test followed the submaximal tests and commenced at 18 $km \cdot h^{-1}$ with the velocity increasing by 1 $km \cdot h^{-1}$ every minute until volitional fatigue. V_E, VO_2, VCO_2 and RER were analyzed using a Sensor Medics 2900 metabolic cart. Two-way (2 conditions X 3 velocities) repeated measures ANOVAs were used to examine differences in V_E, VO_2 and HR. Ventilation was unchanged when skating at the two submaximal velocities. VO_2 max was 48.8 $ml \cdot kg^{-1} \cdot min^{-1}$ using the intra-oral mouthguard and was 52.4 $ml \cdot kg^{-1} \cdot min^{-1}$ without a mouthguard. V_E max was 108.5 $L \cdot min^{-1}$ using the intra-oral mouthguard and was 114.1 $L \cdot min^{-1}$ without a mouthguard. The results showed that V_E max and VO_2 max were lower using the mouthguard compared to the no mouthguard condition.

Résumé

Les athlètes en concurrence dans les sports de contact portent généralement le garde-bouche dentale intra-oral. Les données sont clairsemées concernant l'influence du garde-bouche sur la respiration pendant l'exercice. Nous avons comparé V_E et VO_2 pendant l'exercice sous-maximale et maximale sur la trépigneuse de patinage pendant le port du garde-bouche dentale intra-oral. Douze joueuses d'hockey universitaire ont effectuées 2 examens de patinage sur la trépigneuse avec et sans garde-bouche (WIPSS Jaw-Joint Protector™). Les joueuses ont portée le garde-bouche pendant les pratiques d'hockey avant la collecte de données de ventilation sur la trépigneuse. De plus, les joueuses ont complété un questionnaire examinant leurs perception du garde-bouche concernant la ventilation, le confort et la performance. Une échelle de pointage sur 10 était utilisée pour cette évaluation. Deux examens de performance ont été utilisés sur la trépigneuse pour étudier les effets du garde-bouche sur des exercices aérobiques sous-maximales et maximales. Les sujets ont patinée pendant 4 min à 2 vitesses sous-maximales (14 et 16 $km \cdot h^{-1}$) séparés par 5 min de recouvrement passif. Un examen VO_2 max à suivi les examens sous-maximales et commençant à 18 $km \cdot h^{-1}$. La vitesse augmentait 1 $km \cdot h^{-1}$ par minute jusqu'à la fatigue volitionnelle. V_E, VO_2, VCO_2 et RER ont été analysés en utilisant une charrette métabolique « Sensor Medics 2900 ». Différences en V_E, VO_2 et HR ont été examinés par « two-way repeated measures ANOVAs » (2 conditions X 3 vélocités). La ventilation n'a pas changé lorsque le patinage était à 2 vitesses sous-maximales. VO_2 max était 48.8 $ml \cdot kg^{-1} \cdot min^{-1}$ utilisant le garde-bouche dentale intra-oral et était 52.4 $ml \cdot kg^{-1} \cdot min^{-1}$ sans le garde-bouche. V_E max était 108.5 $L \cdot min^{-1}$ avec le garde-bouche et 114.1 $L \cdot min^{-1}$ sans le garde-bouche. Les résultats ont démontré que V_E max et VO_2 max était plus bas avec le garde-bouche comparativement à sans le garde-bouche.

List of Tables

List of Figures

Does a Mouthguard alter Ventilation of Hockey Players?

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Introduction

Intra-oral dental mouthguards have been classified into three categories: stock, self-adapted or "boil and bite" and custom-made (Guevara and Ranalli, 1991). Athletes competing in contact sports commonly wear dental mouthguards to reduce their risk of orofacial trauma. Intra-oral mouthguards are worn over the teeth and act to absorb the energy from a blow to the mouth or jaw, thereby minimizing the severity of dental and oral injuries (Scott et al., 1994). The reduction in dental injuries while wearing mouthguards is well documented (Chapman, 1990; Kerr, 1986; Randall and Lancaster, 1995).

Since it is not generally mandatory to wear mouthguards while playing ice hockey, many players do not wear one during practice or competition. The major reasons for athletes not wearing a mouthguard are: (1) uncomfortable, (2) verbal communication is hindered and (3) difficulties with breathing (Chapman and Nasser, 1996; Francis and Brasher, 1991). Data are sparse concerning the influence of a mouthguard on breathing during exercise. Our review of the literature located only three studies that examined the influence of sports mouthguards on ventilation during exercise. Francis and Brasher (1991) examined three types of stock or "over-the-counter" mouthguards and concluded that these mouthguards impaired expiratory air flow. An earlier study (Luke et al., 1982) came to the same conclusion. In contrast, a recent study (Amis et al., 2000) found that maxillary mouthguards did not interfere with breathing at high ventilatory rates, suggesting that most individuals were able to overcome the obstruction to the oral breathing route.

The purpose of this study was to compare ventilation (V_E) and oxygen uptake (VO_2) during submaximal and maximal exercise on a skating treadmill (TM) while wearing an intra-oral dental mouthguard.

Methods

Based on VO_2 max values of ice hockey players, an effect size was calculated in accordance with the criteria outlined by Cohen (1998). It was estimated that 11 subjects were needed to obtain statistically significant results in this study. Twelve female university ice hockey players volunteered to participate in this study. These subjects were selected as they represent highly-skilled skaters. Informed consent was obtained, with all procedures approved by the ethics committee of the university. Anthropometric measurements of height, weight, and skinfolds (triceps, subscapula, iliac crest, abdomen, front thigh, rear thigh) were made and percent fat was calculated (Yuhasz, 1966).

The intra-oral mouthguard selected for this study was the WIPSS Jaw-Joint Protector™. The volume and weight of the mouthguard was approximately 14.5 ml and 20.7 g, respectively. This self-adapted mouthguard claims to re-position and lock the lower jaw in a down and forward position, thereby reducing the risk of concussions and jaw-joint injuries from lower jaw impacts. The claim is also made that the WIPSS Jaw-Joint Protector™ "increases airway space for the competitive edge in sports". After inserting the mouthguard, subjects maintained the position of the mouthpiece by lightly biting onto the mouthpiece lugs. The subjects wore the mouthguard during hockey practices prior to collection of ventilation data on the treadmill. None of the subjects wore dentures.

Each subject participated in two treadmill skating sessions described as mouthguard (MG) and no mouthguard (noMG). Both skating sessions were performed following completion of the competitive phase of the season. The subjects were randomly assigned to the two conditions. For both skating protocols, subjects wore the same skates, hockey gloves, track suit, and carried a hockey stick.

The exercise tests were performed on a skating treadmill (Acceleration Canada, Calgary, AB). Subjects performed a minimum of three 30 min familiarization sessions on the treadmill during the two weeks prior to testing. The familiarization sessions provided adequate time for the subjects to skate efficiently, comfortably and confidently on the skating treadmill. The skating treadmill has a skating surface area of 3.20 m^2 (1.80 m wide X 1.78 m long). The surface is covered with a series of parallel polyethylene slats attached to a rubber belt, which rolls over two drums. Prior to each test, the surface was sprayed with silicone oil to reduce friction between the skate blade and the polyethylene surface. During the tests, subjects wore a safety harness that was attached to an overhead track as a precaution if a fall occurred.

The submaximal skating test was performed at two velocities (14 and 16 $km \cdot h^{-1}$) with performance in a progressive manner beginning with the slower velocity. These velocities were selected to represent on-ice skating intensities estimated at 55 to 75% of the VO_2 max of a typical varsity female hockey player and were anticipated to be aerobic intensities for these players. Subjects skated for 4 min at each velocity with physiological data averaged for the last 2 min. A plateau was achieved at these velocities since there was no difference in VO_2 between the 3rd and 4th minutes at each velocity. Subjects had 5 min of passive recovery between each skating bout. After recovery from the second submaximal test, a VO_2 max test was completed. The test was initiated at 18 km·h^{-1} with increments of 1 km·h^{-1} each minute until maximal volitional exhaustion was reached. Grade was constant at 0% for the submaximal and maximal tests.

Expired air was collected using a mask (Hans Rudolph, Kansas City, MO) that was securely sealed against the face. In the mouthguard condition, the face mask did not contact the intra-oral mouthguard. V_E, VO_2 and respiratory exchange ratio (RER) were averaged every 20 s using a metabolic cart (SensorMedics – model 2900). Physiological data were examined to confirm that RER remained below 1.00 for each submaximal skating test and above 1.10 for the VO_2 max test. Heart rate (HR) data were collected every 5 s using a Polar Accurex Plus HR monitor (Polar Electro, Kempele, Finland). Temperature in the laboratory ranged from 20 to 23 °C.

After collection of the physiological data and without knowledge of the results, the subjects responded to four questions pertaining to the mouthguard. A 10-point rating scale was used for each question. The questions were:

1. Did the mouthguard affect your speech?

   (Considerably ....Not at All)

2. The degree you feel wearing the mouthguard was comfortable?

   (Very Uncomfortable ....Very Comfortable)

3. The degree you feel wearing the mouthguard affected your breathing?

   (Hindered ....Unhindered)

4. Would you wear this type of mouthguard in your hockey games?

   (No...Yes)

Two-way repeated measures ANOVAs were used to examine differences in V_E, VO_2 and HR with 2 conditions (MG and noMG) and 3 velocities (14, 16 $km \cdot h^{-1}$, and maximum). When appropriate, post hoc analyses were performed using a Tukey honest significant difference (HSD) test. For all statistical analyses, α was set at $P < .05$.

Results

Physical characteristics of the 12 subjects are included in Table 1. These values are typical of female varsity players. Table 2 shows the V_E, VO_2 and HR results for the MG and noMG conditions. Submaximal ventilation was not affected when wearing the mouthguard as the V_E values were similar when skating at 14 and 16 $km \cdot h^{-1}$ in the MG and noMG conditions. The peak ventilation was lower ($P < .05$) in the MG condition (108.5 $L \cdot min^{-1}$) compared to the noMG condition (114.1 $L \cdot min^{-1}$). Figure 1 illustrates the minute ventilation data.

Figure 2 illustrates the oxygen consumption results. The VO_2 values were similar at 14 and 16 $km \cdot h^{-1}$ in the MG and noMG conditions. The mean VO_2 max was lower in the MG condition (48.8 $ml \cdot kg^{-1} \cdot min^{-1}$) compared to the noMG condition (52.4 $ml \cdot kg^{-1} \cdot min^{-1}$).

Figure 3 illustrates the HR results. The mean HR max was similar in the MG (190.7 $beats \cdot min^{-1}$) and noMG conditions (192.8 $beats \cdot min^{-1}$) indicating that similar maximal efforts were given for both conditions.

The subjective assessment of the mouthguard revealed mean scores of 1.8 for the communication question, 4.5 for the comfort question, 6.4 for the ventilation question and 3.7 for the question related to wearing the mouthguard during games. These perceptions implied that the mouthguard had an affect on verbal communication and "somewhat hindered" ventilation. The mouthguard was perceived to be "somewhat comfortable".

Discussion

The principal findings of this study were: (1) at submaximal skating velocities, V_E and VO_2 were similar with and without a mouthguard and (2) both V_E max and VO_2 max were lower when skating with the WIPSS intra-oral mouthguard compared to skating without a mouthguard. These findings have relevance for ice hockey players since the game has frequent maximal sustained bursts of skating requiring a high percentage of the players' VO_2 max (Montgomery, 2002).

Although treadmill skating is believed to simulate on-ice skating, few studies have compared the physiological responses between the two modalities. Nobes et al. (2002) compared skating economy and VO_2 max on-ice and on the skating treadmill. The physiological demand was greater during submaximal skating on the TM compared to on-ice while VO_2 max was similar on the TM compared to on-ice. The average peak velocity during the final stage of the skating protocol was actually higher on the TM compared to on-ice. Only one other study has compared TM and on-ice physiological demands during submaximal skating. The experimental design utilized by Hinrichs (1994) compared TM and on-ice EMG activity while skating at three stride frequencies described as slow, medium and fast skating. There were no significant differences in muscular activation patterns between TM and on-ice.

Our findings are contrary to the study by Luke et al. (1982) who had their subjects exercise on a cycle ergometer. They reported that mouthguards reduced ventilation when subjects cycled at low workloads. We found no change in either V_E or VO_2 when skating at moderate velocities. One other study (Francis and Brasher, 1991) examined the influence of three types of stock mouthguards during exercise. They concluded that mouthguards impaired forced expiratory ventilation. Peak expiratory air flow was lowered by 7-16%. Also, the volume of air that could be forcefully expired in one second ($FEV_{1.0}$) was reduced by 8-12% with mouthguards compared to no mouthguards.

Mouthguards occupy space and thus influence airway flow dynamics. Amis et al. (2000) measured oral airflow resistance in 10 subjects wearing two custom-made maxillary mouthguards. Airflow resistance was measured during relaxed tidal breathing and during voluntary hyperpnea with a peak inspiratory oral airflow of $1.0\ L \cdot s^{-1}$. When jaw position was controlled, both types of maxillary mouthguards increased airflow resistance. Individual subjects responded differently when jaw position was not controlled. When ventilating at $1.0\ L \cdot s^{-1}$ there was a tendency for both types of mouthguards to increase inspiratory resistance, however, the effect only reached significance for one of the two custom-made mouthguards. In our study we placed no controls over head position since the study was designed to simulate skating in a "field situation".

In summary, these results showed that at submaximal velocities, V_E, VO_2 and HR were similar when skating on a treadmill with and without a mouthguard. Both V_E max and VO_2 max were significantly lower when skating with the WIPSS intra-oral mouthguard compared to skating without a mouthguard. The perception of the players was that the mouthguard was moderately hindering their maximal ventilation. This perception was supported by measurements of ventilation.

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Table 1. Characteristics of the Subjects (n = 12).

Variable	Mean	S.D.
Age (yr)	19.8	0.8
Height (cm)	166.8	7.2
Weight (kg)	63.8	6.6
Percent Fat (%)	21.5	3.3
Sum of 6 Skinfolds (mm)	119.7	15.0

Table 2. V_E, VO_2 and HR while Skating with and without a Mouthguard.

Velocity	**Mouthguard**		**No Mouthguard**	
km·h^{-1}	**Mean**	**S.D.**	**Mean**	**S.D.**
		V_E (L·min^{-1})		
14	71.0	10.8	71.4	12.1
16	78.8	11.2	79.2	15.7
Maximum	108.5	13.8	114.1	13.2
		VO_2 (ml·kg^{-1}·min^{-1})		
14	40.5	2.5	42.2	3.0
16	44.8	1.8	46.4	2.3
Maximum	48.8	2.4	52.4	2.9
		Heart Rate (beats·min^{-1})		
14	170.0	10.6	170.4	10.7
16	180.2	8.0	181.3	7.1
Maximum	190.7	4.9	192.8	5.9

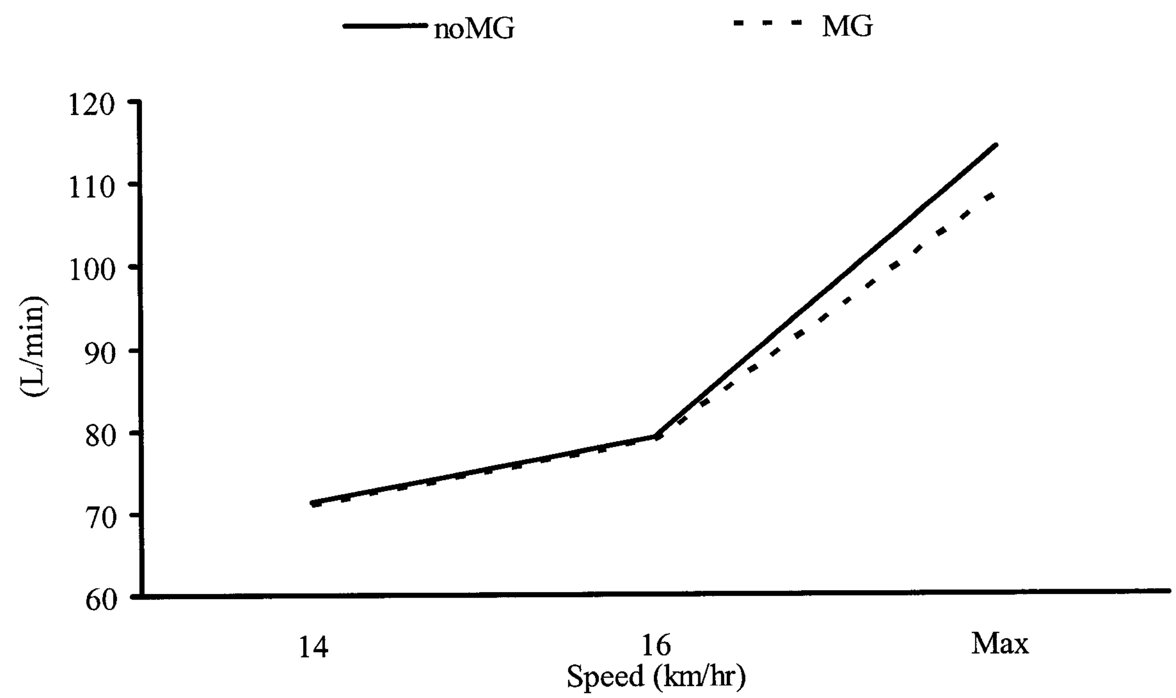

Figure 1. V_E ($L \cdot min^{-1}$) while Skating with (MG) and without (noMG) a Mouthguard.

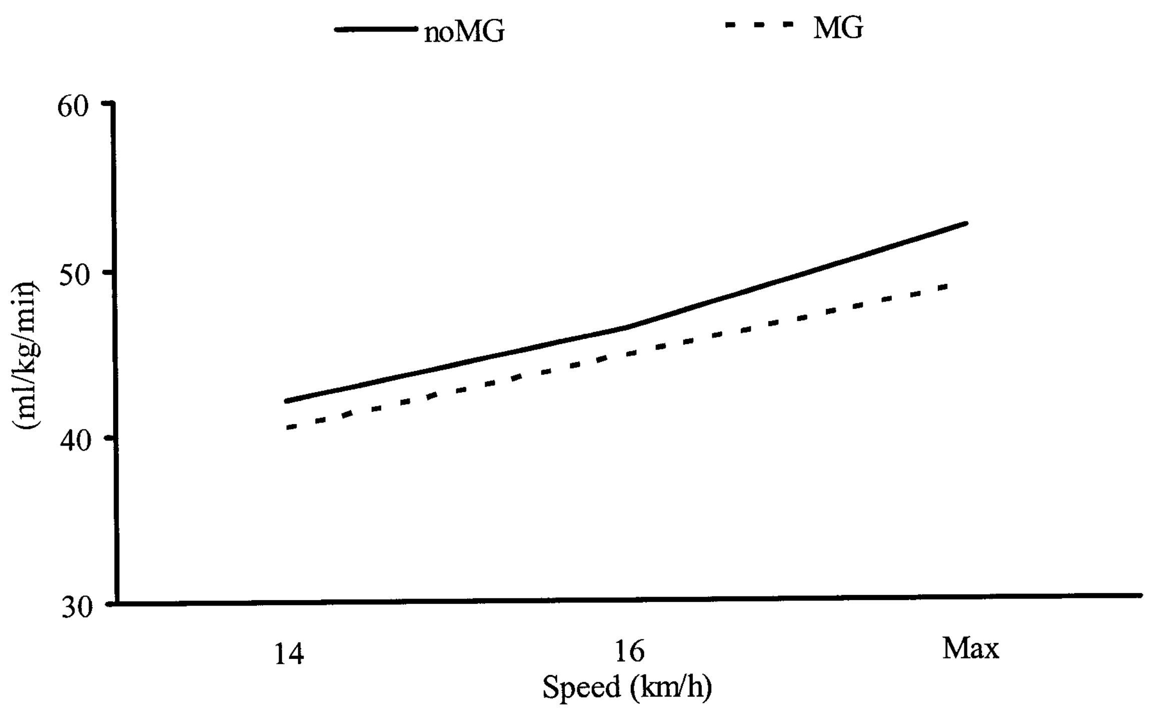

Figure 2. VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) while Skating with (MG) and without (noMG) a Mouthguard.

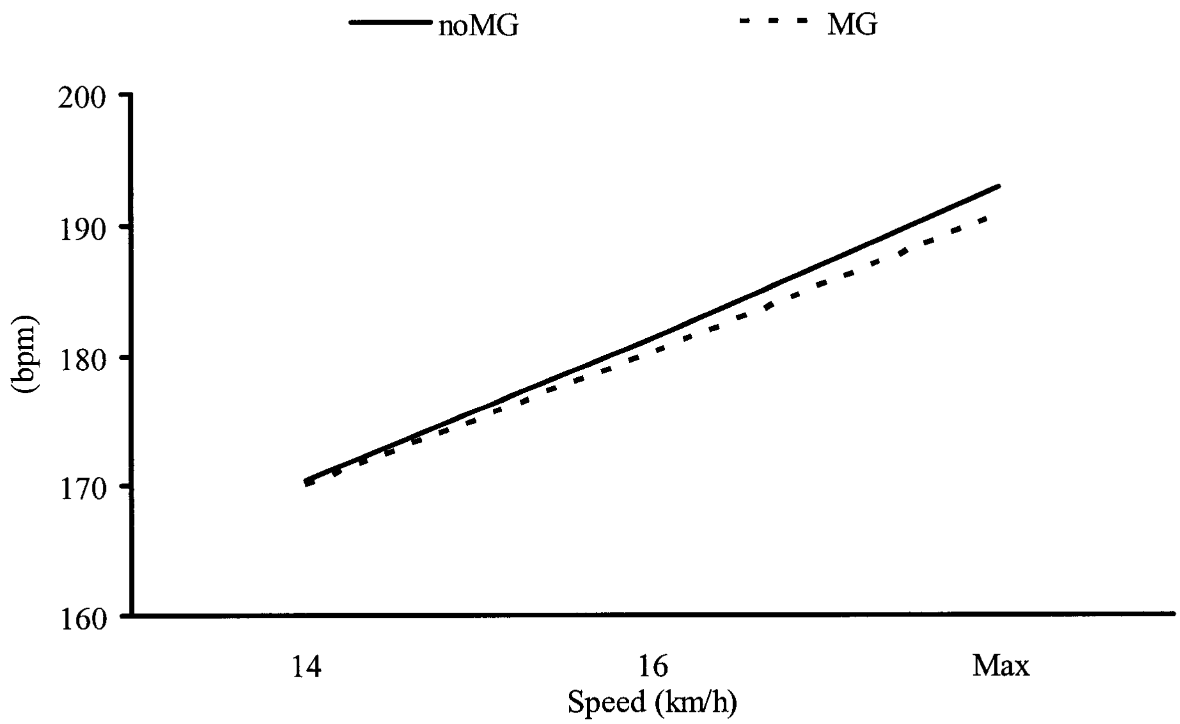

Figure 3. HR (beats·min^{-1}) while Skating with (MG) and without (noMG) a Mouthguard.

Appendix A

Introduction

Introduction

Skating Treadmill

Today's hockey players have become bigger, stronger and faster than players of the past. One reason for this can be attributed to the fact that there have been major improvements in training techniques for athletes over the last few decades. Hockey players have been able to take advantage of specialized training regimens designed to enhance strength, speed, size and, most importantly, aerobic and anaerobic capacity.

Along with improvements in training methods, the field of sport science has also been responsible for new developments with regard to the tools that are used to test and assess athletes in their quest for greatness. One such tool, which is a relatively new piece of equipment, has important implications for the sport of hockey. The skating treadmill can be used by researchers, trainers, therapists and coaches who wish to gain more insight into the science of the sport of hockey. Hockey players themselves can benefit from off-season training sessions using the skating treadmill. Speed, acceleration and aerobic/anaerobic capacity can be enhanced without setting foot on the ice. The skating treadmill can be used to assess and correct, among other things, a player's stride, posture and center of gravity.

As Dreger (1997) points out in his article "Using Skate-Treadmills to Train Hockey Players for Speed", the skating treadmill is very similar in function and design to a running treadmill and its artificial surface allows players to perform their regular skating stride while wearing their skates. The treadmill was manufactured by Standard Industries for Acceleration Products, Inc., of Fargo, ND. The surface consists of a series of plastic slats 72 inches (182.9 cm) long by 1.5 inches (3.8 cm) wide by 0.75 inches (1.9

cm) high. These slats are attached to a rubberized belt, propelled by an electric motor. The treadmill can operate at a wide variety of speeds (0-34 km/h) and slopes (0-32°). Increasing the resistance while skating allows the player to develop strength, and this can be achieved on the treadmill by increasing the grade. This cannot be done on a hockey rink.

The skating treadmill can be easily implemented as a means for performing physiological testing on hockey players at various levels. A number of studies, including those of Watson and Sargeant (1986) and Léger, Seliger and Brassard (1979), have investigated anaerobic and aerobic capacity in hockey players. These researchers have utilized tools such as the Wingate cycle ergometer to measure anaerobic power, and the traditional running treadmill to measure aerobic capacity (VO_2 max). These tools may not allow for an adequate assessment of hockey-specific physiological variables (Smith et al., 1982) because muscle actions elicited during the skating stride are not exactly the same as those elicited on a cycle ergometer or running treadmill. Smith et al. (1982) further stated that the development of a skate-specific ergometer should help in the assessment and analysis of aerobic capacity in hockey players.

Today, physiological variables such as VO_2 max can be assessed using the hockey-specific skating treadmill. Hockey players now have the opportunity to perform these tests while they are engaged in a setting more adaptable and meaningful to their sport. Elite runners or cyclists have had the opportunity to train and be tested on equipment specific to their sports. Runners can lace-up their favourite performance shoes and clothes, step on a treadmill, and train intensively. Hockey players now have the same opportunity to lace-up their favourite skates, step on the skating treadmill, and train or be tested for speed or endurance as it pertains to the sport of hockey specifically.

Although skating treadmills appear to be convenient tools to use with hockey players of all ages and levels, they are expensive and not widely available to the general population of hockey players. Their use has been mostly confined to educational institutes and professional sports teams. Several professional hockey teams have already used skating treadmills for purposes of training, testing, rehabilitation and instruction. Research involving the skating treadmill is still in its infancy. There have been but a few articles published in the hockey literature (Dreger, 1997; Dreger and Quinney, 1999; Hinrichs, 1994; Jacobson and Zapalo, 1997; Nobes et al., 2002).

Sports Mouthguards

As is the case in many other contact sports, the incidence of head trauma (concussions) in ice hockey is a constant concern for athletes as well as the therapists and doctors who treat them. Researchers and professionals are continually trying to develop protective equipment that will help reduce the number and severity of concussions and other injuries. There have been several studies that have investigated the relationship between mouthguards and the incidence of injury, both dental and facial, in contact sports (Chapman, 1990; Chapman and Nasser, 1996; Kerr, 1986; Scott, Burke and Watts, 1994).

The development and manufacture of improved mouthguards that help to reduce or prevent serious trauma or injury has become a more important focus of sport medicine research. One study examined techniques for mouthguard fabrication (Guevara and Ranalli, 1991) while another focused on comfort and wearability (Deyoung, Robinson and Godwin, 1994).

However, one recent study by Amis, Di Somma, Bacha and Wheatley (2000) examined the influence of intra-oral maxillary sports mouthguards on the airflow dynamics of oral breathing. The researchers posited that mouthguards worn during sporting competition may influence oral airway flow dynamics and potentially increase airflow resistance during mouth breathing. They measured oral airflow resistance (R_o) in 10 normal subjects (4 males and 6 females) between the ages of 26 and 32 years. Although the study employed 2 different sports mouthguards, none of the subjects were trained athletes. The results indicated that when jaw position was controlled, intra-oral maxillary mouthguards increased airflow resistance (R_o), however, individual subjects responded differently when in control of mouth opening. It is important to note that the subjects in this study were not trained athletes and were not engaged in physical activity while they were wearing the sports mouthguards.

No study has attempted to determine whether sports mouthguards affect breathing while the subject is engaged in a sporting activity. Perhaps wearing a specially designed sports mouthguard will have an effect on the physiological variable of VO_2 max. Should maximal airflow become restricted in some way by the use of a sports mouthguard, it would appear reasonable to conclude that maximal oxygen uptake (VO_2 max) would be restricted in turn.

Nature and Scope of the Problem

The few studies which have been published on the skating treadmill have investigated either EMG activity in the leg muscles of skaters (Hinrichs, 1994), VO_2 max protocols on the skating treadmill (Dreger and Quinney, 1999; Jacobson and Zapalo III,

1997) and skating economy and VO_2 max on-ice compared to the skating treadmill (Nobes et al., 2002).

Hinrichs (1994) compared muscle recruitment patterns in the legs, as determined by electromyography (EMG), during ice skating to that of treadmill skating. Seven muscles of the right leg were compared via EMG. He used 14 hockey players as subjects. Subjects who had never skated on the treadmill were given sufficient time to skate in order to become familiar with the treadmill before testing. The subjects skated on the treadmill at three velocities (10.5, 14 and 16.5 km/h) and at a 2.5% grade. This resulted in stride frequencies of 42, 49.5 and 54 strides/min. Stride frequencies at each of the velocities were matched for the on-ice condition, however, the resulting skating velocities for the on-ice condition were higher (20.97, 22.88 and 24.98 km/h). Hinrichs indicated that the differences in velocities were due to the higher coefficient of friction and the 2.5% grade that was used on the treadmill. The results indicated that there were no significant differences in the recruitment patterns of the right leg for 6 of the 7 muscles when comparing treadmill skating to on-ice skating. Only the adductor longus (AL) showed a significant difference between the two surfaces. Hinrichs concluded that treadmill skating simulates the skating stride closer than other types of dryland training devices.

Dreger and Quinney (1999) investigated a protocol for the determination of VO_2 max using the skating treadmill. Subjects were 6 elite male hockey players. Each subject performed both a skating treadmill VO_2 max protocol and a cycle ergometer VO_2 max protocol for comparative purposes. Subjects skated on the treadmill at a self-selected, constant speed (14.4 to 16.0 km/h) throughout the test. Initially, the grade was set at 0%

and the subjects skated for a 2-minute stage followed by 2 minutes of rest. The process of skating for 2 minutes and resting for 2 minutes was continued, however, for each 2-minute stage, the grade was elevated by 2%. This continued until volitional exhaustion. The results showed no significant difference in either relative or absolute VO_2 max values between the skating treadmill and cycle ergometer protocols. The researchers concluded that although the physiological responses to both protocols were similar, the skating treadmill might provide more applicable information for the development of hockey-specific training programs because it allows for the replication of the skating stride.

Jacobson and Zapalo III (1997) examined a VO_2 max protocol. Five subjects skated on a treadmill prior to the actual testing and their anaerobic threshold was determined. The VO_2 max skating protocol commenced at the speed that corresponded with the subject's predetermined anaerobic threshold. Initially, the grade of the treadmill was set at 5%. The grade was increased by 1% every 30 seconds until volitional fatigue. The subjects also performed a cycle ergometer VO_2 max test for comparative purposes. The results indicated no significant differences between the VO_2 max values obtained on the skating treadmill and those obtained on the cycle ergometer.

Nobes et al. (2002) compared skating economy and VO_2 max on-ice and on the skating treadmill. Male varsity hockey players (n = 15) performed skating tests on-ice and on a treadmill. Results showed that at submaximal velocities, VO_2, HR and stride rate were higher on the treadmill compared to on-ice. VO_2 max was similar while HR max was higher on the treadmill compared to on-ice.

Significance of the Problem

The research that has been conducted using the skating treadmill is scarce. The one study by Hinrichs (1994) investigated potential differences in EMG activity of leg muscles when comparing skating on a treadmill to skating on ice. The results were not significant.

The two studies by Dreger and Quinney (1999) and Jacobson and Zapalo III (1997) examined potential differences between specific VO_2 max protocols designed for the skating treadmill and those designed for cycle ergometers. Again, their results indicated no significant differences in the resulting VO_2 max values when comparing the skating treadmill to the cycle ergometer.

No study thus far has attempted to investigate whether different skating treadmill protocols will elicit different results with regard to the physiological variables of VO_2 max and skating economy. With the skating treadmill, the opportunity exists to manipulate not only the speed, but the elevation as well. Perhaps a protocol that increases speed while holding the grade constant will yield different results than a protocol that increases the grade while holding the speed constant. Clearly, further research must be conducted in an attempt to validate and understand the value of the skating treadmill as a tool for hockey-specific research.

Further, the only study that examined the influence of intra-oral maxillary sports mouthguards on the airflow dynamics of oral breathing (Amis, Di Somma, Bacha and Wheatley, 2000) employed non-athletes who were not engaged in physical activity. In using hockey players who are engaged in skating on the treadmill, it may be possible to determine whether differences exist in skating economy and maximal oxygen consumption (VO_2 max) when they are outfitted with a specially designed sports mouthguard, as opposed to when they are not wearing a mouthguard. The mouthguard is manufactured by WIPSS Products Inc. and is named the Jaw-Joint Protector™. It is purported that the Jaw-Joint Protector™ reduces the risk of concussions from lower jaw impacts because it repositions and locks the lower jaw in a down and forward position, transmitting the impact energy away from the base of the brain to the Protector. It also promotes better breathing and increases muscle strength up to 35%, while protecting both the upper and lower teeth. One of the attributes of the Jaw-Joint Protector™ is the claim that it increases airway space for the competitive edge in sports.

Finally, with all of the research that is available on the sport of ice hockey, very few studies have employed female hockey players as subjects. Bracko (1998) aimed to identify the on-ice performance characteristics of elite and non-elite female hockey players and to investigate for differences between the two groups. Doyle-Baker, Fagan and Wagner (1997) performed on-ice testing and monitoring of 20 Canadian National Team players over a one-year period. Certainly, no study using the skating treadmill has attempted to use female hockey players as subjects. One reason for this may be because of the fact that the sport of women's ice hockey has grown dramatically only within the last decade. Female ice hockey became a Canadian Interuniversity Sport (CIS) and an Olympic sport in 1998. It is time to begin using elite female skaters as subjects in hockey research.

Statement of the Problem

The main purpose of the present study was to determine whether significant differences would be observed in VO_2 max and skating economy at two (2) skating velocities (14, and 16 km/h) when a specifically designed protective mouthguard (MG) was implemented as compared to when it was not (noMG). The study also aimed to compare the effects of two different protocols on VO_2 max using the skating treadmill. The first protocol (P-flat) elicited VO_2 max by continually increasing the speed of the treadmill (0% grade) until volitional exhaustion, whereas the second protocol (P-grade) elicited VO_2 max by continually increasing the grade of the treadmill (constant speed at 20 km/h) until volitional exhaustion.

The investigation examined the following hypotheses:

1. Maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) will differ significantly between the mouthguard (MG) and the no-mouthguard (noMG) conditions.
2. Oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) at a given velocity will differ significantly between the mouthguard (MG) and the no-mouthguard (noMG) conditions.
3. Maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) will differ significantly between the first protocol (P-flat) and the second protocol (P-grade).

Operational Definitions

Oxygen Uptake (VO_2): Indirect estimates of energy metabolism based on oxygen consumption at rest and/or under steady state exercise conditions.

Maximal Oxygen Uptake (VO_2 max): The maximal volume of oxygen consumed per minute in absolute ($L \cdot min^{-1}$) or relative ($ml \cdot kg^{-1} \cdot min^{-1}$) terms.

Sub-maximal VO_2: Indirect estimates of oxygen consumption during steady state aerobic exercise, representing an intensity less than the maximal aerobic capacity.

Skating Economy: The steady state VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) required to skate at a given sub-maximal velocity.

Skating Stride: A full stride is defined as the point of take-off of the right skate to the point of take-off of the right skate in the next stride.

Stride Rate: The number of strides required to skate for one minute on the treadmill.

Stride Length: The length in meters (m) of one complete stride.

Sub-maximal Velocity: Skating at a velocity (m/min) representing an intensity less than maximum.

Limitations

1. The ambient room temperature in the laboratory did not simulate ice temperature conditions.
2. There is less air resistance in the laboratory compared to on-ice conditions.
3. Players were not wearing full hockey gear while skating on the treadmill.

Delimitations

1. The subjects who participated in this study were 12 female varsity ice hockey players from the McGill University women's ice hockey team.
2. Subjects ranged in age from 18 to 22 years.
3. Only forwards and defense were used as subjects.
4. Only one specific type of sports mouthguard was used in this study.
5. Only two skating velocities (14, and 16 km/h) were studied.

Appendix B

Review of Literature

Review of Literature

This review of the literature is presented as four sections. The first section examines the physiological response to skating and includes sub-headings on the topics of heart rate telemetry and oxygen consumption. The second section examines five factors affecting skating performance – effect of added mass, ice surface, air resistance, aerobic endurance and skating economy. The third section examines sports mouthguards. The last section examines the literature specifically on female hockey players.

Physiological Response to Skating

Heart Rate Telemetry

Heart rate telemetry is a useful means of estimating the aerobic demands of playing hockey. Although used by several researchers over the years, heart rate telemetry has limitations, especially with regard to the sport of hockey. In hockey, heart rate may be influenced by conditions that do not increase the energy costs such as: a) emotion, b) upper body static contractions, c) the intermittent nature of play and d) elevation of core body temperature because the layer of hockey equipment may limit heat dissipation (Montgomery, 1988).

Seliger (1968) published the first heart rate data on ice hockey. He measured the heart rates of 15 junior players between the ages of 16 and 20 years. The players competed for 90 seconds and then recovered for 180 seconds for 3 repetitions. The results showed that the players had an average peak heart rate of 177 bpm and an average on-ice heart rate of 160 bpm. Seliger (1972) also investigated the Czechoslovakian National hockey team. The 13 subjects played in a simulated game where they were on the ice competing for 60 seconds followed by a recovery period of 180 seconds. They performed

6 repetitions of this protocol. The results demonstrated that the players had an average heart rate of 152 bpm, corresponding to 72.5% of their maximum heart rate.

Green et al. (1976), Peddie (1995) and Wilson and Hedberg (1976) monitored the heart rates of elite players during a game. The average heart rates observed in these studies were 173, 165.6 and 178.3 bpm, respectively. Montgomery (1988) stated that the average on-ice heart rate is about 85% of maximum and average peak heart rates are as high as 90% or more of maximum heart rate. Several researchers (Montgomery and Vartzbedian, 1979; Patterson, 1979; Peddie, 1995) have estimated the average on-ice intensity to be in the range of 70 to 90% of VO_2 max.

Davis (1991) monitored the heart rates of 4 members of the Calgary Flames NHL team over a 5-game period. The average heart rate during a shift was found to be 168 bpm and the range was between 145 and 191 bpm. During recovery, the players' heart rates dropped to 120 bpm.

Peddie (1995) investigated the intensity of game play for 3 varsity forwards and 3 defense. The results showed the average on-ice intensity to be 82.5% of maximum heart rate. During stoppages in play the average heart rate dropped to 161.5 bpm or 80.5% of maximum. When the players were recovering on the bench, the average heart rate fell to 138.5 bpm or 69.1% of maximum. Using a similar group of players, Green (1978) found that the average heart rate dropped rapidly during recovery but rarely fell below 125 bpm. Peddie (1995) and Green (1978) both concluded that forwards and defense had similar on-ice heart rates.

Oxygen Consumption

Researchers have used various methods to measure oxygen consumption in hockey players because it is not possible to collect gas samples during a hockey game. Seliger et al. (1972) simulated game conditions in order to measure oxygen consumption whereas Green et al. (1976) estimated oxygen consumption from heart rate data collected during game situations. Green et al. (1976) collected time-motion and physiological data on 8 varsity hockey players during 10 games (age = 21 yrs, height = 177.3 cm, weight = 75.9 kg, VO_2 max = 53.2 $ml\cdot kg^{-1}\cdot min^{-1}$). Based on the average heart rate observed during the 10 games (173 bpm) and treadmill determinations of the relationship between heart rate and oxygen uptake, the researchers estimated the on-ice energy requirements to be between 70 and 80% of VO_2 max. However, the authors noted that it is difficult to ascertain the validity of using heart rate data to estimate energy expenditure in a non steady-state circumstance where much upper body activity is prevalent and where there are many changes in skating velocities.

Seliger et al. (1972) investigated energy expenditure in 13 Czechoslovakian National team players (age = 24.4 yrs, height = 179.3 cm, weight = 81.8 kg) in a simulated game. The game consisted of 6 repetitions of 60 seconds of competition followed by 180 seconds of recovery. Only one shift of 1.17 min was used for analysis. During the shift, oxygen consumption was found to be 32 $ml\cdot kg^{-1}\cdot min^{-1}$ or the equivalent of 66% of the subjects' VO_2 max. Energy metabolism was measured by indirect calorimetry. Seliger et al. (1972) characterized ice hockey as "an activity showing mostly sub-maximal metabolic rate with great participation of anaerobic metabolism (69%), but simultaneously with high requirements for aerobic metabolism (31%)." Montgomery

(1988) and Green et al. (1976) have suggested that Seliger et al. (1972) may have overestimated the anaerobic contribution at the expense of the aerobic contribution. The results of Green et al. (1976) support this notion.

Ferguson et al. (1969) related the oxygen cost to skating velocity in order to estimate the work intensity of hockey players. The researchers had 17 players between the ages of 16 and 25 years perform a VO_2 max skating test around a 140-m oval circuit. The players skated for 3 minutes at velocities of 350, 382, 401, 421 and 443 m/min. These corresponded to lap times of 24, 22, 21, 20 and 19 seconds/lap. It was concluded that the relationship between VO_2 and sub-maximal skating velocity was linear, but that the VO_2 for a given sub-maximal velocity varied considerably amongst the players. As an example, at a velocity of 382 m/min the average VO_2 was 46.7 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ with a range from 40.1 to 54.7 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$. Green et al. (1976) agreed that skating represents a major component of work intensity, however, they stated that using the relationship of oxygen cost versus skating velocity underestimates energy expenditure.

Factors Affecting Skating Performance

<u>Effect of Added Mass</u>

Montgomery (1982) investigated the effect of added mass on skating performance using the Repeat Sprint Skate (RSS) test developed by Reed et al. (1979). Eleven subjects were tested in mid-season in each of four conditions: 1) normal body mass, 2) 5% added body mass, 3) 10% added body mass, 4) 15 % added body mass. Mass was added with a weighted vest which was secured to the waist and shoulders so as not to interfere with skating movements. The weighted vest was designed to simulate excess body fat and/or equipment weight. Added mass resulted in a significantly slower performance for both the speed and anaerobic endurance components of the on-ice test. Anaerobic endurance time increased by 4% with the addition of 5% mass. It was concluded that excess body mass increases the amount of energy required to skate at a particular velocity and also reduces the amount of time that a player can maintain the pace.

Chomay et al. (1982) also investigated the effect of added mass, however, the extra mass was added to the skates. Skating performance on the RSS test was assessed. Eleven subjects performed the RSS under 3 conditions: 1) normal skate weight, 2) 227 g added to each skate, 3) 555 g added to each skate. Results showed that there were significantly slower times on both the speed and anaerobic endurance components of the RSS test when weight was added to the skates.

Léger et al. (1979) investigated the effect of equipment weight (7.3 kg) on aerobic skating performance. During mid-season, 10 players performed a 20-m shuttle skating test to determine VO_2 max. Although VO_2 max was similar with and without equipment, the equipment increased the energy cost of skating by 4.8% and decreased the multi-stage test time by 20.3%. The final skating speed decreased by 7 m/min or 2.9% when players were wearing hockey equipment.

Larivière et al. (1976) asked 18 midget hockey players to skate as many laps as possible of a 100-foot course over a 5-minute period. The subjects had to skate in one direction and stop with one skate crossing the line, before turning to skate back to the starting line. The researchers tested the subjects with and without equipment. The results indicated that the total distance covered with equipment (3973 ± 184 feet) was significantly less than the distance covered without equipment (4124 ± 267 feet).

Air Resistance and Ice Surface (Co-efficient of Friction)

The energy produced by the skater is used predominantly to overcome two opposing forces, namely, air and ice frictional forces. De Koning et al. (1992) stated that the air friction is the greatest resisting force. Total frictional losses can be divided into 75% air friction and 25% ice friction when skating at a velocity of 10 m/s.

Ice Surface

The surface of ice has a very low co-efficient of friction. The reported co-efficient of ice friction varies between 0.003 (De Koning et al., 1992) and 0.030 (Zatsiorski et al., 1987). De Koning et al. (1992) found a similar range of co-efficient but at a different optimal temperature. An optimal temperature of –6 to –9 °C was suggested, whereas Kobayashi (1973) used a weighted sled with skate blades and determined a higher optimal temperature of –2.2 °C.

Several theories purport to describe the physical properties of ice with regard to the relatively low co-efficient of friction of ice. Van Ingen Schenau et al. (1989) suggested that skating occurs due to pressure melting of the ice. The gliding surface of the skate is small and the pressure under the skate is high (up to 20×10^6 N/m^2), which results in a film of water between the skate and the ice. The thin film of water allows the skate to glide over the ice surface with very little friction.

Colbeck (1995) suggested another reason for the low co-efficient of friction, claiming that such pressures needed to achieve "pressure melting" would cause the ice to fracture and that the pressure melting effect at –20 °C would have to be 2700 times atmospheric pressure. At speeds of 5 m/s, a liquid layer of less than 0.1μm thickness exists over only a 15μm length. This would be too short of a distance for the gliding phase of skating. A number of researchers (Mendelson, 1985; Colbeck, 1995) have suggested that the low co-efficient of friction of ice is caused by a melted water film, but that the melting is caused by frictional heating of the sliding surfaces rather than by pressure melting. According to De Koning et al. (1992) both frictional heating and pressure melting should result in the formation of a lubricant (water film) during the skating stride.

Others believe that the friction between ice and the skate blade could be explained by an intrinsic property of the ice surface (De Koning et al., 1992). More recently, modern surface science technology has discovered that the surface of ice has a constant, thin, semi-liquid layer producing low frictional interfaces. As the ice is warmed, the number of liquid layers present increases. This is why colder ice (less water) is faster for skating than warmer ice (more water), (Pearsall et al., 2000).

<u>Air Resistance</u>

According to Van Ingen Schenau et al. (1989), air friction has two major components, friction drag and pressure drag. Friction drag is caused by friction in the layers of air along the body. In speed skating, the roughness of the skater's suit may increase friction drag. Friction drag in speed skating is relatively small because of the type of suits worn. Pressure drag occurs because the relative velocity of the air, with respect to the body, places more pressure in front of the skater than behind the skater. Several variables can influence air friction including: a) skating position, b) body mass and length, c) active drag, and d) shielding (drafting). The air friction constant is dependent on air velocity, according to Van Ingen Schenau (1982). Allinger and Van Den Begert (1997) defined the air friction constant as proportional to the velocity of the skater squared. They used the air friction constant of 0.152 kg/m, an average taken from 6 subjects in Van Ingen Schenau's (1982) study.

Aerobic Endurance

A number of studies have been undertaken to investigate the maximal oxygen uptake of elite hockey players over the past few decades (see Table 3 in Appendix E). Most of the studies have been conducted using the running treadmill or cycle ergometer, however, more recent studies have employed the skating treadmill as a tool for assessing VO_2 max (Dreger and Quinney, 1999; Hinrichs, 1994; Jacobson and Zapalo III, 1997). Using the cycle ergometer, team averages for both forwards and defense ranged from 50.9 to 62.8 $ml \cdot kg^{-1} \cdot min^{-1}$, with only one exception. Using the running treadmill, team averages for both forwards and defense ranged from 51.2 to 65.8 $ml \cdot kg^{-1} \cdot min^{-1}$. According to Montgomery (1988) running on a treadmill usually gives values that are 10% higher than cycle ergometer testing.

Léger et al. (1979) suggested that the VO_2 max of hockey players would be the same whether they were tested on the running treadmill, on the ice while skating a 20-m shuttle course with and without equipment, and on a continuous 140-m oval circuit. The researchers compared the results of 10 hockey players (intercollegiate or equivalent) and 10 runners. The results showed that the hockey players were more efficient on the ice (15%) and less efficient than the runners on the treadmill (7.9%).

Cox et al. (1993) suggested that there has been a progressive increase in VO_2 max results since 1980. The researchers examined the VO_2 max data from 170 NHL players on 4 occasions between 1980 and 1991. In 1980, 58% of the players had a VO_2 max of less than 55 $ml \cdot kg^{-1} \cdot min^{-1}$. In 1991, only 15% of the players had a VO_2 max below 55

$ml \cdot kg^{-1} \cdot min^{-1}$. The authors concluded that improved training methods used by the players resulted in higher VO_2 max values over time.

Dreger and Quinney (1999) compared the VO_2 max results of 6 elite youth hockey players who were either 15 or 16 years old, on a skating treadmill and on a cycle ergometer. The subjects performed a discontinuous skating treadmill protocol at a self-selected speed (14.4 to 16.0 km/h) with increases in grade of 2% every 2 minutes. The results indicated no significant differences in relative VO_2 max values between the skating treadmill (60.4 ± 5.09 $ml \cdot kg^{-1} \cdot min^{-1}$) and the cycle ergometer (59.0 ± 8.31 $ml \cdot kg^{-1} \cdot min^{-1}$) protocols. The VO_2 max values obtained by Dreger and Quinney (1999) are within the range of those previously reported on professional, university and junior hockey players (see Table 3 in Appendix E).

Skating Economy

Daniels (1985) defined running economy as the relationship between the amount of work done and the amount of energy expended. According to Daniels, "Minimizing or eliminating unwanted or counter-productive muscular movement is a desirable goal for any distance runner." Daniels (1985) reported that within a homogeneous group of runners, running economy may be the best predictor of success.

Riby (1994) described skating economy as the steady-state VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) required to skate at a given sub-maximal velocity. Riby (1994) investigated the skating economy of 13 varsity hockey players (age = 20.9 yrs, height = 179.7 cm, weight = 79.9 kg, sum of 5 skinfolds = 40.0 mm, VO_2 max = 60.5 $ml \cdot kg^{-1} \cdot min^{-1}$). Subjects skated on an oval circuit of 140 m. They were asked to perform three 4-minute skating bouts at velocities of 336, 357 and 381 m/min which corresponded to respective lap times of 25.0, 23.5 and 22.0 seconds. Riby (1994) stated that the 4-minute skating bouts were of sufficient duration to allow the subjects to achieve steady-state oxygen consumption. The results indicated that at velocities of 336, 357 and 391 m/min, the average VO_2 max values were 38.6, 44.4 and 55.2 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. The average stride rates were 79.0, 85.2 and 96.6 strides/min, respectively. Riby (1994) concluded that skating economy at velocities between 336 and 381 m/min may be described by a linear regression equation. It was also concluded that there is a low correlation between skating economy and skating ability.

Recently, Nobes et al. (2002) investigated skating economy on-ice and on the skating treadmill. Male varsity players ($n = 15$) skated for 4 min at each of 3 submaximal velocities (18, 20 and 22 km/h), separated by 5 min of passive recovery. A VO_2 max test followed the submaximal tests and commenced at 24 km/h with the velocity increasing by 1 km/h every minute until volitional exhaustion. The results showed that at submaximal velocities, VO_2, HR and stride rate were higher on the treadmill compared to on-ice. VO_2 max was found to be similar while HR max was higher on the skating treadmill compared to on-ice.

Sports Mouthguards

One of the most common types of protective equipment worn by athletes engaged in contact sports is the intra-oral dental mouthguard. These devices are designed to be worn over the teeth and act to absorb the energy produced by blows to the mouth and head. A number of studies have investigated and documented the reduction in sports related injuries, especially dental, with the introduction and widespread use of mouthguards over the years (Chapman, 1990; Kerr, 1986; Ranalli and Lancaster, 1995).

The use of a sports mouthguard during competition has even been mandated in certain sports. NCAA football has specific regulations concerning the use of mouthguards.

A recent study by Amis et al. (2000) investigated the influence of intra-oral maxillary sports mouthguards on the airflow dynamics of oral breathing. According to these researchers, mouthguards can be broadly divided into three main categories: 1) stock mouthguards, 2) self-adapted or "boil and bite" and 3) custom-made. The custom-made mouthguards are usually heat and/or vacuum formed on a stone cast dental model made from an impression of the individual's teeth. Custom-made mouthguards are the most common type of mouthguard worn in high-level sporting competition.

Although it is estimated that use of mouthguards is up to 80 to 100% in specific player groups (Chapman, 1991; Chapman and Nasser, 1996), there are still a number of athletes who refuse to wear a mouthguard during competition. Reasons for not wearing a mouthguard are: a) problems with speech, b) too uncomfortable and c) breathing difficulties (Chapman and Nasser, 1996; Francis and Brasher, 1991).

According to Amis et al. (2000) there is very little information available concerning the influence of a mouthguard on breathing, either at rest or during exercise when breathing is likely to be via the oral route (Niinimma et al., 1981; Wheatley et al., 1991). Francis and Brasher (1991) investigated 3 "over-the-counter" mouthguards and found that all 3 types of mouthguards reduced maximum expiratory flow rates.

The purpose of the study by Francis and Brasher (1991) was to measure the ventilatory and gas exchange effects of wearing a mouthguard. Ten healthy men and 7 women aged 20-36 years participated. Forced expiratory air volume at 1 s (FEV1) and peak expiratory flow rates (PEF) were measured on each subject while wearing either no mouthguard or one of three different over-the-counter mouthguards. To determine the effects of wearing each of the mouthguards during exercise, oxygen consumption (VO_2) was measured while exercising on a cycle ergometer for 5 min at a light and heavy workload. Results showed that, in each case, wearing a mouthguard significantly reduced FEV1 and PEF in comparison to no mouthguard. FEV1 was reduced by 8% with mouthguard 1 and 12% and 14% with mouthguards 2 and 3, respectively. PEF was reduced by 7, 15 and 15.8% with mouthguards 1, 2 and 3, respectively.

Amis et al. (2000) aimed to examine the influence of wearing two different custom-made intra-oral maxillary dental mouthguards on the airflow dynamics of oral breathing under both resting and increased ventilatory conditions. Inspiratory and expiratory airflow dynamics were assessed in the upright (seated) posture in 4 males and 6 females. None of the subjects were trained athletes and only 1 subject had previous experience wearing a mouthguard. The first mouthguard was constructed and fitted by an experienced dental technician. The volume (measured by water displacement) and weight of the first mouthguard ranged from 6.8 to 8.7 ml and from 6.9 to 10.7 g, respectively. The second mouthguard was a commercially available laminated product, custom-made by the supplier to fit each subject from the same stone cast models used to construct the first mouthguard. The volume of the second mouthguard ranged from 7.6 to 10.5 ml with the weight ranging from 8.1 to 11.0 g.

The results of the study showed that during resting tidal breathing via a mouthpiece (with jaw, head and neck position constant), inspiratory airflow resistance was increased in the presence of either of the two custom-made mouthguards. Expiratory airflow resistance was increased only in the presence of the second mouthguard. The authors concluded that although maxillary mouthguards may increase inspiratory and expiratory airflow resistance when the jaw position is controlled, individual subjects may respond differently when in control of mouth opening. The authors stated that this might be due to variable recruitment of compensatory mechanisms (e.g. mouth opening and/or oral airway dilator muscle activity).

Female Hockey Players

Few studies to date have focused on elite female hockey players. Bracko (1998) investigated on-ice performance characteristics of 8 elite and 15 non-elite female hockey players. Subject characteristics were as follows: elite (25.37 ± 5.34 yrs, 176.21 ± 2.32 cm, 68.91 ± 6.49 kg) and non-elite (19.16 ± 2.65 yrs, 168.22 ± 7.64 cm, 65.34 ± 6.65 kg). Seven of the elite players were members of the Canadian National Team and one from the Finnish National Team. All subjects performed 5 skating tests including: 1) 6.10 m Acceleration (ACC), 2) 47.85 m Speed (SPD), 3) 16.3 m Full Speed (FSPD), 4) Agility Cornering S Turn (AGL) and 5) Reed Repeat Sprint Skate (RRS). Calculations were made to determine skating Anaerobic Capacity and Power (W and W/kg) using the formulas suggested by Watson and Sargeant (1986). Results showed that elite and non-elite players were similar in weight, height, acceleration, speed from a stationary position and anaerobic power (W). Elite players were older, had more playing experience and had better performance on the following variables: FSPD, AGL, RRS (Drop-off Time and Sum of 6 Repeats), Anaerobic Capacity (W/Kg and W) and Anaerobic Power (W/kg). The author concluded that the elite players were faster and more agile than their non-elite counterparts. However, when the players were matched for age (elite, n = 6; and non-elite, n = 3) the only difference found between elite and non-elite players was Anaerobic Capacity (W/kg).

Doyle-Baker, Fagan and Wagner (1997) performed on-ice testing and monitored 20 National female hockey players (17-39 yrs). The researchers aimed to monitor individual athletes and investigate the variability of team players during on-ice testing. The 20 subjects performed three on-ice tests and were monitored over a one-year time frame. The tests were: 1) a 6.1 m and a 56.4 m sprint, 2) an anaerobic capacity test consisting of 6 backward and forward repetitions of 18.3 m and 3) a 10, 15 and 20 lap all-out aerobic test consisting of 10, 15 and 20 laps of skating. The authors stated that individual athletes demonstrated improvement over the course of the year and regression toward the mean occurred among the 20 players.

Doyle-Baker et al. (1997) noted that women's hockey has not had access to the sport sciences or external funding to assist with research. In order for the sport of women's hockey to gain recognition and to develop to a level of complexity, a standardized conditioning program must be established. This can only be achieved with the integration of sport science into the realm of women's ice hockey in the future.

Appendix C

Conclusions

Conclusions

The results of the present study showed that at submaximal velocities, V_E, VO_2 and HR were similar when skating on a treadmill with and without a mouthguard. Both V_E max and VO_2 max were significantly lower when skating with the WIPSS intra-oral mouthguard compared to skating without a mouthguard. The perception of the players was that the mouthguard was moderately hindering their maximal ventilation. This perception was supported by measurements of ventilation.

No significant difference was found in VO_2 max using a flat protocol versus a graded protocol. Future research should focus on varying the velocities and degree of slope (grade) at which the subjects skate, both for submaximal and maximal tests, in order to determine the optimal method of eliciting the desired physiological responses. We also need to further understand differences in optimal skating velocities between females and males.

Clearly, further research must be conducted to determine potential differences between the various types of mouthguards, not only in terms of protection but in terms of their effect on ventilation. We must aim to find an acceptable balance between protection, comfortability and ease of respiration with the hope that athletes, both young and old, will choose to wear a mouthguard in contact sports.

One of the aims of this study was to add to the limited base of research that has been conducted on female hockey players to date. As the sport of women's hockey has grown dramatically in the last ten years, it is time to focus on females in hockey research. There have been an extensive number of studies (see Table 3 in Appendix E) that have focused on male players. This has enabled researchers to learn much about the physical and physiological characteristics of elite male hockey players. In this study, data were collected on the physical and physiological characteristics of female hockey players at the university level. While not extensive, we believe the information gathered in this study is valuable and further research should be conducted in order to broaden our knowledge with respect to female hockey players.

Appendix D

References

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Appendix E

Additional Tables

Summary of Tables

Table 3 summarizes various studies that have researched maximal oxygen uptake in hockey players. Different teams from various levels of play were studied, from NHL to Junior and University. The table includes the number of subjects who participated in each study, their average body mass (kg) and average VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$).

Table 4 summarizes the characteristics of the subjects (n = 12) in this study. Age (yrs), height (cm), weight (kg), body fat (%) and sum of 6 skinfolds (mm) are all presented for each subject. Values for mean and standard deviation are included.

Table 5 presents the data gathered on the subjects' perceptions of the mouthguard. The subjects' answers to the 5 questions are shown. Values for mean and standard deviation are included. Refer to the questionnaire on page 60 (Appendix F).

Table 6 presents the subjects' physiological responses (maximal oxygen uptake, ventilation and heart rate) during the graded skating treadmill protocol. Values for mean and standard deviation are included.

Table 7 presents the subjects' physiological responses (maximal oxygen uptake, ventilation and heart rate) during the flat skating treadmill protocol. Values for mean and standard deviation are included.

Table 3. Maximal Oxygen Uptake of Various Teams.

Group	n	Body Mass (kg)	VO_2 max (mL/kg*min)	Reference
Treadmill				
National – American – 1976	22		58.7	Enos et al. 1976
University – CIAU	8	70.5	58.1	Montpetit et al. 1979
University – CIAU	10	72.8 ± 5.4	61.4 ± 6.3	Léger et al. 1979
National – Swedish	24	75.6	57	Forsberg et al. 1974
Junior	18	76.4	56.4 ± 4.3	Green & Houston 1975
National – Finnish	13	77.3	61.5	Rusko et al. 1978
University – CIAU	8	77.4	61.3	Green et al. 1978 (1)
University – CIAU	19	77.6	58.9	Green et al. 1978 (2)
Junior	9	78.7	59.1	Green et al. 1978 (2)
National – Swedish – 1971	24	78.1	56.3	Wilson & Hedberg 1976
Junior	44	78.2	55.4	Houston & Green 1976
University – CIAU	11	79.5	56.4	Montgomery 1982
National – Swedish – 1966	24	80	53.6	Wilson & Hedberg 1976
University	9	80.9	56.3	Hutchinson et al. 1979
Professional	12	83.4	55.3	Green et al. 1979 (2)
Professional – NHL – 1981/82	27	85.9	55.6	Montgomery & Dallaire 1986
Professional – NHL		86.4	53.6	Wilmore 1979
Professional – NHL – Forwards	27	87.1 ± 5.6	57.4 ± 3.1	Rhodes et al. 1986
Professional – NHL – Defense	40	90.3 ± 4.3	54.8 ± 3.9	Rhodes et al. 1986
Professional – NHL – Forwards	26	87.1 ± 5.6	56.3 ± 2.9	Cox et al. 1988
Professional – NHL – Defense	21	90.3 ± 4.3	53.4 ± 3.4	Cox et al. 1988
Professional – NHL	27	85.6 ± 1.4	53.4 ± 0.8	Agre et al. 1988
Swedish Professional (DIF)	22	81.4	62.4	Tegelman et al. 1992
Swedish Professional (SSK)	21	82.4	65.8	Tegelman et al. 1992
Professional – NHL	1100	88.3	51.2	Dewart et al. 1999
Cycle Ergometer				
Professional – 1972/73	12	75.9	54.1	Bouchard et al. 1974
University	15	76.9	54.5	Thoden & Jette 1975
Junior	24	77	58.4	Bouchard et al. 1974
University	9	77.1	53.2	Hermiston 1975
University	18	78.1	55.2	Romet et al. 1978
National – Canadian	34	78.5	53.4	Coyne 1975
National – Czech.	13	79.1	54.6	Seliger et al. 1972
University	5	79.5	54.3	Daub et al. 1983
University	21	79.8	58.4	Krotee et al. 1979
National – Canadian	23	81.1 ± 1.3	54 ± 1.2	Smith et al. 1982
National – Finnish	27	81.1	52	Vainikka et al. 1982
Junior	9	82.4	52.6	Green et al. 1979 (2)
Professional	38	82.3	43.5	Romet et al. 1978
Professional – 1982/83	29	86.8	51.9	Montgomery & Dallaire 1986
Professional – For. – 1985	27	87.1 ± 5.6	53.3 ± 3.1	Rhodes et al. 1986
Professional – Def. – 1985	40	90.3 ± 4.3	51.6 ± 1.5	Rhodes et al. 1986
University – NCAA	25	80.8 ± 10.4	53.3 ± 8.6	Smith, T. et al. 1998
Professional – For.	14	87.1 ± 5.6	53.2 ± 5.2	Cox et al. 1988
Professional – Def.	6	90.3 ± 4.3	50.9 ± 1.5	Cox et al. 1988
Professional – NHL – 1980	38	85.3 ± 1.1	54 ± 1.1	Cox et al. 1993
Professional – NHL – 1984	38	88.2 ± 1.1	54.4 ± 0.8	Cox et al. 1993
Professional – NHL – 1988	23	91.2 ± 1.5	57.8 ± 1.2	Cox et al. 1993
Professional – NHL – 1991	75	88.4 ± 0.8	60.2 ± 0.6	Cox et al. 1993
Team Canada – 1991	55	89.3 ± 0.8	62.4 ± 0.5	Cox et al. 1993
Professional		90.7 ± 4.5	62.8 ± 6.2	Koch et al. 1999
University – NCAA		81.3 ± 8.9	59.1 ± 5.5	Koch et al. 1999
Skating - On - Ice				
University	10	72.8	62.1	Léger et al. 1979
University	17	73.7	55	Ferguson et al. 1969
University	8	78.7	52.8	Green 1978
University	5	79.5	52.1	Daub et al. 1983

Table 4. Characteristics of Individual Subjects.

Subject	Age (yrs)	Height (cm)	Weight (kg)	Body fat (%)	Sum of 6 skinfolds (mm)
1	20	160	58.6	14.2	86.2
2	19	175	57.3	24.5	133.4
3	21	160	73.2	21.2	118.1
4	19	170	55.4	21.5	119.7
5	21	170	63.2	20.8	116.5
6	19	157	73.2	20.6	115.6
7	19	157	60.4	24.7	134.5
8	21	163	57.7	20.2	114.0
9	19	173	63.2	20.8	116.3
10	20	178	68.6	21.9	121.5
11	20	168	61.4	27.6	147.9
12	20	170	73.2	19.9	112.2
Mean	19.8	166.8	63.8	21.5	119.7
S.D.	0.8	7.2	6.6	3.3	15.0

Table 5. Summary of Subjects' Perceptions of WIPSS Jaw-Joint Protector™.

Subject	Q1	Q2	Q3	Q4	Q5
1	1	1	6	B	1
2	2	5	9	B	5
3	2	4	3	C	1
4	1	3	3	B	3
5	1	4	5	B	5
6	2	7	7	C	3
7	1	6	8	A	8
8	5	8	9	A	8
9	3	4	8	B	5
10	1	3	5	B	1
11	1	5	7	B	1
12	2	4	5	B	5
Mean	1.8	4.5	6.2	N/A	3.8
S.D.	1.1	1.8	2.0	N/A	2.5

Table 6. Graded Protocol on Skating Treadmill.

Subject	VO_2 max ($mL \cdot kg^{-1} min^{-1}$)	V_E max ($L \cdot min^{-1}$)	Heart Rate max ($beats \cdot min^{-1}$)
1	53.77	107.20	183
2	45.78	110.13	190
3	60.78	101.03	182
4	60.66	115.37	182
5	43.19	116.93	179
6	45.59	98.50	184
7	44.73	110.27	181
8	45.30	119.27	185
9	49.31	89.07	187
10	39.95	87.80	-
11	38.54	107.93	-
12	51.14	138.47	-
Mean	48.23	108.50	183.67
S.D.	7.22	13.82	3.32

Heart Rate data not available for subjects 10, 11 and 12.

Table 7. Flat Protocol on Skating Treadmill.

Subject	VO_2 max ($mL \cdot kg^{-1} min^{-1}$)	V_E max ($L \cdot min^{-1}$)	Heart Rate max ($beats \cdot min^{-1}$)
1	54.90	119.10	199
2	52.49	96.57	195
3	55.27	121.90	194
4	57.97	130.33	192
5	50.57	122.67	195
6	52.90	93.37	200
7	51.10	105.27	192
8	52.23	131.63	194
9	53.54	113.87	188
10	46.72	98.13	178
11	49.52	111.27	194
12	50.99	124.57	-
Mean	52.35	114.06	192.82
S.D.	2.93	13.20	5.90

Heart Rate data not available for subject 12.

Appendix F

Questionnaire : Subject Perception of Mouthguard

Questionnaire

Please answer the following questions as truthfully and accurately as possible.

1) Indicate (mark an X), on a scale of 1 to 10, the degree to which you feel wearing the mouthguard affected your speech (i.e. ability to communicate verbally).

Considerably Somewhat Not At All

2) Indicate (mark an X), on a scale of 1 to 10, the degree to which you feel wearing the mouthguard was comfortable.

Very Uncomfortable Somewhat Comfortable Very Comfortable

3) Indicate (mark an X), on a scale of 1 to 10, the degree to which you feel wearing the mouthguard affected your breathing.

Hindered Somewhat Hindered Unhindered

4) Which skating treadmill protocol did you prefer to do the maximum test? Please circle your answer.

a) Graded
b) Flat
c) No Preference

5) Indicate (mark an X) whether you would you wear this type of mouthguard in your hockey games?

No Maybe Yes

Appendix G

Testing procedures and Mouthguard Protocol

Testing Procedures

Prior to any testing, you will be given a consent form to read carefully and sign. This will confirm your willingness to participate, on a voluntary basis, in the present study.

You will be asked to participate in 3 separate testing sessions, each separated by at least 24 hours.

The duration of each testing session will be between 45-60 minutes.

You are asked to refrain from eating and drinking (except water and sports drinks) for 2 hours prior to each testing session.

You are asked to wear your own skates, gloves and stick.

Also, you are asked to wear shorts and a t-shirt.

It would be a good idea to bring a water bottle and a small towel.

You will be provided with sufficient time to warm-up and stretch if you have not already done so prior to entering the lab.

Height, weight and body composition will be assessed by a qualified female student.

You will be asked to wear a heart-rate monitor during the testing sessions.

Finally, you are asked to fully bite down (clamp) on the mouthguard with both the upper and lower teeth during the entire session in which the mouthguard will be tested.

Mouthguard Protocol

Procedure for Fitting Mouthguard

Follow the instructions and refer to the diagrams on the sheet that is provided with the mouthguard.

1) Determine the appropriate size. Make any adjustments to the size with scissors or a knife. Cut along one of the 3 "sizing" lines indicated in the diagram.

2) Insert "bite plate" as shown on the diagram.

3) Follow the 2-step boiling procedure. First, place the mouthguard in boiling water ONLY up to the "boil line" and ONLY for 20 seconds. Second, place the entire mouthguard in boiling water for an additional 10 seconds. Time is critical (over 30 seconds total destroys mouthguard).

4) Remove from water and place mouthguard on bottom teeth. The "bite plate" MUST remain fully inserted to maintain proper airway space while biting. Bite down slowly to ensure teeth fit in upper channel. Bite down hard to make an imprint. Mold to mouth. Mouthguard MUST show teeth imprints.

5) Wash with cold water immediately to set form.

It is important that you wear your new mouthguard on at least 3 occasions (20-30 minutes each) before it can be tested in the laboratory. Use the following table to indicate the dates and number of times that you have worn the mouthguard.

Name:______________________________

# of Times Worn	Date	# of Minutes Worn
1		
2		
3		

Appendix H

McGill University Ethics Approval

MCGILL UNIVERSITY
FACULTY OF EDUCATION

CERTIFICATE OF ETHICAL ACCEPTABILITY FOR FUNDED AND NON FUNDED RESEARCH INVOLVING HUMANS

The Faculty of Education Ethics Review Committee consists of 6 members appointed by the Faculty of Education Nominating Committee, an appointed member from the community and the Associate Dean (Academic Programs, Graduate Studies and Research) who is the Chair of this Ethics Review Board.

The undersigned considered the application for certification of the ethical acceptability of the project entitled:

Effect of Protocol and Mouthguard on VO2max in Female Hockey Players using the Skating Treadmill

as proposed by:

Applicant's Name Chris Stefik

Applicant's Signature Chris Stefik

Degree / Program / Course M.A.

Supervisor's Name Dr. David L. Montgomery

Supervisor's Signature David Montgomery

Granting Agency non-funded

The application is considered to be:
A Full Review ______

An Expedited Review X

A Renewal for an Approved Project ______

A Departmental Level Review ______
Signature of Chair / Designate

The review committee considers the research procedures and practices as explained by the applicant in this application, to be acceptable on ethical grounds.

1. Prof. [redacted] Ron Stringer
Department of Educational and Counselling Psychology
Ron Stringer Feb. 16/2001
Signature / date

2. Prof. John Leide
Graduate School of Library and Information Studies
John Leide 01/02/19
Signature / date

3. Prof. René Turcotte
Department of Physical Education
René Turcotte Feb. 19/01
Signature / date

4. Prof. Lise Winer
Department of Second Language Education

Signature / date

5. Prof. Claudia Mitchell
Department of Educational Studies

Signature / date

6. Prof. Kevin McDonough
Department of Culture and Values in Education

Signature / date

7. Member of the Community

Signature / date

Mary H. Maguire Ph. D.
Chair of the Faculty of Education Ethics Review Committee
Associate Dean (Academic Programs, Graduate Studies and Research)
Faculty of Education, Room 230
Tels: (514) 398-7039/398-2183 Fax: (514) 398-1527

Mary Maguire Feb 27, 2001
Signature / date

(Updated January 2000)

MCGILL UNIVERSITY / FACULTY OF EDUCATION
CERTIFICATE OF ETHICAL ACCEPTABILITY FOR FUNDED AND NON FUNDED RESEARCH INVOLVING HUMANS CHECKLIST
(Updated January 2000)

The items indicated below require your attention before the Ethical Review Committee can process and approve your research project. Please make sure to include all of them and refer to the attached Ethical Research Procedures and Ethical Research Guidelines. ***Incomplete applications and or applications with errors will be sent back to the applicant.***

1. __X__ Indicate the Type of Review :
Full Review __________________ Expedited Review ____X__________
Annual Renewal of Approved Project __________________________
Departmental Approval as Part of Undergraduate or Graduate Course Work ____________

2. __X__ Certificate of Ethical Acceptability for **Funded and Non Funded Research Involving Humans**
It includes:
• name of the applicant and signature
• name of the supervisor and signature (if applicable)
• title of the research project
• degree program (if applicable)
• granting agency (if applicable)

3. __X___ A clear, comprehensible Statement of Ethics of Proposed Research and your signature. (Refer to Form - items 1 to 6).

4. __X___ An abstract or brief summary (1-2 pages) of the research proposal.

5. __X___ Submission requirements:
A. For Expedited Review submit **2** copies of the certificate and statement forms, and a summary (1-2 pages) or abstract of the research proposal.
B. For Full Review submit **8** copies of the certificate and statement forms and the entire proposal.
C. For Departmental Review submit **1** copy of the completed statement form and the certificate signed by the Department Chair, or Designate.

6. __X___ A copy of informed consent form(s) and procedures for obtaining free and informed consent. The informed consent must be written in language that is appropriate for the participants.

7. ______ If applicable, a copy of the instrument to be used for collecting the data (e.g. questionnaire, interview, etc.) or, if using a commercial test, include a copy of the test and a brief description of it.

8. ______ Any other certificate of ethics which funding agencies may require.

9. ______ For Review of Research in other jurisdictions or countries: Submit a copy of Ethics Review Approval from the relevant agency or institution for research to be performed outside the jurisdiction or country of the institute which employs the researcher.

IMPORTANT POLICY STATEMENTS:

- Approval of ethics acceptability must be obtained before data collection for a funded or non funded project.
- All funded and non funded research undertaken at McGill University must be verifiable.
- All researchers must be able to have respondents confirm that they gave specific data.
- Confidentiality must be ensured. It can be generally achieved by establishing a system such as matching identification numbers with names and placing the names in a sealed envelope that is kept in a secure place.
- The exact procedures used should be clearly explained in (6.1) of the statement of ethics form.
- All researchers in the Faculty of Education must obtain the name and informed consent of all research participants 18 years of age or older. For populations under 18, in most circumstances, informed consent must be obtained from parents or guardians as well as children.

Submit to the Office of the Associate Dean (Academic Programs, Graduate Studies and Research)
Faculty of Education, Room 230
Tel: (514) 398-7039/2183 / Fax: (514) 398-1527

Updated January 2000

MCGILL UNIVERSITY FACULTY OF EDUCATION

STATEMENT OF ETHICS OF PROPOSED RESEARCH

It is assumed that the responses to the questions below reflect the author's (or authors') familiarity with the ethical guidelines for funded and non funded research with human subjects that have been adopted by the Faculty of Education and that responses conform to and respect the Tri-council Policy Statement: Ethical Conduct for Research Involving Humans (1998).

1. Informed Consent of Subjects

Explain how you propose to seek informed consent from each of your subjects (or should they be minors, from their parents or guardian). Informed consent includes comprehension of the nature, procedures, purposes, risks, and benefits of the research in which subjects are participating. Please append to this statement a copy of the consent form that you intend to use.

Prior to testing, each subject will be given a consent form which will describe the nature, purpose, procedure and potential risks and benefits of the study. Each subject will be made aware of their right to withdraw from the study at any time. The graduate student (Chris Stefik) will read the consent form with each subject, ensuring that they clearly understand the terms of the study and their rights as individuals participating in research. Testing will begin only after the subject has agreed to participate in the study and has signed the consent form. All subjects will be eighteen (18) years of age or older.

2. Subject Recruitment

2.1 Are the subjects a "captive population" (e.g., residents of a rehabilitation centre, students in a class, inmates in a penal establishment)?

No. The subjects will be elite female ice hockey players, between the ages of 18 and 24 years.

2.2 Explain how institutional or social pressures will not be applied to encourage participation. (See attached guidelines)

All of the subjects will participate in the study on a volunteer basis only.

2.3 What is the nature of any inducement you intend to present to prospective subjects to persuade them to participate in your study?

The study offers each subject a chance to skate on a synthetic surface (skating treadmill) and receive valuable feedback regarding their personal level of fitness, as it relates to their sport (hockey).

2.4 How will you help prospective participants understand that they may freely withdraw from the study at their own discretion and for any reason?

Subjects will be informed verbally of their right to withdraw from the study at any time and for any reason before the study begins. This will also be made clear in the informed consent form.

3. Subject Risk and Well-being

What assurance can you provide this committee (as well as the subjects) that the risks, physical and/or psychological, that are inherent to this study are either minimal or fully justifiable given the benefits that these same subjects can reasonably expect to receive?

The physical risks involved in this study are not different from those inherent to normal participation in high intensity exercise. The subjects will be healthy female athletes (varsity hockey players) who habitually engage in exercise at similar intensities to those that will be required during the testing sessions. Also, when skating on the treadmill, a harness will always be securely attached to the subject to protect her from falling off the treadmill.

4. Deception of Subjects

4.1 Will the research design necessitate any deception to the subjects?

No.

4.2 If so, what assurance can you provide this committee that no alternative methodology is adequate?

Not Applicable.

4.3 If deception is used, how do you intend to nullify any negative consequences of the deception?

Not Applicable.

5. Privacy of Subjects

How will this study respect the subjects' right to privacy, that is, their right to refuse you access to any information which falls within the private domain?

The information collected from each subject is not expected to be of such a personal nature that they would refuse access. However, subjects will be clearly informed of their right to deny access to any personal information at any time during the course of the study.

6. Confidentiality/Anonymity

6.1 How will this study ensure that (a) the identity of the subjects will be concealed and (b) the confidentiality of the information which they will furnish to the researchers or their surrogates will be safeguarded? (See guidelines on confidentiality/anonymity section).

Each subject's name will be replaced by a number in order to ensure the anonymity of the subjects. All data collected for all subjects will be analyzed only by the graduate student (Chris Stefik) and his supervisor (Dr. David L. Montgomery). All data stored on computer will be coded and all other data will be locked in a filing cabinet with access given only to the persons mentioned above. In publications (thesis and research article), the subjects' identities will remain unknown.

6.2 If applicable, explain how data will be aggregated in such a way that even should the identity of the participants become known, no reasonable inference could be made about the performance, competence, or character of any one of these participants.
If data will not be aggregated, provide a detailed explanation.
For case study research see attached guidelines, section case studies.

All individual subject data will be aggregated into means and standard deviations. No individual data will appear in publications (thesis or research article). No personal information will be used.

Signature of researcher: Chris Stefik

If this project has been submitted to another ethics committee, please note the particulars:

Submit this statement to:
Office of the Associate Dean
(Academic Programs, Graduate Studies and Research)
Faculty of Education, Room 230
Tel: (514) 398-7039/2183
Fax: (514) 398-1527

Overview of the Study

The present study will employ a skating treadmill to elicit maximal aerobic capacity (VO_2 max) in athletes. The study aims to determine whether there is a difference between two protocols designed to elicit VO_2 max on the skating treadmill and whether the use of a specific mouth guard, designed to help reduce the risk of head injury, has an effect on VO_2 max.

The skating treadmill is similar to a running treadmill, however, the surface is comprised of polyethylene slats over which the skate blade can slide. Researchers, trainers, therapists, coaches and the players themselves benefit from a tool that can replicate the skating stride in a laboratory setting. The speed of the skating treadmill can be adjusted from 0 to 32 km/h and the slope can be adjusted from 0 to 16% grade.

The participants in this study will be 15 female varsity ice hockey players from McGill University who will range in age from 18 to 24 years and have differing levels of playing experience at the varsity level (i.e. one to four years). The height and weight of each subject will be collected. Body composition will be assessed using the sum of six skinfolds (triceps, abdomen, subscapula, iliac crest, thigh, medial calf). Prior to data collection, each subject will skate a minimum of three 30-minute sessions to allow for familiarization with the treadmill. Subjects will be asked to skate on the treadmill on three separate occasions. Each session will last approximately 1 hour with the subjects actually skating between 16 and 20 minutes. Each subject will read and sign a consent form prior to testing.

In the first session, subjects will skate for 4 minutes at each of three increasing velocities (14, 16 and 18 km/h) interspersed with 5 minutes of rest. This will establish submaximal norms and serve as a warm-up period. Upon completion of the third velocity and recovery period, a VO_2 max test will begin whereby the subject will begin skating at 20 km/h at 0% grade with the speed increasing by 1 km/h each minute until volitional fatigue is attained. Expired air will be analyzed continuously throughout each testing session using a Sensor Medics Metabolic Cart. Heart rate will be recorded for each minute of the test using a Polar Electro Sport Tester. Stride rate will be measured at each velocity by visually counting the number of strides taken per minute.

In the next session, subjects will perform the same protocol as the previous session, however, they will wear a specially designed athletic mouth guard during the testing.

In the final session, subjects will perform only a VO_2 max test preceded by a warm-up. The protocol will differ in that the grade of the treadmill will be increased by 1% each minute while the speed will remain constant at 18 km/h. Subjects will be asked to skate until volitional exhaustion.

The independent variables in this study will be the protocol (flat with increasing speed vs constant speed with increasing grade) and the use of the mouth guard vs no mouth guard. The dependent variables will be VO_2 max (ml/kg*min), heart rate (bpm), stride rate (strides/min) and stride length (m/stride). Following the completion of data analysis, each subject will be presented with a summary and explanation of their individual results. The data collected in this study will also help to establish a set of norms depicting female varsity ice hockey players' maximal aerobic capacity.

Appendix I

Subject Information and Consent Form

McGill University
Seagram Sport Science Centre

Dr. David L. Montgomery
Exercise Physiology Laboratory

Chris Stefik
Graduate Student

Consent Form for Exercise Testing

I, (print name) ______________________________ authorize Dr. David L. Montgomery and Chris Stefik to administer the exercise tests outlined below which will be used for research purposes. I understand that the staff conducting the tests may ask me to discontinue the tests if any indication of an abnormal response becomes apparent. I understand that I will perform the tests as listed below.

Tests to be Performed

1. **Body Composition:** Age (years), height (cm) and weight (kg) will be measured. Body composition will be assessed using skinfold measurements at the following six (6) sites: triceps, subscapula, iliac crest, abdominal, front thigh and rear thigh.

2. **Treadmill Skating Economy and VO_2 max Tests:** You will be asked to perform a skating economy test followed by a VO_2 max test on two (2) separate occasions. You will be asked to perform only a VO_2 max test on a third occasion. For the skating economy tests, you will be asked to skate on the treadmill for four (4) minutes at each of two (2) increasing velocities (14 and 16 km/h). You will have five (5) minutes of recovery between each skating velocity. Following completion of the second velocity, a VO_2 max test will commence at 18 km/h with speed increasing by 1 km/h each minute until such time as you become exhausted and decide to end the test. Upon your third visit to the lab, you will be asked to perform a VO_2 max test at a constant speed (16 km/h) while the grade (slope) of the treadmill is increased by 1% each minute until such time as you become exhausted and decide to end the test.

3. **Recap:** You will be asked to visit the lab on three (3) separate occasions as follows:

    1. Body Composition, skating economy and VO_2 max without a mouth guard (flat treadmill protocol).
    2. Skating economy and VO_2 max with a mouth guard (flat treadmill protocol).
    3. VO_2 max without a mouth guard (graded treadmill protocol).

The purpose of this study, the procedures to be used, the benefits and risks associated with my participation in this study, as well as the confidentiality of the data that will be collected during the study have all been clearly explained to me and I have understood what my participation in this study entails.

I have had the opportunity to ask questions concerning aspects of this study and my questions have been answered to my satisfaction.

I acknowledge that I have read and fully comprehend this information. I voluntarily accept participation in this study. I am aware that I am free to withdraw from this study at any time and for any reason without penalty or consequence.

I acknowledge that I have received a signed copy of this consent form.

____________________	____________________	____________________
Name of subject	Signature	Date
____________________	____________________	____________________
Name of Witness	Signature	Date
____________________	____________________	____________________
Name of researcher	Signature	Date

Appendix J

Contribution of Co-Authors in the Research Article

Christopher J. Stefik was involved in the recruitment of subjects, collection of data and the writing of this thesis.

Dr. David L. Montgomery was the thesis advisor and was an integral part of writing the research article.

Dr. Scott Delaney was a member of the thesis advisory committee and obtained the mouth guards that were used in this study.

Dr. David Pearsall was a member of the Bauer hockey research team and provided technical support.

Dr. Rene Turcotte was a member of the Bauer hockey research team and provided technical support.