THE COMPARISON OF DIFFERENCES IN LOWER BODY KINEMATICS DURING FORWARD TREADMILL SKATING BETWEEN TWO DIFFERENT HOCKEY SKATE DESIGNS

MICHAEL HELLYER

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

Faculty of Kinesiology and Recreation Management

University of Manitoba

Winnipeg, Manitoba

Abstract

The purpose of this study was to investigate the kinematic differences in ankle plantar flexion range of motion and angular velocity during propulsion of the forward hockey skating stride between a traditional hockey skate and a hockey skate that has a flexible rear tendon guard. Secondary purposes included investigating the kinematic differences in range of motion and angular velocity at both the knee and hip during propulsion while participants were wearing both skate designs. Differences in stride length, stride width and stride velocity during propulsion between the two different skate designs were then investigated. Finally differences in range of motion and angular velocity of the ankle, knee, and hip along with the velocity of the skating stride and the time the skate blade was in contact with the treadmill were investigated as the skating treadmill increased in speed from 3.33 m/s to 8.05 m/s.

Eight elite hockey players were selected for the present study, which was conducted on an Endless Ice Skating Treadmill. Variables were recorded using a three-camera setup and measured at five selected treadmill speeds using Dartfish Team Pro version six software. Kinematic variables were then compared between the two skate designs with a doubly multivariate repeated measures design. Statistical significance was set at $p<0.05$. Post hoc univariate tests comparing skate designs displayed significant increases in plantar flexion, plantar flexion angular velocity, hip extension, hip extension angular velocity, stride length, and stride velocity while participants were wearing the skate that had a flexible rear tendon guard. Significant increases were also displayed in plantar flexion, plantar flexion angular

velocity, knee extension, knee extension angular velocity, hip extension, hip extension angular velocity, hip abduction range of motion, hip abduction angular velocity, stride width, stride length, and stride velocity as the treadmill speed increased. There was also a significant decrease in the time the skate was in contact with the treadmill as treadmill speed increased. The results suggested that while skating forward, hockey players could improve their hockey skating technique by using a hockey skate that has a flexible rear tendon guard.

Table of Contents

ACKNOWLEDGEMENTS

I would like to thank my thesis committee members: Dr. Marion Alexander, Dr. Cheryl Glazebrook, Dr. Jeff Leiter, and Dr. David Telles-Langdon. Thank you so much for your time and guidance in helping with the completion of this study. I would like to offer special thanks to Dr. Marion Alexander for her countless hours of reading, reviewing and passing on valuable insight. I also want to thank Winnpro Hockey and Sheena of the Biomechanics Lab at the University of Manitoba for their assistance with filming.

I would like to extend my thanks to Easton Hockey for donating the Easton Mako hockey skates, as well to the participants of the study for their participation. Lastly, I would like to thank my family for all their support throughout my post-secondary education. I am very grateful and could not have accomplished my goals without you.

List of Figures

LIST OF TABLES

CHAPTER 1

INTRODUCTION

The Sport of Hockey

Although the roots of the game of hockey date back to c. 600 - 480 BCE where it was played in civilizations such as Egypt, Persia, and Greece it was not until March 3, 1878 that James Creighton organized the first ice hockey game at the Victoria skating rink in Montreal, Quebec (McKinley, 2009). Creighton and his peers played hockey for two 30-minute periods wearing spring skates and leather gloves. A flat circular piece of wood that was not allowed to leave the ice was used as a puck, goaltenders had to stay on their feet, and forward passing was a penalized action. This nine vs. nine match was the first ever-recorded ice hockey game (Mckinley, 2009).

Ice hockey has changed dramatically since Creighton and his peers played in front of a small crowd back in 1878 and has developed into one of the most popular sports in the world. This popularity is shown with increases in participation of the youth age group which saw participation levels reach 548 000 in Canada and 350 885 in the USA during the 2010-2011 season (Smith, 2010; USA hockey, 2011). Hockey players now wear helmets made of carbon fiber or other hard protective materials, composite skates, shoulder, elbow, and knee pads made with hard plastic protective caps, pants with protective inserts, and use carbon fiber hockey sticks to shoot and pass a hard rubber puck into the opposing teams net. The advancement in technology has improved equipment and along with the addition of modern strength and conditioning programs athletes are now bigger, stronger, and faster than they have ever been. Hockey players have been reported to skate at speeds over 12.5 meters/second (45km/hr) and possess the ability to shoot a hockey puck over 44.4 meters/second (160km/hr) making it one of the fastest sports in the modern era (Hutchison, Comper, Meeuwisse, & Echemendia, 2013).

Skating in Hockey

Hockey is a sport that requires a high level of strength, power, and skill. To be successful at the professional level you need to be proficient in all the skills required to play the game; however skating has come to the forefront as one of the most important skills in which a player must excel (McPherson, Wrigley, & Montelpare, 2004). Players must be able to skate forwards, backwards, crossover, pivot, start, and stop during a hockey game. Players who have the ability to skate faster than their opponent are able to travel down the ice gaining possession of a puck putting them into position to aid their team in scoring or denying a goal.

The research completed in hockey skating has been focused on the physiology of training and conditioning along with skill development. There has been minimal research conducted on how the biomechanical design of equipment can affect skating performance (Robert-Lachaine, Turcotte, Dixon, & Pearsall, 2012). The performance of a hockey player depends on several factors, including strength, agility, aggression, shooting ability, and skating skill, which includes the equipment used during play. A study performed by Hoshizaki, Kirchner, & Hall, (1989) compared ankle range of motion while skating in different ice hockey skates and concluded that conventional hockey skates restrict the range of motion at the ankle joint for a hockey player. These authors suggested that skate manufacturers should consider altering skate flexibility when designing skates in the future.

Skate researchers have started to focus on new ways to increase the range of motion at the ankle joint in the traditional hockey skate design. The attempt to develop innovative hockey skate designs, shares the same revolutionary concept the klapskate brought to the sport of speed skating by increasing ankle range of motion (Hoshizaki, Hall, & Bourque, 1989; Madore, 2003). This new type of hockey skate design allowing greater plantar flexion should be thoroughly investigated as it has the potential to provide ice hockey players with added joint range of motion, potentially increasing forward skating speed. This investigation has been selected due to the recent trend in the hockey community to pursue biomechanical advancements in the design of the hockey skate (Turcotte, Pearsall, & Montgomery, 2001; Hancock, Lamontagne, Stothart, & Sveistrup, 1999; Pitkin, Smirnova, Scherbina, & Zvonareva, 2002; D. J. Pearsall, Paquette, Baig, Albrecht, & Turcotte, 2012; Robert-Lachaine et al., 2012).

The Hockey Skate

John Forbes the foreman for the Starr manufacturing company and Thomas Batemen, his assistant, revolutionized ice skating by inventing the self-fastening spring skate in 1865 (Figure 1). This invention allowed ice hockey to become faster and more exciting as skates were securely fastened to the boots with the flick of a lever. This was an improvement from previous skates which were held to a skaters' boot by leather straps, buckles, or rope (G. Vaughan, 1996).

The next step in improving the hockey skate design was also attributed to Forbes's company. With skate companies appearing all over Canada, the U.S., and Europe the Starr hockey skate was the first to implement a curved, wider blade with rounded ends allowing for faster turning and direction changes. This was a marked change from the traditional long, flat, thin blade which was ideal for long gliding stokes (Vaughan, 1996).

Figure 1. Starr hockey skates.
(Vaughan, 1996, p. 122).

In 1900 Tube skates, which were lighter in weight, came in many different styles. These skates were produced to improve the speed and agility of hockey players. The modern skate era has evolved dramatically since this time when new skate blades would be purchased from the hardware store, the skate boots from the shoe store and combined at home by the consumer (Vaughan, 1996). Skate blades are now sold to players as one piece, connected to a skate boot by a blade holder that helps to improve the performance of skating in hockey.

The Modern Hockey Skate

Hockey skate manufacturers have improved skating performance by making skates more stable, reducing their weight, and adding protection for the foot (Robert-Lachaine et al., 2012). The modern hockey skate consists of a skate boot with upper and lower portions, blade holder, and skate blade (Bourque, 1985). This traditional skate design has improved skating performance over time: however, it has also maintained some of the characteristics seen in hockey skates of the past. Skate boots are now more rigid, possess higher ankle collars and have stiff achilles tendon guards providing players with stability to help balance over the small skate blade. These characteristics also protect the skater's ankle from opponent's sharp skate blades and sticks along with hard rubber pucks travelling at high speeds that may result in injury during this fast paced sport.

Although these characteristics provide the athlete with stability and protection they also limit the skater from producing a full range of motion at the ankle joint (Robert-Lachaine et al., 2012). This reduction in ankle range of motion could possibly lead to limiting the range of motion not only at the ankle but also at the knee and hip reducing a player's maximum skating speed.

The Klapskate

Figure 2. The Klapskate

The ice skates used in the sport of speed skating went through a revolutionary transformation in 1997. This time period saw the introduction of the klapskate (Figure 2) which enabled athletes to improve skating performance immediately along with shattering all of the current world records (Houdijk, De Koning, De Groot, Bobbert, & van Ingen Schenau, 2000).

The speed at which speed skaters could skate increased by 0.3 m/s in the first year alone (Kuper & Sterken, 2003). It was presented by Houdijk., Heijnsdijk, De Koning, De Groot, & Bobbert, (2000) that klapskates not only enabled skaters to skate at a higher velocity, 10 m/s compared to 9.6 m/s, but also allowed them to maintain an equal velocity at a lower metabolic level compared to the conventional skate. The difference between the conventional speed skate and the klapskate was that the klapskate was equipped with a hinge between the shoe and blade under the ball of the foot. This hinge allows the skater to plantar flex the foot at the end of push-off while the entire blade of the skate remains in contact with the ice (Houdijk et al., 2000).

Ankle Range of Motion Affecting The Knee

It has been established that the range of motion occurring at the ankle joint influences the range of motion at the knee joint during sport performance (Haguenauer, Legreneur, & Monteil, 2006; Houdijk et al., 2000). When comparing push-offs in speed skating between conventional speed skates and klapskates Houdijk et al., (2000) concluded that klapskates, which enabled the skater to increase the range of motion at the ankle, also increased the work output at the knee joint. In the final 50 ms of force production during the skating stride the center of pressure of the propulsion force reaches the ball of the skaters foot. The center of pressure will stay under the ball of the foot for speed skaters wearing the klapskate design, as the hinge placed under the ball of the foot allows the entire skate blade to stay in contact with the ice as the skater plantar flexes the ankle. A skater wearing a conventional skate design will see the center of pressure pass from the ball of the foot and move forward to the end of the blade. This occurs because the entire skate blade is fixed to the boot of the conventional skate design (Houdijk et al., 2000).

The skate blade must be rotated laterally and positioned perpendicular to the direction of force applied by the skater. This is necessary to grip the ice with the inside edge of the blade producing enough friction to develop a propulsive force. If this perpendicular position of the skate blade is not met the skate will slip forwards or backwards due to the lack of frictional force applied to the ice by the skate blade. The klapskate design allows the skater to direct the propulsive force perpendicular to the blade of the skate as the ankle is plantar flexed and the knee is fully extended (Houdijk et al., 2000).

This transpires as the klapskate keeps the blade in a perpendicular position until the knee reaches full extension. As a skater reaches the maximum amount of plantar flexion while wearing the restrictive conventional skate, fully extending the knee will now create a forward directed force relative to the skate blade. Therefore, it is a position of knee flexion during the latter stages of propulsion that is required to direct the propulsive force perpendicular to the skate blade while wearing the conventional skate. This prevents the knee from fully extending and contributing in the later stages of force production during forward skating (Houdijk, et al., 2000).

Haguenauer et al., (2006) also compared the effects ankle range of motion has on the knee joint. Elite figure skaters performed vertical jumps on a force plate for three separate conditions: barefoot, wearing a 1.5 kg ankle weight on both legs simulating the weight of the skates, and while wearing figure skates. These authors found that the stiff design of the figure skate boot decreased the athlete's ability to jump by limiting plantar flexion at the ankle joint. This decrease in ankle joint range of motion had significant implications on the knee joint during leg extension. Haguenauer et al., (2006) concluded that participants displayed significant decreases in knee extension at the instant of toe-off when wearing the restrictive skate boot. Participants displayed knee extension values 8.59 degrees less when wearing the skate boot compared to wearing ankle weights. This finding coincides with Houdijk et al., (2000) that reducing the amount of ankle plantar flexion an athlete has will reduce the amount of knee extension during extension of the lower limbs, which is crucial in force production during forward skating in ice hockey.

Skates Used In This Study

The participant's personal skates were considered the traditional skate design for this study. The materials the particpant's personal skates are made from may differ slightly from other skates on the current market but contained the biomechanical properties of a high ankle collar, and stiff achilles tendon guard that are consistent with other modern skates on store shelves.

The Easton Mako hockey skate (Figure 3) served as the new skate design during this study. This skate was chosen due to the new biomechanical characteristics it possesses. Developed by the chief of skating speed at Easton hockey, Dave Cruikshank, this new skate design includes a raised heel, an asymmetrical skate boot with the medial side sitting five millimeters taller than the lateral side of the boot (Figure 3), and an active extendon guard on the rear of the skate boot (Figure 4).

Figure 3. Easton Mako hockey skate

Purpose

The purpose of this study was to investigate the kinematic differences in ankle plantar flexion range of motion and angular velocity during propulsion of the forward hockey skating stride between a traditional hockey skate and a hockey skate that has a flexible rear tendon guard. Secondary purposes included investigating the kinematic differences in range of motion and angular velocity at both the knee and hip during propulsion while participants were wearing both skate designs. As well, differences in stride length, stride width and stride velocity during propulsion between the two different skate designs were then investigated. Finally differences in range of motion and angular velocity of the ankle, knee, and hip were investigated along with stride velocity, and the time the skate blade was in contact with the treadmill as the skating treadmill increased in speed from 3.33 m/s to 8.05 m/s.

Null Hypotheses

1. There will be no difference in ankle plantar flexion range of motion and angular velocity between the traditional ice hockey skate design and the skate design with the flexible tendon guard.
2. There will be no difference in knee range of motion and angular velocity between the traditional ice hockey skate design and the skate design with the flexible tendon guard.

3. There will be no difference in hip range of motion and angular velocity between the traditional ice hockey skate design and the skate design with the flexible tendon guard.
4. There will be no difference in stride length, stride width, stride velocity, and the time the skate blade is in contact with the treadmill for participants while wearing both the traditional ice hockey skate design and the skate design with the flexible tendon guard.
5. There will be no difference in the following variables between the treadmill speeds of 3.33 m/s and 8.05 m/s: ankle plantar flexion range of motion and angular velocity, knee range of motion and angular velocity, hip range of motion and angular velocity, stride length, stride width, stride velocity, and the time the skate blade is in contact with the treadmill.

Rationale For The Study

A hockey player's ability to be effective for his/her team is highly dependent on their ability to skate faster than their opponents. Past literature has focused primarily on the kinematic variables of skating performance while neglecting what impact biomechanical changes in skate design can offer a player (Chang, Turcotte, & Pearsall, 2009; Lafontaine, 2007; Marino & Weese, 1979; Robert-Lachaine et al., 2012; Upjohn, Turcotte, Pearsall, & Loh, 2008). The sport of speed skating was subjected to a change in skate design that saw athletes improve skating performance dramatically (Houdijk et al., 2000). The introduction of the klapskate in 1997 allowed speed skaters to keep their blade in contact with the ice longer as they pushed into the ice. This was done with a hinge placed under the ball of the foot between the skate boot and the blade (Houdijk et al., 2000)(Figure 2).

This new hinge allowed the skater to increase the amount of plantar flexion at the end of push off which is correlated to the amount of time the blade is in contact with the ice surface during force production of the forward skating stride. The increase in time the blade is in contact with the ice during force production increases the impulse a forward skater can create against the ice as impulse is the product of force and time (Behm, Wahl, Button, Power, & Anderson, 2005). This increase in impulse will allow the skater to travel faster down the ice enabling them to finish before their opponents.

Figure 4. Flexible rear tendon guard on the Easton Mako skate.

Although a hinge under the ball of the foot is not practical in the sport of ice hockey due to the variety of skills a hockey player must complete during a game, other design modifications can be made to the traditional hockey skate in order to take advantage of the klapskate concept without compromising performance in other skills that a player must be proficient. Easton hockey has developed a new skate that houses a flexible rear tendon guard (Figure 4). This new tendon guard was constructed to allow added plantar flexion as a hockey skater pushes into the ice surface just as the klapskate does for a speed skater. This added plantar flexion is said to occur without reducing the player's ability to complete other skills that are needed to be an elite ice hockey skater. This skate also has an asymmetrical skate boot with the lateral side resting five millimeters lower than the medial portion of the boot (Figure 3). This characteristic was designed to promote a larger angle of eversion, which could potentially lead to a longer hockey stride while skating forward.

The results of this study will provide insight into the biomechanical advantages a hockey skater might have while wearing a new skate design that includes a flexible rear tendon guard. This new tendon guard aims to increase plantar flexion during the hockey stride, which in turn should increase a hockey player's skating speed and performance while not inhibiting his/her performance in other aspects of skating such as stopping, turning and changing direction.

Limitations

- Participants will wear their own personal skates during part of this study. This may result in differences in technique due to skate differences when considering the participant's personal skates as the traditional hockey skate design.
- The participants were filmed wearing only compression shorts or pants rather than a full set of hockey equipment. This may have altered their skating kinematics compared to skating with hockey equipment in an actual game.
- There may be differences in skating technique due to the use of the skating treadmill and not an actual ice surface.
- The video cameras used in this study are also a limitation as they were not high-speed cameras. This may produce variance in the time in which the skate blade left the treadmill at the end of propulsion.
- Stationary camera positioning may lead to errors in measurement, as the cameras are unable to stay in the primary plane for the duration of the movement.

Delimitations

- Using only male participants may not allow the researcher to generalize the findings to female ice hockey players.
- Using elite hockey skaters may not allow the researcher to generalize the findings to all hockey players.

Definition of Terms

Active Range of Motion: the range of motion achieved by the participant using active muscular contraction with no assistance from the primary researcher (Roberts & Wilson, 1999).

Angular velocity: the rate of change of angular displacement over a given time (Robertson, 2004).

Blade Hollow: the distance of the hollow created at the running surface of the skate blade (Federolf & Redmond, 2010).

Double support: the time during the hockey stride in which two skates are in contact with the ice.

Impulse: the product of the average force and the time interval during which the force acts: impulse = force x time.

Momentum: the product of an object's mass and velocity (Robertson, 2004).

Passive Range of Motion: the range of motion achieved by the participant as the primary researcher moved the joint through the range of motion with no contribution from the participant (Roberts & Wilson, 1999).

Power: the amount of work divided by the time in which the work acted on or P = W/t (Robert-Lachaine et al., 2012; Robertson, 2004).

Propulsion: the position at the last frame before loss of treadmill contact of the force producing leg.

Range of motion: the angle through which a joint moves from anatomical position to the extreme limit of segment motion in a particular direction (Hall, 2007).

Recovery: the movement occurring from propulsion to weight acceptance.

Single support: the time during the hockey stride in which one skate is in contact with the ice.

Stride length: the distance the skate blade travels from weight acceptance to propulsion.

Stride Rate: the number of strides taken per second.

Stride velocity: the rate of change of displacement of the blade in the direction of the stride over a given time.

Weight acceptance: the first frame in which the rear of the skate blade comes in contact with the skating treadmill.

CHAPTER 2

REVIEW OF LITERATURE

Skating Kinematics

The hockey stride is a biphasic movement consisting of a support phase that has both a single and double support phase, and a swing or recovery phase (Upjohn et al., 2008). The right and left legs work together in a cyclic pattern propelling the skater down the ice surface. The single support phase, which is 75-85 percent of the stride, begins as soon as the rear foot lifts off the ice-surface and ends as it touches back on the ice surface near the midline of the body (Marino & Weese, 1979). Double support occurs as soon as the recovery leg touches the ice near the midline of the body and ends when the contralateral skate lifts off the ice surface. Marino & Weese (1979) concluded that the acceleration of the hockey stride begins approximately half way through single support continuing into double support. Researchers have attributed the ability to accelerate during both single and double support to the placement of the recovery foot coming down into a position ready for propulsion (McPherson et al., 2004). Marino & Weese (1979) found hockey skaters showing greater skill are able to maintain acceleration throughout both the single and double support phases.

It is the phase of propulsion, or time of force production, that is being investigated during the current study. Increasing force production during the stride enables the skater to "develop a relatively high horizontal velocity over a relatively short period of time" (Marino & Weese, 1979). The power generated during propulsion comes from sequential extension of the hip, knee, and ankle in a lateral thrust and abduction of the hip (Alexander, M. J. L., Taylor, C., & Shackel, B., 2007). The hip, knee, and ankle should almost reach full extension enabling a player to push against the ice as long as possible. Each push should be done with the weight of the player on the ball of the foot and be executed directly against the entire length of the blade for as long as possible (Alexander et al., 2007). This is done by externally rotating the hip prior to propulsion that places the blade of the skate perpendicular to the line of force.

There has been evidence suggesting that as a skater accelerates their skating kinematics change. De Koning, Thomas, Berger, De Groot, & van Ingen Schenau, (1995) analyzed the kinematics of the starting technique in five elite speed skaters using high-speed cameras. The authors concluded that during the first few strides of the start skaters would extend the hip and knee directly behind the body, as they continued increasing speed skaters would show more hip abduction creating more of a lateral skating stride. This lateral stride occurred on the eighth push-off. Lafontaine (2007) studied the starting kinematics in ice hockey players. He concluded that the starting kinematics were similar to that of speed skaters; however the transition from a posteriorly directed stride to a laterally directed stride occurred during the third stride.

This type of wider stride with focus in the frontal plane is known to be a characteristic of high-calibre hockey skaters (Greer, 1990). When comparing skating kinematics between high and low-calibre skaters Upjohn et al., (2008) noted that even though stride rate was similar the increase in skating speed was attributed to greater stride width, greater hip flexion at weight acceptance, and greater knee and ankle range of motion. The greater amount of hip flexion at weight acceptance allows the skater to produce a greater stretch in the anterior thigh and hip extensor muscles before the concentric contraction occurs during propulsion. This was also true for the position of the knee joint. Upjohn et al. (2008) discovered that high-calibre skaters produced larger angles of knee flexion at weight acceptance. This was suggested to "transfer more elastic energy to the quadriceps for concentric contraction during the propulsive phase, which translates to a greater power generation during the end of propulsion" (p.214).

Increasing the range of motion at the knee and ankle joints has also been a characteristic of high-calibre hockey skating. The greater the range of motion at the knee and ankle during propulsion suggests there is more power being generated and likely contributes to an increase in skating speed of hockey players (Upjohn et al., 2008). Increasing the angular velocities occurring about these two joints will also have implications in increasing a hockey players' ability to skate forward. Pagé (1975) stated that high velocity skating was created partly by higher angular velocities occurring in the lower limbs throughout propulsion.

Pearsall et al., (2001) studied the kinematics of the foot and ankle in forward ice hockey skating with the use of bilateral twin axis goniometers. They found the ankle to increase in dorsiflexion from 7.1 degrees, at the beginning of single support, to 11.8 degrees at takeoff. Once the player lifted the blade off the ice plantar flexion occurred to a position of 1.9 degrees of dorsiflexion. This dorsiflexed position of the ankle was explained as being necessary to prevent scraping of the skate tip on the ice surface which in turn would create a large unwanted frictional force (Pearsall et al., 2001). These authors also found that their participants were in a constant state of eversion during propulsion reaching a maximum eversion at the ankle of 7.1 degrees. This was reached just prior to blade takeoff and was likely a result of the need to generate a laterally directed force against the ice surface (Pearsall et al., 2001).

Dewan, Pearsall, & Turcotte., (2004) studied the ankle kinematics during forward hockey skating of five university hockey players. With the use of goniometers they concluded that there was a trend for an increase in range of motion at the ankle joint as the hockey players accelerated to a high velocity. A study by Robert-Lachaine et al., (2012) also investigated the kinematics at the ankle during skating by comparing a modified skate with an elastic tendon guard to a traditional skate. The modified skate demonstrated substantial and significant gains in plantar flexion range of motion during forward ice-skating. They found a maximal plantar flexion of 16 degrees during forward skating, which was four to five degrees larger than the traditional skate. With the use of force measuring strain gages in their modified skate these authors concluded that the total peak force of the plantar flexors occurred later during plantar flexion. These findings suggest that the increased range of motion in the ankle joint resulted in a more prolonged effective force generation during propulsion. Although this change in ankle range of motion did not lead to an increase in skating speed in this study it may lead to “delaying fatigue during the course of a game as a higher effective range of motion would allow a more optimal force-length relationship of the muscles involved" (p.203).

A recent study by Tidman, Lambert, Cruikshank, & Silver-Thorn, (2014) compared skate design with performance by comparing the Easton Mako skate to a traditional skate design. Fifteen male subjects aged 12 and 13 were given a training program that lasted six sessions. With the use of a six-camera Vicon motion analysis system it was established that the Easton Mako skate increased maximum speed (13%) and stride width relative to height (4%) while ankle sagittal range of motion and subtalar ranges of motion were both decreased. These authors went on to conclude, "further investigation is warranted to investigate this unanticipated result" (p. 2).

Hockey Player Anatomy

In order to investigate the effects that skate design has on the performance in forward skating it is important to have an understanding of which joint and muscle structures are involved during the specific movements of the skating stride.

Ankle Anatomy

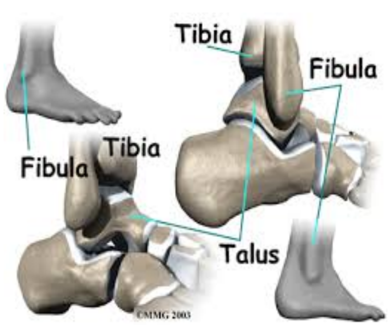


Figure 5. Ankle joint

The talocrural joint, more commonly known as the ankle joint, is a hinge-type synovial joint that is located between the distal ends of the tibia and the fibula and the superior part of the talus (Moore, Dalley, & Agur, 1999). The proximal articular surfaces of the ankle joint are the distal surface of the tibia and the tibial and fibular malleoli (Figure 5). The distal articulation of the ankle joint is the body of the talus, which has three different articulating surfaces. The three surfaces consist of a lateral fibular facet that acts as the largest articulating surface, a smaller medial tibial facet, and finally a trochlear or superior facet (Levangie & Norkin, 2011).

Ligaments of the Ankle

There are several ligaments that support the ankle joint during the hockey stride. The ligaments that stabilize the tibiofibular joints are: the crural tibiofibular interosseous ligament, the anterior and posterior tibiofibular ligaments, and the tibiofibular interosseous membrane. These all help with supporting this synovial structure while a player skates down the ice (Levangie & Norkin, 2011). The lateral side of this joint is supported by three separate ligaments that are collectively called the lateral collateral ligaments of the ankle. The anterior talofibular ligament extends from the anterior side of the joint to the medial side running from the lateral malleolus to the neck of the talus. Known to be stronger than the anterior talofibular ligaments, the posterior talofibular ligament runs horizontally medially and slightly posteriorly from the malleolar fossa to the lateral tubercle of the talus. The final ligament stabilizing the lateral side of this joint is the calcaneofibular ligament. It passes from the tip of the

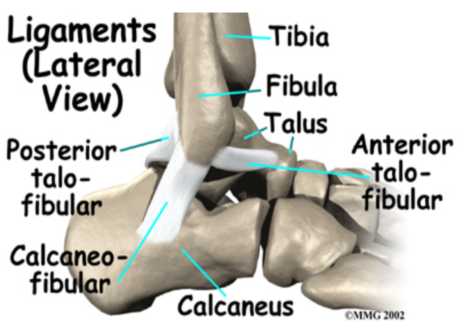


Figure 6. Lateral view of the ligaments of the ankle joint.

lateral malleolus to the lateral surface of the calcaneus in a posterior inferior direction (Moore et al., 1999)(Figure 6).

The medial side of the ankle joint is supported by the thick and strong deltoid ligament that is made up of four ligaments (Figure 7). The tibionavicular, tibiocalcaneal, anterior tibiotalar, and posterior tibiotalar ligaments attach the medial malleolus to the talus, calcaneus, and the navicular (Moore et al., 1999). This structure is known to be extremely strong as injury occurring here has a very low frequency (Moore et al., 1999). Eversion and/or pronation of the ankle and talus can injure the deltoid ligament. However in some cases because of it's strong nature the tibial malleolus has been known to fracture before any damage occurs to the deltoid ligament (Levangie & Norkin, 2011).

Figure 7. Medial ligaments of the ankle

Muscles acting on the Ankle

Figure 8. Anterior and Lateral muscles of the ankle.

There are three fascial compartments that contain muscles which act on the ankle joint during the hockey stride; anterior, lateral, and posterior. The anterior compartment (Figure 8), which is responsible for dorsiflexing the ankle joint, is comprised of four main muscles: tibialis anterior, extensor digitorum longus, extensor hallucis longus, and fibularis tertius. This muscle group has been known to have significant implications on transferring power from weight acceptance to propulsion during the hockey stride. It is known that maximum static and dynamic plantar flexion torques are the greatest at a position of maximum dorsiflexion (Fugl-Meyer, 1981). This suggests that the greater the position of dorsiflexion a skater can attain at weight bearing the greater the torque that is produced during propulsion from the plantar flexors which helps in propelling the skater down the ice. Tibialis anterior, the strongest of the dorsiflexors as well as aiding in inverting the foot, begins at the lateral condyle and superior half of the lateral surface of the tibia and interosseous membrane then travels down across the ankle joint to the medial and inferior surfaces of medial cuneiform as well as the base of the first metatarsal (Moore et al., 1999).

De Koning , De Groot, & van Ingen Schenau (1991) along with Hinrichs et al., (1994) report this muscle to be active during the whole stride other than a short inactive period existing in the middle of propulsion. Extensor digitorum longus, responsible for dorsiflexing the foot and extending the lateral four digits, originates on the lateral condyle of the tibia and the superior three quarters the of medial surface of the fibula and interosseous membrane (Moore et al., 1999). Another muscle responsible for dorsiflexing the ankle as well as extending the great toe is extensor hallucis longus. This muscle originates at the middle part of the anterior surface of the fibula and interosseous membrane and extends to its insertion at the dorsal aspect of the base of the great toe. The final muscle that is considered part of this dorsiflexor compartment is fibularis tertius. This muscle dorsiflexes the ankle as well as assisting in everting the foot, which is important in increasing, stride length during forward hockey skating (Humble & Gastwirth, 1988). Fibularis terius begins at the inferior third of the anterior surface of the fibula and interosseous membrane while inserting at the dorsum of the base of the fifth metatarsal (Moore et al., 1999).

The lateral compartment of the leg consists of two muscles: peroneus longus , and peroneus brevis which are also known as fibularis longus and fibularis brevis. These two muscles are responsible for everting the foot as well as playing a small part in plantar flexing the ankle. This eversion is important for a hockey player in order to angle the skate to push sideways with the inside edge of the skate blade against the ice. This increases the friction between the blade and ice allowing acceleration to occur (Humble & Gastwirth, 1988). Fibularis longus originates at the head and superior two thirds of the lateral surface of the fibula and inserts into the base of the first metatarsal and medial cuneiform (Figure 8). Fibularis brevis attaches proximal to the inferior two thirds of the lateral surface of the fibula to the distal attachment at the dorsal surface of the tuberosity on the lateral side of the base of the fifth metatarsal (Moore et al., 1999). These everters of the subtalar joint are extremely important to a hockey player as the ankle is in constant eversion throughout the propulsion phase of the hockey stride (Upjohn et al., 2008). Lafontaine (2007) also documented the importance of eversion during the hockey stride. This author suggested, “as speed increases, eversion also increases, thus allowing skaters to apply force to the ice in a more tangential direction on the ice surface.”

The final compartment when considering the lower leg muscles acting on the ankle joint is the posterior compartment (Figure 10). Also known as the plantar flexor compartment; this area of the lower leg consists of a superficial muscle group and a deep muscle group. The superficial muscle group of the posterior compartment consists of gastrocnemius, soleus, and plantaris. Gastrocnemius has two heads; the lateral head originates at the lateral aspect of the lateral condyle of the femur while the medial head originates on the popliteal surface of the femur superior to the medial condyle. The lateral and medial heads both plantar flex the ankle when the knee is extended and flex the leg at the knee joint, while inserting on the posterior surface of the calcaneus (Moore et al., 1999). Gastrocnemius, the main plantar flexor of the ankle, is thought to be active throughout most of the hockey stride until after toe-off. Working eccentrically during knee flexion at weight bearing and concentrically throughout propulsion it is suggested that gastrocnemius was active in speed skaters from the beginning of weight acceptance until toe-off with activity declining after toe-off (De Koning et al, 1991).

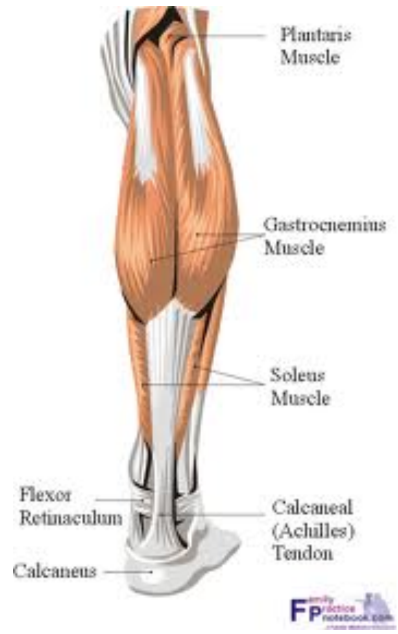


Figure 9. Posterior muscles of the leg.

The soleus muscle runs to the posterior surface of the calcaneus from the posterior aspect of the superior quarter of the fibula, soleal line and middle third of the medial tibia, and the tendinous arch extending between bony attachments. This muscle is responsible for plantar flexing the ankle independent of knee position which aids force production during propulsion of the hockey stride (Moore et al., 1999; Fugl-Meyer, 1981). The final muscle of this superficial group is plantaris, a very small muscle that weakly assists gastrocnemius in plantar flexing the ankle. Plantaris originates at the inferior end of the lateral supracondylar line of the femur and the oblique popliteal ligament, while inserting on the posterior surface of the calcaneus (Moore et al., 1999).

There are four muscles considered part of the deep muscle group of the posterior compartment of the leg with three of them acting on the ankle joint. Flexor hallucis longus originates on the inferior two thirds of the posterior surface of the fibula and inserts on the base of the great toe to weakly plantar flex the ankle. Flexor digitorum longus runs from the medial part of the posterior surface of the tibia and attaches on the bases of the lateral four digits. This muscle along with tibialis posterior passes from the posterior surface of the tibia and fibula to the navicular, cuneiform, cuboid, talar shelf of the calcaneus, and bases of the second, third, and fourth metatarsals plantar flexing the ankle joint (Moore et al., 1999). All of these plantar flexors are important in producing force during the hockey stride as the lower limb extends from weight bearing to propulsion. This has been documented by Upjohn et al., (2008) as they compared kinematics of the lower limbs between high and low-caliber skaters. These authors concluded that high-caliber skaters had shown greater plantar flexion during propulsion when compared to low-caliber skaters.

Ankle Range of Motion

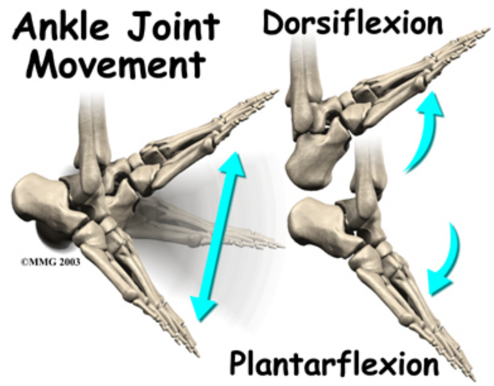


Figure 10. Sagittal ankle range of motion.

The primary motions that occur at the ankle joint are dorsiflexion and plantar flexion, which a hockey skater uses to produce force as he pushes against the ice. Normal range of motion occurring at this joint is 20 degrees of dorsiflexion and 50 degrees of plantar flexion (Levangie & Norkin, 2011). These movements are restricted by soft tissue limitations, dorsiflexion is primarily restricted by the tension of the gastrocnemius and soleus muscles while tension in the tibialis anterior, extensor hallucis longus, and extensor digitorum longus muscles primarily restrict plantar flexion. Dorsiflexion is also restricted by the position of the knee. Typically we see more dorsiflexion in a subject who has a knee in a flexed position rather than a position of knee extension. This is attributed to the lengthening of the gastrocnemius muscle across two joints as the knee is extended (Levangie & Norkin, 2011). The ankle range of motion during forward ice hockey skating does not approach the normal anatomical range of motion reported above. Lafontaine (2007) also documented this restricted ankle range of motion during the hockey stride. He found that skaters participating in a number of starting techniques kept a position of dorsiflexion throughout the entire movement. Another study investigating ankle range of motion in the hockey skate concluded that plantar flexion in hockey skating is restricted primarily due to the stiff achilles tendon guard on the rear of the skate boot (Robert-Lachaine et al., 2012).

Knee Anatomy

The knee joint is composed of two separate articulations, the tibiofemoral joint and the patellofemoral joint (Figure 13). The tibiofemoral joint is a double condyloid articulation between the medial and lateral tibial condyles of the proximal tibia and the medial and lateral condyles of the distal femur. The medial condyle of the distal femur is larger than that of its lateral counterpart, which causes the knee to lock when fully extended with the foot on the ground (Moore et al., 1999). The patellofemoral joint is the articulation between the posterior surface of the patella and the femur. The main purpose of the joint is to lengthen the moment arm of the quadriceps by increasing the distance of the quadriceps tendon and patellar tendon from the axis of the knee joint (Levangie & Norkin, 2011).

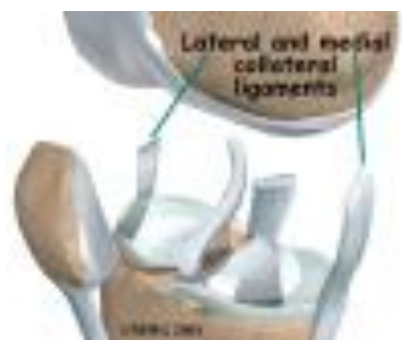


Figure 11. Ligaments of the knee.

Ligaments of the Knee

Extracapsular

The patellar, fibular collateral, tibial collateral, oblique popliteal, and arcuate popliteal are the five extracapsular ligaments mentioned when discussing the knee joint. The patellar ligament is the anterior ligament of the knee that passes through the apex of the patella and joins to the tibial tuberosity. The lateral ligament of the knee is known as the fibular collateral ligament and supports the knee during the support phase of the hockey stride (Humble & Gastwirth, 1988). This ligament extends from the lateral epicondyle of the femur to the lateral surface of the fibular head. The tibial collateral ligament or medial ligament of the knee passes from the medial epicondyle of the femur to the medial condyle of the tibia. This ligament stabilizes the knee joint of a hockey player towards the end of propulsion (Humble & Gastwirth, 1988). The oblique and arcuate popliteal ligaments strengthen the joint capsule of the knee posteriorly. The oblique popliteal ligament runs from the medial tibial condyle blending into the central part of the posterior joint capsule while the arcuate popliteal ligament originates from the posterior aspect of the fibular head and spreads over the posterior surface of the knee joint (Moore et al., 1999).

Intra-articular Structures

There are also ligaments that lie within the knee joint. These ligaments are referred to as intra-articular ligaments and consist of the anterior and posterior cruciate ligaments along with the medial and lateral menisci. The anterior cruciate ligament (ACL) is the weaker of the two cruciate ligaments beginning at the anterior intercondylar area of the tibia and attaches to the posterior aspect of the medial side of the lateral condyle of the femur. This ligament consists of two bundles that wrap around each other, the anteriomedial and posterolateral bundles. The ACL limits posterior rolling of the femoral condyles on the tibial plateau during flexion, prevents the femur from posterior displacement on the tibia, hyperextension of the knee joint as well as providing rotary stability to the knee during medial/lateral rotation and varus/valgus angulations (Levangie & Norkin, 2011; Moore et al., 1999).

The posterior cruciate ligament (PCL) runs superiorly from the posterior tibial surface to the lateral aspect of the medial femoral condyle. The PCL is composed of two bands the posteromedial bundle and the anterolateral bundle. The PCL has a cross-sectional area of 120% to 150% greater than the ACL making it much stronger (Levangie & Norkin, 2011). The function of this strong ligament is to restrain posterior displacement of the tibia below the femur as well as playing a role in restraining varus and valgus stresses at the knee joint during propulsion of the hockey stride. This reaches maximum tension as the skater transfers the body weight to the supported foot (Humble & Gastwirth, 1988).

Medial and Lateral Menisci

The medial meniscus is a "C" shaped structure that improves stability, and provides shock absorption. The lateral meniscus is almost circular in shape and smaller than the medial. The menisci must be able to slide on the tibial surface as the contact points between the femur and tibia change during flexion and extension of the knee joint.

Muscles acting on the Knee

The muscles of the anterior thigh are responsible for extending the knee joint during the hockey stride (Figure 14). This muscle group is known as the quadriceps muscle group and is composed of rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. Rectus femoris is the only knee extensor to cross multiple joints. It originates at the anterior inferior iliac spine and the ilium superior to the acetabulum, inserting on the common attachment all four muscles share, the quadriceps tendon. It is the only knee extensor that aids in flexing the hip, which is required during the recovery phase of the hockey stride. Vastus lateralis originates at the greater trochanter and lateral lip of the linea aspera of the femur. Vastus medialis originates at the intertrochanteric line and medial lip of the linea aspera of the femur while vastus intermedius originates at the anterior and lateral surfaces of the shaft of the femur. Vastus medialis acts eccentrically during weight bearing and concentrically during force production peaking at 0.6s before

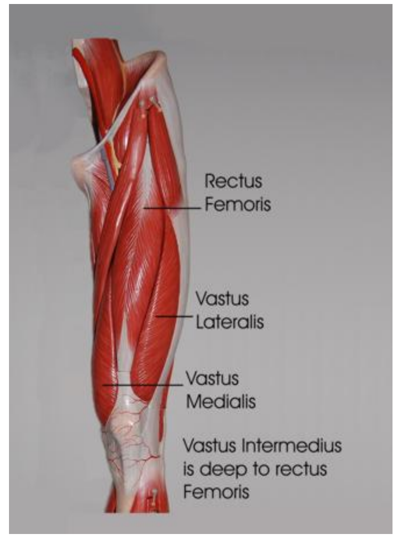


Figure 12. Muscles of the anterior thigh.

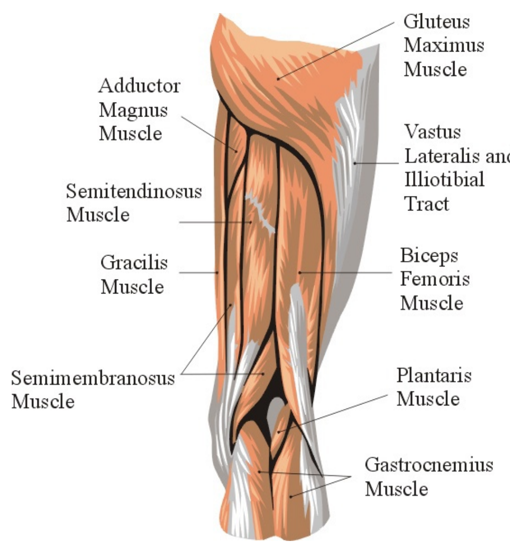


Figure 13. Muscles of the posterior thigh.

the end of toe-off with little activity occurring during the recovery phase of the stride (De Koning et al, 1991).

All three muscles making up this vastus group contribute to knee extension (Moore et al., 1999). The extension of the knee is critical for a hockey skater who wants to travel down the ice at high speeds as elite skaters show greater knee extension at propulsion than non-elite skaters (Upjohn et al., 2008). The knee extensors also have implications for isokinetic torques of the plantar flexors. The plantar flexors that are situated in the posterior compartment of the lower leg show higher peak electromyographic activity in a position of greater knee extension (Fugl-Meyer, 1981). This implies that if a skater can reach a position of greater knee extension during the stride they will be able to produce more force with the plantar flexors at the ankle.

The muscle group situated on the posterior thigh is responsible for flexing the knee joint (Figure 15). Along with flexing the knee this group of muscles, commonly referred to as the hamstrings, extends the hip joint. Hockey players require large ranges of both knee flexion and hip extension to be considered an elite skater (Pagé, 1975; Upjohn et al., 2008). The three posterior thigh muscles include semitendinosus, semimembranosus, and biceps femoris. Semitendinosus originates at the ischial tuberosity and inserts on the medial surface of the superior part of the tibia. Semimembranosus also originates on the ischial tuberosity but inserts on the posterior part of the medial condyle of the tibia (Moore et al., 1999). Both semitendinosus and semimembranosus are responsible for flexing the knee and rotating it medially when the knee is flexed which is important during the recovery phase of the hockey stride. These muscles are also involved in extending the thigh, which is critical during force production. Biceps femoris is made of two separate heads. The long head originates at the ischial tuberocity while the short head originates at the linea aspera and the lateral supracondylar line of the femur. Both the long and short heads insert on the lateral side of the head of the fibula. This muscle is responsible for flexing the knee and rotating it laterally along with extending the hip (Moore et al., 1999).

Biceps femoris is said to be active during both force production (hip extension) and recovery (knee flexion) of the hockey stride (De Koning, 1991). The final muscle that is discussed when describing knee movement is sartorius. Sartorius crosses both the hip and knee joints originating at the anterior superior iliac spine and inserting to the superior part of the medial surface of the tibia. It is responsible for flexing, abducting, and laterally rotating the thigh at the hip joint along with flexing the knee joint (Levangie & Norkin, 2011). These muscles are important for hockey skaters, as differences in knee flexion at weight bearing have been found to be a good indicator of skating ability. Elite hockey skaters showing greater knee flexion at weight bearing possess a greater ability to transfer more elastic energy to the quadriceps for concentric contraction during force production than non-elite skaters (Upjohn et al., 2008).

Knee Range of Motion

The actions occurring at the knee in the sagittal plane include flexion and extension. Passive range of motion in the sagittal plane for the knee is reported to be 130 degrees to 140 degrees (Levangie & Norkin, 2011). A study comparing active range of motion of the knee by Roach & Miles, (1991) found the average range of flexion for participants aged 25 to 74 to be 132 degrees. Roaas & Andersson (1982) stated the average passive range of knee flexion to be 144 degrees. When the knee is flexed it can also move in the transverse plane by internally or externally rotating.

Normal range of motion in the transverse plane for the knee when flexed at 90 degrees is 35 degrees. Lateral rotation is shown to be larger with a range of 0 degrees to 20 degrees where as medial rotation shows values ranging between 0 degrees and 15 degrees. With the use of a measure device called a rottometer Almquist, Ekdahl, Isberg, & Fridén (2013) also measured the range of knee rotation. They found knee rotation to be 33 to 44 degrees in females and 30-38 degrees in males when a 9N m torque was applied to a knee that was in 90 degrees of flexion.

Hip Anatomy

The coxofemoral joint, more commonly known as the hip joint, is a ball and socket joint formed by the articulation occurring between the concave acetabulum of the pelvis and the convex head of the femur (Figure 16). Positioned laterally with an inferior and anterior tilt the acetabulum lies within the three bones of the pelvis: the pubis, the ischium, and the ilium (Levangie & Norkin, 2011).

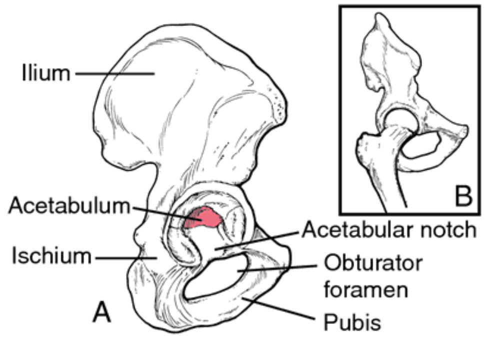


Figure 14. The hip joint

Ligaments of the Hip

Ligamentum teres is a ligament that runs transversely through the head of the femeur connecting the head to the acetabulum of the pelvis. This ligament is responsible for supplying the head of the femur with blood as well as playing a role in stabilizing the hip joint (Levangie & Norkin, 2011). Another stabilizing structure aiding in the protection of this joint is the labrum of the acetabulum. This ring of cartilage around the acetabulum deepens the joint socket keeping the head of the femur inside the acetabulum. There are three other reinforcing ligaments that help stabilize this very mobile joint. The iliofemoral ligament that passes from the ilium to the intertrochanteric line of the femur and the pubofemoral ligament, which starts at the pubis and runs to the joint capsule

Figure 15. Ligaments of the hip joint.

both help reinforce the anterior side of this joint while the ischiofemoral ligament helps reinforce the posterior portion by connecting the ischium to the femoral neck (Moore et al., 1999).

Muscles of the Hip

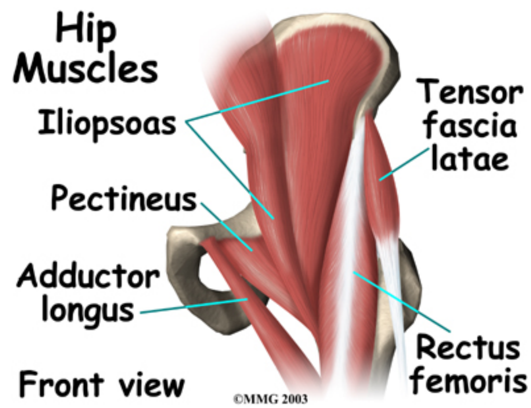


Figure 16. Muscles of the hip.

The main flexors of the hip joint include: pectineus, iliopsoas, psoas minor, iliacus, and sartorius. These muscles are used for stability, to decelerate the leg at the end of the stride, and to help with the recovery of the leg while returning to the weight bearing position. Pectineus adducts and flexes the hip while assisting with medial rotation. This muscle originates at the superior ramus of the pubis and attaches to the pectineal line of the femur. Iliopsoas, which is a combination of iliacus and psoas major, is the most powerful of the hip flexors originating from the iliac fossa and lumbar vertebrae while inserting on the lesser trochanter of the femur. Psoas minor also aids in flexing the hip as it passes from the iliac crest, fossa and sacrum to the psoas major tendon and lesser trochanter of the femur (Moore et al., 1999). High-calibre skaters use these muscles to achieve faster skating velocities by producing greater hip range of motion (Upjohn et al., 2008).

The adductor muscle group (Figure 19) consists of five muscles, which are used in ice-skating to balance on the hockey skate blades, decelerate the leg at the end of force production by eccentrically contracting, and concentrically contracting

Figure 17. Hip adductor muscles of the right leg.

during recovery (Chang et al., 2009). The primary action of adductor longus, which passes from the pubis to the linea aspera of the femur, is to adduct the hip. In addition to also adducting the hip adductor brevis creates a flexion moment at the hip. It begins at the pubic bone as well but travels to the pectineal line and proximal part of the femur. Adductor magnus is the largest hip adductor of this group creating the most power from its two different parts. It has shown larger activation magnitudes and prolonged activation times in ice-skating when compared to other adductor muscles (Chang et al., 2009). The adductor part of this muscle flexes the hip while originating from the pubis and ischium and inserting on the medial supracondylar line. The hamstring part of this muscle passes from the ischial tuberosity and attaches to the adductor tubercle of the femur to extend the hip. Gracilis aids in adducting the thigh while flexing and medially rotating it as well. It originates at the inferior ramus of the pubis and attaches to the superior medial tibia. The last muscle of this group is obturator externus that laterally rotates the thigh and aids in holding the head of the femur tightly in the acetabulum (Moore et al., 1999).

This muscle group is also one of the most injured sites affecting hockey players, accounting for approximately 10% of all injuries (Chang et al., 2009). In a study examining preseason hip strength and the risk of receiving a hip adductor injury Tyler, Nicholas, Campbell, & McHugh (2001) concluded that a player was seventeen times more likely to sustain an adductor strain if the adductor strength was less than 80% of his abductor strength.

Muscles that aid in extending the hip to help push a player down the ice include the previously mentioned hamstring group, and the gluteus maximus. Starting at the ilium posterior to the gluteal line, sacrum, and coccyx the gluteus maximus assists in lateral rotation of the hip by inserting into the gluteal tuberosity and the lateral condyle of the tibia via the iliotibial tract. This large extensor of the hip is active during the early part of the stride until toe-off (Hinrichs, 1994). The rest of the gluteal muscles; medius and minimus along with tensor fascia latae abduct and medially rotate the hip. These muscles are of critical importance for a hockey player to be successful on the ice. Upjohn et al., (2008) found that high-caliber skaters have a greater rate of adduction during weight acceptance and a greater range of hip abduction during force production when compared to low-caliber skaters.

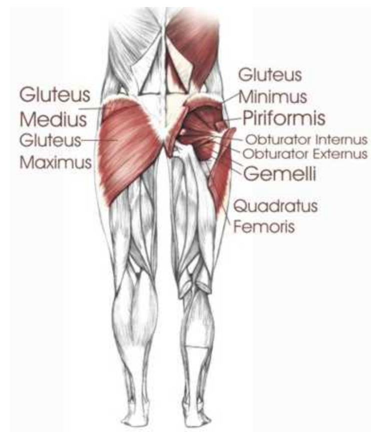


Figure 18. Extensors and abductors of the hip.

The piriformis, obturator internus, and the superior and inferior gemelli muscles originate at the sacrum, pelvic surface of the obturator membrane, and ischial spine and tuberosity respectively (Moore et al., 1999). All of these muscles insert on the greater trochanter of the femur playing a role in laterally rotating the extending hip. This aids in turning the blade perpendicular to the line of travel and increasing stride length; two characteristics exhibited by high caliber skaters (Upjohn et al., 2008). They also play a role in abducting the hip when it is in a position of flexion (Moore et al., 1999).

Hip Range of Motion

The hip has a very large range of motion. Normally the hip can be flexed to a position of 140 degrees and extended to a position of 20 degrees. The hip is capable of externally rotating 30 degrees when the hip is in a position of extension, 50 degrees when the hip is flexed and medially or internally rotating to a position of 40 degrees. The other two movements this versatile joint is capable of are abduction and adduction. Abduction range of motion is regularly 50 degrees when the hip is extended and 80 degrees while in flexion, whereas adduction shows normal values of 30 degrees for the extended position and 20 degrees with flexion (Nordin & Frankel, 2001).

The Skating Treadmill

With the dynamic environment of forward skating during the sport of hockey it has been difficult for researchers to produce accurate kinematic data to quantify this important skill. The recent development of the skating treadmill consisting of parallel polyethylene slats has made this quantification possible (Nobes et al., 2003; Upjohn et al.,2008; Morrison et al., 2005). The three major companies that manufacture this specialized piece of equipment are Infinity Ice, previously known as Endless Ice, Woodway which manufactures “the blade”, and Xplosive Ice. Skating treadmills are typically 2.4-3.66 m (8-12 feet) in length, 1.82-2.6 m (6-8.5 feet) wide, operate to a speed of 8.94 m/s (20mph), have a stick handling deck in front of the track, and come with a safety harness system (Figure 23). This piece of equipment has proven to be very useful to skating researchers whose objective is to set up a controlled environment while investigating forward skating in ice hockey (Hinrichs, 1995; Tidman et al., 2014; Upjohn et al., 2008).

Hinrichs (1994) compared EMG activity while skating on ice and a treadmill. He found there to be no difference in EMG activity for the tibialis anterior, vastus medialis, and rectus femoris. Although he found significant differences in the EMG activity of gastrocnemius, adductor longus, biceps femoris, and gluteus maximus these differences occurred during the recovery phase. Since the propulsion phases were similar he concluded that the treadmill is a valuable training device to help examine skating mechanics (Hinrichs, 1994). A study comparing the skating economy of ice hockey players on-ice and on a skating treadmill by Nobes et al., (2003) found that on-ice V02max was similar to V02max on a treadmill. Turcotte et al., (2004) compared plantar force distribution patterns while skating on ice and a skating treadmill by taping sensors to the removable insole of the subject's skates. This study concluded the distributions to be very similar in both conditions and went on to suggest the skating treadmill "will allow for rapid in-depth analysis of potential changes in skating performance induced by changes in skate design" (p. 271).

Dartfish TeamPro Video Analysis Software

Dartfish Teampro version six video analysis software (2013) was used to analyze the video during this study. When compared to a 3D motion capture system (Vicon) it was concluded that Dartfish has serious potential for future studies involving complex movements (Eltoukhy, Asfour, Thompson, & Latta, 2012). Extensive research in image and processing at the Swiss Federal Institute of Technology led to the creation of SimulCam™ in the year 1997. After a positive response from the sporting community InMotion Technologies (now known as Dartfish) was founded the following year, in 1998, to commercially develop SimulCam™ and other digital imaging applications. Dartfish now employs more than 50 people with headquarters in nine different countries (Dartfish, 2013). This software allows researchers to transfer and review video from a number of different sources into a computer. Once imported this video can be used to analyze specific skills both quantitatively and qualitatively.

Impulse momentum

An important factor when considering ice hockey skating speed is the force applied to the ice by the hockey player. The greater the force applied to the ice by the player the faster he will skate forwards. Using all of the joints in the lower body to their maximum capability increases the force applied to the ice surface. The force applied to the ice can be estimated by the use of the Impulse-Momentum relationship. This relationship states that the impulse applied will alter the momentum (Hall, 2007).

Impulse is the product of the average force and the time interval during which the force acts: impulse = force x time or impulse = F x t. Momentum is equal to the product of an object's mass and velocity: momentum = mass x velocity or m x v. In the case of skating the impulse applied to the ice surface by the hockey player will change their momentum as they travel down the ice. This relationship is defined by: impulse = (momentum final) – (momentum initial) or $Ft = mv_f - mv_i$.

If the velocity of the skater before and after the stride being analysed is known and the time in which force application of the stride was executed is known, the force produced by the hockey skater during that specific stride can be calculated since mass is constant. This concept can also be used when discussing the advantages of increasing the ankle range of motion during forward skating. If force were to remain the same and the time in which that force was applied is increased, due to the increase in ankle range of motion allowing the blade of the skate to stay in contact with the ice surface longer, then final velocity of the skater will increase since we know mass of the skater and initial velocity will be constant.

Angular Velocity

Angular velocity is defined as the rate of change of angular displacement over a given time (Robertson, 2004). High calibre skaters show greater angular velocity of the hip, knee, and ankle during propulsion when compared to low calibre skaters (Upjohn et al., 2008). These authors reported values of hip abduction (63.6 degrees/second), knee extension (212.1 degrees/second), and ankle plantar flexion (214.4 degrees/second) to be larger in high calibre skaters than their lower calibre counterparts during propulsion. Page (1975) concurred with the results of Upjohn et al., (2000) and concluded that high velocity skating was partly due to higher angular velocities in the joints of the lower limbs during propulsion. Page (1975) also gave special consideration to the angular velocity of knee joint extension when discussing skating velocity. When comparing push-off mechanics in skating with the klapskate and conventional skate Houdijk et al., (2000) found peak angular velocities in the ankle to be greater while wearing the klapskate. The results from this study suggest that increasing ankle range of motion by implementing a new skate design may lead to an increase in angular velocity of the lower limbs, which may lead to increased performance in skating.

Angular Work and Power

Angular work can be expressed as W = F x θ x r where W is angular work, F is the force applied, θ is the angular displacement, and r is the distance of the force being applied to the axis of rotation. This can be simplified to W = T x θ, where T is the torque applied to the segment and θ is angular displacement. Angular power is the amount of angular work divided by the time in which it acts on or P = W/t, where P is power, W is work and t is time (Robertson, 2004). This can also be calculated as P = (T x θ) / t *or* $P = T x \omega$, where ω is the angular velocity of the segment. Therefore an increase in angular velocity (ω) would lead to an increase in power. This increase in angular velocity, which is a characteristic of elite skaters, increases the power in which they have in the lower legs to propel them down the ice at faster speeds (Upjohn et al. 2008).

Work and Power

Two measurements used commonly in skating are work and power. Work is defined as the product of force and distance covered or W=F x Δd. In skating the longer the stride at a given speed, the greater the amount of work per stride (Vaughan, 1988 p. 146). Power is defined as the amount of work divided by the time in which the work acted on or P = W/t (Robert-Lachaine et al., 2012; Robertson, 2004). Increasing both work and power during a given time period enable a skater to travel faster down the ice (Vaughan, 1988).

When comparing work and power between a modified skate with a flexible rear tendon guard and a traditional skate Robert-Lachaine et al., (2012) found that total work was significantly higher (14-20%) for the modified skate. The results from this study also displayed higher values of power (17-21%) for participants wearing the modified skate when compared to the traditional skate design. Although not significant these results suggest that adding range of motion at the ankle joint during forward skating can increase the work and power output of a skater which will increase the speed at which they can propel themselves down the ice.

Stride rate vs Stride length

Stride rate and stride length are two variables discussed throughout the skating literature when discussing changes in skating velocity (Marino, 1977; Marino & Weese, 1979; Humble & Gastwirth, 1988; Page., 1975; Upjohn et al., 2008). There has been disagreement throughout the literature towards the contribution both these variables have with increasing skating velocity. Marino (1977) related changes in velocity to stride rate. He reported that stride rate was high, when skating velocity was high, and as velocity decreased so did stride rate. There was also a noted decrease in stride length as skating velocity increased during the study (Marino, 1977). Humble & Gastwirth (1988) concurred by stating "stride rate is important with regard to skating velocity, whereas stride length is not" (p. 374).

Upjohn et al., (2008) found that high caliber players skated faster by increasing stride length, more specifically stride width, rather than stride rate. Pagé, (1975) attributed increases in skating velocity to both stride rate and stride length. Pagé (1975) concluded characteristics of skaters with higher skating velocities were longer, wider strides, accompanied by a faster stride rate. Nobes et al., (2003) also found that both stride rate and stride length increased as skating velocity increased. Participants skating on a treadmill at speeds of 5 m/s, 5.56 m/s, and 6.11 m/s displayed increases in both stride rate and stride length as the treadmill increased in speed.

While investigating hip adductor function during forward skating Chang et al., (2009) also concluded that both stride rate and stride length are increased as skating velocity increases. Participants of Chang et al.. (2009) skated at a low speed of 3.33 m/s, and a maximum speed of 6.66 m/s on a skating treadmill. Skaters displayed increases in stride rate of 0.38 strides/second along with a 1.53 m increase in mean stride length as the treadmill went from 3.33 m/s to 6.66 m/s. If the Easton Mako skate is capable of increasing stride length by increasing ankle range of motion, it may be capable of increasing skating velocity in the forward hockey stride.

Flexibility testing

There are a number of different ways to test the range of motion at the ankle joint (Magee, 2000; Clarkson, 2000). Magee (2000) states that dorsiflexion and plantar flexion should be tested with the participant lying in a supine position and the knee joint fully extended due to the gastrocnemius muscle crossing both the knee and the ankle. Clarkson (2000) shows two ways to measure the dorsiflexion and plantar flexion of the ankle. The first with the participant lying supine with the knee in a position of 20 degrees to 30 degrees of flexion by placing a roll under the knee and the second with the participant sitting at the end of the table with the lower leg hanging off the edge with the knee at a position of 90 degrees of flexion.

Chapter 3

Methods

Participants

A power analysis based on ankle plantar flexion data from the pilot study was conducted to determine the optimal sample size of this study. A significance level (alpha) of 0.05 and type two-error beta of 0.2 was set to produce a desired power of at least 0.80. Using G*Power version 3 software, which is a reliable power analysis program, it was determined that a minimum of 8 participants were required to ensure adequate power during this study (Faul, Erdfelder, Lang, & Buchner, 2007). Participants were recruited via email (Appendix D). Coaches at the university level were emailed and asked to forward a document (Appendix D) to current and previous hockey players who have competed at the university and/or professional level. Participants then voluntarily contacted the primary investigator (Appendix F). Recruiting elite skaters who have skated at the university or professional level helped with minimizing the risk involved with skating on the treadmill. Recruiting this type of participant also helped in gaining insight into the biomechanical changes this new skate design will have at an elite level of competition. There was no compensation offered to participants for taking part in this study.

Acquisition of Experimental Skates

The Easton Mako skates were obtained for the duration of the study from an Easton sales representative located in Winnipeg, Manitoba. The appropriate sizes were loaned to fit the different sized feet of the participants.

Pre-Testing Procedure

Prior to the study participants were required to provide written consent by signing an informed consent form approved by the Education/Nursing Research Ethics Board (ENREB) from the University of Manitoba (Appendix B). Participants then signed a Physical Activity Readiness Questionnaire for Everyone (Appendix C) from the Canadian Society for Exercise Physiology (CSEP). This form was used as a health-screening tool in order to determine if participants were fit to participate. Participants then answered a short questionnaire to collect information including: height (cm), weight (kg), age (yrs), hockey experience (yrs), and skate brand (Appendix F). At this time participants were assigned a number by which they were tracked and recorded during the data collection process.

The participant's personal skates and the Easton Mako skates were both sharpened with a 0.5 inch hollow and similar rocker radius by Custom Edge Skate Service to help eliminate skate blade differences between the two pairs of skates. Foot and ankle flexibility measurements were then taken with a Canon GL2 video camera to later be calculated using Dartfish Team Pro version six (Dartfish, 2013). This included both passive and active range of motion testing for the foot and ankle in three different conditions: while wearing no skate, while wearing the current skate they are using (traditional design), and while wearing the Easton Mako skate.

Ankle range of motion testing

Ankle range of motion testing was accomplished by videotaping movements with a Canon GL2 video camera. Video was then transferred to a Dell laptop where measurements were calculated using Dartfish Team Pro version six software (Dartfish, 2013). Ankle dorsiflexion and plantar flexion in both passive and active conditions were measured with participants lying supine on a table (Clarkson, 2000). A rolled towel was placed under the knee to maintain 20 to 30 degrees of knee flexion. This position of flexion rather than knee extension was used, as it more accurately simulates the position of the lower limb during hockey skating.

The tibia and fibula were stabilized with the axis of rotation marked just inferior to the lateral malleolus. The stationary arm of the joint was placed parallel to the longitudinal axis of the fibula with the movable arm of the joint marked parallel to the inferior aspect of the heel eliminating forefoot movement from the measurement. Ankle dorsiflexion and plantar flexion were measured while wearing the hockey skate with the same procedure. This was accomplished by measuring the distance between points on the lower limb and the lateral malleolus to help estimate it's position within the hockey skate boot (Figure 21).

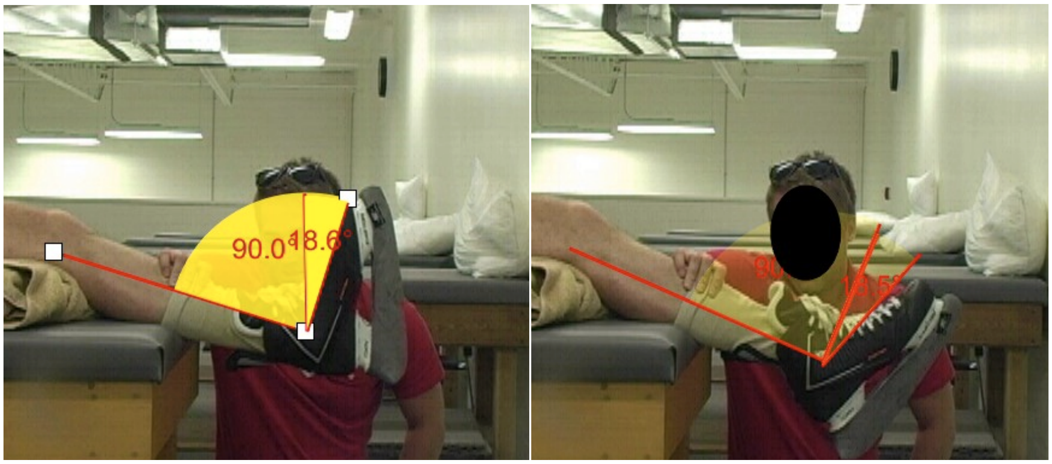


Figure 19. Measurement of ankle dorsiflexion (18.6 degrees) and plantar flexion (18.5 degrees) of the right ankle while wearing the Easton Mako skate.

Inversion and eversion of the subtalar joint were measured with the participant lying prone and the feet positioned beyond the end of the table (Clarkson, 2000). The ankle was set in a neutral position with two markings on the skin being placed over the midline of the superior aspect of the calcaneus posteriorly, and the inferior aspect of the heel pad. The tibia and fibula were then stabilized with the axis of rotation placed at the midline of the superior aspect of the calcaneus. The stationary arm of the joint was placed parallel to the longitudinal axis of the lower leg with the movable arm of the joint being placed along the midline of the posterior aspect of the calcaneus in line with the mark on the heel pad posteriorly (Clarkson, 2000)(Figure 22). Inversion and eversion with the hockey skate was measured with the same procedure however the movable arm was modified to align with the center of the skate blade, as the mark on the heel pad was not visible.

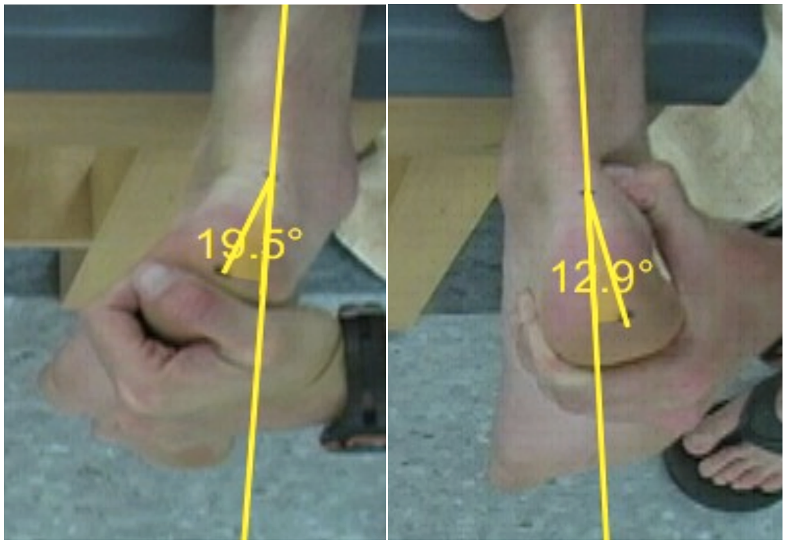


Figure 20. Measurement of subtalar inversion (19.5 degrees) and eversion (12.9 degrees) with no skate of the right leg.

Filming Technique

Filming of the participants while skating took place on an Endless Ice skating treadmill located at Custom Edge Skate Service in Winnipeg, MB (Figure 23). A three-camera set-up was used to capture video for the right side of the body. A Canon GL2 camera was used to film the sagittal view from the right. This camera was placed on a tripod approximately 230 cm from the skating zone. A Fujifilm EXR camera was attached to a tripod and fixed to the wall in

Figure 21. Endless ice skating treadmill

front of the skating treadmill at an approximate distance of 240 cm from the skating zone capturing data in the frontal plane. A third camera (Canon GL2) was placed in the direction of the stride of the right leg. This camera position was altered during the filming of each participant to remain in the sagittal plane of the right leg at toe-off.

Procedure

Participants were instructed by the primary researcher to perform a dynamic warm-up consisting of approximately five minutes of aerobic activity and five minutes of total body calisthenics. Forward lunges, backward lunges, lateral lunges, high knees, butt kicks, quadriceps dynamic stretches, hamstring touches, lateral side shuffles, grapevine, and short bouts of forward sprints were conducted in order to allow participants an adequate warm-up. Following the warm up participants were randomly selected to the traditional skate group or the Easton Mako group. Each participant was then outfitted with body markers at the right hip (RHIP) and right knee (RKNE). RHIP was located at the superior aspect of the right greater trochanter while RKNE was located at the lateral epicondyle of the right femur. These marker locations are consistent with the University of Ottawa's gait laboratory protocol (Robertson, 2009) and were used to help in consistently measuring joint angles with Dartfish Team Pro version six (Dartfish, 2013).

At this time participants were harnessed to the overhead track of the treadmill for safety. The safety harness is a modified climbing harness that is connected to an overhead tracking system and wired to the control panel. If the safety harness undergoes ≥ 15lbs of pressure at any given time during operation of the treadmill it sends a signal to the control panel that shuts off the treadmill instantly. This weighted kill switch attached to the safety harness along with a padded bar positioned across the front of the treadmill for participants to hold on to are designed to prevent injury in the case of a fall.

A fifteen-minute familiarization period was then given to the participants so they could become accustomed to skating on the treadmill. This familiarization period was instructed by a WinnPro Hockey skating instructor and included forward skating, outside and inside edge control drills while on both skates, one leg squats, and outside and inside edge control drills for both the right and left legs individually. Participants then skated at three different velocities 3.33 m/s (8 mph), 5.00 m/s (11 mph), and 6.66 m/s (14 mph) for twenty-seconds each with a two-minute rest break between trials. These speeds are based on self-selected treadmill skating speeds of elite hockey players, while the time-interval gives sufficient time to gather ≥ 20 consecutive strides at each speed (Chang et al., 2009).

Participants then skated at two additional speeds. This portion of the test consisted of skating at speeds of 6.71 m/s (15 mph) and 8.05 m/s (18 mph) for twenty-seconds with a thirty-second rest period between intervals. Participants then changed into the second pair of skates depending on their initial skate selection group. Another familiarization period was completed and participants then preformed the same task while wearing the second pair of skates.

Video Data Analysis

Video was transferred to a Dell latitude E6520 laptop where video analysis was completed using Dartfish Team pro version six to collect quantitative data (Dartfish, 2013). Although the primary purpose of the study was to compare the differences in ankle range of motion between the two different skate designs a number of additional variables were measured. These additional variables were used to help the primary researcher understand the implications this new skate design has on hockey skating technique.

Measurement of Skating Variables

The variables measured for the current study were blinded for speed. All video was separated into coded folders. This enabled the treadmill speed to be blinded from the primary researcher as each variable was measured. The measurement of joint angles was conducted using the angle tool in analyzer mode of Dartfish team pro version six (Dartfish, 2013). All variables were measured from anatomical position. Anatomical position of zero degrees is known as the position when the body is erect, arms are down at the sides, and the palms face forward (Baechle & Earle., 2008). There were two positions of interest when calculating variables related to the position of the push off leg in skating, weight acceptance and propulsion. Weight acceptance was considered the position when the heel of the skate blade came in contact with the skating treadmill just after recovery of the right leg. Propulsion was considered the position when the toe of the right skate blade was last seen in contact with the skating treadmill prior to takeoff. Ankle dorsiflexion, knee flexion, hip flexion, hip adduction, hip abduction, and hip adduction were measured at weight acceptance. Ankle plantar-flexion, knee flexion, hip flexion, and hip abduction were measured at propulsion. Each variable was measured for each subject during ten consecutive strides at each of the five speeds while wearing both skate designs. For the purposes of this study a stride was defined as the time from weight acceptance to propulsion.

Joint Range of Motion Analysis

To ensure the most accurate angle possible the display video full screen mode was used in Dartfish team pro version six (Dartfish, 2013). Ankle plantar-flexion range of motion was calculated from the positions of ankle dorsiflexion at weight acceptance (Figure 24) and ankle plantar-flexion at propulsion (Figure 25).

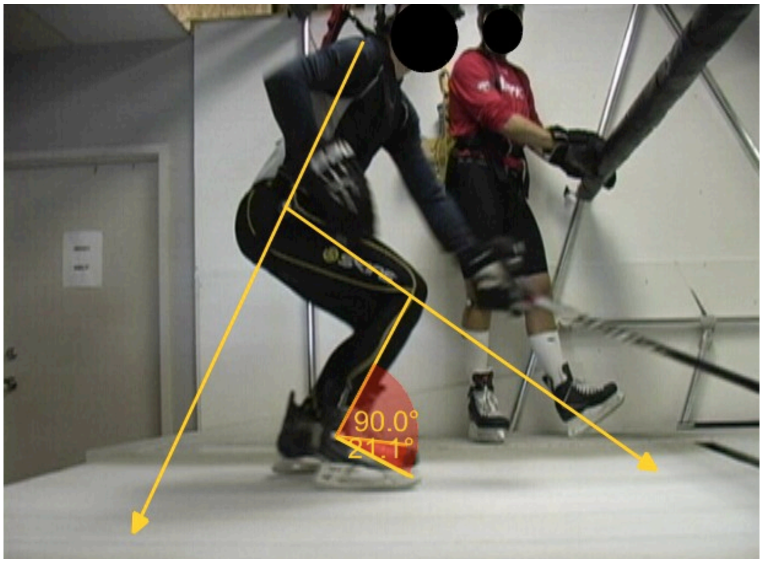


Figure 22. Ankle Dorsiflexion at weight acceptance.

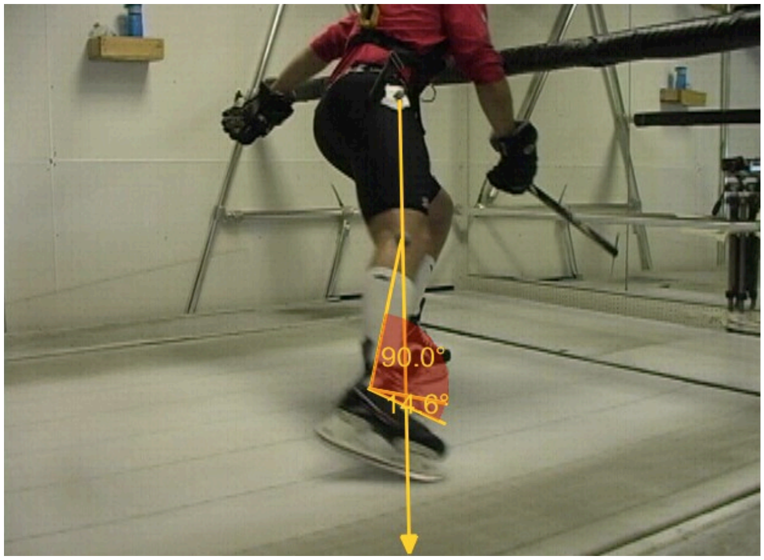


Figure 23. Plantarflexion at propulsion

Knee extension range of motion was calculated by subtracting the amount of knee flexion the subject had at propulsion (Figure 27) from the amount of knee flexion measured at weight acceptance (Figure 26). Two separate camera angles were used to measure the range of motion occurring at the ankle and knee. The camera located in the sagittal plane was used to measure joint angles at weight bearing while the camera in the plane of the stride was used to measure joint angles at propulsion. As the leg of the player moved from weight bearing to propulsion the skate blade was laterally rotated and positioned perpendicular to the direction of force applied by the skater. This was necessary to grip the treadmill with the inside edge of the skate blade producing enough friction to develop a propulsive force. The second camera view in the plane of the stride was needed due to this lateral rotation of the skate blade. The second camera view more accurately recorded video in the plane of movement at propulsion for the ankle and knee.

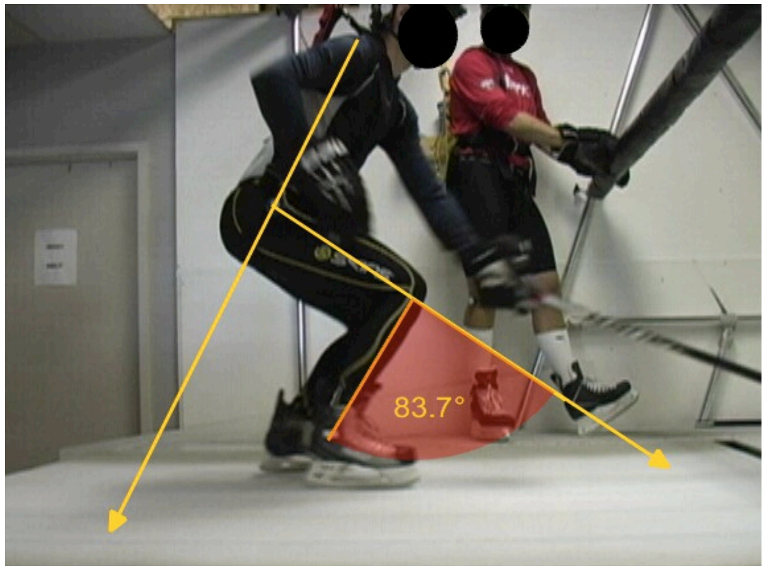


Figure 24. Knee flexion at weight acceptance.

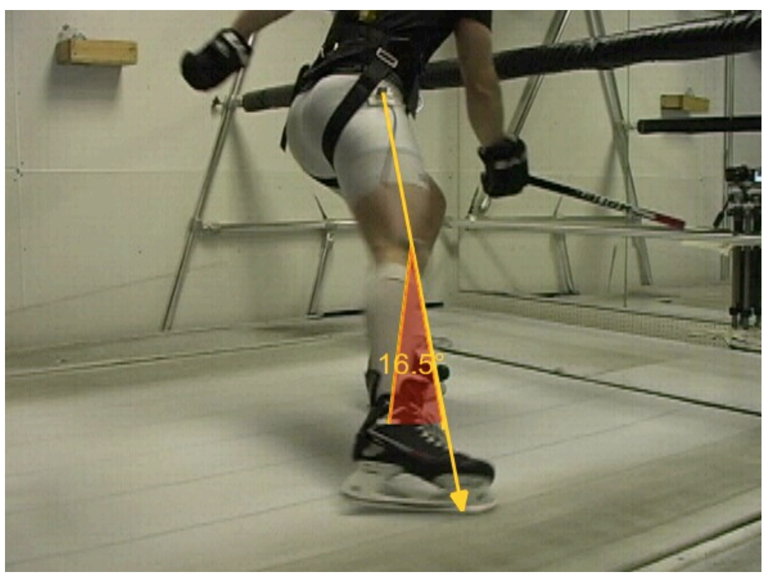


Figure 25. Knee flexion at propulsion.

Hip extension range of motion was measured by subtracting the amount of hip flexion at propulsion (Figure 29) from the amount of hip flexion at weight acceptance (Figure 28). In the case where a subject did not show a recovery past a neutral position hip abduction range of motion was calculated by subtracting the amount of hip abduction at weight acceptance from the amount of hip abduction at propulsion (Figure 31). If the subject showed hip adduction at weight acceptance (Figure 30) it was added to the amount of hip abduction at propulsion (Figure 31) to calculate the range of hip abduction.

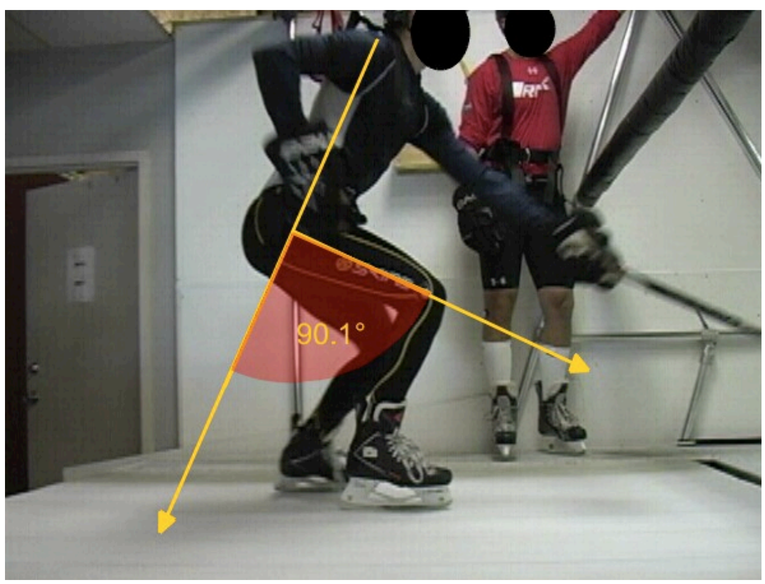


Figure 26. Hip flexion at weight acceptance.

Figure 27. Hip flexion at propulsion.

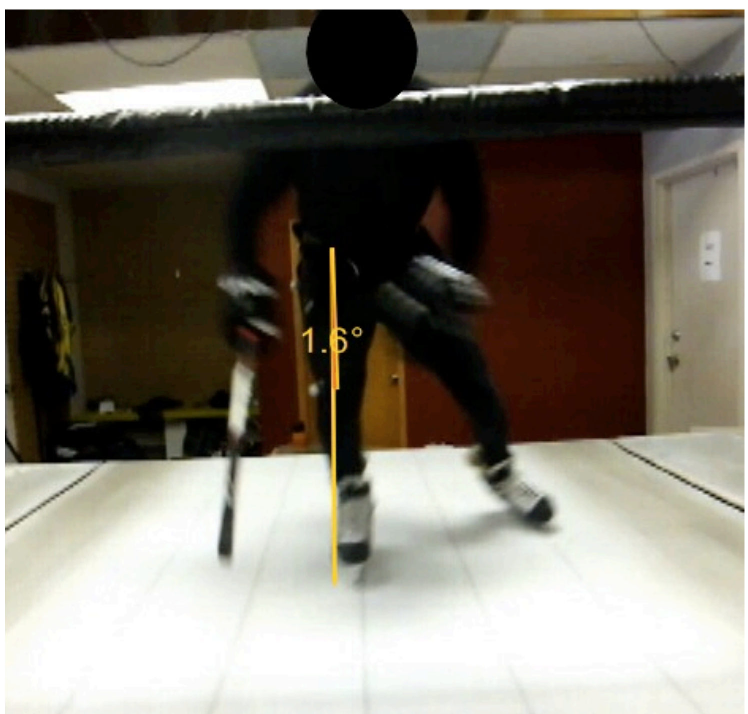


Figure 28. Hip adduction at weight acceptance.

Figure 29. Hip abduction at propulsion.

Stride length was calculated by using the distance tool in the analyzer mode of Dartfish team pro version six (Dartfish, 2013). The length of the treadmill track was used as a reference measure in the sagittal plane. Stride length in the sagittal plane was then measured as the distance the right skate blade travelled from weight acceptance to propulsion (Figure 32). The width of the treadmill track was used as a reference measure in the frontal plane. The distance the right skate blade traveled in the frontal plane from weight acceptance to propulsion was then calculated to be stride width (Figure 33). Total stride length was then calculated by using the Pythagorean theorem where the length of one side of a right triangle can be found given the lengths of the other two sides (Maor, 2007). For the purposes of this study stride length was calculated using the formula: Stride length = $\sqrt{}$ (($Stride\ width^2$) + (Sagittal plane stride length^2)).

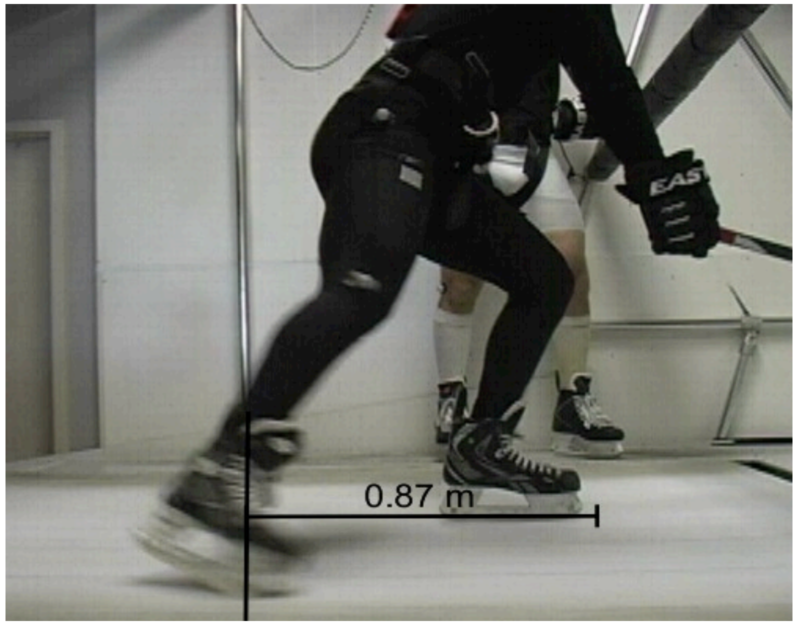


Figure 30. Stride length of the right skate in the sagittal plane, measured from weight bearing to propulsion.

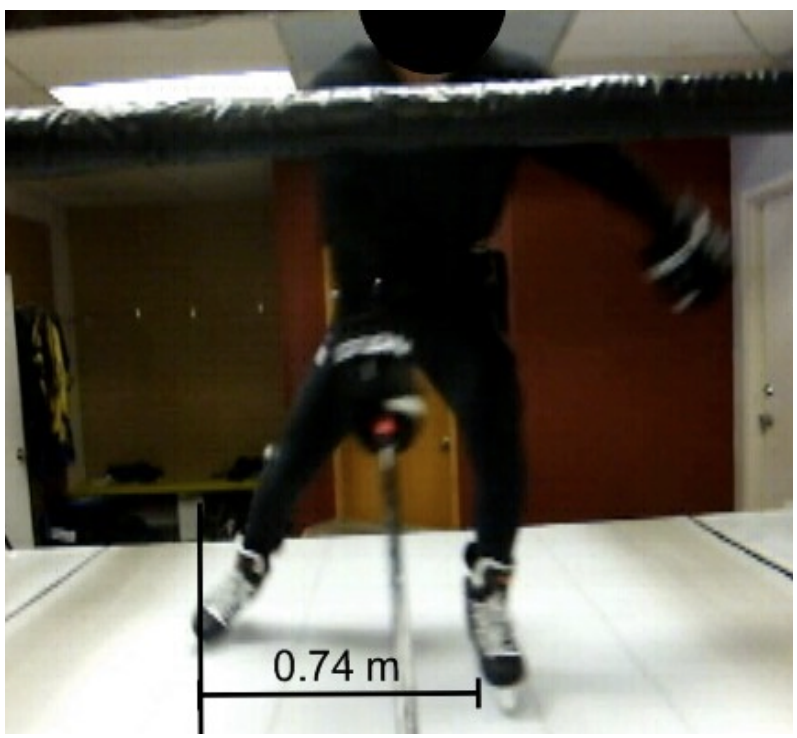


Figure 31. Stride width of the right skate, measured from weight bearing to propulsion.

Blade time on the treadmill was calculated as the time from weight acceptance to propulsion by using the time tool in analyzer mode of Dartfish team pro version six (Dartfish, 2013). Ankle plantar flexion angular velocity, knee extension angular velocity, hip extension angular velocity, hip abduction angular velocity, and stride velocity were then calculated by dividing their measured range of motion by blade time on ice. All variables were measured for ten consecutive strides of the right leg while wearing both the traditional skate and the Easton Mako skate at 3.33 m/s (8 mph), 5.00 m/s (11 mph), 6.66 m/s (14 mph), 6.71 m/s (15 mph), and 8.05 m/s (18 mph).

Table1. Dartfish team pro version six (2013) tools used in this study

Tool	Function
Key Position tool	Takes a still shot of a frame of video, which is then available to analyze
Angle Tool	Measures Angles on screen
Line Tool	Draws a straight line on screen
Distance Tool	Measures distances that are based on a known object reference distance set by the researcher
Time Tool	Tracks time as video progresses
Vertical Line Tool	Places vertical reference lines on screen

Statistical Analysis

Reliability Test

A reliability test was conducted in order to assess the accuracy of the measured variables. All variables including both pre-procedure range of motion testing and skating treadmill testing were measured in the reliability analysis using Cronbach's alpha. Cronbach's alpha is a sound measure of proportion of error variance (Cortina, 1993). The desired value of Cronbach's alpha is 0.7. If a test presents a large alpha it is concluded that a large portion of the variance is attributed to general and group factors, thus implying that there is very little item-specific variance (Cortina, 1993).

Range of motion comparisons between skate designs

Means and standard errors of all the variables measured were calculated while participants were wearing no skate, the traditional skate, and the Easton Mako skate. Following consultation with the bio statistical department at the University of Manitoba it was determined that differences in passive and active range of motion along with the type of skate participants were wearing would be examined using a doubly multivariate repeated-measures test with SPSS 20 statistical software for Mac operating system ("IBM SPSS software," 2013). Statistical significance was set at $p<0.05$.

Plantar flexion, dorsiflexion, eversion, and inversion were all measured while participants wore no skate, their own skate, and the Easton Mako skate. A doubly multivariate repeated-measures design is used to compare differences in one or more groups of participants that provide data on multiple variables (Lix & Sajobi, 2010). Post hoc univariate tests and pairwise comparisons were then completed to determine where the differences in range of motion occurred between the three conditions of no skate, traditional skate, and Easton Mako skate. Pairwise comparisons are used rather than a traditional t-test when investigating multiple comparisons at the same time (Hochberg, 1987). This controls for a Type 1 error, which is an incorrect rejection of the null hypothesis, with the use of a procedure that adjusts the desired p value. This study used a Bonferroni procedure as it is recommended when the univariate tests produce values that are not exactly equal to alpha, but are less than alpha in most situations (Lix & Sajobi, 2010).

Treadmill skating comparisons between skate design and speed

Means and standard errors of all the variables measured while participants were skating on a treadmill were calculated for 10 consecutive strides per condition. A total of 10 conditions were analyzed in the present study, the traditional skate at five speeds and the Easton Mako skate at five speeds. Differences between skate design and treadmill speed while participants were skating on the treadmill were calculated with a 2 x 5 x 13 doubly multivariate repeated-measures design. There were two levels of skate type (traditional/Easton Mako), five levels of treadmill speed (3.33 m/s, 5.00 m/s, 6.66 m/s, 6.71 m/s, 8.05 m/s), and 13 outcome variables. Post hoc univariate tests and pairwise comparisons were then completed to further investigate where the differences in skating kinematics occurred. A Bonferroni adjustment was once again used to help control for a Type 1 error.

Finally a Pearson's correlation analysis was conducted to determine the correlations that existed between treadmill speed and the measured skating variables. Pearson's coefficient is the centered and standardized sum of the cross product of two variables. This coefficient is used to examine and quantify the relationship between two different variables (Lee Rodgers & Nicewander, 1988). A Pearson r-value between 0 and 1 represents a positive correlation, whereas a negative correlation is represented by a Pearson r-value between 0 and -1. The closer the r-value is to 1 in a positive correlation or -1 in a negative correlation the higher the correlation between the two variables at question. A Pearson r-value of 0 indicates no correlation (Zou, Tuncali, & Silverman, 2003).

CHAPTER 4

Results

Participants

Descriptive characteristics were recorded for all eight participants including age, height, weight, hockey experience, and current skate brand (Appendix F). Means, standard deviations, and ranges of the participants involved in the current study are reported in Table 2.

Table 2. Descriptive characteristics of participants.

	Mean ± SD	Range
Age (Years)	24.50 ± 3.42	20.00 – 30.00
Height (m)	1.80 ± 0.08	1.68 – 1.90
Weight (kg)	82.55 ± 11.29	68.04- 102.06
Hockey Experience (Years)	18.5 ± 2.14	16.00-22.00

Reliability Results

All variables were measured in the reliability analysis using Cronbach's alpha. Cronbach's alphas for the 24 pre-procedure range of motion items and the 130 skating treadmill items were 0.684 and 0.947 respectively. The results for the pre-procedure range of motion items may be questionable as they were slightly below the desired Cronbach's alpha value of 0.7 (Cortina, 1993).

Pre-Procedure Range of Motion Results

The doubly multivariate repeated-measures test produced significant differences between passive and active range of motion yielding a significance value of $p=.025$ (Table 3). Post hoc univariate tests (Table 4) displayed significant differences between eversion $F(1,7) = 27.42$, $p<.005$ and inversion $F(1,7) = 20.311$, $p<.005$ along with non-significant differences in dorsiflexion $F(1,7) = 0.01$, $p>.910$ and plantar flexion $F(1,7) = 0.22$, $p>.65$. Further complex contrast comparisons stated that passive eversion range of motion displayed a mean increase of 3.08 degrees ($p<.01$) when compared to active eversion range of motion. Passive inversion range of motion displayed a mean increase of 6.30 degrees ($p<.01$) greater than active inversion range of motion.

Table 3. Multivariate results for pre-procedure range of motion (*p<.05).

Within Subjects Effect	F	Hypothesis df	Error df	Significance
Passive ROM vs Active ROM	9.526	4.00	4.00	.025*
Skate Type	7.104	8.00	22.00	.000*

Table 4. Univariate tests comparing passive and active range of motion (*p<.05).

Measure	Range of Motion	Mean	Std.Error	F	Significance
Dorsiflexion	Passive	20.20	0.78	0.011	.919
	Active	20.13	0.90		
Plantar flexion	Passive	21.23	.0.88	0.218	.655
	Active	20.87	0.73		
Eversion	Passive	11.36	0.79	27.419	.001*
	Active	8.28	0.75		
Inversion	Passive	20.19	1.77	20.311	.003*
	Active	13.89	0.93		

The doubly multivariate repeated-measures test also revealed a significant difference (p=.000) when comparing the three conditions: wearing no skate, wearing their own skate, and wearing the Easton Mako skate (Table 3). Post hoc univariate tests (Table 5) indicated differences in plantar flexion range of motion $F(2,14) = 28.56$, $p<.001$ and inversion range of motion $F(2,14) = 7.24$, $p<.01$ with non-significant differences in dorsiflexion $F(2,14) = 0.95$, $p>0.40$ and eversion $F(2,14) = 1.01$, $p>0.30$. Complex contrast comparisons further determined that plantar flexion while wearing no skate was shown to have an increase of 18.36 degrees ($p<.005$) when compared to the participant's own skate. Plantar flexion while wearing no skate was also greater by 12.45 degrees ($p<.005$) when compared to the Easton Mako skate. There was a mean increase in plantar flexion of 5.91 degrees (p<.005) when participants were wearing the Easton Mako skate compared to their own skate. Participants wearing no skate displayed a mean increase of 5.97 degrees (p=.012) of inversion range of motion when compared to wearing the Easton Mako skate.

Table 5. Unvariate tests comparing no skate, traditional skate, and Easton Mako skate (*p<.05).

Measure	Skate Type	Mean	Std.Error	F	Significance
Dorsiflexion	No skate	21.05	1.84		
	Traditional	20.68	1.06	.950	.410
	Easton Mako	18.77	0.62		
Plantar flexion	No skate	31.32	2.23		
	Traditional	12.96	1.49	28.555	.000*
	Easton Mako	18.87	0.66		
Eversion	No skate	10.75	1.16		
	Traditional	8.67	0.67	1.006	.376
	Easton Mako	10.03	1.40		
Inversion	No skate	20.41	2.24		
	Traditional	16.28	0.60	7.237	.007*
	Easton Mako	14.44	1.33		

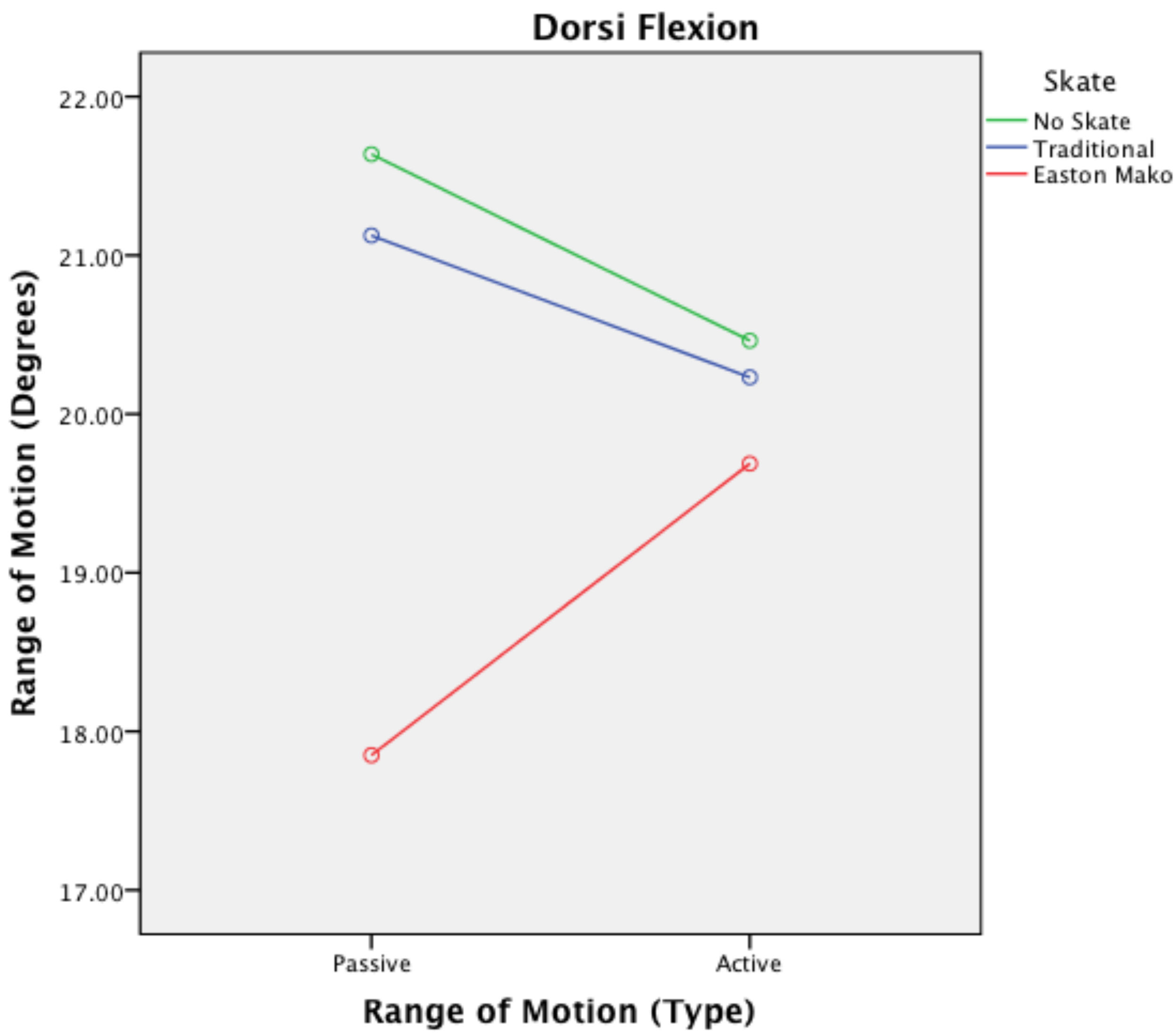


Figure 32. Dorsiflexion range of motion in passive and active conditions.

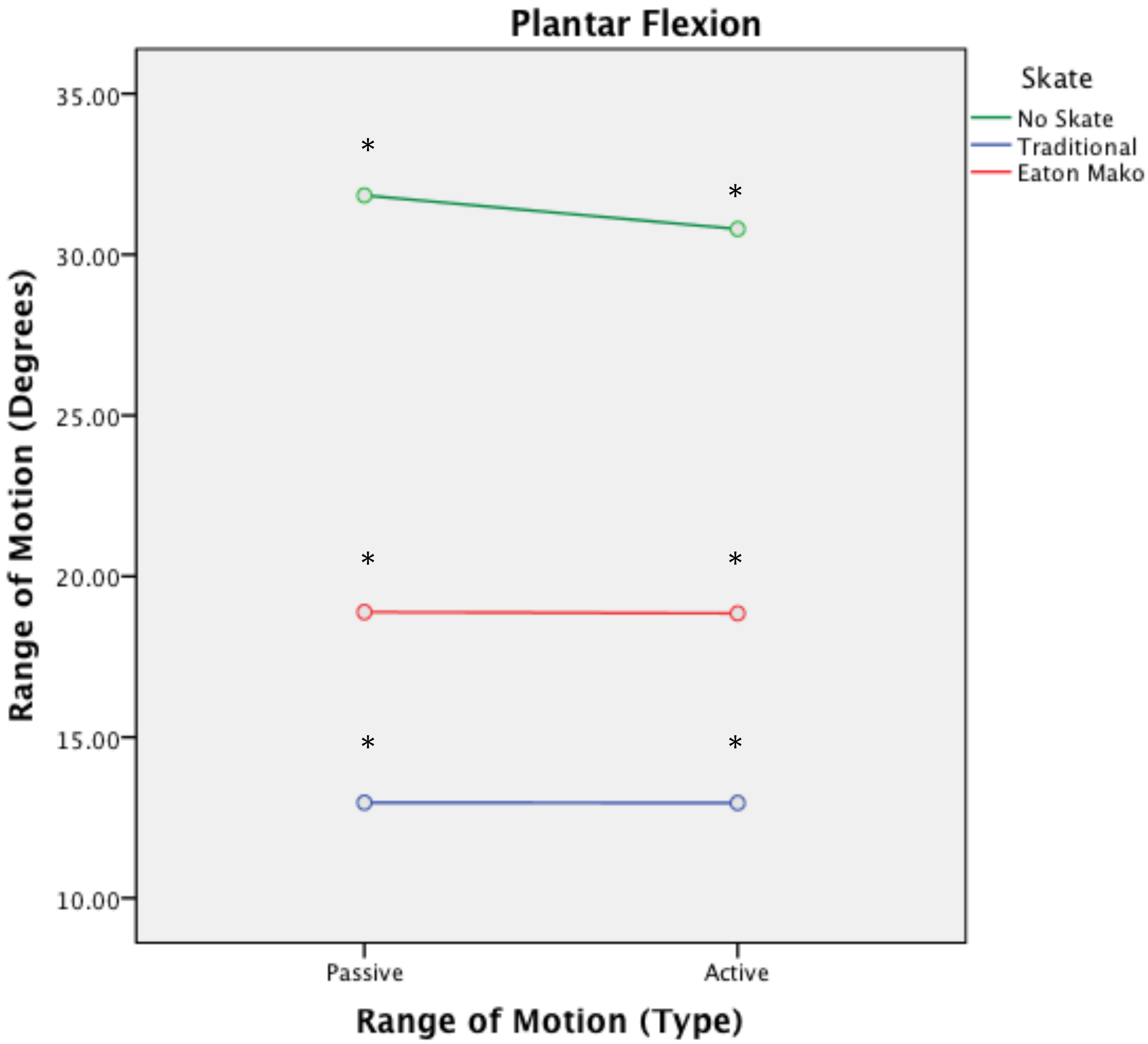


Figure 33. Plantar flexion range of motion in passive and active conditions

(*p<.05 between skate type).

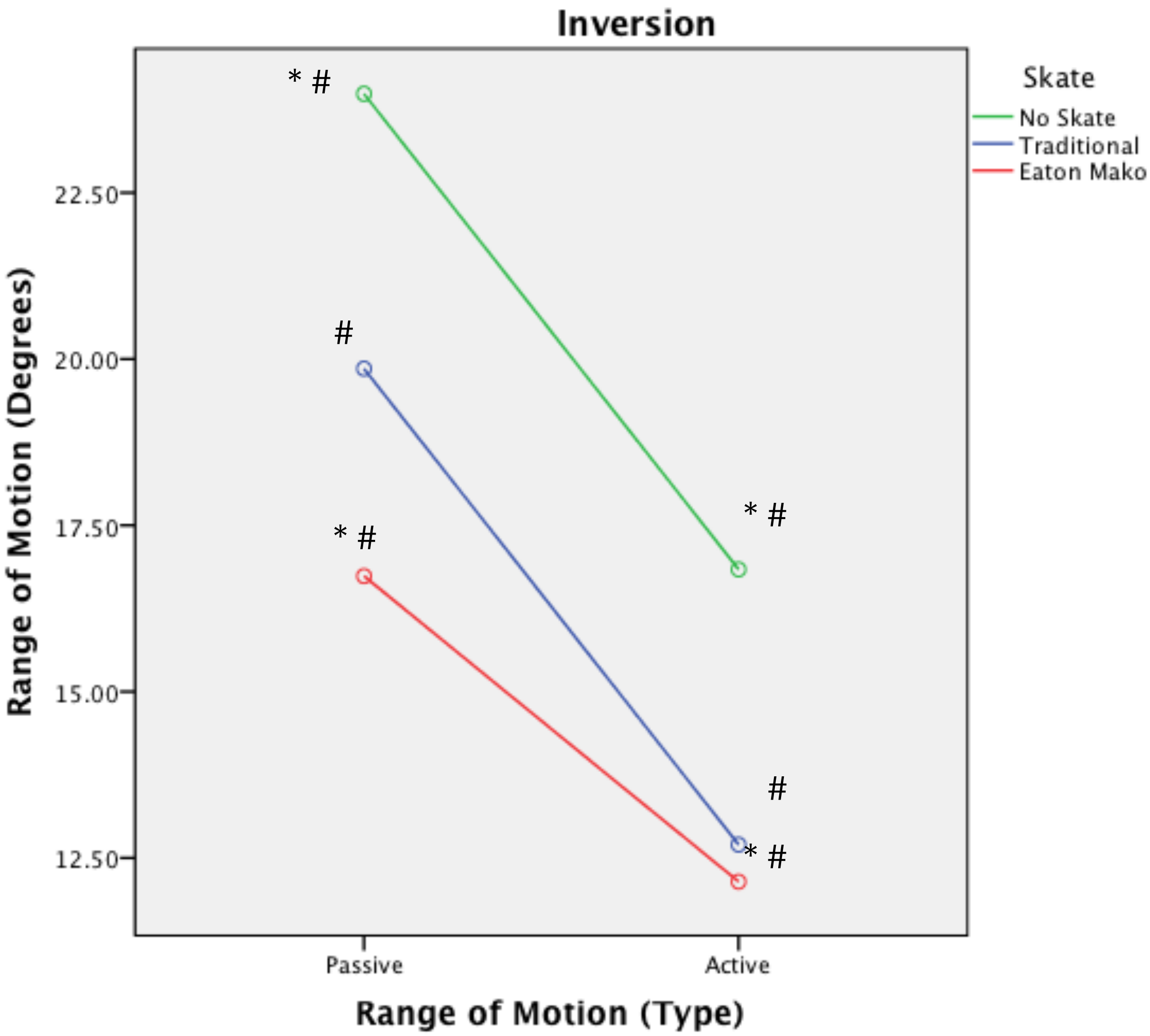


Figure 34. Eversion range of motion in passive and active conditions.

(*p<.05 between skate type)
(#p<.05 between passive and active range of motion)

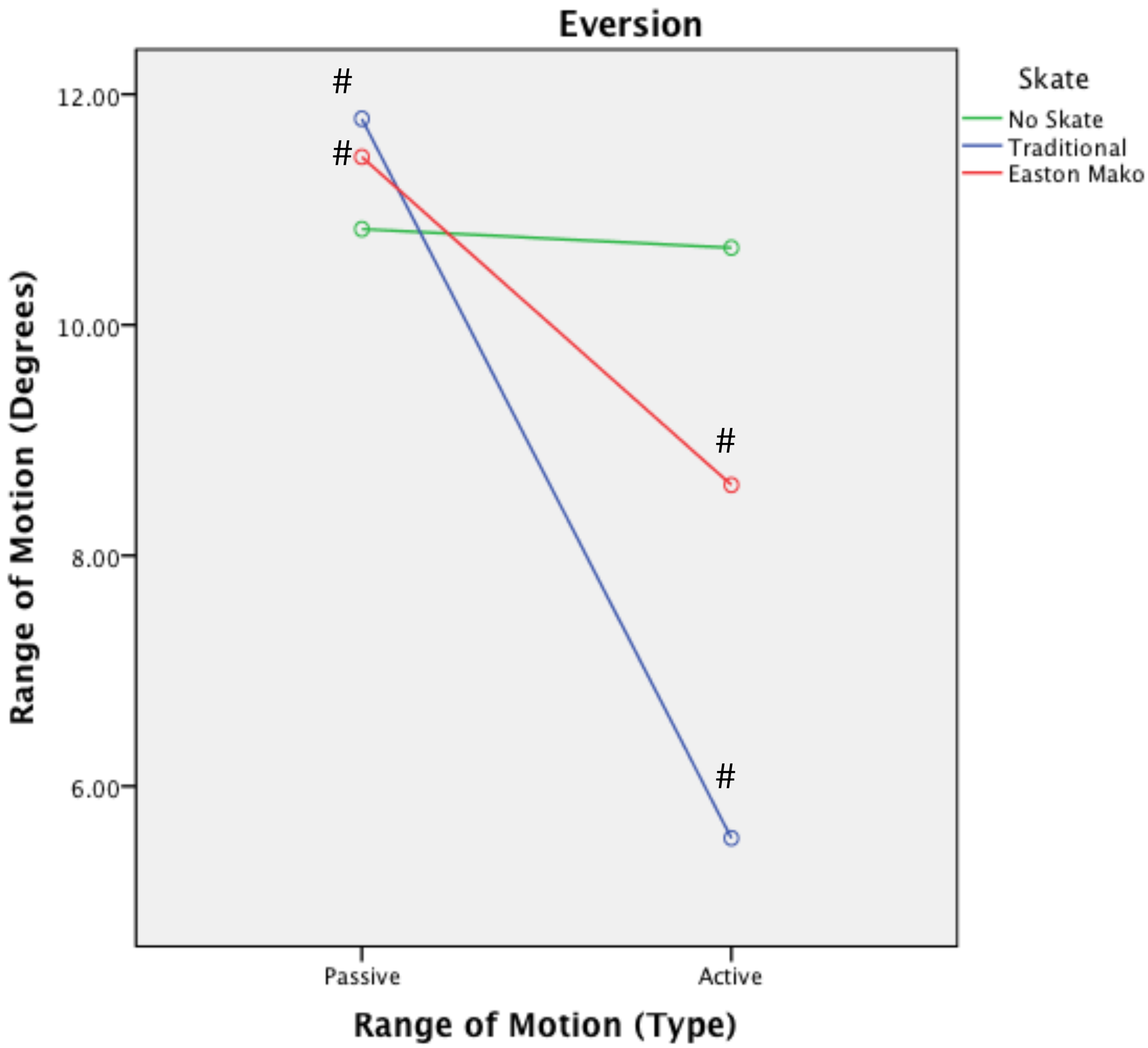


Figure 35. Inversion range of motion in passive and active conditions.

(#p<.05 between passive and active range of motion)

Skating Treadmill Testing Results

The means and standard errors of the 13 variables calculated for all eight participants while wearing their own traditional hockey skate and the Easton Mako skate are shown in Appendix J. Mean values and standard errors of the 13 variables within each treadmill speed are also included in Appendix J. The results of the doubly multivariate repeated-measures test suggested significant differences in skating technique within both skate design (p=.022) and treadmill speed (p=.000) (Table 6).

Table 6. Multivariate results for the skating treadmill test (*p<.05).

Within Subjects Effect	F	Hypothesis df	Error df	Significance
Skate	1248.64	7.00	1.00	.022*
Speed	3.51	52.00	64.08	.000*

Post hoc univariate tests were then completed on each variable to determine differences in skating kinematics while participants skated using the two different skate designs. Significant differences were observed between ankle plantar flexion range of motion $F(1,7) = 52.51$, $p<.001$, ankle plantar flexion angular velocity $F(1,7) = 19.79$, $p<.005$, hip extension range of motion $F(1,7) = 6.40$, $p<.05$, hip extension angular velocity $F(1,7) = 9.00$, $p<.05$, stride length $F(1,7) = 6.26$, $p<.05$, and stride velocity $F(1,7) = 11.62$, $p<.05$. In all cases the variables increased when using the Easton Mako skate. There were no significant differences shown in knee extension range of motion $F(1,7) = 6.39$, $p>.13$, knee extension angular velocity $F(1,7) = 3.64$, p>.09), hip abduction range of motion $F(1,7) = 1.26$, $p>.29$, hip abduction angular velocity $F(1,7) = 0.39$, $p>.55$, sagittal stride length $F(1,7) = 4.77$, $p>.06$, stride width $F(1,7) = 0.46$, $p>.52$, and skate time on the treadmill $F(1,7) = 3.95$, $p>.09$ between skate designs.

Contrast comparisons were then completed to gain further understanding of the significant differences between skating performance and the two skate designs. Table 7 and Table 8 display the differences between skate design in both range of motion and angular/linear velocity respectively. Ankle plantar flexion range of motion was a significant 6.17 degrees larger while participants were wearing the Easton Mako skate. Ankle plantar flexion angular velocity was also significantly larger while participants were wearing the Easton Mako skate showing an increase of 9.84 deg/s. Participants also displayed significant increases in hip extension range of motion (1.72 degrees) and hip extension angular velocity (5.42 deg/s) while wearing the Easton Mako skate. Significant increases in stride length (0.06 m) and stride velocity (0.15 m/s) were also evident while participants were wearing the Easton Mako skate.

Table 7. Mean range of motion measured pairwise comparisons between skate designs while skating on a treadmill (*p<.05).

Measure	Skate	Mean	Mean Difference	Std. Error	Significance
Plantar flexion (degrees)	Traditional	13.54	-6.17	1.94	.000*
	Mako	19.71	6.17	1.98	.000*
Knee extension (degrees)	Traditional	45.37	-2.78	2.56	.133
	Mako	48.15	2.78	3.61	.133
Hip extension (degrees)	Traditional	50.26	-1.72	1.82	.039*
	Mako	51.98	1.72	1.82	.039*
Hip abduction (degrees)	Traditional	34.11	0.86	3.16	.299
	Mako	33.25	-0.86	2.85	.299
Sagittal stride length (meter)	Traditional	0.94	-0.05	0.04	.065
	Mako	0.99	0.05	0.03	.065
Stride width (meter)	Traditional	0.65	-0.01	0.03	.520
	Mako	0.66	0.01	0.04	.520
Stride length (meter)	Traditional	1.15	-0.05	0.04	.041*
	Mako	1.20	0.05	0.03	.041*

Table 8. Mean angular and linear velocity measured pairwise comparisons between skate designs while skating on a treadmill (*p<.05).

Measure	Skate	Mean	Mean Difference	Std. Error	Significance
Plantar flexion angular velocity (deg/s)	Traditional	19.41	-9.84	2.48	.003*
	Mako	29.25	9.84	3.00	.003*
Knee extension angular velocity (deg/s)	Traditional	65.99	-5.87	3.52	.098
	Mako	71.86	5.87	5.17	.098
Hip extension angular velocity (deg/s)	Traditional	73.18	-5.42	4.42	.020*
	Mako	78.60	5.42	5.04	.020*
Hip abduction angular velocity (deg/s)	Traditional	48.32	-0.74	2.19	.553
	Mako	49.06	.074	1.54	.553
Stride velocity (m/s)	Traditional	1.67	-0.15	0.08	.011*
	Mako	1.82	0.15	0.10	.011*
Skate time on treadmill (s)	Traditional	0.71	0.03	0.03	.087
	Mako	0.68	-0.03	0.04	.087

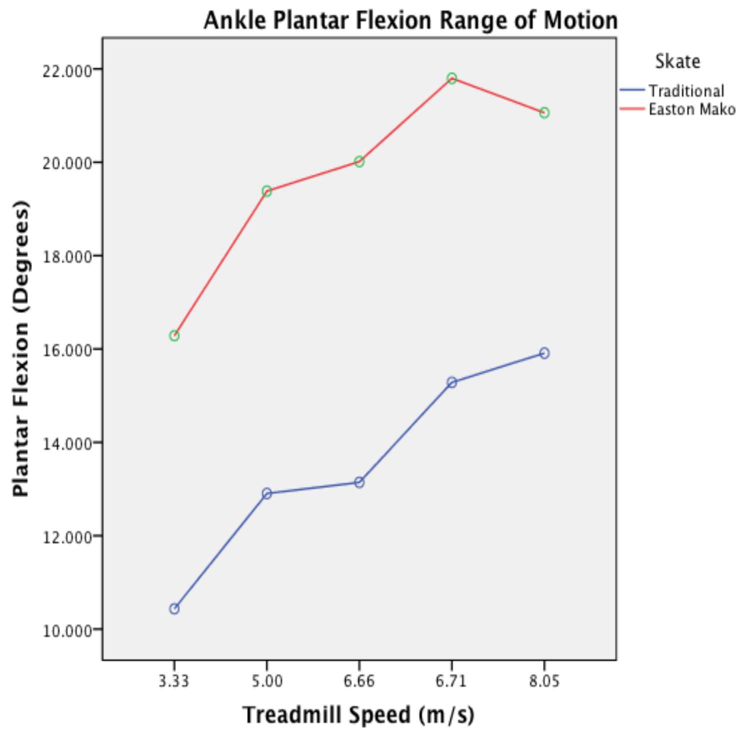


Figure 36. Skate comparison of ankle plantar flexion range of motion

(Skate x Speed = No Interaction)

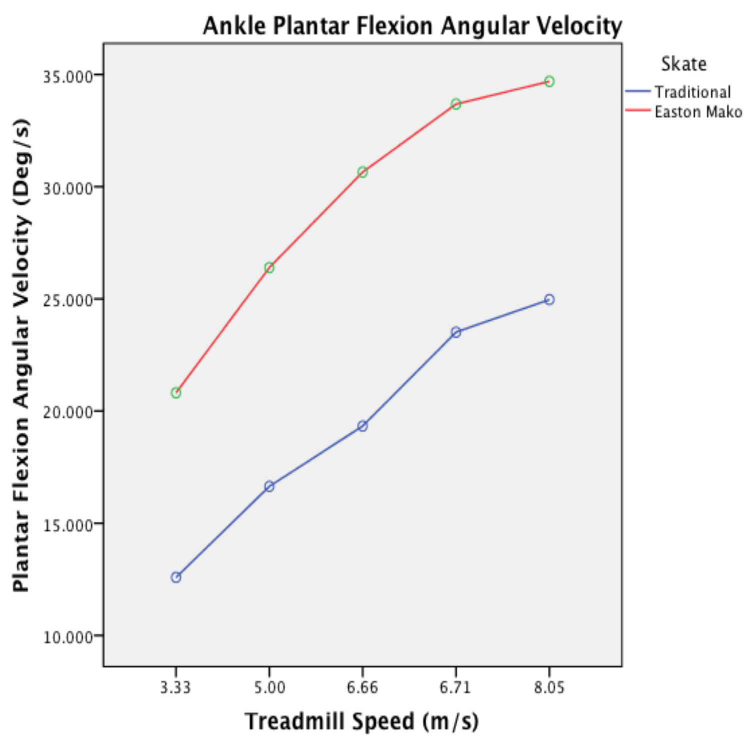


Figure 37. Skate comparison of ankle plantar flexion angular velocity

(Skate x Speed = No Interaction)

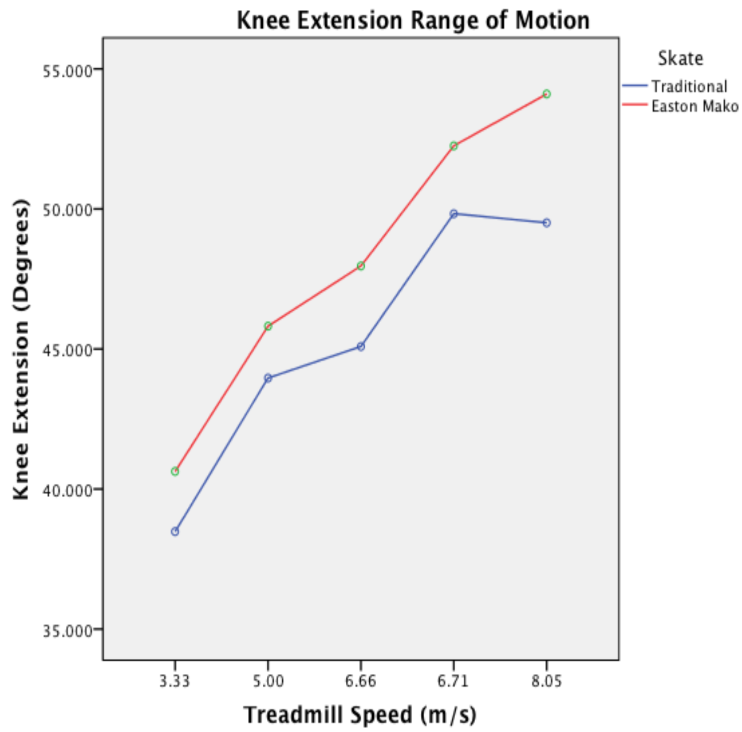


Figure 38. Skate comparison of knee extension range of motion

(Skate x Speed = No Interaction)

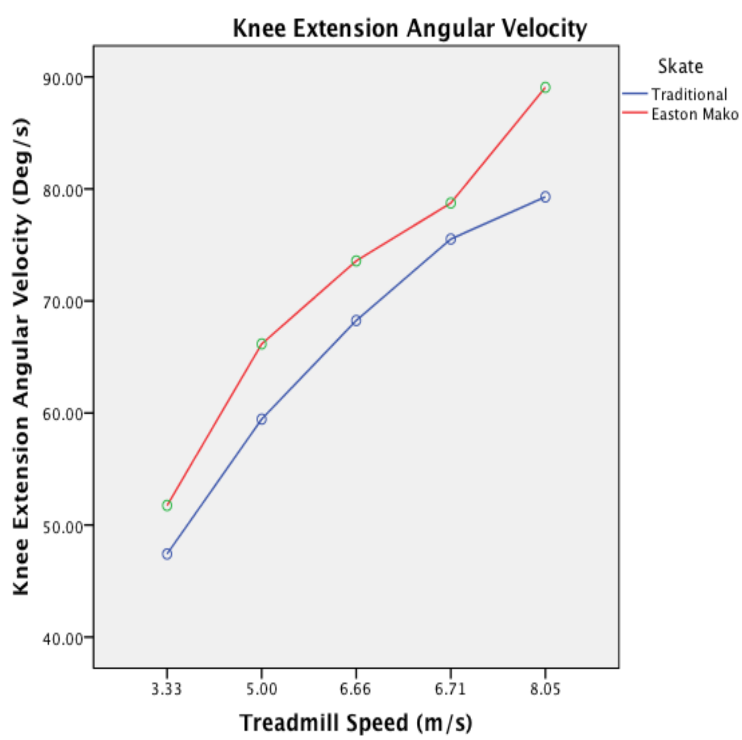


Figure 39. Skate comparison of knee extension angular velocity

(Skate x Speed = No Interaction)

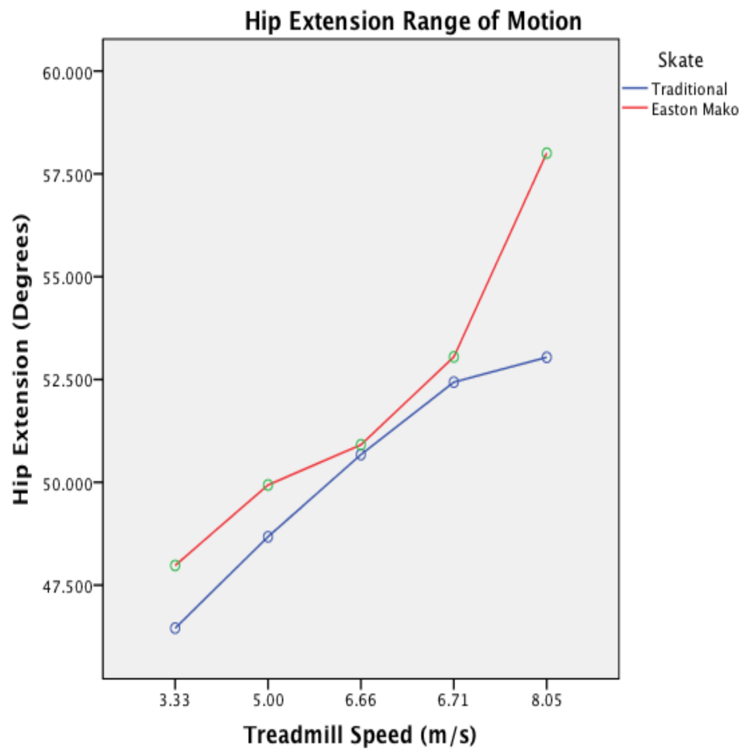


Figure 40. Skate comparison of hip extension range of motion

(Skate x Speed = No Interaction)

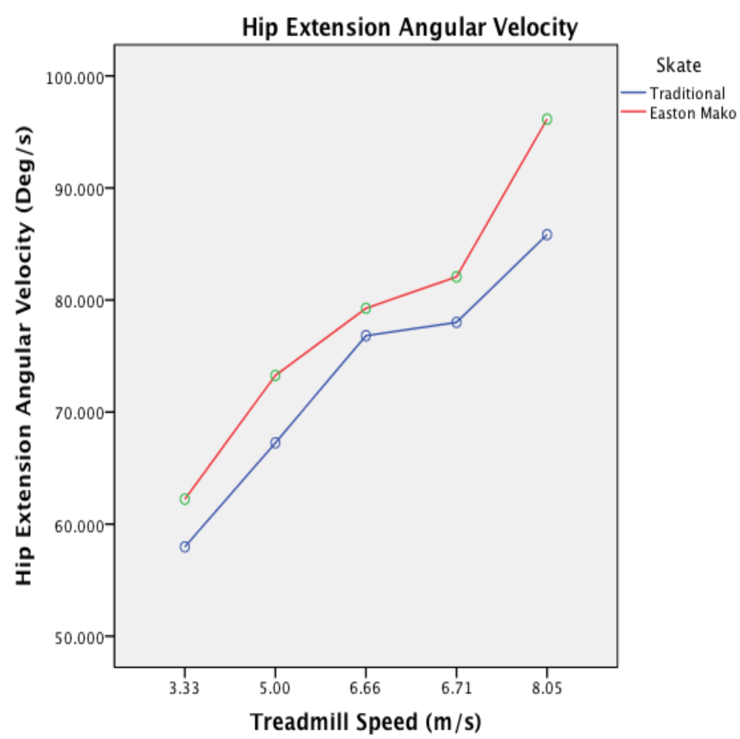


Figure 41. Skate comparison of hip extension angular velocity

(Skate x Speed = No Interaction)

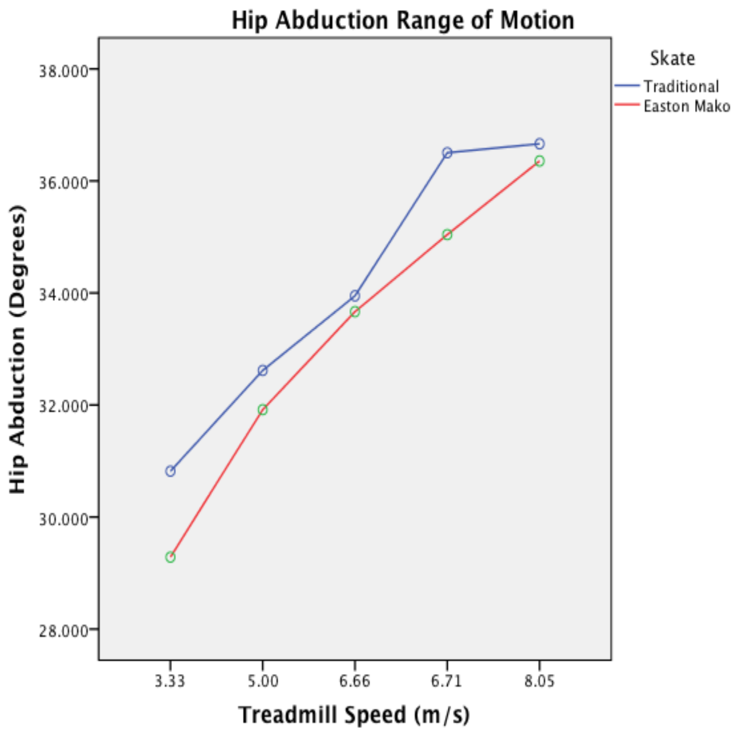


Figure 42. Skate comparison of hip abduction range of motion

(Skate x Speed = No interaction)

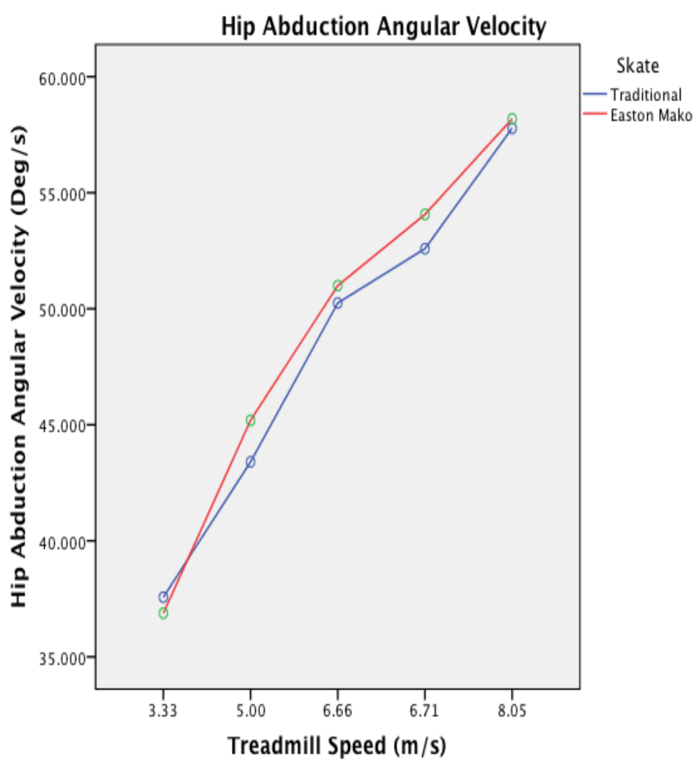


Figure 43. Skate comparison of hip abduction angular velocity

(Skate x Speed = No interaction)

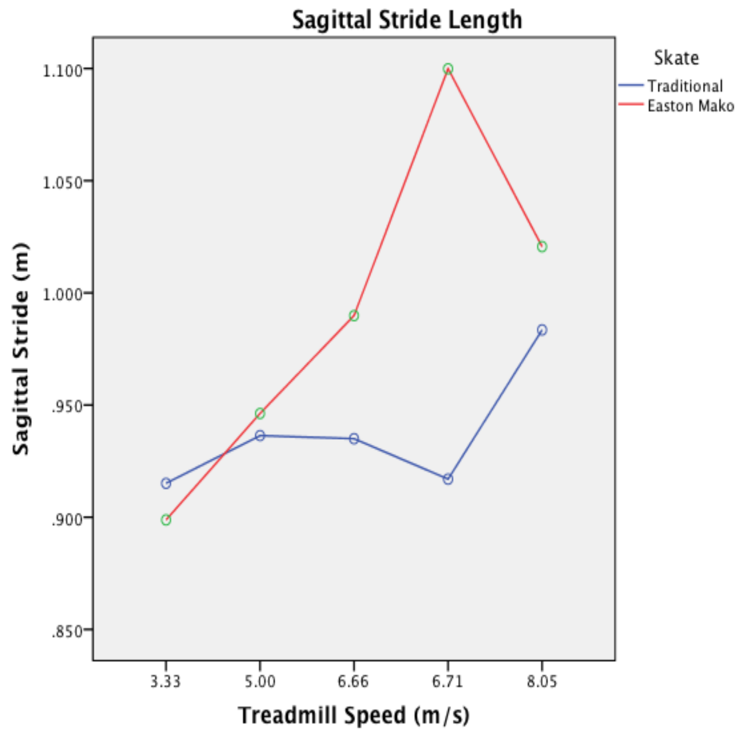


Figure 44. Skate comparison of sagittal stride length

(Skate x Speed = No interaction)

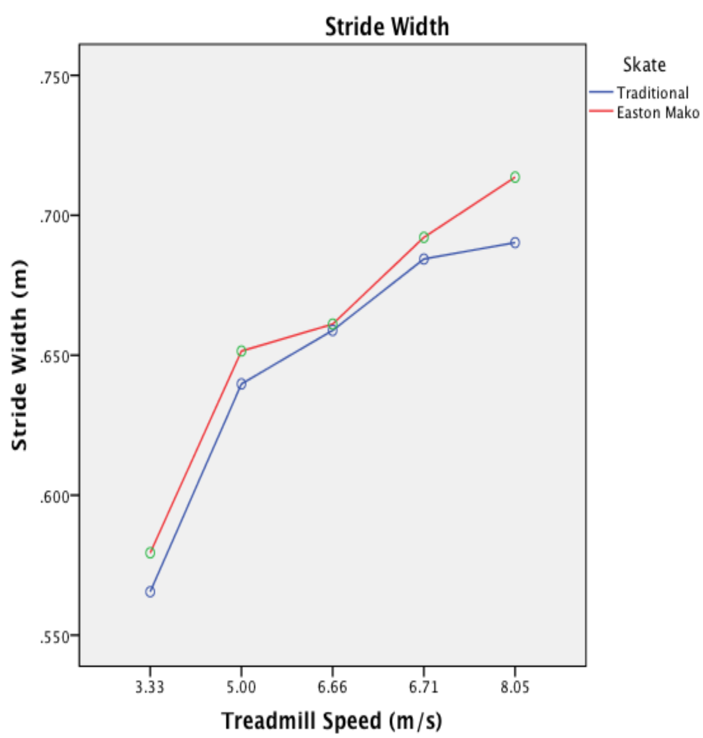


Figure 45. Skate comparison of stride width

(Skate x Speed = No interaction)

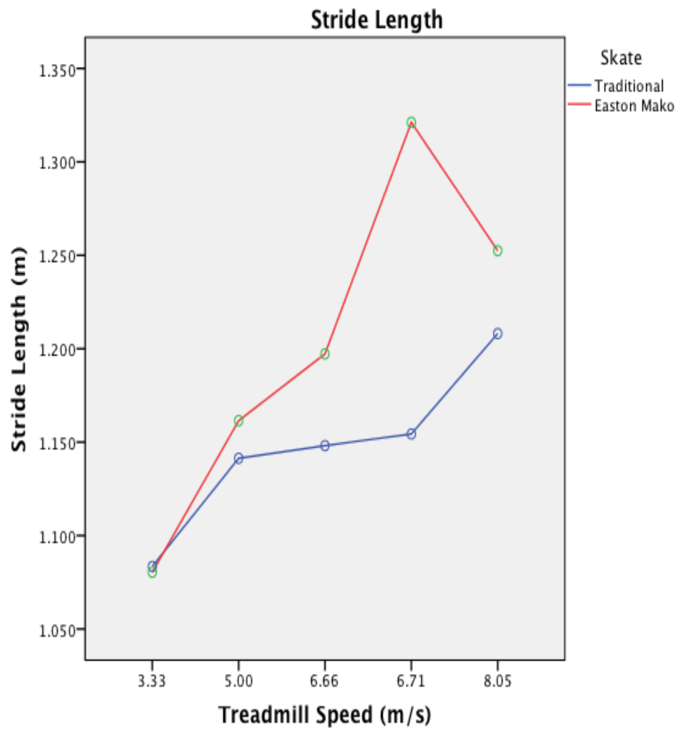


Figure 46. Skate comparison of stride length

(Skate x Speed = No interaction)

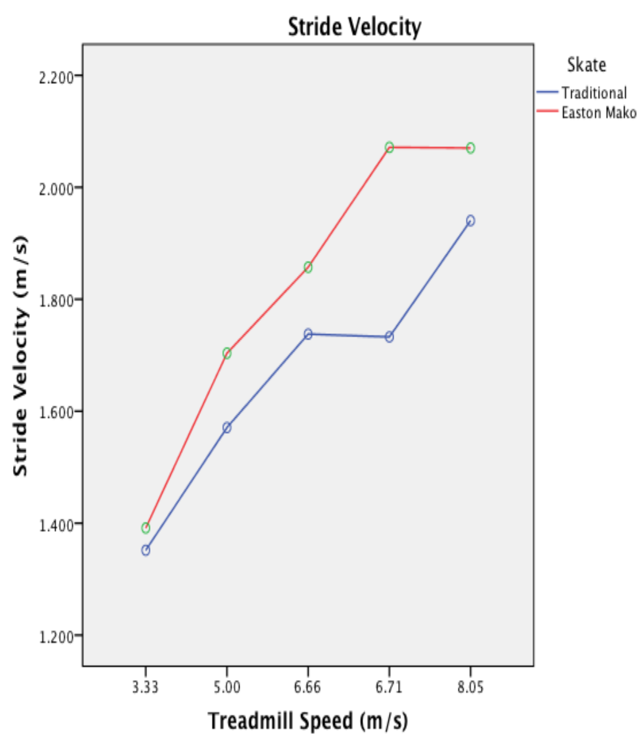


Figure 47. Skate comparison of stride velocity

(Skate x Speed = No interaction)

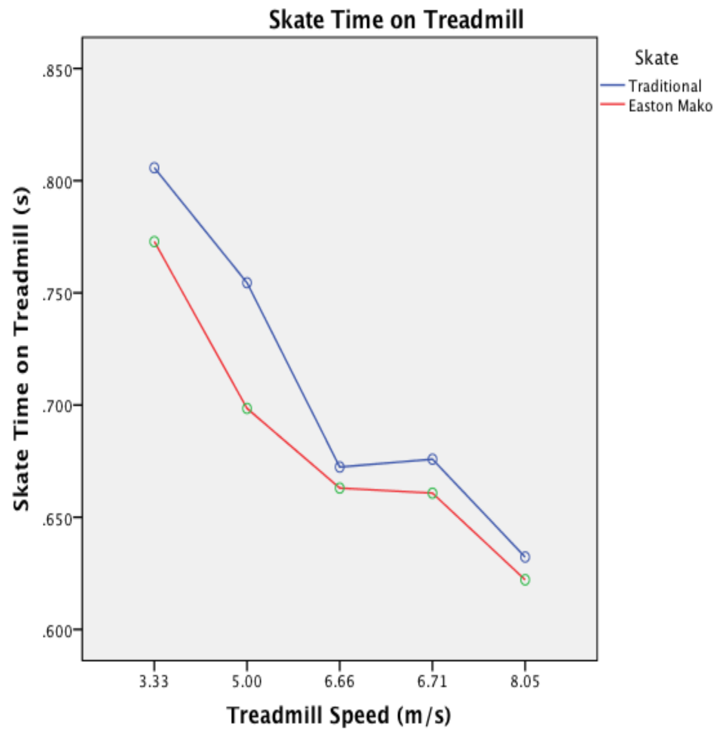


Figure 48. Skate comparison of skate time on treadmill during stride.

(Skate x Speed = No interaction)

The means and standard errors of the 13 variables calculated for all eight participants while at each treadmill speed are shown in Appendix J. Post hoc univariate tests were completed to further understand the effect speed had on each skating variable. Data from the two skate designs were combined, and significant differences between skating speed were displayed in ankle plantar flexion range of motion $F(4,28)=13.21$, $p<.001$, ankle plantar flexion angular velocity $F(4,28) = 28.49$, $p<.001$, knee extension range of motion $F(4,28) = 33.82$, $p<.001$, knee extension angular velocity $F(4,28) = 48.72$, $p<.001$, hip extension range of motion $F(4,28) = 15.65$, $p<.001$, hip extension angular velocity $F(4,28) = 40.53$, $p<.001$, hip abduction range of motion F(4,28) = 15.39, p<.001, hip abduction angular velocity F(4,28) = 107.71, p<.001, stride width F(4,28) = 13.43, p<.001, stride length F(4,28) = 6.39, p<.05, stride velocity F(4,28) = 39.82, p<.001, and skate time on the treadmill F(4,28) = 46.39, p<.001 (Table 10). There was no significant difference found between speed and sagittal stride length F(4,28) = 2.63, p>.10.

Table 9 and 10 display pairwise comparisons between the slowest speed of 3.33 m/s and the highest speed of 8.05m/s. These comparisons were completed to further examine the results of the significant univariate tests and their interactions as skating speed increased. Participants exhibited an increase in ankle plantar flexion range of motion of 5.13 degrees (p<.001) as speed went from 3.33 m/s to 8.05 m/s. A significant increase in ankle plantar flexion angular velocity of 13.13 deg/s (p<.001) was also shown as speed increased. Knee extension range of motion (12.26 degrees, p<.001) and angular velocity (34.59 degrees/sec, p<.04) also increased with skating speed (Table 9). Significant increases in hip extension range of motion (8.30 degrees, p<.005) and hip extension angular velocity (30.89 deg/s, p<.001) were also observed as speed increased from 3.33 m/s to 8.05 m/s. Increases of 6.46 degrees in hip abduction range of motion (p<.005) and 20.75 degrees/sec of hip abduction angular velocity (p<.001) were also observed as speed increased. As participants skating speed increased stride width (0.13 m, p<.005), stride length (0.15 m, p<.005), and stride velocity (0.63 m/s, p<.001) all increased significantly. Finally there was a significant decrease in the amount of time the participants skate was in contact with the treadmill of 0.16 seconds (p<.001) as skating speed increased from 3.33 m/s to 8.05 m/s.

Table 9. Mean range of motion measured comparisons between 3.33 m/s and 8.05 m/s (*p<.05).

Measure	Speed (m/s)	Mean	Mean Difference	Std. Error	Significance
Plantar flexion (degrees)	3.33	13.36	-5.13	1.78	.001*
	8.05	18.49	5.13	1.81	.001*
Knee extension (degrees)	3.33	39.55	-12.26	3.37	.001*
	8.05	51.81	12.26	3.27	.001*
Hip extension (degrees)	3.33	47.22	-8.30	2.06	.008*
	8.05	55.52	8.30	1.91	.008*
Hip abduction (degrees)	3.33	30.05	-6.46	2.87	.007*
	8.05	36.51	6.46	3.18	.007*
Sagittal stride length (meter)	3.33	0.91	-0.09	0.04	.158
	8.05	1.00	0.09	0.04	.158
Stride width (meter)	3.33	0.57	-0.13	0.04	.009*
	8.05	0.70	0.13	0.04	.009*
Stride length (meter)	3.33	1.08	-0.15	0.03	.014*
	8.05	1.23	0.15	0.04	.014*

Table 10. Mean angular and linear velocity measured comparisons between treadmill speeds 3.33 m/s and 8.05 m/s (*p<.05).

Measure	Speed (m/s)	Mean	Mean Difference	Std. Error	Significance
Plantar flexion angular velocity (degrees/s)	3.33	16.70	-13.13	1.83	.000*
	8.05	29.83	13.13	2.76	.000*
Knee extension angular velocity (degrees/s)	3.33	49.59	-34.59	2.93	.000*
	8.05	84.18	34.59	5.88	.000*
Hip extension angular velocity (degrees/s)	3.33	60.10	-30.89	2.92	.001*
	8.05	90.99	30.89	5.80	.001*
Hip abduction angular velocity (degrees/s)	3.33	37.23	-20.75	1.69	.000*
	8.05	57.98	20.75	2.10	.000*
Stride velocity (meter/s)	3.33	1.37	-0.64	0.07	.000*
	8.05	2.01	0.64	0.10	.000*
Skate time on treadmill (seconds)	3.33	0.79	0.16	0.04	.000*
	8.05	0.63	-0.16	0.03	.000*

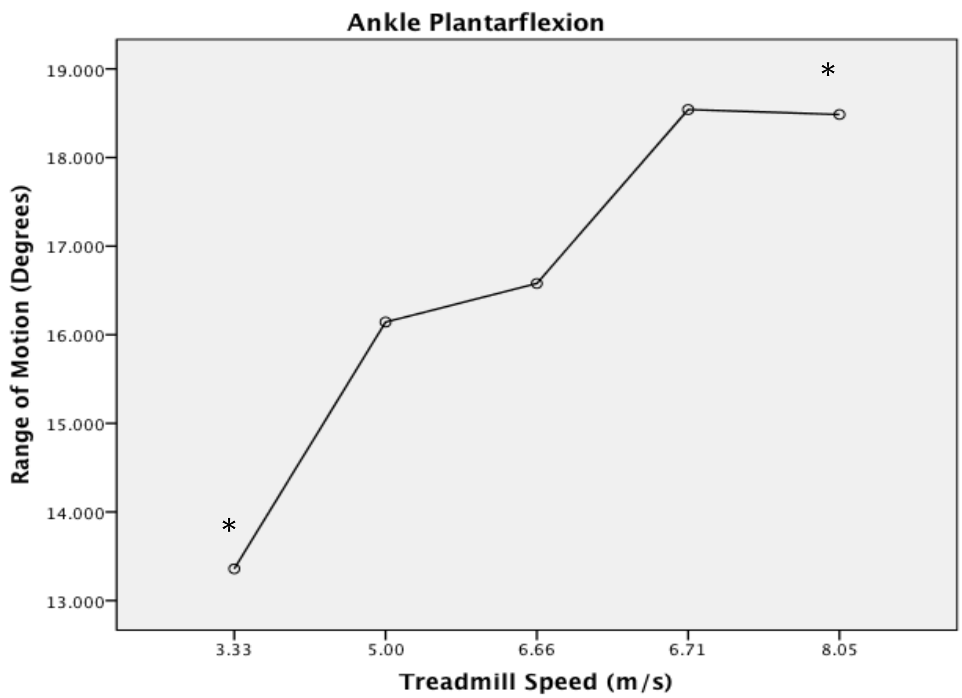


Figure 49. Ankle plantar flexion range of motion vs Treadmill speed (*p<.05).

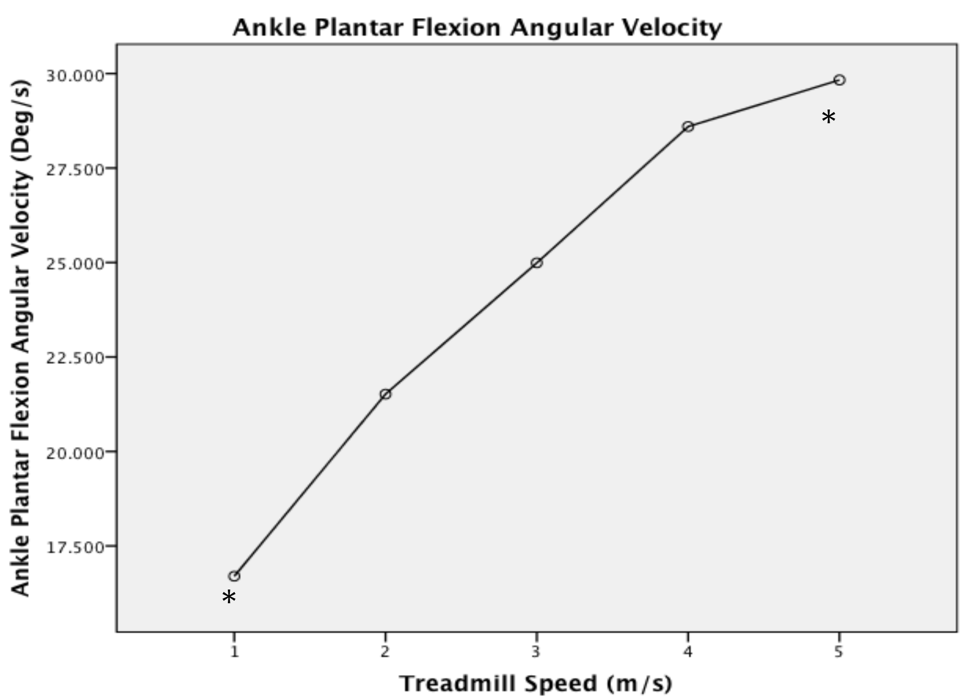


Figure 50. Ankle plantar flexion angular velocity vs Treadmill speed (*p<.05).

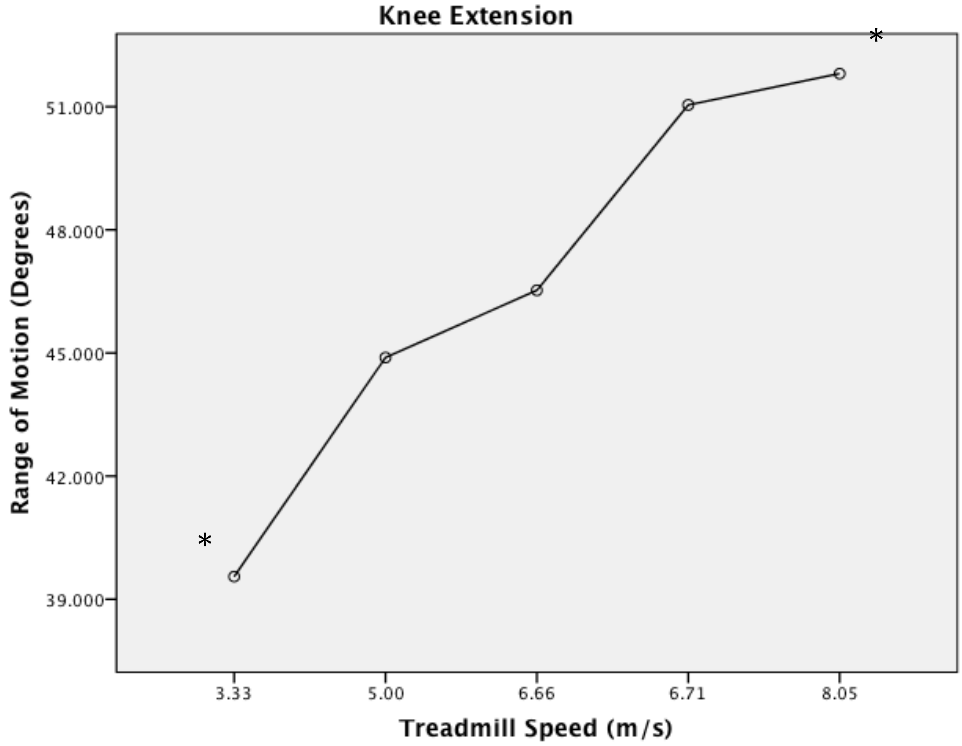


Figure 51. Knee extension range of motion vs Treadmill speed (*p<.05).

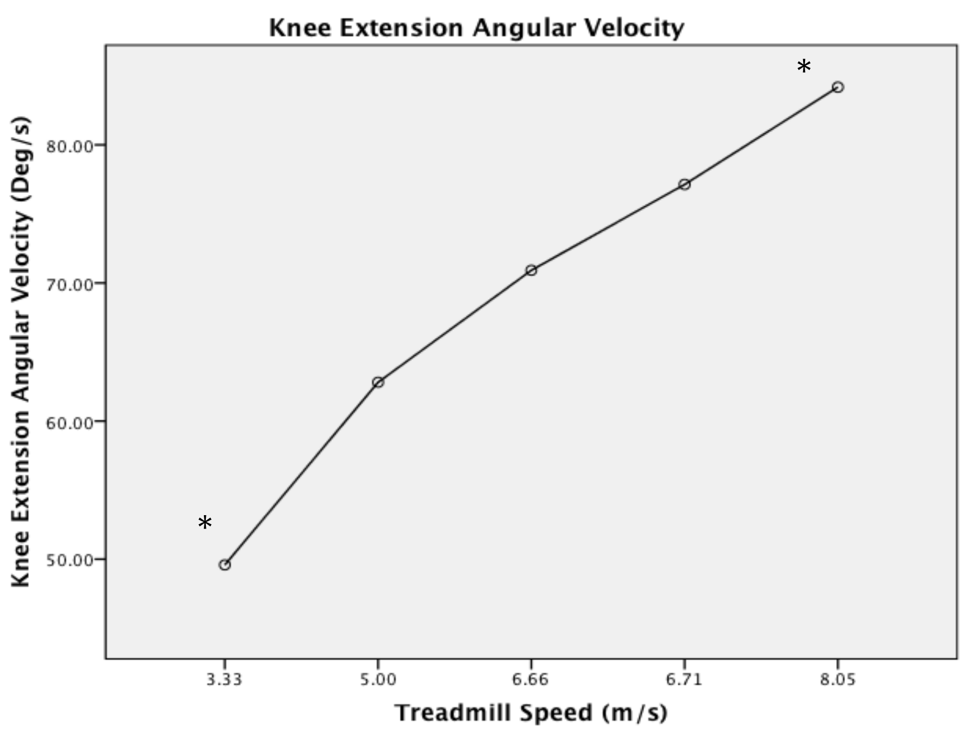


Figure 52. Knee extension angular velocity vs Treadmill speed (*p<.05).

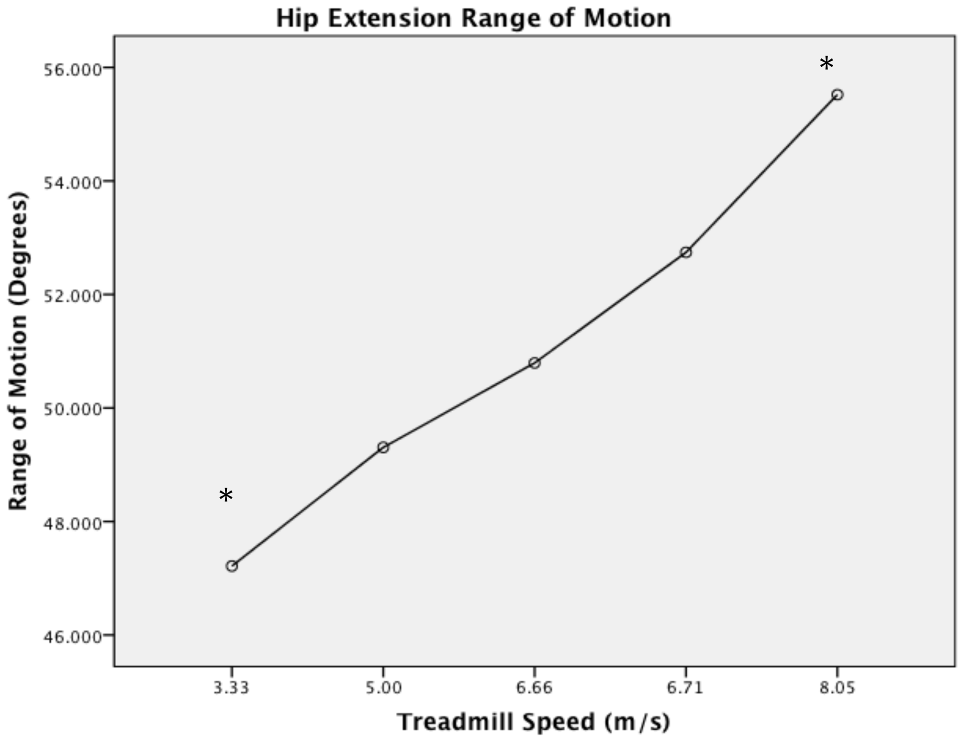


Figure 53. Hip extension range of motion vs Treadmill speed (*p<.05).

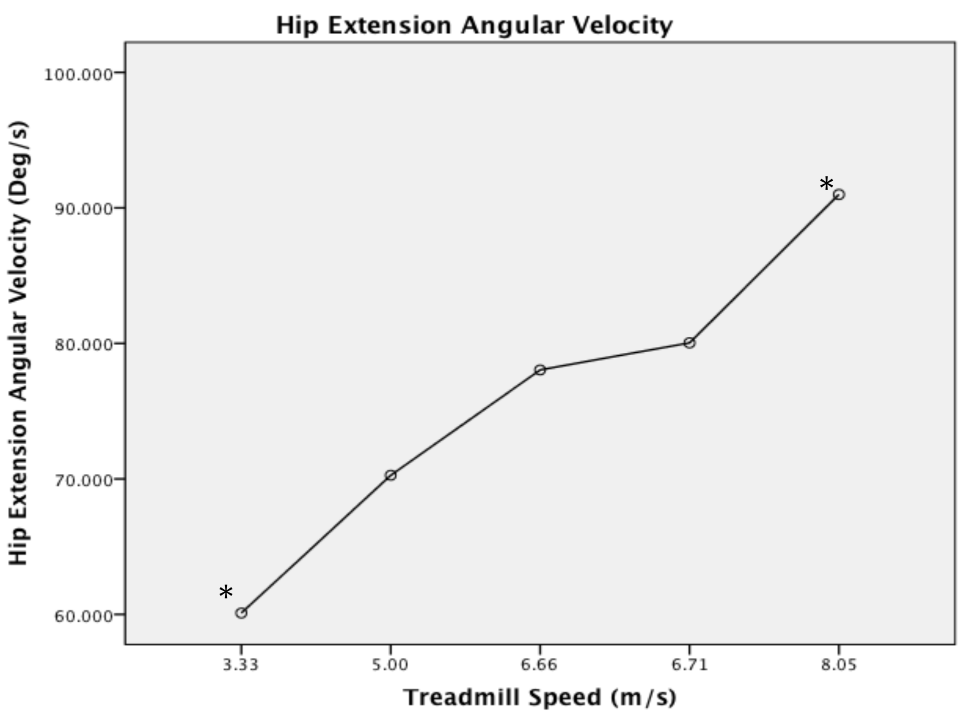


Figure 54. Hip extension angular velocity vs Treadmill speed (*p<.05).

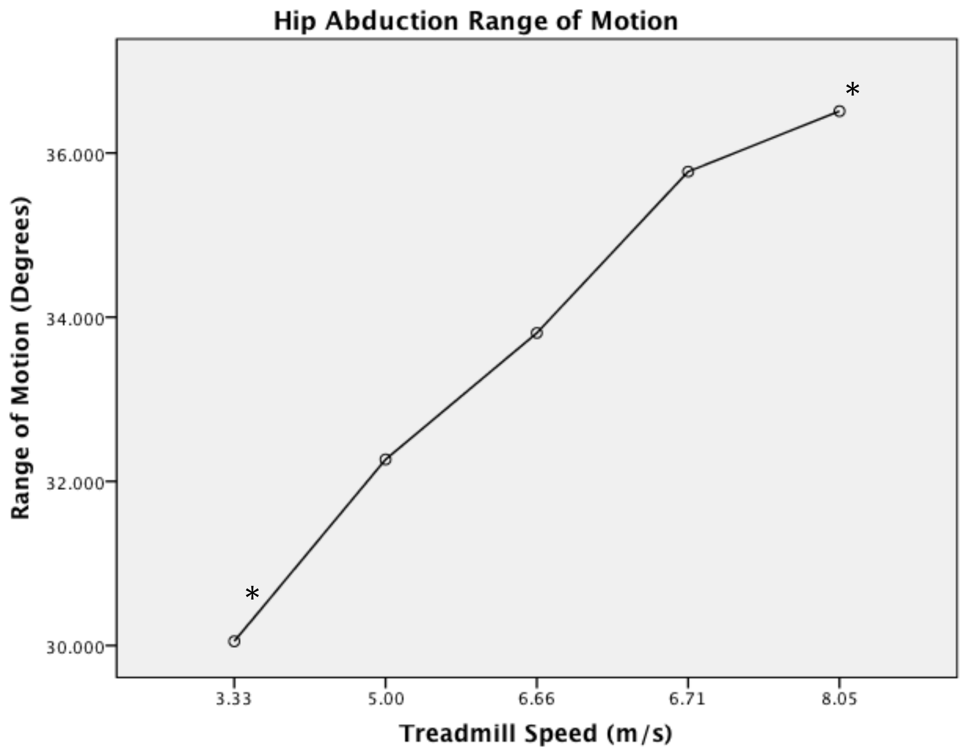


Figure 55. Hip abduction range of motion vs Treadmill speed (*p<.05).

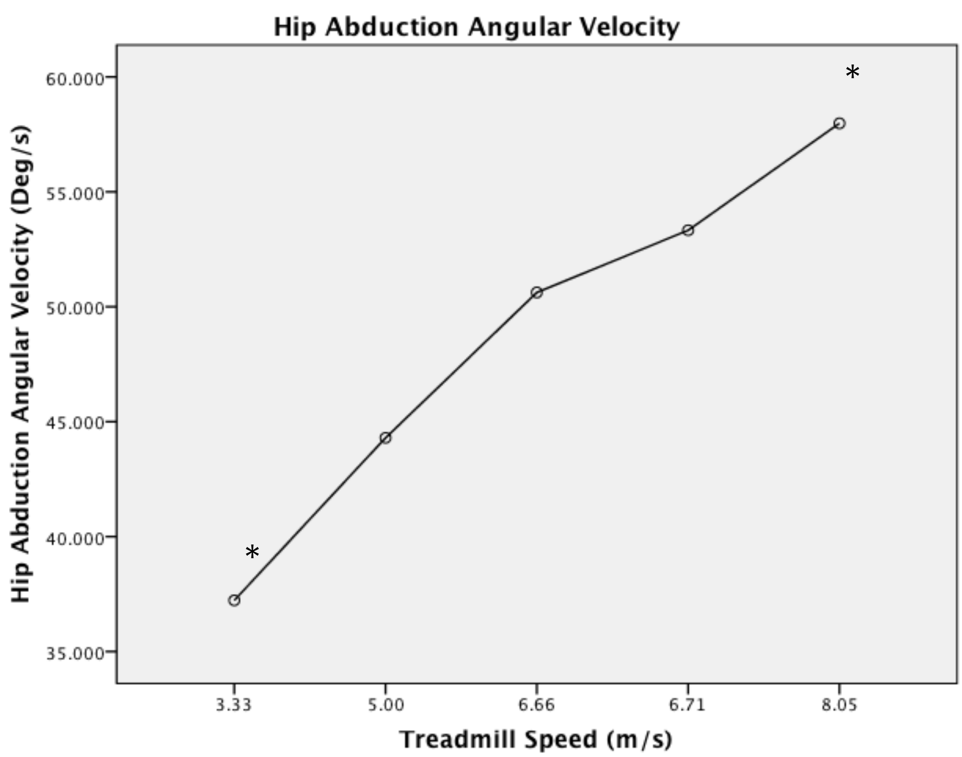


Figure 56. Hip abduction angular velocity vs Treadmill speed (*p<.05).

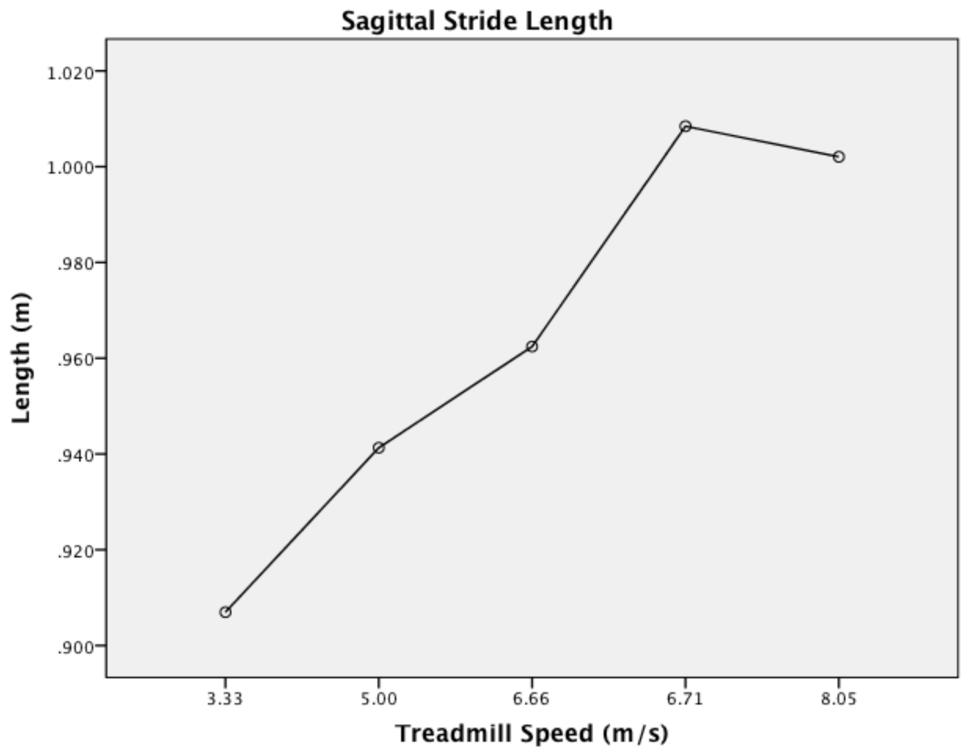


Figure 57. Sagittal stride length vs Treadmill speed (*p<.05).

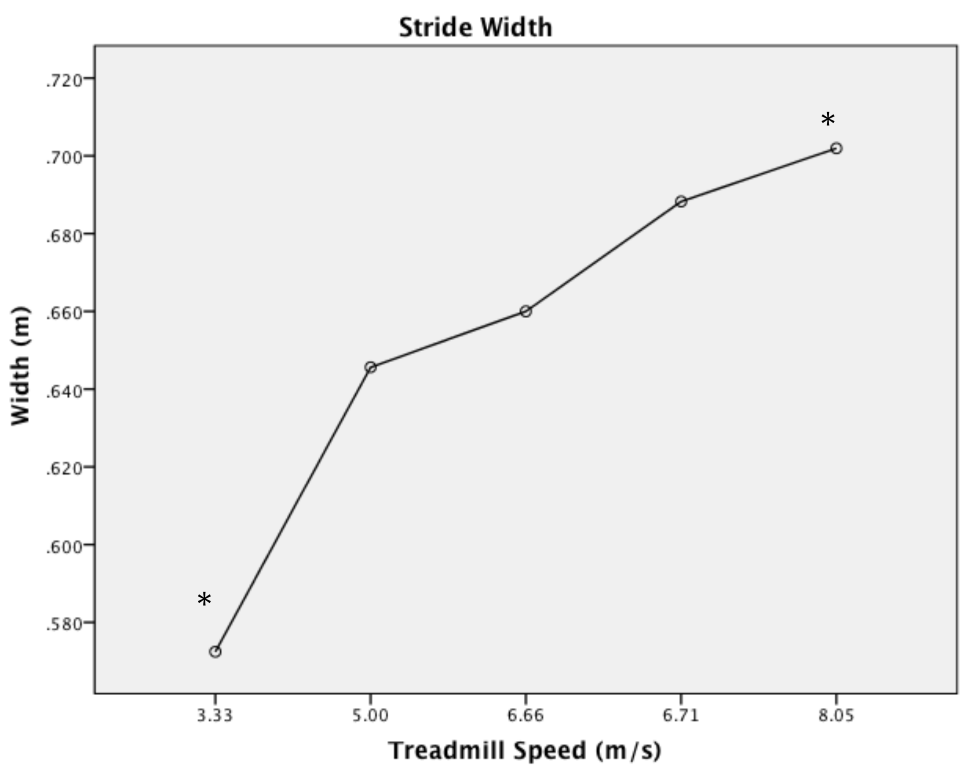


Figure 58. Stride width vs Treadmill Speed (*p<.05).

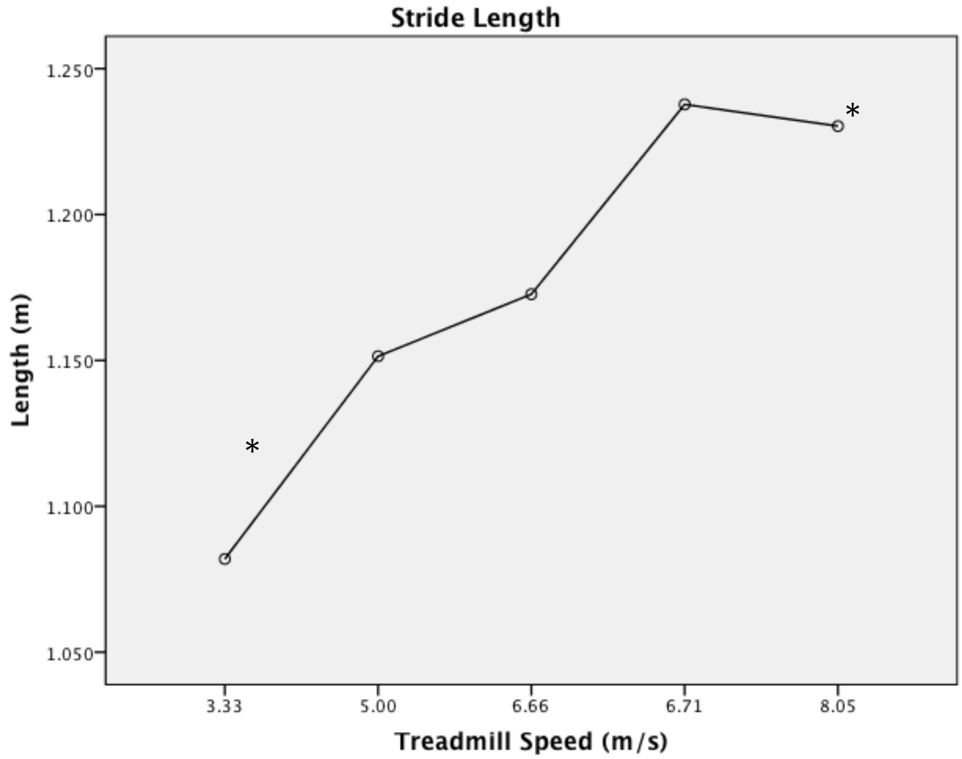


Figure 59. Stride length vs Treadmill speed (*p<.05).

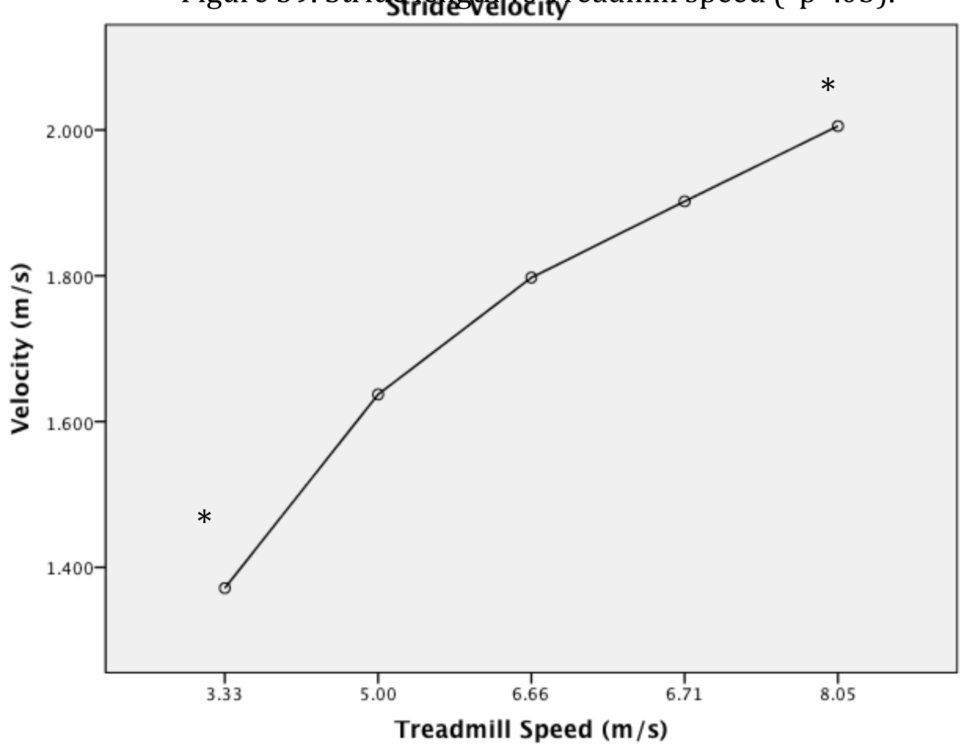


Figure 60. Stride velocity vs Treadmill speed (*p<.05).

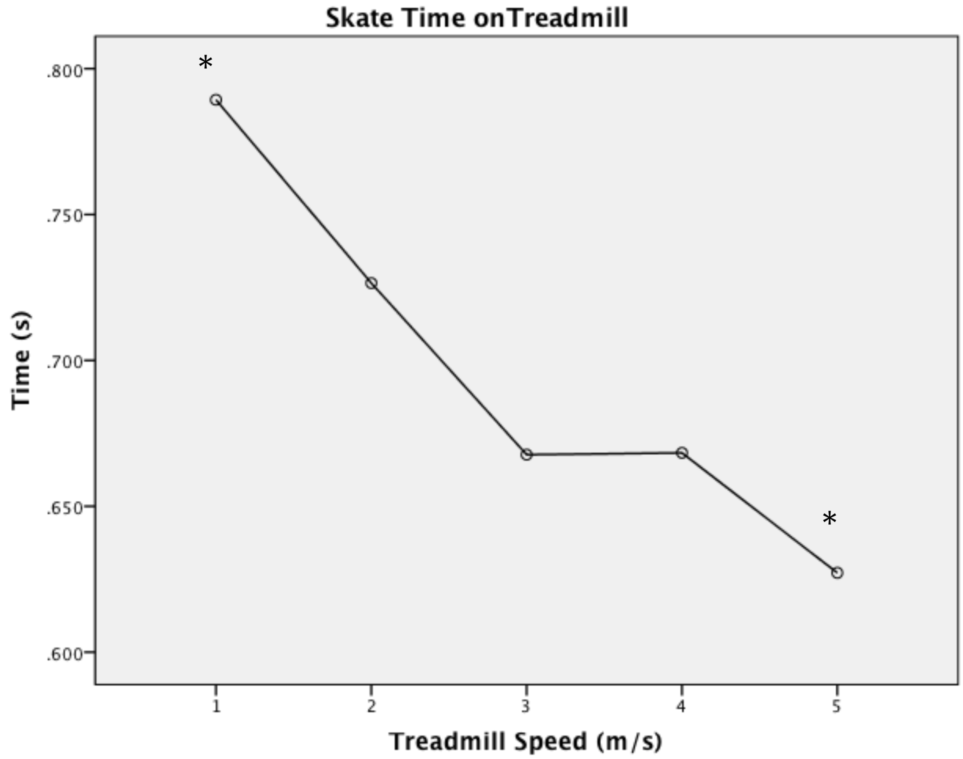


Figure 61. Skate time on treadmill vs Treadmill speed (*p<.05).

Correlation Analysis of Skating Variables and Treadmill Speed

As significant differences were calculated in skating kinematic values as the treadmill speed increased a correlation analysis was completed to determine which variables were highly associated with increased skating speed. The correlations between the treadmill speed and the variables measured during the skating treadmill test are reported in Table 11.

Table 11. Correlation between treadmill speed and variables measured. (*p<.05,**p<.01)

	Correlation n=80	
Variable	**r-value**	**Significance**
Ankle Plantar Flexion	0.267	0.017*
Ankle Plantar Flexion Angular Velocity	0.442	0.000**
Knee Extension	0.427	0.000**
Knee Extension Angular Velocity	0.658	0.000**
Hip Extension	0.435	0.000**
Hip Extension Angular Velocity	0.587	0.000**
Hip Abduction	0.263	0.018*
Hip Abduction Angular Velocity	0.778	0.000**
Sagittal Stride Length	0.250	0.025*
Stride Width	0.377	0.001**
Stride Length	0.381	0.000**
Stride Velocity	0.605	0.000**
Skate Blade Time on Ice	-0.466	0.000**

Through examination of the correlation analysis it was evident that the angular velocity occurring at each joint displayed a higher correlation with treadmill speed than did the range of motion occurring about the joint. Hip Abduction angular velocity had the highest correlation with treadmill speed. This variable had a high positive correlation (0.778) with treadmill speed, indicating that as the treadmill speed was increased the skaters increased their angular velocity of hip abduction.

Knee extension angular velocity also had a high positive correlation (0.658) with increasing treadmill speed, which suggests that increases in the skater's angular velocity at the knee was associated with the increase in treadmill speed. Stride velocity was the variable to produce the next highest positive correlation (0.605) followed by hip extension angular velocity (0.587) and plantar flexion angular velocity (0.442). Positive correlations between treadmill speed and the range of motion occurring about each joint displayed moderate r values for hip extension (0.435) and knee extension (0.427), with small r- values being observed in ankle plantar flexion (0.267) and hip abduction (0.263).

Correlations between treadmill speed and stride characteristics were also examined. Sagittal stride length had a small r value of 0.250, suggesting a weak positive association. Moderate r values were calculated for both stride width (0.377) and stride length (0.381), indicating that stride width and stride length were increased as the treadmill speed increased. The final correlation calculated was between treadmill speed and the time the skate blade was in contact with the treadmill. This was the only correlation to display a negative r-value. The r-value of -0.466 suggests there was a moderate negative correlation between the time the skate blade was on the treadmill and treadmill speed. This means that as treadmill speed increased the time the skate blade was on the treadmill decreased.

CHAPTER 5

Discussion

Introduction

The purpose of the present study was to investigate the effect a new skate design has on lower body kinematics during the propulsive phase of forward hockey skating. There was an emphasis here in examining the ankle joint, more specifically ankle plantar flexion range of motion and ankle plantar flexion angular velocity, as the new skate design adopted a flexible rear tendon guard. Changing the biomechanical design of the hockey skate, which is a piece of equipment that plays such a huge role in determining whether an athlete is successful, may lead to significantly improving a player's ability to excel over their opponents.

Pre-procedure range of motion

The present study analyzed differences in passive and active dorsiflexion, plantar flexion, eversion, and inversion while participants were wearing no skate, their own skate, and the Easton Mako skate. Comparing all three scenarios allowed the researcher to not only compare range of motion between the two skate designs but also compare the range of motion that is available to a skater while they are not restricted by the confines of a skate boot. Significant differences were found between both plantar flexion ($p<.001$) and inversion ($p<.01$). Plantar flexion was greatest when players were wearing no skate (31.32 degrees) followed by the

Easton Mako skate (18.87 degrees) and finally the traditional skate design (12.96 degrees). Although the Easton Mako skate increased ankle plantar flexion range of motion when compared to the traditional skate design it was evident that the player was still restricted from using their entire range of motion. These findings agree with those of Hoshizaki et al., (1989) who found a skate with a modified boot to increase plantar flexion when compared to a traditional hockey skate design. New skate designs that allow participants to use more of this available range of motion at the ankle joint should be investigated in future studies as they may have a positive effect on increasing forward skating performance. Contrary to the modified skate designer's beliefs that the Easton Mako would increase eversion, the Easton Mako skate did not show any significant difference in eversion range of motion when compared to the traditional skate design ($p>0.30$). The design of the new skate boot with the medial side placed five millimeters higher than the lateral side was designed to promote eversion and increase a player's ability to turn on the ice.

While forward skating hockey players use both the talocrural and subtalar joints simultaneously. It may be more sport specific to investigate pronation and supination of the foot rather than inversion and eversion as these two joints are in constant movement as a player moves throughout the course of a game (Hoshizaki et al., 1989). During the range of motion testing in the current study it was obvious that several participants had difficulty displaying true active values of eversion and inversion. This difficulty may describe the lower cronbach's alpha of 0.684 present in the reliability of the range of motion testing. The eversion and inversion calculations in this study may more appropriately indicate values of pronation and supination of the foot. Future studies should investigate differences in eversion, inversion, pronation, and supination while skating and turning to understand the implications an asymmetrical skate boot such as the Easton Mako has on performance.

Skating Kinematics

Lower body kinematic comparisons while skating on a treadmill were the primary focus of this study. Thirteen variables were measured during the propulsive phase of the hockey stride, for eight participants, while skating forwards on a skating treadmill. Each participant skated at five different speeds while wearing two different types of hockey skates. Therefore the thirteen variables were recorded for each participant during ten different conditions. Following the measurement of the skating variables statistical analysis was completed to find kinematic differences within each participant as they experienced both skate designs. Through the statistical analysis there were significant differences found in lower body kinematics between the two skate designs ($p<.05$). These findings are consistent with Robert-Lachaine et al., 2012; Tidman et al., (2014) that a change in the biomechanical design of the hockey skate can alter skating kinematics. There was also an observed significant difference in lower body kinematics as the speed of the treadmill increased ($p<.001$). These findings are consistent with Upjohn et al., (2008), Page (1975), Haguenauer et al., (2006), and Houdijk et al., (2000) that lower body kinematics change as skating speed is increased.

Ankle Kinematics

The results of this study supported the primary research hypothesis as both plantar flexion range of motion and plantar flexion angular velocity significantly differed as athletes utilized the two different skate designs. It was apparent that the Easton Mako skate outperformed the traditional skate design when it came to these two skating variables (Figure 64). Plantar flexion range of motion was calculated to be 6.17 degrees larger while participants were wearing the Easton Mako skate (19.71 degrees) when compared to the traditional skate design (13.54 degrees). These findings are similar to those of Robert-Lachaine et al., (2012) who found plantar flexion values of 16 degrees in participants using a skate with a flexible rear tendon guard and Upjohn et al., (2008) who found plantar flexion values of 13.5 degrees for participants using a traditional skate design. The increase in plantar flexion increases the effective ankle range of motion players have while pushing into the ice during propulsion of the hockey stride. This increased range of motion will increase the propulsive output aiding players to skate faster down the ice.

Plantar flexion angular velocity was also significantly increased by 9.84 deg/s with the use of the Easton Mako skate (29.25 deg/s) when compared to the traditional design (19.41 deg/s). This difference combined with the added range of motion exhibited by the use of this new skate design suggests that not only was the range of motion larger while wearing the Easton Mako skate, but the movement was occurring at a faster rate. Assuming the recovery phase of the stride does not change while using this new skate design, the increase in angular velocity will increase the stride rate, which is a characteristic of faster skaters (Upjohn et al., 2008; Page 1975).

Plantar flexion torques have been said to be greatest at a position of maximum dorsiflexion (Fugl-Meyer, 1981). The greater amount of dorsiflexion a player has at weight bearing places the plantar flexors at a position of greater tension. This pre-stretched position stores energy in the elastic and contractile components of the plantar flexors, which induces a stronger force as propulsion is initiated (Nordin & Frankel, 2001). Therefore the greater the position of dorsiflexion a skater can attain at weight bearing the greater the torque that is produced during propulsion from the plantar flexors which helps in propelling the skater down the ice. There was no significant difference ($p>0.80$) found between dorsiflexion at weight bearing while wearing the traditional skate (12.71 degrees) and the Easton Mako skate (12.58 degrees). With the use of a strain gauge transducer system Robert-Lachaine et al., (2012) investigated a hockey skate with a flexible back tendon. These authors discovered that the "total peak force occurred later during plantar flexion which suggested the increased range of motion resulted in a more prolonged effective force generation during a given skating stride" (pg. 205).

The increased range of motion displayed in the current study by the implementation of the Easton Mako skate will therefore likely give players greater force generation from the plantar flexors during the hockey stride. This increase in force generation along with the increase in angular displacement of the ankle increases the total work produced by the skater as work (W) = Torque (T) x angular displacement (Θ). Due to this increase in total work and the increase in angular velocity (ω) seen while participants were wearing the Easton Mako skate we know that the power output (P = T x ω), which is a characteristic of faster skaters, was higher when participants were using the Easton Mako skate compared to the traditional design. These results correspond with authors Robert-Lachaine et al., (2012) as they found that the total work and power were greater when participants were wearing a modified skate design with a flexible rear tendon guard. Increasing both work and power during a given time period enables a skater to travel faster down the ice (Vaughan, 1988).

Luhtanen & Komi (1978) found the plantar flexors of the ankle to be important contributors in vertical jumping. They found the plantar flexors to contribute 22% of the total vertical jump height. This suggests that as the ankles are concentrically plantar flexed during the forward hockey stride the plantar flexors play an important role in producing force into the ice. Given the evidence provided by these studies of the contribution plantar flexors have during leg extension, hockey players should be using skates that enable them to use the plantar flexors through their maximum range of motion. The Easton Mako skate has been developed with the same concept the klapskate brought to the sport of speed skating. The klapskate immediately increased speed by 0.4 m/s and enabled skaters to maintain an equal velocity at a lower metabolic level by increasing ankle range of motion and angular velocity (Houdijk et al., 2000). As presented in the results of the current study the Easton Mako skate duplicates the increases in ankle range of motion and angular velocity seen by the klapskate, which suggests that this new skate design will allow skaters to skate faster as well as maintain a velocity at a lower metabolic level.

As the treadmill speed increased from 3.33 m/s to 8.05 m/s there were again significant differences in both plantar flexion range of motion (5.13 degrees) and plantar flexion angular velocity (13.13 degrees/s). While skating at 3.33 m/s plantar flexion range of motion was shown to be 13.36 degrees and increased to 18.49 degrees at a speed of 8.05 m/s. Participants exhibited 16.70 deg/s of plantar flexion angular velocity while skating at 3.33 m/s and 29.83 deg/s of plantar flexion angular velocity at 8.05 m/s. This again agrees with authors Robert-Lachaine et al., (2012), and Vaughan (1988) that increased plantar flexion range of motion and increased plantar flexion angular velocity lead to faster skating. Taking into account that plantar flexion range of motion and angular velocity increased as speed increased we can conclude the Easton Mako improves performance at the ankle joint allowing participants to skate faster as it led to an increase in both plantar flexion range of motion and plantar flexion angular velocity.

Figure 62. Comparisons of dorsiflexion and plantar flexion between the traditional skate (left) and the Easton Mako skate (right) at 6.71 m/s. The Easton Mako shows an increase of 15.9 degrees of plantar flexion during propulsion.

Knee Kinematics

The results of this study did not support the secondary hypothesis, as there was no significant difference in knee extension range of motion or knee extension angular velocity when skate design was altered. Recent literature by Haguenauer et al., 2006, and H. Houdijk et al., (2000) has concluded that the range of motion occurring at the ankle joint during athletic movements affects the kinematics of the knee joint. When comparing push-offs in speed skating between conventional speed skates and klapskates Houdijk et al., (2000) concluded that klapskates, which increased the range of motion at the ankle, increased the work output at the knee joint. Another study investigating the effects ankle range of motion has on the vertical jump during figure skating by Haguenauer et al., (2006) concluded that the stiff design of the figure skating boot decreased performance by limiting plantar flexion, decreasing work at the ankle joint, and decreasing knee angular velocity. According to Haguenauer et al., (2006) this was done by restricting movement at the ankle joint causing a “redistribution of the energy produced by the knee extensors to the hip and ankle joints” (p. 706).

The findings of the current study do not agree with these previous studies, as there was no increase in knee extension range of motion or knee extension angular velocity as plantar flexion range of motion and angular velocity increased. One explanation for this unanticipated result could be the selection of elite hockey skaters as participants. The elite hockey skaters in the current study displayed large ranges of motion occurring at the knee during force production. They may have already optimized the position of the knee during forward skating, which is why no significant difference was found between the two skate designs.

Although not significant the present study displayed a mean increase of 2.78 degrees in knee extension range of motion while participants were wearing the Easton Mako skate (48.15 degrees) when compared to the traditional skate design (45.37 degrees). These values are similar to those of Lafontaine (2007) who reported knee extension values of 55.6 degrees and Upjohn et al., (2008) who reported knee extension values of 34.80 degrees. The slight increase in knee extension during the present study when compared to those of Upjohn et al., (2008) may be attributed to the use of faster treadmill speeds. An increase of 5.87 degrees in knee extension angular velocity was also a non-significant observation when comparing the Easton Mako skate (71.86 degrees/s) to the traditional skate design (65.99 degrees/s). Contrary to previous studies by Haguenauer et al., (2006), and Houdijk et al., (2000) the present study does not substantiate that producing significant increases in joint range of motion at the ankle leads to significantly increasing the knee extension range of motion during propulsion in forward ice skating. However the Easton Mako skate did not limit range of motion or angular velocity at the knee joint which is important to hockey players as faster skaters exhibit increases in both of these characteristics when compared to slower skaters (Upjohn et al., 2008). The relationship between the knee and ankle during forward skating in hockey should be investigated further as it could lead to improvements in knee extension during the propulsive phase.

As treadmill speed increased from 3.33 m/s to 8.05 m/s knee extension range of motion significantly increased from 39.55 degrees to 51.81 degrees (Figure 65). This increase in range of motion at the knee may possibly lead to an increase in the duration of the quadriceps EMG activity during force production. This increase in EMG activity of the quadriceps has a strong correlation with skating speed (Behm et al., 2005). Knee extension angular velocity significantly increased from 49.59 deg/s to 84.18 deg/s. The results of the current study agree with authors Upjohn et al., (2008), and Page (1975) that faster skaters exhibit greater knee extension and knee extension angular velocity. Fugi-Meyer (1981) found the knee extensors to have implications on the isokinetic torques of the plantar flexors. These authors reported the plantar flexors to show higher peak electromyographic activity as the knee was in a position of greater extension (Fugi-Meyer, 1981). It is therefore important to further investigate the effects that increasing ankle range of motion with a new skate design may have on the knee as it could possibly have implications in regards to the activity of the plantar flexors during forward skating in hockey.

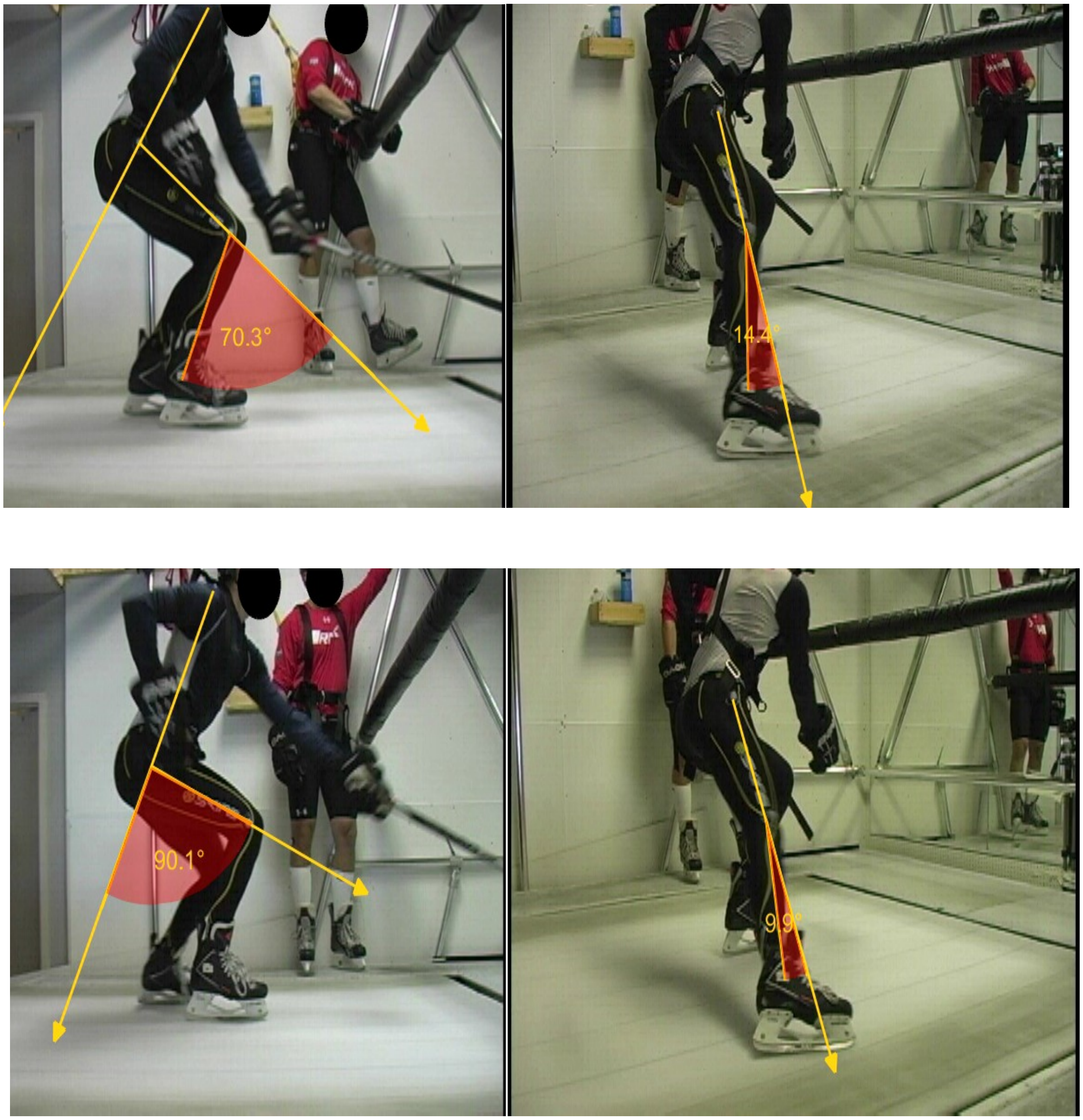


Figure 63. Comparison of knee extension while skating at 3.33 m/s (top) and 8.05 m/s (bottom) with the Easton Mako skate. Participant shows an increase of 24.3 degrees of knee extension during propulsion as treadmill speed increased.

Hip Kinematics

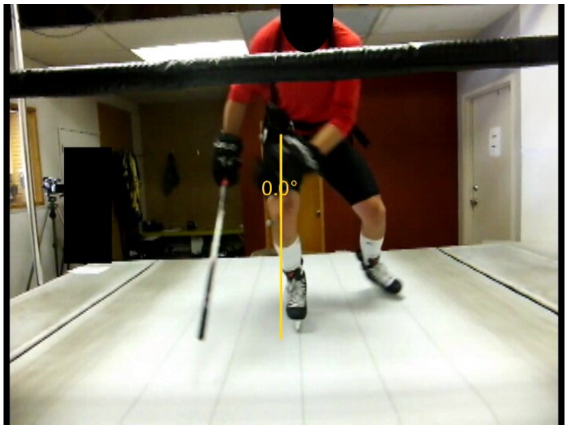
The results of the current study agree with the secondary hypothesis that the hip extension range of motion and hip extension angular velocity are significantly different as participants changed skate designs. The Easton Mako skate outperformed the traditional skate design once again when it came to hip extension kinematics (Figure 66). Hip extension range of motion was increased by 1.720 degrees while participants were wearing the Easton Mako skate (51.98 degrees) when compared to the traditional skate design (50.26 degrees). These values are similar to those of Upjohn et al., (2008) who reported hip extension range of motion to be 40.3 degrees. The slight increase in hip extension between the two studies could once again be attributed to the different treadmill speeds. This increase in hip extension allows skaters to increase the force production by the hip extensors during the propulsion phase. This increase in range of motion also places the hip flexor muscles in a position of greater tension as they reach toe off.

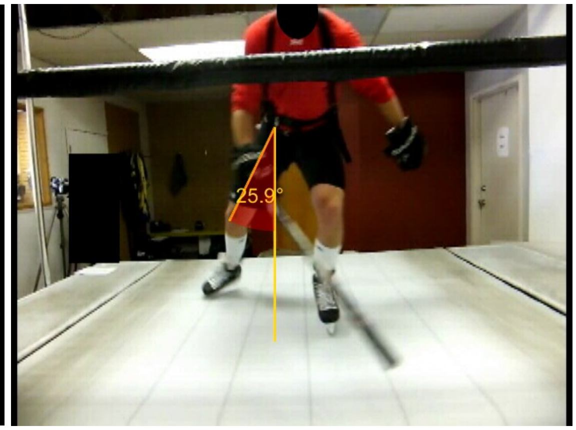
The greater tension induces the hip flexors to be pre-stretched which stores energy in both of its elastic and contractile components. This ultimately induces a stronger force as the hip flexors contract at the beginning of recovery (Nordin & Frankel, 2001). This stronger contraction will make for a faster recovery during the swing phase of the hockey stride increasing stride rate, which is a characteristic of faster skaters (Page 1975; Upjohn et al., 2008).

The Easton Mako skate (78.60 deg/s) also improved angular velocity of the hip extensors during propulsion when compared to the traditional skate design (73.18 deg/s). This increase in angular velocity, which is a characteristic of elite skaters, increases the power they have in the lower legs to propel them down the ice at faster speeds. Hip extension and hip extension angular velocity were also significantly affected by the speed at which participants were skating. Hip extension range of motion increased 8.30 degrees from 47.22 degrees to 55.52 degrees. These values are slightly larger than the 40.3 degrees of hip extension range of motion reported by Upjohn et al., (2008) due to the variance in treadmill speeds. Hip extension angular velocity was increased by 30.89 deg/s from 60.10 deg/s to 90.99 deg/s as the treadmill speed increased from 3.33 m/s to 8.05 m/s. These increases agree with De Koning, Thomas, Berger, De Groot, & van Ingen Schenau (1995) who concluded as skating speed is increased, hip extension range of motion and hip extension angular velocity also increase. If we relate these findings to the differences found between skate design we can suggest that because the Easton Mako skate increased both hip extension range of motion and hip extension angular velocity which are characteristics of faster skaters, players wearing this skate design rather than a traditional skate design will potentially skate faster.

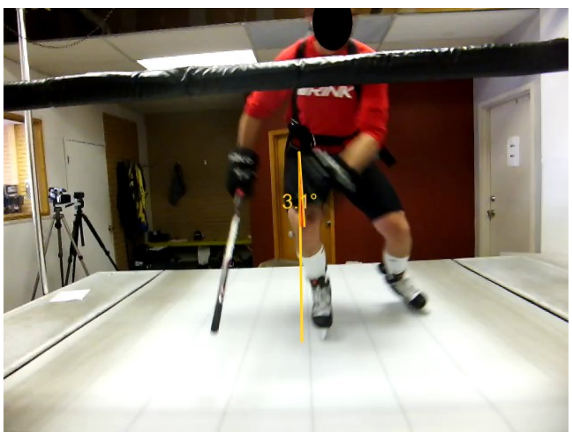
Figure 64. Comparisons of hip extension between the traditional skate (left) and the Easton Mako skate (right) at 8.05 m/s. The Easton Mako shows an increase of 18.2 degrees of hip extension during propulsion.

Hip abduction range of motion was not significantly different between the two skate designs. Hip abduction was measured to be 33.25 degrees as participants were wearing the Easton Mako skate and 34.11 degrees when they were wearing the traditional skate. These findings are similar to those of Bracko, (2004) who found hip abduction to be 35.33 degrees in slow National Hockey League skaters and 48.33 degrees in fast National Hockey League skaters. Hip abduction angular velocity was also not significantly different in the present study. As participants were wearing the Easton Mako skate they had a measured hip abduction angular velocity of 49.06 deg/s compared to 48.32 deg/s when they were wearing the traditional skate design. Hip abduction range of motion along with hip abduction angular velocity was however significantly increased as the treadmill speed went from 3.33 m/s to 8.05 m/s (Figure 67). These findings agree with the findings of Bracko, (2004), De koning et al., (1995), and Upjohn et al., (2008) that faster skaters posses greater hip abduction and hip abduction angular velocity when compared to slower skaters.





Weight bearing hip adduction at 3.33 m/s   Propulsion hip abduction at 3.33 m/s



Weight bearing hip adduction at 8.05 m/s   Propulsion hip abduction at 8.05 m/s

Figure 65. Comparison of hip abduction while skating at 3.33 m/s (top) and 8.05 m/s (bottom). Participant shows an increase of 10.7 degrees of hip abduction during propulsion as treadmill speed increased.

Stride characteristics

There were no differences in sagittal stride length and stride width between the two skate designs in the present study. These findings differ from those reported by Tidman et al., (2014) who found the Easton Mako skate to increase stride width. The participants of the Tidman study were given instruction and encouraged to skate with a "wider stride". There was no instruction given during the current study, which could explain the difference in results. A wider stride is useful to improve skating efficiency at a constant speed but if acceleration is the goal a stride directed more backwards is desired (Marcotte, 1975). Speed skaters use this technique to accelerate quickly at the start of a race. De Koning et al., (1995) reported that speed skaters transitioned from this backwards-directed stride to a more lateral stride around the eighth push-off. This transition during acceleration from a backwards-directed stride to a more lateral stride in ice hockey occurs earlier around the third push-off (Lafontaine, 2007). If the Easton Mako skate was to promote a wider stride such as concluded from Tidman et al., (2014) it may have a negative effect on the acceleration of an ice hockey player. Future studies should investigate how changes in skate design, which may promote a wider stride, affect acceleration in ice hockey.

Significant differences were evident in total stride length and stride velocity as skate design was altered. Increased stride length, which is a characteristic of faster skaters, was shown to be greater by 0.05 m when participants were wearing the Easton Mako skate (Upjohn et al, 2008; Page 1975; Nobes et al., 2003; Chang

2009). While wearing the Easton Mako skate participants in the current study increased both plantar flexion and hip extension during force production without significantly reducing knee extension and hip abduction. These movements enabled participants to increase the length of their stride. Forward skating in hockey is a skill that emphasizes the impulse produced during force production of the skating stride (Behm et al., 2005). The increases in joint range of motion and stride length suggest that by implementing this new skate design participants were able to increase the impulse produced against the ice which should enhance their skating speed (Behm et al., 2005). Stride velocity was also greater by 0.15 m/s when participants were wearing the Easton Mako skate when compared to the traditional skate design. The increase in stride velocity aids skaters in acquiring more powerful strokes as they move down the ice.

As speed was increased from 3.33 m/s to 8.05 m/s all stride variables excluding sagittal stride length were significantly different. Stride width increased from 0.57 m to 0.70 m as the treadmill speed was increased. These stride width values are similar to those reported by Bracko (2004) of 0.51 m for fast National Hockey League skaters and 0.74 m for slow National Hockey League skaters. Stride length increased by 0.15 m as it went from 1.08 m at 3.33 m/s to 1.23 m at 8.05 m/s. Finally stride velocity increased (0.64 m/s) from 1.37 m/s to 2.01 m/s. as the treadmill speed was increased from 3.33 m/s to 8.05 m/s. The results from the present study agree with the results of studies from Bracko (2004), Chang et al.,(2009), Nobes et al., (2003), Pagé, (1975), and Upjohn et al., (2008) that elite skaters exhibit greater stride width, stride length, and stride velocity than their non-elite counterparts. Using the results from the speed comparisons we can suggest that because the Easton Mako skate significantly increased both stride length and stride velocity without compromising sagittal stride length and stride width, participants wearing this new skate design will skate faster than if they were wearing the traditional skate design.

Time of Propulsion

The final variable calculated was the time the skate blade was in contact with the treadmill during the propulsive phase. There were no significant differences in the time the skate blade was in contact with the treadmill between skate designs however the time in which the skate blade was in contact with the treadmill significantly decreased as treadmill speed increased. The time the skate blade was in contact with the treadmill significantly decreased by 0.16 s as speed went from 3.33 m/s to 8.05 m/s. These results agree with past literature in that as skating speed increases the time in which the skate blade is in contact with the ice decreases, which ultimately increases stride rate (Bracko, 2004, Chang et al., 2009, Pagé, 1975, Upjohn et al., 2008).

Correlation Analysis

The correlation analysis completed from the skating treadmill test variables produced significant associations between all 13 variables and treadmill speed. The highest r-values were present in the angular velocities occurring at each joint. These results indicated that as skating speed increased the angular velocities in the hip, knee and ankle also increased. The higher correlations present in angular velocities when compared to the correlations present in the range of motion of the lower limbs suggest that increases in angular velocity may be more important than increases in joint range of motion when it comes to increasing skating speed. This high correlation of angular velocity agrees with Bracko, (2004), De koning et al., (1995), and Upjohn et al., (2008) who found increases in angular velocities of the joints of the lower limbs to be a characteristic of faster skaters.

The stride characteristics presented similar results. Although a moderate correlation existed between treadmill speed and both stride width (0.377) and stride length (0.381), the r-value was higher for stride velocity (0.605). These results suggest that stride velocity or the rate in which it takes a player to go from weight bearing to propulsion, may be the most important stride characteristic a player should focus on when trying to increase skating speed.

CHAPTER 6

Summary, Conclusion, and Recommendations

Summary

Skating ability in the sport of hockey is one of the most important skills a player must excel at to be successful (McPherson et al., 2004). The research completed in hockey skating has been focused on the physiology of training and conditioning along with skill development. There has been minimal research conducted on the biomechanical design of equipment and the effect it has on skating performance (Robert-Lachaine et al., 2012).

The purpose of this study was to investigate the kinematic differences in ankle plantar flexion range of motion and angular velocity during propulsion of the forward hockey skating stride, between a traditional hockey skate and a hockey skate that has a flexible rear tendon guard. It was hypothesized that the skate design with a flexible rear tendon guard would increase both of these kinematics occurring at the ankle. Secondary purposes included investigating the kinematic differences in range of motion and angular velocity at both the knee and hip during propulsion while participants were wearing both skate designs. It was hypothesized that the skate design with a flexible rear tendon guard would increase motion variables at both the knee and hip when compared to the traditional skate design. Differences in stride length, stride width and stride velocity along with the time the skate blade was in contact with the treadmill during propulsion between the two different skate designs were then investigated. It was hypothesized that the skate with a flexible rear tendon guard would increase stride length, stride width, stride velocity, and the time the skate blade was in contact with the treadmill during propulsion. Finally differences in range of motion and angular velocity of the ankle, knee, and hip, along with the velocity of the skating stride and the time the skate blade was in contact with the treadmill were investigated as the skating treadmill increased in speed from 3.33 m/s to 8.05 m/s. It was hypothesized that plantar flexion range of motion and angular velocity, knee extension range of motion and angular velocity, hip extension range of motion and angular velocity, hip abduction range of motion and angular velocity, stride width, and stride length would all increase as speed of the treadmill increased. It was also hypothesized that stride velocity would increase and the time the skate blade was in contact with the treadmill would decrease as treadmill speed increased.

Eight elite male hockey players participated in the study, which was conducted on an Endless Ice Skating Treadmill. Each participant skated at five speeds while wearing the traditional skate and the skate design that has a flexible rear tendon guard. Variables were recorded using a three-camera setup and measured using Dartfish Team Pro version six software (Dartfish, 2013). Means and standard errors of all the variables were measured for 10 consecutive strides per condition. Kinematic variables were then compared between the two skate designs with a doubly multivariate repeated measures design at a significance level of $p<0.05$. Further post hoc univariate tests and planned pairwise comparisons were completed to determine where the differences in skating kinematics occurred.

Skate Comparison

Ankle kinematics proved to be significantly different between the two skate designs. The skate with the flexible rear tendon guard increased both ankle plantar flexion range of motion and angular velocity during propulsion of the forward skating stride. There were no significant differences of knee extension or knee extension angular velocity found between skate designs. At the hip, significant increases during propulsion were found in hip extension and hip extension angular velocity as participants utilized the skate with a flexible rear tendon guard, while there was no difference found in hip abduction or hip abduction angular velocity. Stride length and stride velocity were both significantly increased as participants were wearing the skate with a flexible rear tendon guard, while there was no difference in sagittal stride length or stride width.

Treadmill Speed Comparison

Significant differences were also found as treadmill speed increased from 3.33 m/s to 8.05 m/s. Ankle plantar flexion range of motion and angular velocity, knee extension range of motion and angular velocity, hip extension range of motion and angular velocity, hip abduction range of motion and angular velocity, stride width, stride length, and stride velocity all significantly increased as the treadmill speed was increased. The time the skate blade was in contact with the treadmill decreased as the treadmill speed increased from 3.33 m/s to 8.05 m/s.

Correlation analysis was then completed to determine which variables were highly associated with increased skating speed. Through examination of the correlation analysis it was evident that the angular velocity occurring at each joint displayed a higher correlation with treadmill speed than did the range of motion occurring about the joint. These results suggest that increases in joint angular velocity may be more important than increases in joint range of motion when it comes to increasing skating speed. The stride characteristics measured in the treadmill test displayed similar correlations of those regarding joint range of motion. Stride velocity presented a greater correlation with treadmill speed than that of stride length and stride width. These results suggest that stride velocity, or the rate in which it takes to go from weight bearing to propulsion, may be the most important stride characteristic for a player who is trying to increase skating speed.

Conclusions

Based on the findings of this study the following conclusions have been determined:

- Ankle plantar flexion range of motion and ankle plantar flexion angular velocity during propulsion of the forward skating stride are increased with the implementation of a flexible rear tendon guard.
- Hip extension range of motion and hip extension angular velocity during propulsion of the forward skating stride are increased with the implementation of a flexible rear tendon guard.
- Hockey players increased stride length and stride velocity of propulsion when using a skate that has a flexible rear tendon guard.

- Ankle plantar flexion range of motion and ankle plantar flexion angular velocity during propulsion of the forward skating stride are increased as skating speed increases.
- Knee extension range of motion and knee extension angular velocity during propulsion of the forward skating stride are increased as skating speed increases.
- Hip extension range of motion and hip extension angular velocity during propulsion of the forward skating stride are increased as skating speed increases.
- Hip abduction range of motion and hip abduction angular velocity during propulsion of the forward skating stride are increased as skating speed increases.
- Hockey skaters increase stride width, stride length, and stride velocity as skating speed increases.
- The time the skate blade is on the treadmill decreases as skating speed increases.

Recommendations

- Future studies should utilize a three-dimensional motion capture system in order to avoid errors in measurement as stationary cameras are unable to stay in the primary plane for the duration of the movement.
- Future studies should investigate the effect an asymmetrical skate boot has on both forward skating and turning during hockey.

- Future studies should investigate how changes in skate design, which may promote a wider stride, affect acceleration in ice hockey.
- Future studies should have participants wear full hockey equipment to ensure kinematic data that is more generalizable in a hockey game.
- Future studies should investigate both kinematic data and on-ice speed simultaneously to determine the relationship these kinematics have with skating speed.
- Future studies should include more subjects to ensure the significance of results and to better generalize the findings to a wider range of hockey players.

References

Alexander, M. J. L., Taylor, C., & Shackel, B. (2007). *Forward skating checklist.* Unpublished manuscript, Sport Biomechanics Laboratory, Faculty of Kinesiology & Recreation Management, University of Manitoba.

Almquist, P. O., Ekdahl, C., Isberg, P.-E., & Fridén, T. (2013). Knee rotation in healthy individuals related to age and gender. *Journal of Orthopaedic Research*, *31*(1), 23–28.

Baechle, T. R., Earle, R. W., & National Strength and Conditioning Association (2008). *Essentials of Strength Training and Conditioning*. Champaign, IL: Human Kinetics.

Behm, D. G., Wahl, M. J., Button, D. C., Power, K. E., & Anderson, K. G. (2005). Relationship between hockey skating speed and selected performance measures. *The Journal of Strength & Conditioning Research*, *19*(2), 326–331.

Bourque, R. (1985, April 9). Composite skate boot and method of making the same. *US Patent No. 4,509,276*. Montreal, Canada.

Bracko, M. R. (2004). Biomechanics powers ice hockey performance. *Biomechanics*, 47–53.

Chang, R., Turcotte, R., & Pearsall, D. (2009). Hip adductor muscle function in forward skating. *Sports Biomechanics*, *8*(3), 212–222.

Clarkson, H. M. (2000). *Musculoskeletal assessment: joint range of motion and manual muscle strength*. Philadelphia: Lippincott Williams & Wilkins.

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology*, *78*(1), 98–104.

Dartfish (2013). Dartfish Analysis Software. Retrieved from: http://www.dartfish.com/en/software/dartfish-prosuite/index.htm.

De Koning, J. J., Thomas, R., Berger, M., De Groot, G., & van Ingen Schenau, G. J. (1995). The start in speed skating: from running to gliding. *Medicine and Science in Sports and Exercise*. (27) 1703-1708.

Dewan, C., Pearsall, D., & Turcotte, R. (2004). *Proceedings from International Symposium on Biomechanics in Sports (ISBS) Conference*: Ankle kinematics during forward hockey skating: Acceleration to constant velocity. 387-390.

Easton hockey. (n.d.). Retrieved August 22, 2013, from:
http://www.easton.com/hockey/products/skates

Eltoukhy, M., Asfour, S., Thompson, C., & Latta, L. (2012). Evaluation of the Performance of Digital Video Analysis of Human Motion: Dartfish Tracking System, *International Journal of Scientific & Engineering Research*. *3*(3) 1-6.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191.

Federolf, P., & Redmond, A. (2010). Does skate sharpening affect individual skating performance in an agility course in ice hockey? *Sports Engineering*, *13*(1), 39–46.

Fugl-Meyer, A. R. (1981). Maximum isokinetic ankle plantar and dorsal flexion torques in trained subjects. *European Journal of Applied Physiology and Occupational Physiology*, *47*(4), 393–404.

Greer, N. (1990). Biomechanics of skating. *Winter Sports Medicine.* M.J. Casey (Ed.). Philadelphia: Davis Co, 241–247.

Haguenauer, M., Legreneur, P., & Monteil, K. M. (2006). Influence of figure skating skates on vertical jumping performance. *Journal of Biomechanics*, *39*(4), 699–707.

Hancock, S., Lamontagne, M., Stothart, J. P., & Sveistrup, H. (1999). *Proceedings from XVIth of the International Society of Biomechanics*. The influence of three hockey skate boots on the range of motion, elastic moment and stiffness of the human ankle joint complex. *Calgary, Canada*.

Hinrichs, J. N. (1995). EMG activity of ice skating and treadmill skating in hockey players. *Clinical Journal of Sport Medicine*, *5*(4), 278.

Hoshizaki, T. B., Hall, K., & Bourque, R. (1989, June 6). Skate boot. *US. Patent No. 4,835,885*. Montreal, Canada.

Hoshizaki, T. B., Kirchner, G., & Hall, K. (1989). *Safety in Ice Hockey: Kinematic analysis of the talocrural and subtalar joints during the hockey skating stride*. West Conshohocken: American Society for Testing and Materials, *1*, 141.

Houdijk, H., De Koning, J. J., de Groot, G., Bobbert, M. F., & van Ingen Schenau, G. J. (2000). Push-off mechanics in speed skating with conventional skates and klapskates. *Medicine and Science in Sports and Exercise*, *32*(3), 635–641.

Houdijk, H., Heijnsdijk, E. A., de Koning, J. J., de Groot, G., & Bobbert, M. F. (2000). Physiological responses that account for the increased power output in speed skating using klapskates. *European Journal of Applied Physiology*, *83*(4-5), 283–288.

Humble, R. N., & Gastwirth, B. W. (1988). The biomechanics of forward power skating. *Clinics in Podiatric Medicine and Surgery*, *5*(2), 363.

Hutchison, M. G. (2011). *Concussions in the National Hockey League (NHL): The Video Analysis Project*. (Unpublished doctoral dissertation). Faculty of Kinesiology and Physical Education. University of Toronto, Toronto.

IBM SPSS software. (2013, August 19). [CT500]. Retrieved August 22, 2013, from http://www-01.ibm.com/software/analytics/spss/

Kuper, G. H., & Sterken, E. (2003). Endurance in speed skating: The development of world records. *European Journal of Operational Research*, *148*(2), 293–301.

Lafontaine, D. (2007). Three-dimensional kinematics of the knee and ankle joints for three consecutive push-offs during ice hockey skating starts. *Sports Biomechanics*, *6*(3), 391–406.

Lee Rodgers, J., & Nicewander, W. A. (1988). Thirteen ways to look at the correlation coefficient. *The American Statistician*, *42*(1), 59–66.

Levangie, P. K., & Norkin, C. C. (2011). *Joint structure and function: a comprehensive analysis* Phladelphia: FA Davis Co.

Lix, L. M., & Sajobi, T. (2010). Testing multiple outcomes in repeated measures designs. *Psychological Methods*, *15*(3), 268.

Luhtanen, P., & Komi, P. V. (1978). Segmental contribution to forces in vertical jump. *European Journal of Applied Physiology and Occupational Physiology*, *38*(3), 181–188.

Madore, C. (2003, April 22). Skate having dynamic range of motion. *US. Patent No. 6,550,159*. Montreal, Canada.

Magee, D. J. (2000). *Orthopaedic physical assessment 4th ed*. Philadelphia: Saunders

Maor, E. (2007). *The Pythagorean Theorem: A 4,000-year History*. Princeton University Press.

Marino, G. W. (1977). Kinematics of Ice Skating at Different Velocities. *Research Quarterly*, *48*(1), 93–97.

Marino, G. W., & Weese, R. G. (1979). A kinematic analysis of the ice skating stride. In J. Terauds (Ed), *Science in Skiing, Skating and Hockey*, 65–74. Del Mar, CA: Academic Publishers.

McKinley, M. (2009). *Hockey: A People's History.* Toronto: McClelland & Stewart.

McPherson, M. N., Wrigley, A., & Montelpare, W. J. (2004). The biomechanical characteristics of development-age hockey players: Determining the effects of body size on the assessment of skating technique. *American Society for Testing and Materials (ASTM) Special technical publication,* 272–287.

Moore, K. L., Dalley, A. F., & Agur, A. M. R. (1999). *Clinically oriented anatomy (Vol. 5)*. Philadelphia: Lippincott Williams & Wilkins Philadelphia

Nobes, K. J., Montgomery, D. L., Pearsall, D. J., Turcotte, R. A., Lefebvre, R., & Whittom, F. (2003). A comparison of skating economy on-ice and on the skating treadmill. *Canadian Journal of Applied Physiology*, *28*(1), 1–11.

Nordin, M., & Frankel, V. H. (2001). *Basic Biomechanics of the Musculoskeletal System*. Lippincott Williams & Wilkins.

Pagé, P. (1975). *Biomechanics of forward skating in ice hockey*. (Unpublished M. Sc. Thesis). Dalhousie University, Halifax.

Pearsall, D. J., Paquette, Y. M., Baig, Z., Albrecht, J., & Turcotte, R. A. (2012). Ice hockey skate boot mechanics: Direct torque and contact pressure measures. *Procedia Engineering*, *34*, 295–300.

Pearsall, D., Turcotte, R., Lefebvre, R., Bateni, H., Nicolaou, M., Montgomery, D., & Chang, R. (2001). *Proceedings from International Symposium on Biomechanics in Sports (ISBS) Conference:* Kinematics of the foot and ankle in forward ice hockey skating (Vol. 1).

Pitkin, M., Smirnova, L., Scherbina, K., & Zvonareva, E. (2002). Proceedings of the *7th Annual Russian National Congress:* Biomechanics of ice hockey skating in amputees with foot and ankle prostheses. St. Petersburg, Russia

Roaas, A., & Andersson, G. B. J. (1982). Normal Range of Motion of the Hip, Knee and Ankle Joints in Male Subjects, 30–40 Years of Age. *Acta Orthopaedica*, *53*(2), 205–208.

Roach, K. E., & Miles, T. P. (1991). Normal Hip and Knee Active Range of Motion: The Relationship to Age. *Physical Therapy*, *71*(9), 656–665.

Robert-Lachaine, X., Turcotte, R. A., Dixon, P. C., & Pearsall, D. J. (2012). Impact of hockey skate design on ankle motion and force production. *Sports Engineering*, *15*(4), 197–206.

Robertson, D. G. E. (2004). *Research Methods in Biomechanics*. Champaign, IL: Human Kinetics.

Smith, S. (2010). *Proceedings* of the *World Hockey Summit.* Growing the game: vision 20/20.

Stidwill, T. J., Pearsall, D., & Turcotte, R. (2010). Comparison of skating kinetics and kinematics on ice and on a synthetic surface. *Sports Biomechanics*, *9*(1), 57–64.

Tidman, R., Lambert, L., Cruikshank, D., & Silver-Thorn, M. (2014). *Proceedings of the Marquette University Biomedical Engineering Symposium.* Hockey Skating Kinematics, 17–18.

Turcotte, R. A., Pearsall, D. J., & Montgomery, D. L. (2001). An apparatus to measure stiffness properties of ice hockey skate boots. *Sports Engineering*, *4*(1), 43–48.

Turcotte, R. A., Pearsall, D. J., Montgomery, D. L., Lefebvre, R., Ofir, D., & Loh, J. J. (2004). Comparison of Ice Versus Treadmill Skating-Plantar Force Distribution Patterns. *American Society of Testing and Materials (ASTM) Special technical publication*, 265–271.

Tyler, T. F., Nicholas, S. J., Campbell, R. J., & McHugh, M. P. (2001). The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *The American Journal of Sports Medicine*, *29*(2), 124–128.

Upjohn, T., Turcotte, R., Pearsall, D. J., & Loh, J. (2008). Three-dimensional kinematics of the lower limbs during forward ice hockey skating. *Sports Biomechanics*, *7*(2), 206–221.

USA hockey (2011). Annual Report. Retrieved from: http://www.usahockey.com/about_usa_hockey/Annual_Report.aspx

Vaughan, C. L. (1988). *Biomechanics of Sport* (1st ed.). Boca Raton: CRC Press.

Vaughan, G. (1996). *The Puck Starts Here: the Origin of Canada's Great Winter Game, Ice Hockey*. Fredericton, NB: Goose Lane Editions.

Zou, K. H., Tuncali, K., & Silverman, S. G. (2003). Correlation and Simple Linear Regression. *Radiology*, *227*(3), 617–628.

Appendix A

Ethics Approval

UNIVERSITY OF MANITOBA | Research Ethics and Compliance
Office of the Vice-President (Research and International)

Human Ethics
208-194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2
Phone +204-474-7122
Fax +204-269-7173

APPROVAL CERTIFICATE

June 10, 2014

TO: **Michael Robert Hellyer** (Advisor M. Alexander)
Principal Investigator

FROM: **Lorna Guse, Chair** [redacted]
Education/Nursing Research Et[redacted]ENREB)

Re: **Protocol #E2014:071**
"The comparison of differences in lower body kinematics during forward treadmill skating between two different hockey skate designs"

Please be advised that your above-referenced protocol has received human ethics approval by the **Education/Nursing Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement (2). **This approval is valid for one year only**.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- **If you have funds pending human ethics approval, please mail/e-mail/fax (261-0325) a copy of this Approval (identifying the related UM Project Number) to the Research Grants Officer in ORS in order to initiate fund setup. (How to find your UM Project Number: http://umanitoba.ca/research/ors/mrt-faq.html#pr0)**

- **if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.**

The Research Quality Management Office may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba *Ethics of Research Involving Humans*.

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/orec/ethics/human_ethics_REB_forms_guidelines.html) **in order to be in compliance with Tri-Council Guidelines.**

Appendix B

Informed Consent

Faculty of Kinesiology
and Recreation Management
307 Max Bell Centre
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-7087
Fax (204) 261-4802

UNIVERSITY OF MANITOBA | Health, Leisure & Human Performance Research Institute

Informed Consent

Research Project Title: The measurement of lower body kinematics between two different skate designs in treadmill hockey skating.

Principal Researcher:
Mike Hellyer, BKin, M.Sc Candidate
Faculty of Kinesiology and Recreation Management
University of Manitoba
204-474-8675 (umhellye@myumanitoba.ca)

Research Supervisor:
Marion Alexander, PhD
Faculty of Kinesiology and Recreation Management
University of Manitoba
204-474-8642 (marion.alexander@umanitoba.ca)

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Outline of the Study:

The purpose of this study is to examine the differences in lower body kinematics between two different hockey skate designs while skating on a treadmill.

Methodology:

You will be filmed, on one occasion only, while practicing the desired task using filming equipment from the Biomechanics Laboratory in the Faculty of Kinesiology and Recreation Management. The primary investigator Mike Hellyer will instruct you regarding the skills to perform. Prior to filming you, the filming procedures will be explained. You will be asked to perform the skills as you normally would in a game situation, and your techniques will be filmed. You must provide informed consent for the study prior to filming. All filming procedures lasting approximately two hours will be scheduled, organized, and administered by the principal investigator Mike Hellyer.

The participant will be asked to fill-out a PAR-Q disclosing any type of health condition or musculoskeletal injury that may lead to withdrawal. At this time this informed consent will be signed if the participant chooses to participate. Age, height, mass, hockey experience, personal skate brand, personal skate model, and skate size will all be recorded. The participant will then be assigned a number at this time and will be tracked and recorded through the data collection process by number only. Flexibility testing including both passive and active range of motion for the foot and ankle in three different conditions: wearing no skate, wearing the current skate they are using (traditional design), and wearing the Easton Mako skate will be recorded with the use of video cameras.

The participant will then be instructed to perform a dynamic warm-up consisting of approximately five minutes of aerobic activity and five minutes of total body calisthenics. Following the warm up you will be randomly selected to either the traditional design group or the Easton Mako design group. At this time participants of the traditional design group will be instructed to put on their own personal skates and hockey gloves whereas the Easton Mako design group will be instructed to put on their personal hockey gloves along with the Easton Mako skates. A qualified treadmill operator from Custom Edge Skate Services will then harness the participant to the overhead track of the treadmill for safety. This safety harness is a modified climbing harness that is connected to an overhead tracking system and wired to the control panel. This safety harness along with the padded bar positioned across the front of the treadmill for participants to hold on to are designed to prevent injury in the case of a fall.

A fifteen-minute familiarization period will then be given so participants can become accustomed to skating on the treadmill. This familiarization period will be instructed by a Custom Edge Skate Service professional and will include forward skating, outside and inside edge control drills while on both skates, one legged squats, and outside and inside edge control drills for both the right and left legs while on one skate.

Participants will then skate at three different velocities (3.33 m/s (8mph), 5.00 m/s (11mph), 6.66m/s (14mph)) for twenty-seconds each with a two-minute rest break between trials. Participants will then take part in a graded treadmill test. This section will begin at a speed of 15mph and will be increased by 3mph every twenty-seconds until the participant terminates the test verbally, the principal investigator or treadmill operator terminate the test verbally due to safety or the safety harness shuts off the treadmill. Participants will then change skates and complete another familiarization period wearing the other skate design. Once the familiarization period is completed the participants will perform the same task once more.

Four video cameras will be used to film the participant: one placed at the side of the athlete, one placed to the front of the athlete, one placed behind the athlete, and one overhead at a safe distance from the athlete. The video cameras will be started together to ensure that they start and stop at the same instant, the primary investigator will instruct you regarding which skills are to be performed while the cameras are filming. The cameras will continue to film you until all of the skills of interest have been performed.

When filming is completed, the principal investigator will analyze the films. The types and ranges of motion of each of the body parts in each of the skills, as well as selected angular velocities and accelerations of the various body segments in each of the skills will be described. It is possible that some of the descriptions developed from this analysis may eventually be published in a technical journal in the sport being examined.

Risks and Benefits:

The task participants will be performing is a physical task therefore there may be risk involved. To minimize the risk involved specific participants are desired. Recruiting participants who have skated at the university or professional level should help minimize the risk. Their experience and skating ability should minimize the risk while skating on the treadmill. Participants will also be required to sign a PAR-Q before the study to rule out any health risk while performing the desired task. Participants will be properly instructed on how to use the overhead safety harness and horizontal safety bar by a trained professional while skating on the treadmill to minimize the risk during the study. The treadmill operator along with the principal investigator will stop testing should they feel that the participant is distressed in any way.

The data collected during this study has the ability to provide evidence of how a new skate design may improve forward skating in hockey. Participants in this study will also benefit from the video analysis. If the participant shows unusual skating technique the video analysis may help identify areas of improvement, which could lead to improved performance on the ice during competition. Volunteering for this study will also give participants insight into the research process of a graduate thesis along with valuable volunteer experience in the realm of kinesiology.

Withdrawal:

The participant may withdraw from this study at any point in time, and should notify the principal investigator as soon as possible if they should choose to withdraw. Any data collected on such a participant will be deleted.

Confidentiality:

The film will be viewed only by the researchers involved in the study. The data derived from the film will be available to the participants in order to help improve performance. The video films and all of the research data will be kept in a locked cabinet in the biomechanics laboratory, and will not be used for any other purpose than the current study. No one will have access to the films or data except the principal investigator and the research supervisor upon request. Upon completion of the study the primary researcher will destroy all of the video files and data per PHIA policy.

Signatures:

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba Research Ethics Board(s) and a representative(s) of the University of Manitoba Research Quality Management / Assurance office may also require access to your research records for safety and quality assurance purposes.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

<u>Principal Researcher</u>: **Mike Hellyer, Msc. student, Faculty of Kinesiology and Recreation Management, University of Manitoba, Ph 204-474-8675**

____

Participant Name

____

Participant Signature Date

____

Parent and/or guardian's signature (if under 18 years of age) Date

____

Researcher or Delegate's Signature Date

If you would like to receive a copy of the results of this study please provide your mailing address below and a copy will be sent upon completion.

____
____
____
____
____
____
____

Health, Leisure & Human Performance RESEARCH INSTITUTE

APPENDIX C

PAR-Q PLUS

CSEP approved Sept 12 2011 version

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

	Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.	Has your doctor ever said that you have a heart condition OR high blood pressure?	☐	☐
2.	Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	☐	☐
3.	Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4.	Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐
5.	Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
6.	Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	☐	☐
7.	Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.

Go to Section 3 to sign the form. You do not need to complete Section 2.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- You may take part in a health and fitness appraisal.
- If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist® (CSEP-CEP) or CSEP Certified Personal Trainer® (CSEP-CPT).
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the questions above, please GO TO SECTION 2.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity programme.

CSEP | SCPE THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

SECTION 2 - CHRONIC MEDICAL CONDITIONS

		Please read the questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.		Do you have Arthritis, Osteoporosis, or Back Problems?	☐ If yes, answer questions 1a-1c	☐ If no, go to question 2
	1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	☐	☐
	1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	☐	☐
2.		Do you have Cancer of any kind?	☐ If yes, answer questions 2a-2b	☐ If no, go to question 3
	2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	☐	☐
	2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	☐	☐
3.		Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm	☐ If yes, answer questions 3a-3e	☐ If no, go to question 4
	3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	3b.	Do you have an irregular heart beat that requires medical management? (e.g. atrial brillation, premature ventricular contraction)	☐	☐
	3c.	Do you have chronic heart failure?	☐	☐
	3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)	☐	☐
	3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	☐	☐
4.		Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes	☐ If yes, answer questions 4a-4c	☐ If no, go to question 5
	4a.	Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)	☐	☐
	4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	☐	☐
	4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	☐	☐
5.		Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)	☐ If yes, answer questions 5a-5b	☐ If no, go to question 6
	5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	5b.	Do you also have back problems affecting nerves or muscles?	☐	☐

Please read the questions below carefully and answer each one honestly: check YES or NO.			YES	NO
6.	Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure		☐ If yes, answer questions 6a-6d	☐ If no, go to question 7
	6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	☐	☐
	6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	☐	☐
	6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	☐	☐
7.	Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia		☐ If yes, answer questions 7a-7c	☐ If no, go to question 8
	7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	☐	☐
	7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	☐	☐
8.	Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event		☐ If yes, answer questions 8a-c	☐ If no, go to question 9
	8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	8b.	Do you have any impairment in walking or mobility?	☐	☐
	8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	☐	☐
9.	Do you have any other medical condition not listed above or do you live with two chronic conditions?		☐ If yes, answer questions 9a-c	☐ If no, read the advice on page 4
	9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	☐	☐
	9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	☐	☐
	9c.	Do you currently live with two chronic conditions?	☐	☐

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

- You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a or qualified exercise professional (CSEP-CEP) for further information.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise profesional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- Please read and sign the declaration below:

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME ____ DATE ___________________________________

SIGNATURE ______________________________ WITNESS ____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ____

For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES

1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the eectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Appendix D

Letters to coaches and participants

Faculty of Kinesiology
and Recreation Management
307 Max Bell Centre
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-7087
Fax (204) 261-4802

University of Manitoba | Health, Leisure & Human Performance Research Institute

Dear Coach:

My name is Mike Hellyer and I am a Graduate Student at the University of Manitoba. For my thesis project, I am doing a biomechanical analysis of forward skating in hockey. I will be comparing the kinematics of forward treadmill skating between two different hockey skate designs.

I am hoping to recruit hockey players 18 years of age and older who play at a university or a professional level as participants for my thesis research. Participation means attending one session of one to two hours where players will be asked to skate on a skating treadmill using either their own skates or a new brand of skates. Safety precautions will be in place and a safety harness will be used. Players will be asked questions about their age, height, mass, hockey experience, personal skate brand, personal skate model and skate size. Measurements of the flexibility of their feet and ankles will be conducted and the players will be videotaped while they are skating on the skating treadmill at three different velocities (3.33m/s or 8 mph; 5.00m/s or 11 mph; 6.66 m/s or 14 mph). Players will be asked to complete a PAR-Q. The session will take place at Custom Edge Skate Services.

Because you are a coach of a university or professional level hockey team, I am asking you to forward this email to your players so that they can choose to contact me at my email address if they would like further information on the project or if they are interested in participating. I will provide more information to players once they contact me by email. Let me emphasize that participation is voluntary and I am only asking you to forward this email to your players. I hope to hear from players and I will create a list of participants as soon as possible for testing in mid to late June. Thank you very much for your time.

I look forward to hearing from you,

Primary Researcher
Mike Hellyer
B.Kin
umhellye@myumanitoba.ca

Faculty Advisor
Dr. Marion Alexander
marion.alexander@umanitoba.ca

This research has been approved by the Education Nursing Research Ethics Board. If you have any concerns or complaints about this project, you may contact Mike Hellyer or Dr. Dr. Marion Alexander or the Human Ethics Coordinator (HEC) at 204-474-7122 or email: Margaret.bowman@umanitoba.ca

UNIVERSITY OF MANITOBA

Health, Leisure & Human Performance Research Institute

Faculty of Kinesiology
and Recreation Management
307 Max Bell Centre
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-7087
Fax (204) 261-4802

Hello,

Thank you for expressing interest in this study. You have been added to the list of participants that may be included in this study, in the order of when they first contacted me.
Once the date is set for testing, I will contact the first 8 participants to see if they are available at the requested time. If any participants are not able to attend, the individuals next on the list will be contacted. It is expected that you will only be required to come to Custom Edge Skate Service on one day, for approximately 1 to 2 hours. This will be in mid to late June. I have also attached the Informed Consent Form, which provides further information on what you are to expect if you choose to participate.

To ensure that you are eligible to participate, please read through the inclusion and exclusion criteria below and then reply to this email stating "I confirm that I am eligible for this study" if it is true. After you have read the consent form, please also indicate in your email if you are interested in participating and I will send further information on testing times. Once we meet at the testing place, Custom Edge Skate Service, I will ask that you sign the consent form.

Inclusion Criteria:

- Male Hockey Player
- 18+ years of age
- Skated at the University or Professional level
- No current musculoskeletal injury (within last 3 months)
- Owns a pair of hockey skates in safe working condition

Exclusion Criteria

- Failure to meet the 5 necessary inclusion criteria

Thank you very much for your interest; I look forward to working with you!

Sincerely,

Mike Hellyer
B.Kin
umhellye@myumanitoba.ca

Appendix E

Pilot Study

Introduction

The purpose of the pilot study was to collect video from participants skating on a treadmill while wearing two different skate designs. The pilot study provided the primary investigator an opportunity to test the methods that will be utilized during an upcoming thesis. This included the range of motion testing, camera set-up, procedure, and statistical analysis. The data collected from the study was also used in a power analysis to calculate the number of participants needed for the upcoming thesis.

Methods

PARTICIPANTS

Two participants were recruited for the study ranging in age from 25 to 28. The participants were recruited through a previous relationship between the primary investigator and the University of Manitoba men's hockey team. Both participants were considered to be very skilled hockey skaters as one had played hockey at the Canadian university level with the second playing professional hockey in the United States of America. Subject one was 25 years of age and had completed a five-year university career, which was followed by playing for the Florida Everblades of the east coast hockey league. He stood at a height of 179.07cm and had a mass of 76.20kg. The hockey skate he wore for the traditional skate design was a size 7.5 Bauer NXG. Subject two also completed a successful five-year university hockey career and is currently a strength and conditioning coach in the city of Winnipeg Manitoba. He was 28 years of age, 172.72cm tall and had a mass of 72.57kg. His personal skates were size 6.5 Bauer X60.

PRE-TESTING PROCEDURE

Prior to the study participants were required to provide written consent by signing an ethics waiver approved by the ENREB research group from the university of Manitoba. Participants then answered a short questionnaire to collect information which included: height(cm), weight (kg), age, hockey experience, skate brand, skate model, and skate size. The demo Mako skates supplied by Easton hockey were then sharpened with the same hollow and rocker radius as the participants personal skates to eliminate any difference in the blades between skates. Both participants used a 0.5-inch hollow during the study that was sharpened by Custom Edge Skate Service. Flexibility was then measured with the use of a goniometer. This included both passive and active range of motion testing for the foot and ankle in three different conditions: while wearing no skate, while wearing the current skate they are using (traditional design), and while wearing the Easton Mako skate.

FLEXIBILITY TESTING

Ankle dorsiflexion and plantar flexion was measured with the participants lying supine on a table. A rolled towel was placed under the knee to maintain 20 to 30 degrees of knee flexion. The tibia and fibula were stabilized with the axis of the goniometer placed inferior to the lateral malleolus. The stationary arm of the goniometer was placed parallel to the longitudinal axis of the fibula with the movable arm of the goniometer parallel to the inferior aspect of the heel, which eliminated forefoot movement from the measurement . Ankle dorsiflexion and plantar flexion was measured while wearing the hockey skate with the same procedure. It was accomplished by measuring the distance between a mark on the lower limb to the lateral malleolus to help estimate it's position within the hockey skate boot.

Inversion and eversion of the subtalar joint was measured with the subject prone and the feet positioned beyond the end of the table. The ankle was set in a neutral position with two marks on the skin being placed over the midline of the superior aspect of the calcaneus posteriorly, and the inferior aspect of the heel pad. The tibia and fibula were stabilized with the goniometer axis placed at the midline of the superior aspect of the calcaneus. The stationary arm was placed parallel to the longitudinal axis of the lower leg with the movable arm along the midline of the posterior aspect of the calcaneus in line with the mark on the heel pad posteriorly (Clarkson, 2000). Inversion and eversion with the hockey skate was done with the same procedure however the movable arm was modified to align with the center of the skate blade, as the mark on the heel pad was not visible.

FILMING TECHNIQUE

Filming of the participants for the pilot study took place on an Endless Ice skating treadmill located in Winnipeg, Manitoba at Custom Edge Skate Service. A five camera set-up approach was used to capture video in all three planes. Two Canon GL2 cameras were used to film the sagittal view. The right view camera was placed on a tripod 231cm from the skating zone. The left view camera was situated 175cm from the skating zone by securing it to the wall adjacent the treadmill. A Fujifilm EXR camera attached to a tripod was fixed to the wall in front of the skating treadmill at a distance of 240cm from the skating zone to capture data in the frontal plane.

A fourth camera was held by an assistant to capture movements in the frontal plane from the rear view. A final camera (Cannon HV10) was mounted to an air vent 276cm above the treadmill in order to capture data in the transverse plane. This overhead camera was connected to a Dell laptop by a fire wire cable to record live footage of the skill with the In the Action mode in Dartfish Team Pro version six.

Procedure

Participants were instructed to perform a dynamic warm-up consisting of approximately five minutes of aerobic activity and five minutes of total body calisthenics. Forward lunges, backward lunges, lateral lunges, high knees, butt kicks, quadriceps dynamic stretches, hamstring touches, lateral side shuffles, grapevine, and short bouts of forward sprints were conducted in order to allow the participants an adequate warm-up. At this time participants were harnessed to the ceiling track for safety and given a fifteen-minute familiarization period where they became accustomed to skating on the treadmill with their own skates. This familiarization period was instructed by Custom Edge Skate Services and included forward skating, outside and inside edge control drills while on both skates, one leg squats, and outside and inside edge control drills for both the right and left legs while on one skate.

Participants then skated at three different velocities (3.33 m/s (8mph), 5.00 m/s (11mph), 6.66m/s (14mph)) for thirty-seconds each with a two-minute rest break between trials. These speeds were based on self-selected treadmill skating speeds of elite hockey players, while the time-interval gives sufficient time to gather ≥ 20 consecutive strides at each speed (Chang et al., 2009). The participants then changed into the Easton Mako skates and completed a familiarization period. Once the familiarization period was completed the participants preformed the task once more while wearing the Easton Mako skates.

Video Data Analysis

Video was transferred to a Dell latitude E6520 laptop where video analysis was completed using Dartfish Team pro version six to collect quantitative data. Although the primary purpose of the study was to compare the differences in ankle range of motion between the two different skate designs a number of additional variables were measured. These additional variables were used to help the primary researcher in understanding the implications this new skate design has on hockey skating technique.

Measurement of Skating Variables

The measurement of joint angles was conducted using the angle tool in analyzer mode of Dartfish team pro version six. All variables were measured from anatomical position. Anatomical position of zero degrees is known as the position when the body is erect, arms are down at the sides, and the palms face forward (Baechle et al., 2008). There were two positions of interest for this study when calculating variables related to the position of the push off leg in skating, weight acceptance and propulsion. Weight acceptance was considered the position when the heel of the skate blade comes in contact with the skating treadmill. Propulsion was considered the position when the toe of the skate blade is last seen in contact with the skating treadmill before takeoff.

Ankle dorsiflexion, knee flexion, hip flexion, hip adduction, hip abduction, and trunk flexion were measured at weight acceptance. Ankle plantar-flexion, knee flexion, hip flexion, hip abduction, and trunk flexion were measured at propulsion. Each variable was calculated for each of the participants during ten strides at each of the three speeds while wearing both skate designs. For the purposes of this study a stride was defined as the time from weight acceptance to propulsion.

Results

Multiple variables were calculated for both participants while wearing their own traditional hockey skate and the Easton Mako skate ("Easton hockey," n.d.). Upon completion of quantifying variables from the video recorded in Dartfish teampro version six software variables were compared using a paired t-test with SPSS 20 statistical software for Mac operating system ("IBM SPSS software," 2013). Statistical significance was set at $P<0.05$. Several differences were found when comparing the participants forward skating kinematics during the propulsion phase of the hockey stride while wearing their own personal skates and the Easton Mako skates.

Ankle range of motion was significantly larger for both participants while wearing the Easton Mako skate at 11mph and 14mph. Subject one had a mean taken from 10 separate strides of 57.27 degrees of ankle plantarflexion at 11mph while wearing the Easton Mako skate and a mean of 47.47 degrees while wearing the traditional skate. Subject two had a mean of 68.23 degrees of plantarflexion while wearing the Easton Mako skate and 45.86 degrees while wearing the traditional skate. At 14mph subject one produced a mean ankle extension of 61.67 degrees of plantarflexion while wearing the Easton Mako skate and a mean of 36.28 degrees of plantarflexion while wearing the traditional skate. Subject two skated with means of 73.33 degrees of ankle plantarflexion and 37.41 degrees of ankle plantarflexion while wearing the Easton Mako skate and traditional skate respectively.

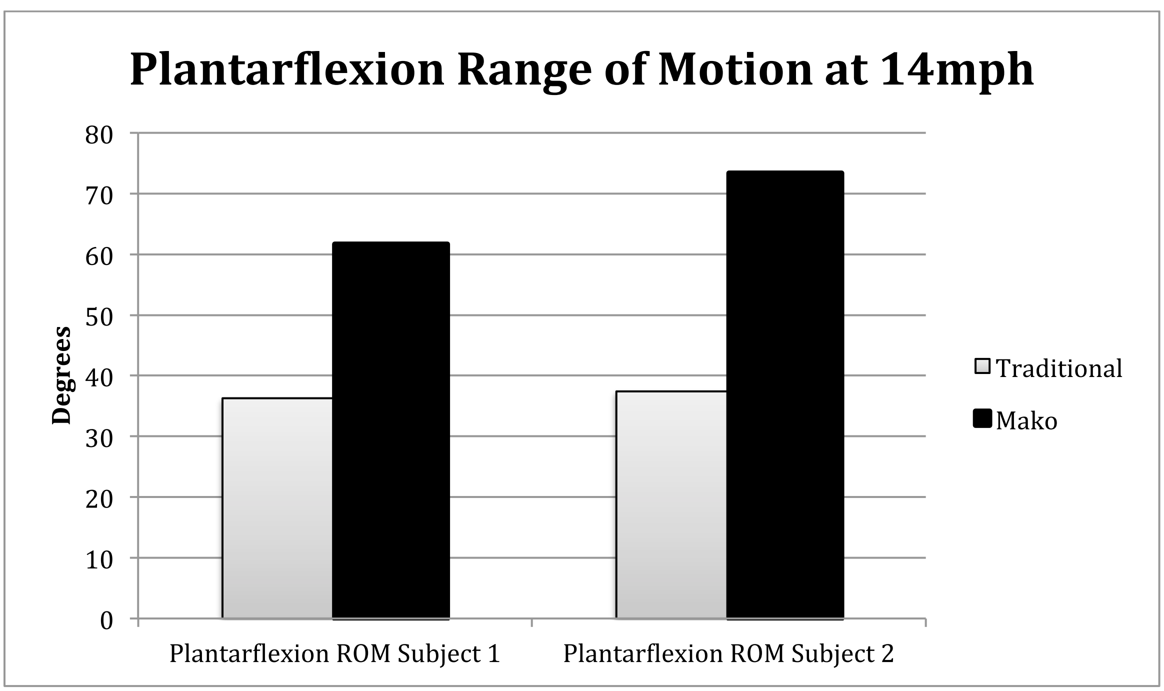


Figure 34. Comparison of plantarflexion range of motion at 14mph between skate designs.

Ankle plantarflexion angular velocity was also significantly greater for both participants while wearing the Easton Mako skate at 11mph and 14mph. Ankle plantarflexion angular velocity for subject one at 11mph skated with mean of 87.97 degrees/s while wearing the Easton Mako skate and mean of 67.03 degrees/s while wearing the traditional skate. Subject two skated at 11 mph with mean values of 86.27 degrees/s and 58.53 degrees/s for the Easton Mako skate and traditional skate respectively. At 14 mph subject one had a mean ankle plantarflexion angular velocity of 95.5 degrees/s while wearing the Easton Mako skate and a mean of 56.74 degrees/s while wearing the traditional skate. Subject two had a mean ankle plantarflexion angular velocity of 107.34 degrees/s while wearing the Easton Mako skate and a mean of 54.61 degrees/s while wearing the traditional skate at 14mph.

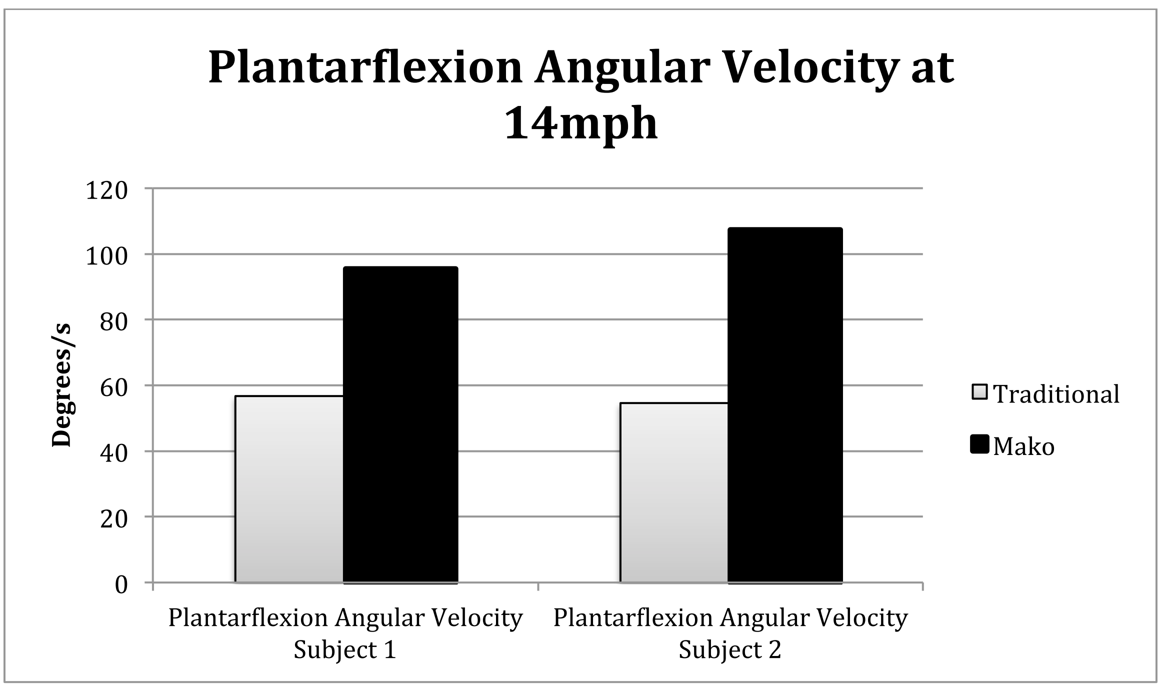


Figure 35. Comparison of plantarflexion angular velocity at 14mph between skate designs.

Knee extension range of motion was significantly larger for both participants when wearing the traditional skate design at 8mph. Subject one skated with a mean of 23.57 degrees while wearing the traditional skate and 19.44 degrees while wearing the Easton Mako skate. Subject two skated with a mean of 35.44 degrees for the knee extension while wearing the traditional skate and 29.88 degrees while wearing the Easton Mako skate. At 11mph knee extension range of motion was significantly larger for subject two while wearing the Easton Mako skate (44.31 degrees) when compared to the traditional skate (32.21 degrees). At 14mph it was significantly larger for both participants while wearing the Easton Mako skate showing means of 30.68 degrees for subject one and 43.21 degrees for subject two.

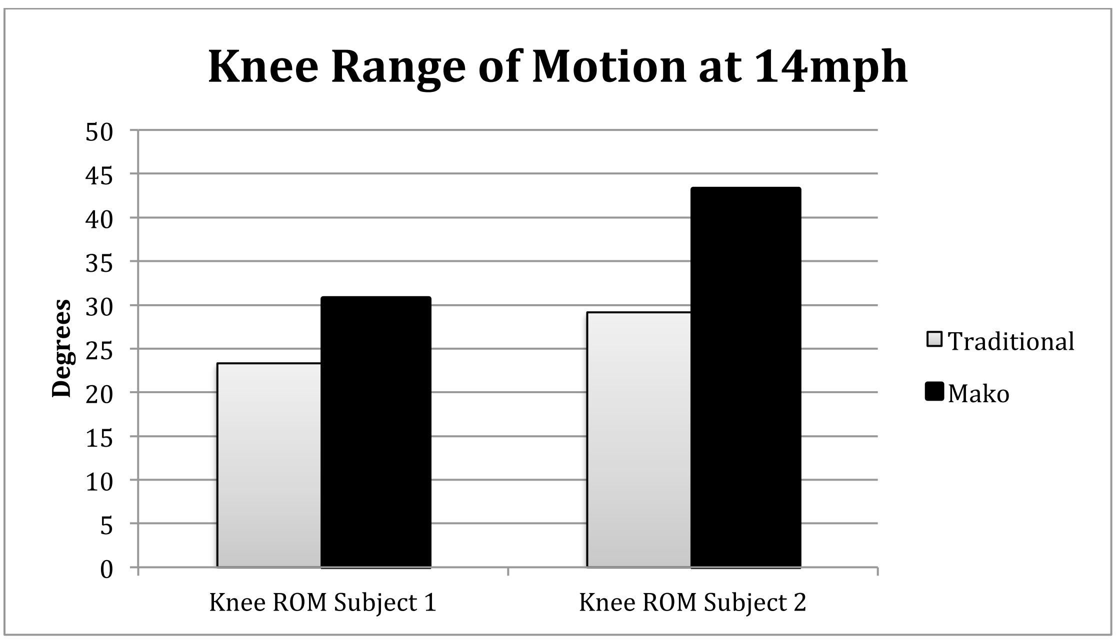


Figure 36. Comparison of knee range of motion at 14mph between skate designs.

Both participants had significantly larger knee extension angular velocity while wearing the traditional skate at 8mph. Subject one showed a mean value of

30.22 degrees/s while wearing the traditional skate and a mean value of 19.44 degrees/s while wearing the Easton Mako skate. Subject two had mean values of 38.38 degrees/s while wearing the traditional skate design and 34.64 degrees/s while wearing the Easton Mako skate. At 11mph knee extension angular velocity was significantly larger for subject one while wearing the Easton Mako skate producing a mean value 45.72 degrees/s compared to 35.10 degrees/s in the traditional skate. At 14mph knee extension angular velocity was significantly larger while skating in the Easton Mako skate for subject one with a mean of 47.67 degrees/s and for subject two with a mean of 63.36 degrees/s.

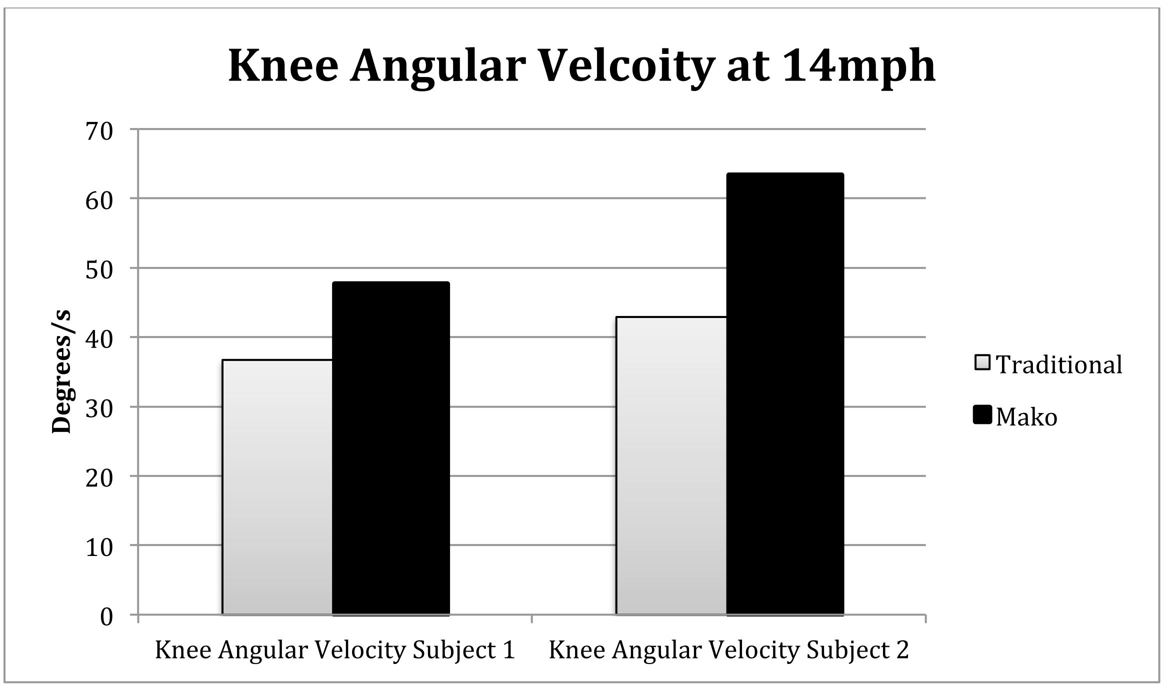


Figure 37. Comparison of knee angular velocity at 14mph between skate designs.

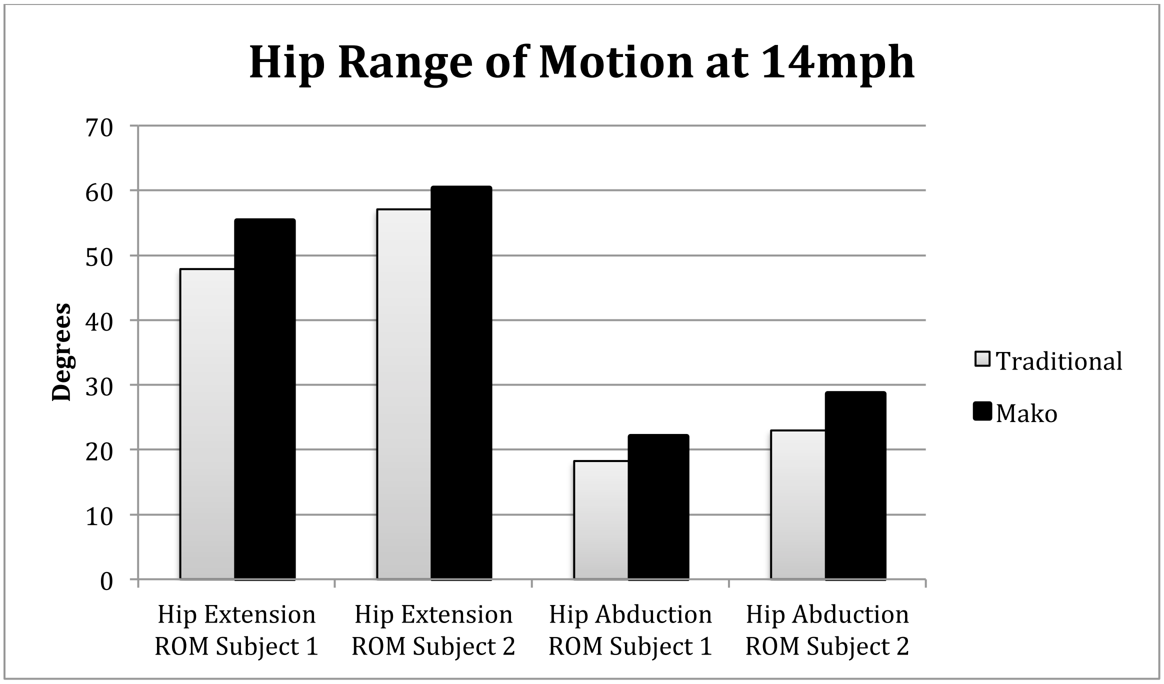


Figure 38. Comparison of hip range of motion at 14mph between skate designs.

Hip extension range of motion was significantly larger for subject two at 8mph while wearing the traditional skate. Hip extension range of motion was also significantly larger for subject one while wearing the Easton Mako skate at 14mph with a mean of 55.26 degrees. Hip extension angular velocity was significantly larger in both participants at 8mph while wearing the traditional skate. Subject one skated with a mean value of 71.03 degrees/s while wearing the traditional skate and 59.17 degrees/s with the Easton Mako skate. Subject two skated with mean values of 65.58 degrees/s and 51.10 degrees/s for the traditional and Easton Mako skates respectively.

Hip extension angular velocity was significantly larger for subject one while wearing the Easton Mako skate at both 11mph and 14mph. At 11mph hip extension angular velocity had mean values for the Easton Mako skate and traditional skate of

79.95 degrees/s and 68.12 degrees/s respectively, while at 14mph means were 85.58 degrees/ s in the Easton Mako skate and 74.91 degrees/s in the traditional skate.

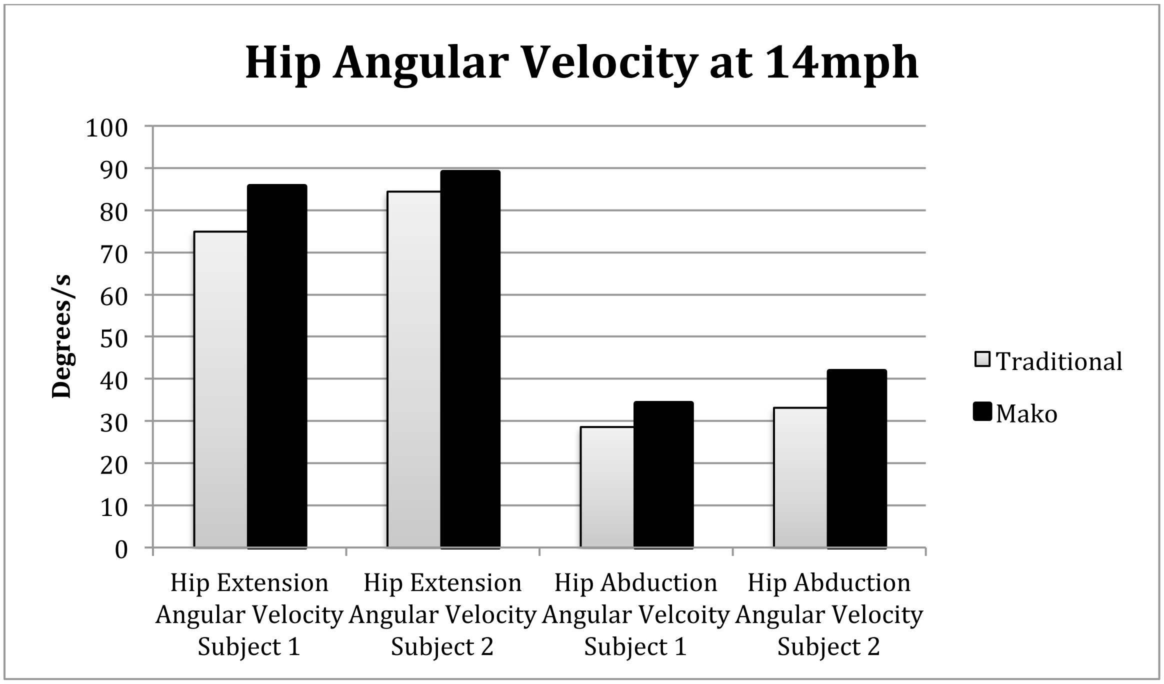


Figure 39. Comparison of hip angular velocity at 14mph between skate designs.

Hip abduction range of motion was significantly larger for subject two at 8mph while wearing the Easton Mako skate showing a mean of 18.97 degrees compared to the traditional skate showing a mean of 9.97 degrees. It was also significantly larger for subject two while wearing the Easton Mako skate at 14mph with a mean value of 28.67 degrees. Hip abduction angular velocity was only significantly larger for subject two with the Easton Mako skate at 14mph showing a mean value of 41.70 degrees/s.

Stride length was significantly larger for the Easton Mako skate (0.74m) at 8mph when compared to the traditional skate (0.64m) for subject one, and for both participants at 14mph. Subject one skated with mean values of stride length at 14mph of 0.86m for the Easton Mako skate and 0.68m for the traditional skate. Subject two skated with mean values of 1.04m while wearing the Easton Mako skate and 0.79m while wearing the traditional skate.

Stride velocity was significantly larger for subject one at all three speeds while wearing the Easton Mako skate producing mean values of 0.92m/s at 8mph, 1.25m/s at 11mph, and 1.34m/s at 14mph. It was also significantly larger for subject two while wearing the Easton Mako skate at 8mph with a mean of 0.93m/s and at 14mph. Blade time on the ice during a stride was significantly larger for the traditional skate with subject two at 8mph (0.93s) and with subject one at 11mph (0.71s).

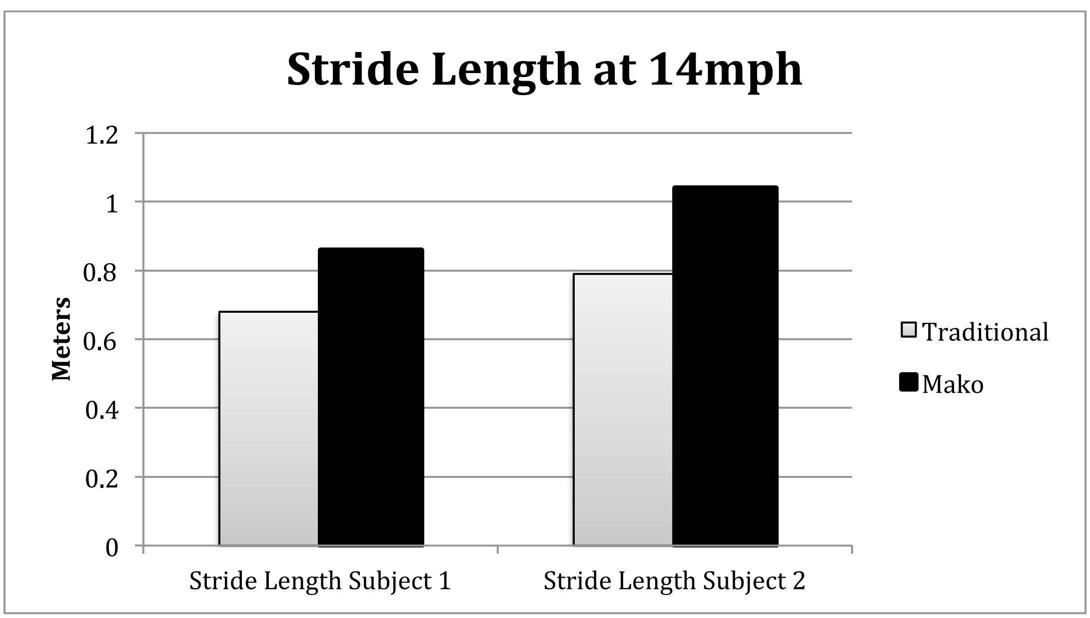


Figure 40. Comparison of stride length at 14mph between skate designs.

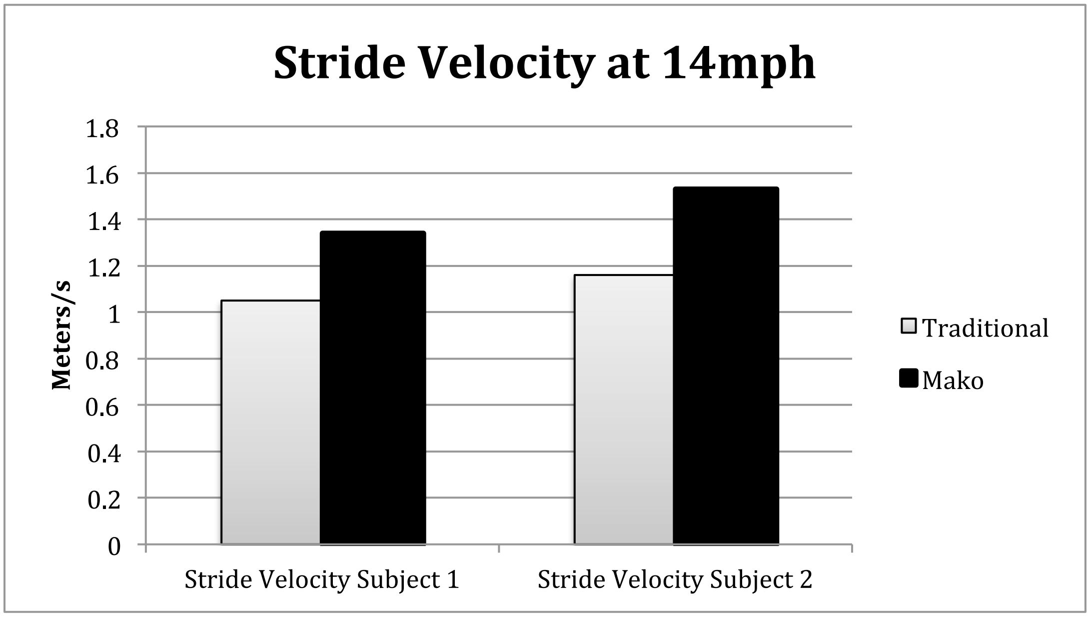


Figure 41. Comparison of stride velocity at 14mph between skate designs.

DISCUSSION

This study was designed to investigate the kinematic differences in ankle plantarflexion range of motion between two different skate designs. The results of this study supported the hypothesis that there is a difference in ankle plantarflexion range of motion while wearing the traditional ice hockey skate design and the Easton Mako skate design with the Easton Mako skate showing greater ankle plantarflexion range of motion and ankle plantarflexion angular velocity. This is a very important performance characteristic in forward skating during hockey.

Robert-Lachaine et al., (2012) discovered that a modified skate with a flexible tendon guard similar to the Easton Mako skate demonstrated significant gains in plantarflexion and net plantarflexion range of motion. These authors also concluded that “total peak force occurred later during plantarflexion which suggested the increased range of motion resulted in a more prolonged effective force generation during a given skating stride” (pg. 205). Authors Luhtanen & Komi, (1978) found the plantarflexors of the ankle to be important contributors in vertical jumping. They found the plantarflexors contribute 22% of the vertical height jump of their participants. This suggests that as the ankles are concentrically extended during the forward hockey stride the plantarflexors play an important role in producing force. Hockey players should be using equipment that will allow them to use this muscle group to its maximal capability.

The results of this study also support the secondary hypotheses that there is a difference in knee joint and hip joint kinematics, as well as a difference in stride length for participants wearing the two separate skate designs. Both participants significantly increased ankle plantarflexion range of motion and ankle plantarflexion angular velocity while wearing the Easton Mako skate, which has the new flexible tendon guard. As stated previously this added range of motion at the ankle joint has implications affecting many other kinematics of the lower body that in turn have the potential to increase a hockey player’s skating ability. Recent literature has concluded that the range of motion occurring at the ankle joint during athletic movements affects the kinematics of the knee joint.

When comparing push-offs in speed skating between conventional speed skates and klapskates authors (H. Houdijk et al., 2000) concluded that klapskates, which increased the range of motion at the ankle, increased the work output at the knee joint. Another study investigating the effects ankle range of motion has on the vertical jump during figure skating by (Haguenauer et al., 2006) concluded that the stiff design of the figure skating boot decreased performance by limiting plantarflexion, decreasing work at the ankle joint, and decreasing knee angular velocity. According to Haguenauer et al., (2006) this was done by restricting movement at the ankle joint causing a “redistribution of the energy produced by the knee extensors to the hip and ankle joints” (p. 706).

The findings of the current study agree with these previous studies in that increasing the ankle range of motion during the forward skating stride, by wearing a new skate design with a flexible rear tendon guard, increased the range of motion occurring at the knee joint. The results from this study also suggested increasing ankle range of motion also increased the range of motion of the hip joint. Increasing the range of motion at all three lower body joints has positive implications on the performance of a hockey skater’s forward skating. As mentioned earlier the power generated during propulsion of the hockey stride comes from a sequential extension of the hip, knee, and ankle. This extension of the lower body joints should reach full extension to enable a player to push against the ice as long as possible (Alexander, 2007).

The participants in this study wearing Easton Mako skates increased the range of motion at all three lower body joints travelled during force production. This enabled them to increase stride length while in the force production phase of the hockey stride. The increases in joint range of motion and stride length suggest that by increasing ankle range of motion both participants were able to increase the impulse produced while forward skating. Angular velocities at the ankle, knee, and hip were also significantly larger for both participants while skating at 14mph with the new Easton Mako skate. The increase in angular velocity of the joints in the lower body and the increase of the impulse produced by both participants show the potential this new skate design has on increasing skating performance in the hockey forward skating stride.

CONCLUSION

This study investigated the kinematic differences in ankle dorsi-plantar flexion range of motion and angular velocity during the forward hockey skating stride between a traditional hockey skate design and the Easton Mako hockey skate. Eight test variables displayed significant increases in performance while participants were wearing the Easton Mako skate when compared to wearing a traditional skate. It is evident that this new hockey skate design with a flexible tendon guard is effective in improving forward skating performance in hockey skaters.

APPENDIX F
Participant Characteristics

Descriptive characteristics of participants.

Participant	Age	Height (m)	Weight (kg)	Hockey Experience (Years)	Current Skate Brand
1	23	1.75	79.38	17	Reebok
2	27	1.90	102.06	19	Bauer
3	25	1.73	68.04	18	Bauer
4	30	1.83	86.18	22	Bauer
5	25	1.88	88.45	20	Bauer
6	26	1.78	76.20	20	Bauer
7	20	1.83	89.81	16	Bauer
8	20	1.68	70.31	16	Bauer
Mean	24.50	1.80	82.55	18.5	
SD	3.42	0.08	11.29	2.14	
Range	20 - 30	1.68 – 1.90	68.04- 102.06	16.00-22.00	

APPENDIX G
Flexibility Raw Data

Pre-Procedure Range of Motion

		No Skate				Traditional				Easton Mako			
Participant	ROM	DF	PF	EV	IN	DF	PF	EV	IN	DF	PF	EV	IN
1	Passive	23.5	28.3	13.2	18.8	25.1	11.7	8.3	16.5	12.7	20.5	9.6	16.5
	Active	29.7	31.4	13.1	12.7	22.3	12.1	6.0	10.7	17.9	20.1	4.7	16.4
2	Passive	20.8	39.9	8.9	10.9	17.2	9.7	10.0	17.0	17.6	17.5	8.9	9.5
	Active	14.0	30.4	8.7	8.6	17.5	8.7	2.6	11.6	20.0	14.7	7.6	7.0
3	Passive	25.6	24.5	8.3	24.3	26.5	10.0	10.3	18.2	18.7	16.5	8.5	15.9
	Active	18.6	22.3	8.1	12.3	24.3	11.8	4.8	13.2	18.8	25.4	7.3	12.8
4	Passive	15.0	29.6	8.4	33.3	19.9	10.6	13.5	22.9	20.2	18.6	9.8	22.3
	Active	13.8	29.9	7.6	15.6	21.3	10.9	9.7	13.4	20.8	18.8	13.6	18.1
5	Passive	25.8	29.1	10.3	18.1	14.1	13.1	13.3	20.1	16.6	19.0	22.1	13.8
	Active	24.0	29.4	11.6	17.0	18.6	11.2	7.5	12.8	21.7	15.8	16.4	10.9
6	Passive	27.8	27.6	15.8	32.5	23.1	16.8	16.4	24.4	20.0	20.1	9.9	26.8
	Active	28.4	28.0	19.4	20.1	20.0	18.8	4.0	12.4	22.4	21.6	5.4	9.0
7	Passive	17.8	46.6	11.7	22.9	22.4	9.0	9.7	22.2	17.1	18.1	9.9	12.5
	Active	21.0	42.9	9.2	20.9	17.2	10.7	4.9	11.6	19.6	16.0	6.3	11.1
8	Passive	16.7	29.0	10.0	31.1	20.6	22.8	12.8	17.5	19.8	20.6	12.9	16.6
	Active	14.1	32.0	7.6	27.5	20.6	19.4	4.8	15.9	16.3	18.30	6.0	11.8

Appendix H
Skating Treadmill Raw Data

Subject One Kinematics (8mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	11.000	16.300	11.300	18.000	10.500	16.600	11.900	14.700	11.200	15.800	16.600	19.000	11.200	16.500	10.800	11.800	9.300	14.000	12.900	17.600	10.570	14.400
(D/P)	Propulsion	9.100	7.600	1.100	7.500	1.500	4.400	1.500	4.300	1.900	2.200	3.000	5.600	1.900	4.200	0.300	4.300	2.700	5.300	0.400	5.600	1.430	4.340
Ankle ROM		20.100	23.900	12.400	25.500	12.000	21.000	13.400	19.000	13.100	18.000	19.600	24.600	13.100	20.700	11.100	16.100	12.000	19.300	13.300	23.200	12.000	18.740
Ankle Angular Velocity	(Deg/s)	24.393	31.824	17.689	32.526	14.981	26.250	18.663	23.750	17.080	24.000	26.703	34.262	16.034	27.563	12.788	21.467	15.979	26.294	17.710	30.248	15.763	24.636
Knee Flexion	Weight Acceptance	70.300	73.900	72.000	73.200	70.300	71.000	70.500	71.500	68.600	72.700	68.500	72.200	69.800	70.100	68.000	71.900	69.400	68.700	70.700	72.600	62.780	64.390
	Propulsion	19.400	33.700	27.600	47.900	29.700	40.000	26.100	39.800	26.100	36.000	30.300	36.700	27.800	37.800	29.600	37.200	29.800	32.300	30.200	31.300	25.720	33.900
Knee Extension (ROM)		50.900	40.200	44.400	25.300	40.600	31.000	44.400	31.700	42.500	36.700	38.200	35.500	42.000	32.300	38.400	34.700	39.600	36.400	40.500	41.300	37.060	30.490
Knee Angular Velocity	(Deg/s)	61.772	53.529	63.338	32.270	50.687	38.750	61.838	39.625	55.411	48.933	52.044	49.443	51.408	43.009	44.240	46.267	52.730	49.591	53.928	53.846	48.562	40.174
Hip Flexion	Weight Acceptance	72.800	79.300	78.800	79.200	75.100	73.600	79.300	72.500	75.400	73.600	74.300	71.500	73.400	76.000	70.700	72.800	76.900	72.500	76.400	73.800	68.030	66.550
	Propulsion	26.600	24.700	26.100	27.500	25.700	24.000	30.400	21.200	27.000	25.100	29.800	20.100	32.000	27.100	28.000	20.600	34.400	21.400	35.300	22.400	26.870	20.940
Hip Extension ROM		46.200	54.600	52.700	51.700	49.400	49.600	48.900	51.300	48.400	48.500	44.500	51.400	41.400	48.900	42.700	52.200	42.500	51.100	41.100	51.400	41.160	45.610
Hip Angular Velocity	(Deg/s)	56.068	72.703	75.178	65.944	61.673	62.000	68.106	64.125	63.103	64.667	60.627	71.588	50.673	65.113	49.194	69.600	56.591	69.619	54.727	67.014	53.987	59.967
Hip Abduction/Adduction	Weight Acceptance	-1.000	-4.800	-0.900	-1.800	-2.100	-1.800	-0.700	-2.000	-0.800	-5.200	-0.600	-2.000	-4.100	-0.900	-3.200	-0.800	-2.700	-0.900	-2.800	0.700	-1.790	-1.470
(Abd/Add)	Propulsion	30.800	29.000	31.800	28.600	32.200	33.100	33.000	34.100	33.100	26.400	28.800	28.800	30.000	32.600	30.800	30.400	26.800	30.500	29.800	31.800	27.630	27.630
Hip Abduction ROM		31.800	33.800	32.700	30.400	34.300	34.900	33.700	36.100	33.900	31.600	29.400	30.800	34.100	33.500	34.000	31.200	29.500	31.400	32.600	31.100	29.420	29.100
Hip Angular Velocity	(Deg/s)	38.592	45.007	46.648	38.776	42.821	43.625	46.936	45.125	44.198	42.133	40.054	42.897	41.738	44.607	39.171	41.600	39.281	42.779	43.409	40.548	38.426	38.209
Stride Length	Sagittal (m)	0.820	0.940	0.720	0.920	0.690	0.860	0.610	0.900	0.870	0.950	0.590	0.880	0.780	0.850	0.830	0.900	0.760	0.850	0.780	0.880	0.663	0.799
	Frontal (m)	0.540	0.650	0.580	0.580	0.600	0.620	0.560	0.550	0.510	0.620	0.630	0.540	0.530	0.530	0.540	0.570	0.530	0.540	0.540	0.560	0.502	0.511
	Total (m)	0.982	1.143	0.925	1.088	0.914	1.060	0.828	1.055	1.008	1.134	0.863	1.032	0.943	1.002	0.990	1.065	0.927	1.007	0.949	1.043	0.835	0.949
Stride Velocity	(m/s)	1.192	1.522	1.319	1.387	1.142	1.325	1.153	1.318	1.315	1.513	1.176	1.438	1.154	1.334	1.141	1.420	1.234	1.372	1.263	1.360	1.090	1.247
Blade Time on Ice (s)	Weight Acceptance	4.704	1.718	6.139	3.069	7.440	4.371	8.858	5.739	10.143	7.157	11.478	8.491	12.746	9.809	14.147	11.161	15.615	12.479	16.983	13.780	10.355	7.606
	Propulsion	5.528	2.469	6.840	3.853	8.241	5.171	9.576	6.539	10.910	7.907	12.212	9.209	13.563	10.560	15.015	11.911	16.366	13.213	17.734	14.547	11.046	8.291
	Total	0.824	0.751	0.701	0.784	0.801	0.800	0.718	0.800	0.767	0.750	0.734	0.718	0.817	0.751	0.868	0.750	0.751	0.734	0.751	0.767	0.691	0.685

Subject One Kinematics (11mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	15.000	14.400	10.100	14.100	9.100	18.200	20.800	17.300	17.200	16.500	15.500	20.500	14.600	23.300	12.000	20.100	15.600	18.700	20.400	18.000	15.030	18.110
(D/P)	Propulsion	2.400	2.500	4.100	10.300	2.100	8.700	4.100	12.000	6.400	8.100	0.700	5.500	3.600	3.900	4.600	3.600	8.100	2.100	4.700	7.000	4.080	6.370
Ankle ROM		17.400	16.900	14.200	24.400	11.200	26.900	24.900	29.300	23.600	24.600	16.200	26.000	18.200	27.200	16.600	23.700	23.700	20.800	25.100	25.000	19.110	24.480
Ankle Angular Velocity		30.634	22.034	19.320	36.527	14.286	44.759	34.728	45.008	30.102	35.965	20.225	38.922	24.234	40.780	20.724	33.054	31.558	32.808	31.336	37.425	25.715	36.728
Knee Flexion	Weight Acceptance	77.800	74.500	77.300	75.200	62.100	74.000	79.700	73.300	76.700	74.200	73.600	75.100	77.800	76.300	74.200	72.200	75.100	74.700	74.800	74.300	74.910	74.380
	Propulsion	34.400	21.900	25.100	28.300	26.700	27.400	31.700	23.700	30.100	20.100	27.600	21.600	27.700	27.300	30.900	26.700	26.600	25.400	25.500	26.800	28.630	24.920
Knee Extension (ROM)		43.400	52.600	52.200	46.900	35.400	46.600	48.000	49.600	46.600	54.100	46.000	53.500	50.100	49.000	43.300	45.500	48.500	49.300	49.300	47.500	46.280	49.460
Knee Angular Velocity	(Deg/s)	76.408	68.579	71.020	70.210	45.153	77.537	66.946	76.190	59.439	79.094	57.428	80.090	66.711	73.463	54.057	63.459	64.581	77.760	61.548	71.108	62.329	73.749
Hip Flexion	Weight Acceptance	79.500	74.300	78.700	70.700	74.500	74.300	79.300	74.900	82.400	78.000	84.000	73.100	80.100	67.500	86.200	75.000	80.900	74.300	75.200	74.300	80.080	73.640
	Propulsion	32.000	28.800	44.900	19.800	31.400	28.000	33.800	28.300	42.800	28.800	33.000	27.800	35.400	26.800	37.300	29.400	28.400	18.500	36.200	27.600	35.520	26.380
Hip Extension ROM		47.500	45.500	33.800	50.900	43.100	46.300	45.500	46.600	39.600	49.200	51.000	45.300	44.700	40.700	48.900	45.600	52.500	55.800	39.000	46.700	44.560	47.260
Hip Angular Velocity	(Deg/s)	83.627	59.322	45.986	76.198	54.974	77.038	63.459	71.582	50.510	71.930	63.670	67.814	59.521	61.019	61.049	63.598	69.907	88.013	48.689	69.910	60.139	70.642
Hip Abduction/Adduction	Weight Acceptance	-0.800	-0.900	-3.300	2.800	-4.900	-0.900	-6.900	-0.800	-4.900	-0.500	-2.300	-0.500	-2.800	-2.000	-2.100	-2.400	-5.300	-1.000	-4.200	-4.600	-3.750	-1.080
(Abd/Add)	Propulsion	26.300	26.100	30.600	31.000	31.000	31.600	33.800	30.000	31.000	30.300	31.600	31.900	32.400	28.900	33.500	27.200	33.300	28.200	32.700	30.400	31.620	29.560
Hip Abduction ROM		27.100	27.000	33.900	28.200	35.900	32.500	40.700	30.800	35.900	30.800	33.900	32.400	35.200	30.900	35.600	29.600	38.600	29.200	36.900	35.000	35.370	30.640
Hip Angular Velocity	(Deg/s)	47.711	35.202	46.122	42.216	45.791	54.077	56.764	47.312	45.791	45.029	42.322	48.503	46.871	46.327	44.444	41.283	51.398	46.057	46.067	52.395	47.328	45.840
																						0	0
Stride Length	Sagittal (m)	0.930	0.910	0.850	0.770	0.700	0.740	0.800	0.750	0.810	0.700	0.750	0.920	0.730	0.870	0.720	0.860	0.670	0.950	0.860	0.810	0.782	0.828
	Frontal (m)	0.580	0.690	0.670	0.630	0.710	0.650	0.670	0.650	0.670	0.660	0.670	0.580	0.640	0.600	0.760	0.630	0.620	0.610	0.670	0.620	0.666	0.632
	Total (m)	1.096	1.142	1.082	0.995	0.997	0.985	1.044	0.992	1.051	0.962	1.006	1.088	0.971	1.057	1.047	1.066	0.913	1.129	1.090	1.020	1.030	1.044
Stride Velocity	(m/s)	1.930	1.489	1.473	1.489	1.272	1.639	1.455	1.525	1.341	1.407	1.256	1.628	1.293	1.584	1.307	1.487	1.216	1.781	1.361	1.527	1.390	1.556
																						0	0
Blade Time on Ice (s)	Weight Acceptance	5.638	2.869	6.639	4.170	7.974	5.338	9.309	6.439	10.577	7.607	11.978	8.808	13.413	10.043	14.764	11.211	16.199	12.479	17.517	13.646	11.401	8.261
	Propulsion	6.206	3.636	7.374	4.838	8.758	5.939	10.026	7.090	11.361	8.291	12.779	9.476	14.164	10.710	15.565	11.928	16.950	13.113	18.318	14.314	12.150	8.934
	Total	0.568	0.767	0.735	0.668	0.784	0.601	0.717	0.651	0.784	0.684	0.801	0.668	0.751	0.667	0.801	0.717	0.751	0.634	0.801	0.668	0.749	0.673

Subject One Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	16.600	20.300	17.900	21.000	17.900	17.800	16.200	17.100	16.600	16.000	17.800	20.000	16.500	21.800	15.000	19.300	20.100	17.600	20.600	19.800	17.520	19.070
(D/P)	Propulsion	6.100	8.300	6.200	6.200	2.800	4.800	3.600	6.900	2.500	8.200	0.500	9.700	2.000	3.800	6.300	10.900	5.200	9.100	0.200	6.700	3.540	7.460
Ankle ROM		22.700	28.600	24.100	27.200	20.700	22.600	19.800	24.000	19.100	24.200	18.300	29.700	18.500	25.600	21.300	30.200	25.300	26.700	20.800	26.500	21.060	26.530
Ankle Angular Velocity	Deg/s	32.062	47.667	40.100	47.972	32.650	38.699	28.947	38.898	30.126	35.380	31.336	50.943	29.984	42.596	32.719	48.867	39.905	43.274	32.000	42.950	32.983	43.725
Knee Flexion	Weight Acceptance	76.400	75.600	77.800	75.300	75.700	77.300	74.800	75.200	76.700	73.200	75.600	70.600	74.300	75.200	74.900	75.900	75.300	72.600	76.500	73.500	75.800	74.440
	Propulsion	21.800	29.400	27.000	34.200	24.800	30.700	33.100	32.000	26.900	29.300	29.000	28.400	31.800	28.700	26.000	28.100	19.200	31.900	22.400	29.000	26.200	30.170
Knee Extension (ROM)		54.600	46.200	50.800	41.100	50.900	46.600	41.700	43.200	49.800	43.900	46.600	42.200	42.500	46.500	48.900	47.800	56.100	40.700	54.100	44.500	49.600	44.270
Knee Angular Velocity	(Deg/s)	77.119	77.000	84.526	72.487	80.284	79.795	60.965	70.016	78.549	64.181	79.795	72.384	68.882	77.371	75.115	77.346	88.486	65.964	83.231	72.123	77.695	72.867
Hip Flexion	Weight Acceptance	80.000	79.100	76.500	76.400	81.500	78.600	84.300	68.100	77.400	69.700	79.000	70.300	86.300	77.800	78.600	78.200	75.100	70.600	75.400	75.200	79.410	74.400
	Propulsion	39.100	32.700	34.100	26.100	35.900	30.100	38.200	30.100	39.400	35.100	32.200	34.200	34.900	24.800	36.500	28.400	39.000	31.200	35.100	31.800	36.440	30.450
Hip Extension ROM		40.900	46.400	42.400	50.300	45.600	48.500	46.100	38.000	38.000	34.600	46.800	36.100	51.400	53.000	42.100	49.800	36.100	39.400	40.300	43.400	42.970	43.950
Hip Angular Velocity	(Deg/s)	57.768	77.333	70.549	88.713	71.924	83.048	67.398	61.588	59.937	50.585	80.137	61.921	83.306	88.186	64.670	80.583	56.940	63.857	62.000	70.340	67.463	72.615
Hip Abduction/Adduction	Weight Acceptance	-6.100	-0.800	-1.700	-0.400	-4.200	-2.500	3.300	-3.300	-0.600	-0.400	-3.400	-1.800	-3.600	-1.700	-4.600	-1.100	-3.300	1.300	-4.800	-2.600	-2.900	-1.330
(Abd/Add)	Propulsion	31.100	31.200	32.600	30.400	30.700	30.400	30.100	29.400	29.600	29.700	27.000	32.600	30.100	35.000	33.800	31.500	33.300	34.000	29.100	33.000	30.740	31.720
Hip Abduction ROM		37.200	32.000	34.300	30.800	34.900	32.900	26.800	32.700	30.200	30.100	30.400	34.400	33.700	36.700	38.400	32.600	36.600	32.700	33.900	35.600	33.640	33.050
Hip Angular Velocity	(Deg/s)	52.542	53.333	57.072	54.321	55.047	56.336	39.181	52.998	47.634	44.006	52.055	59.005	54.619	61.065	58.986	52.751	57.729	52.998	52.154	57.699	52.702	54.451
Stride Length	Sagittal (m)	0.670	0.930	0.920	0.890	0.910	0.810	0.850	0.900	0.770	0.950	0.890	0.940	0.720	0.780	0.650	0.870	0.720	0.930	0.770	0.890	0.787	0.889
	Frontal (m)	0.650	0.550	0.590	0.670	0.680	0.710	0.590	0.640	0.540	0.600	0.600	0.580	0.700	0.670	0.630	0.600	0.650	0.650	0.550	0.660	0.618	0.633
	Total (m)	0.933	1.080	1.093	1.114	1.136	1.077	1.035	1.104	0.940	1.124	1.073	1.105	1.004	1.028	0.905	1.057	0.970	1.135	0.946	1.108	1.004	1.093
Stride Velocity	(m/s)	1.318	1.801	1.819	1.965	1.792	1.844	1.513	1.790	1.483	1.643	1.838	1.895	1.628	1.711	1.390	1.710	1.530	1.839	1.456	1.796	1.577	1.799
Blade Time on Ice (s)	Weight Acceptance	4.647	4.888	5.972	5.972	7.107	7.023	8.258	8.108	9.442	9.209	10.610	10.377	11.695	11.444	12.862	12.545	14.097	13.663	15.265	14.781	9.996	9.801
	Propulsion	5.355	5.488	6.573	6.539	7.741	7.607	8.942	8.725	10.076	9.893	11.194	10.960	12.312	12.045	13.513	13.163	14.731	14.280	15.915	15.398	10.635	10.410
	Total	0.708	0.600	0.601	0.567	0.634	0.584	0.684	0.617	0.634	0.684	0.584	0.583	0.617	0.601	0.651	0.618	0.634	0.617	0.650	0.617	0.640	0.609

Subject One Kinematics (15mph)

Variable	Stride Number	1 Own	1 Mako	2 Own	2 Mako	3 Own	3 Mako	4 Own	4 Mako	5 Own	5 Mako	6 Own	6 Mako	7 Own	7 Mako	8 Own	8 Mako	9 Own	9 Mako	10 Own	10 Mako	Average Own	Average Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	15.100	19.800	18.300	21.200	17.500	16.400	16.300	20.900	18.200	19.600	14.300	20.700	17.200	15.800	14.900	20.200	17.200	18.200	14.400	14.900	16.340	18.770
(D/P)	Propulsion	2.000	8.100	3.000	15.000	6.500	12.000	4.500	8.400	6.400	6.600	5.100	3.800	8.600	11.300	4.800	6.600	7.200	13.400	4.200	13.200	5.230	9.840
Ankle ROM		17.100	27.900	21.300	36.200	24.000	28.400	20.800	29.300	24.600	26.200	19.400	24.500	25.800	27.100	19.700	26.800	24.400	31.600	18.600	28.100	21.570	28.610
Ankle Angular Velocity	Deg/s	25.000	47.774	33.596	58.671	35.088	41.520	30.409	46.215	35.965	46.208	27.675	45.880	44.178	50.749	31.073	42.271	36.582	55.732	25.306	48.116	32.487	48.314
Knee Flexion	Weight Acceptance	74.300	77.000	75.900	78.300	73.600	78.100	77.300	74.600	77.700	74.500	70.600	76.100	79.800	72.900	72.200	76.000	72.800	74.400	74.500	71.300	74.870	75.320
	Propulsion	27.800	33.000	26.800	26.900	24.600	22.800	30.200	21.700	29.600	26.600	25.100	28.500	25.800	23.200	24.900	28.500	29.300	27.100	30.700	29.000	27.480	26.730
Knee Extension (ROM)		46.500	44.000	49.100	51.400	49.000	55.300	47.100	52.900	48.100	47.900	45.500	47.600	54.000	49.700	47.300	47.500	43.500	47.300	43.800	42.300	47.390	48.590
Knee Angular Velocity	(Deg/s)	67.982	75.342	77.445	83.306	71.637	80.848	68.860	83.438	70.322	84.480	64.907	89.139	92.466	93.071	74.606	74.921	65.217	83.422	59.592	72.432	71.303	82.040
Hip Flexion	Weight Acceptance	82.200	74.900	80.200	78.200	75.100	74.100	78.800	78.400	75.600	76.800	80.500	75.400	84.900	72.100	79.300	73.300	79.800	75.700	76.500	76.200	79.290	75.510
	Propulsion	29.400	29.300	32.200	30.400	33.700	30.600	35.700	31.800	45.300	24.600	29.400	23.900	32.100	31.500	31.900	27.200	39.400	24.400	38.400	27.900	34.750	28.160
Hip Extension ROM		52.800	45.600	48.000	47.800	41.400	43.500	43.100	46.600	30.300	52.200	51.100	51.500	52.800	40.600	47.400	46.100	40.400	51.300	38.100	48.300	44.540	47.350
Hip Angular Velocity	(Deg/s)	77.193	78.082	75.710	77.472	60.526	63.596	63.012	73.502	44.298	92.063	72.896	96.442	90.411	76.030	74.763	72.713	60.570	90.476	51.837	82.705	67.122	80.308
Hip Abduction/Adduction	Weight Acceptance	-1.400	-0.400	-2.500	-0.300	-2.500	-3.400	-1.600	-2.200	-3.000	-0.100	-5.900	-3.600	-6.100	-0.400	-5.100	-1.000	-8.600	-4.000	-5.200	-6.400	-4.190	-2.180
(Abd/Add)	Propulsion	32.700	27.800	35.800	36.700	35.100	34.800	35.300	34.200	30.500	31.600	34.300	28.700	33.200	30.900	34.900	31.600	34.800	31.500	31.900	34.600	33.850	32.240
Hip Abduction ROM		34.100	28.200	38.300	37.000	37.600	38.200	36.900	36.400	33.500	31.700	40.200	32.300	39.300	31.300	40.000	32.600	43.400	35.500	37.100	41.000	38.040	34.420
Hip Angular Velocity	(Deg/s)	49.854	48.288	60.410	59.968	54.971	55.848	53.947	57.413	48.977	55.908	57.347	60.487	67.295	58.614	63.091	51.420	65.067	62.610	50.476	70.205	57.143	58.076
Stride Length	Sagittal (m)	0.550	1.000	0.560	0.900	0.420	0.810	0.500	0.790	0.560	0.960	0.480	1.110	0.490	1.030	0.420	0.710	0.430	0.860	0.550	1.000	0.496	0.917
	Frontal (m)	0.690	0.670	0.690	0.640	0.710	0.820	0.690	0.860	0.660	0.740	0.690	0.610	0.720	0.650	0.740	0.760	0.780	0.710	0.720	0.750	0.709	0.721
	Total (m)	0.882	1.204	0.889	1.104	0.825	1.153	0.852	1.168	0.866	1.212	0.841	1.267	0.871	1.218	0.851	1.040	0.891	1.115	0.906	1.250	0.867	1.173
Stride Velocity	(m/s)	1.290	2.061	1.402	1.790	1.206	1.685	1.246	1.842	1.265	2.138	1.199	2.372	1.491	2.281	1.342	1.640	1.335	1.967	1.233	2.140	1.301	1.992
Blade Time on Ice (s)	Weight Acceptance	15.315	4.871	16.483	5.972	17.617	7.073	18.818	8.274	20.086	9.376	21.287	10.443	22.522	11.478	23.590	12.512	24.741	13.680	25.975	14.781	20.643	9.846
	Propulsion	15.999	5.455	17.117	6.589	18.301	7.757	19.502	8.908	20.770	9.943	21.988	10.977	23.106	12.012	24.224	13.146	25.408	14.247	26.710	15.365	21.313	10.440
	Total	0.684	0.584	0.634	0.617	0.684	0.684	0.684	0.634	0.684	0.567	0.701	0.534	0.584	0.534	0.634	0.634	0.667	0.567	0.735	0.584	0.669	0.594

Subject One Kinematics (18mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	21.000	13.700	20.700	17.500	12.400	20.800	18.000	15.600	15.000	14.900	17.200	15.300	18.800	14.500	13.200	15.800	16.600	13.600	14.300	12.500	16.720	15.420
(D/P)	Propulsion	6.500	9.000	5.700	7.000	11.200	15.800	2.100	4.500	7.000	10.200	2.500	13.600	2.700	12.500	9.100	6.800	5.900	9.300	9.000	9.900	6.170	9.860
Ankle ROM		27.500	22.700	26.400	24.500	23.600	36.600	20.100	20.100	22.000	25.100	19.700	28.900	21.500	27.000	22.300	22.600	22.500	22.900	23.300	22.400	22.890	25.280
Ankle Angular Velocity	(Deg/S)	45.757	33.187	46.561	43.134	35.329	66.425	29.386	32.577	38.732	47.004	33.733	52.545	36.815	47.535	38.185	42.322	32.895	42.884	36.751	34.462	37.414	44.207
Knee Flexion	Weight Acceptance	79.600	76.200	77.500	76.700	78.300	76.600	74.600	73.400	74.900	75.800	74.100	73.400	78.700	75.700	77.800	76.200	76.600	74.400	77.900	77.200	77.000	75.560
	Propulsion	25.700	26.200	27.200	22.000	19.400	22.900	26.200	23.400	29.100	26.300	28.500	25.300	34.200	27.600	32.100	24.800	39.200	25.600	30.800	30.100	29.240	25.420
Knee Extension (ROM)		53.900	50.000	50.300	54.700	58.900	53.700	48.400	50.000	45.800	49.500	45.600	48.100	44.500	48.100	45.700	51.400	37.400	48.800	47.100	47.100	47.760	50.140
Knee Angular Velocity	(Deg/s)	89.684	73.099	88.713	96.303	88.174	97.459	70.760	81.037	80.634	92.697	78.082	87.455	76.199	84.683	78.253	96.255	54.678	91.386	74.290	72.462	77.947	87.283
Hip Flexion	Weight Acceptance	84.000	80.000	79.900	82.200	83.800	77.400	79.700	79.000	78.000	77.800	78.200	73.400	79.300	81.900	80.700	77.500	82.000	78.000	88.700	78.700	81.430	78.590
	Propulsion	36.100	36.500	33.000	28.200	40.600	27.400	29.200	27.900	34.200	27.900	34.800	24.100	35.200	29.500	37.800	27.100	38.400	25.000	28.300	35.700	34.760	28.930
Hip Extension ROM		47.900	43.500	46.900	54.000	43.200	50.000	50.500	51.100	43.800	49.900	43.400	49.300	44.100	52.400	42.900	50.400	43.600	53.000	60.400	43.000	46.670	49.660
Hip Angular Velocity	(Deg/s)	79.700	63.596	82.716	95.070	64.671	90.744	73.830	82.820	77.113	93.446	74.315	89.636	75.514	92.254	73.459	94.382	63.743	99.251	95.268	66.154	76.033	86.735
Hip Abduction/Adduction	Weight Acceptance	-2.400	-3.300	-2.500	-0.900	-2.700	-1.300	-1.800	-2.200	-2.000	-2.700	-2.800	-0.400	-2.200	-0.100	-4.400	-1.200	-1.100	-7.300	-0.300	-0.100	-2.220	-1.950
(Abd/Add)	Propulsion	32.700	32.100	32.900	33.400	31.000	35.500	35.300	36.000	33.000	34.700	31.300	32.900	30.000	31.600	34.000	30.300	34.800	30.600	34.600	32.100	32.960	32.920
Hip Abduction ROM		35.100	35.400	35.400	34.300	33.700	36.800	37.100	38.200	35.000	37.400	34.100	33.300	32.200	31.700	38.400	31.500	35.900	37.900	34.900	32.200	35.180	34.870
Hip Angular Velocity	(Deg/s)	58.403	51.754	62.434	60.387	50.449	66.788	54.240	61.912	61.620	70.037	58.390	60.545	55.137	55.810	65.753	58.989	52.485	70.974	55.047	49.538	57.396	60.674
Stride Length	Sagittal (m)	0.780	0.760	0.900	0.790	0.910	0.960	0.520	0.770	0.580	0.730	0.940	0.950	0.960	0.980	0.870	0.950	0.680	0.970	0.890	0.840	0.803	0.870
	Frontal (m)	0.610	0.740	0.700	0.600	0.650	0.670	0.590	0.650	0.730	0.600	0.690	0.610	0.640	0.590	0.590	0.620	0.610	0.620	0.670	0.660	0.648	0.636
	Total (m)	0.990	1.061	1.140	0.992	1.118	1.171	0.786	1.008	0.932	0.945	1.166	1.129	1.154	1.144	1.051	1.134	0.914	1.151	1.114	1.068	1.037	1.080
Stride Velocity	(m/s)	1.648	1.551	2.011	1.747	1.674	2.125	1.150	1.633	1.641	1.770	1.997	2.053	1.976	2.014	1.800	2.124	1.336	2.156	1.757	1.643	1.699	1.881
Blade Time on Ice (s)	Weight Acceptance	16.032	6.072	17.167	7.273	18.234	8.341	19.386	9.359	20.603	10.443	21.721	11.478	22.822	12.495	23.923	13.546	24.991	14.597	26.192	15.582	21.107	10.919
	Propulsion	16.633	6.756	17.734	7.841	18.902	8.892	20.070	9.976	21.171	10.977	22.305	12.028	23.406	13.063	24.507	14.080	25.675	15.131	26.826	16.232	21.723	11.498
	Total	0.601	0.684	0.567	0.568	0.668	0.551	0.684	0.617	0.568	0.534	0.584	0.550	0.584	0.568	0.584	0.534	0.684	0.534	0.634	0.650	0.616	0.579

Subject Two Kinematics (8mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	12.900	9.100	10.000	14.500	9.100	10.900	18.000	12.600	12.300	17.500	16.600	10.500	13.000	14.400	20.500	9.000	13.400	6.000	15.900	9.700	14.170	11.420
(D/P)	Propulsion	4.100	1.100	2.500	2.800	5.800	12.000	-11.200	10.200	1.400	5.700	3.300	8.800	2.900	2.800	4.800	2.000	-2.500	7.200	4.500	3.800	1.560	5.640
Ankle ROM		17.000	10.200	12.500	17.300	14.900	22.900	6.800	22.800	13.700	23.200	19.900	19.300	15.900	17.200	25.300	11.000	10.900	13.200	20.400	13.500	15.730	17.060
Ankle Angular Velocity	(Deg/s)	24.854	11.765	12.913	20.329	18.602	28.589	7.684	26.792	16.099	23.577	22.087	22.679	20.281	17.462	28.620	12.443	11.670	15.511	24.969	14.983	18.778	19.413
Knee Flexion	Weight Acceptance	65.200	56.700	63.100	64.100	61.900	63.000	66.400	60.700	65.300	65.400	66.400	63.000	65.700	66.900	71.000	61.100	69.700	56.600	68.000	59.100	66.270	61.660
	Propulsion	34.900	21.000	22.700	22.800	21.700	15.800	41.700	10.300	24.700	10.300	17.100	7.200	31.800	18.100	14.600	18.500	26.100	19.500	12.600	17.600	24.790	16.110
Knee Extension (ROM)		30.300	35.700	40.400	41.300	40.200	47.200	24.700	50.400	40.600	55.100	49.300	55.800	33.900	48.800	56.400	42.600	43.600	37.100	55.400	41.500	41.480	45.550
Knee Angular Velocity	(Deg/s)	44.298	41.176	41.736	48.531	50.187	58.926	27.910	59.224	47.709	55.996	54.717	65.570	43.240	49.543	63.801	48.190	46.681	43.596	67.809	46.060	48.809	51.681
Hip Flexion	Weight Acceptance	82.800	75.600	80.000	74.700	75.000	78.400	78.400	76.200	86.700	75.300	79.500	76.800	75.000	83.300	78.000	71.800	78.700	73.500	82.000	70.200	79.610	75.580
	Propulsion	28.500	21.900	21.700	16.200	20.300	14.800	14.400	14.700	17.100	12.400	17.400	16.400	29.400	12.000	27.300	16.800	12.000	16.500	35.600	16.100	22.370	15.780
Hip Extension ROM		54.300	53.700	58.300	58.500	54.700	63.600	64.000	61.500	69.600	62.900	62.100	60.400	45.600	71.300	50.700	55.000	66.700	57.000	46.400	54.100	57.240	59.800
Hip Angular Velocity	(Deg/s)	79.386	61.938	60.227	68.743	68.290	79.401	72.316	72.268	81.786	63.923	68.923	70.975	58.163	72.386	57.353	62.217	71.413	66.980	56.793	60.044	67.465	67.887
Hip Abduction/Adduction	Weight Acceptance	-2.100	-4.800	-1.700	-2.800	-2.400	-2.200	-1.100	-2.700	-3.600	-3.500	-2.500	-2.600	-4.100	-0.400	-2.100	-1.700	-1.700	-0.800	-2.900	2.300	-2.420	-1.920
(Abd/Add)	Propulsion	25.900	24.300	30.400	32.700	34.900	31.800	26.300	34.000	22.300	30.300	32.300	29.900	30.900	31.000	29.000	29.100	32.400	26.200	30.400	28.400	29.480	29.770
Hip Abduction ROM		28.000	29.100	32.100	35.500	37.300	34.000	27.400	36.700	25.900	33.800	34.800	32.500	35.000	31.400	31.100	30.800	34.100	27.000	33.300	26.100	31.900	31.690
Hip Angular Velocity	(Deg/s)	40.936	33.564	33.161	41.716	46.567	42.447	30.960	43.126	30.435	34.350	38.624	38.190	44.643	31.878	35.181	34.842	36.510	31.727	40.759	28.968	37.777	36.081
Stride Length	Sagittal (m)	0.770	1.050	1.120	0.850	1.260	1.010	0.880	0.970	0.990	1.110	0.790	1.050	0.870	1.090	0.970	0.950	0.720	0.880	0.990	1.210	0.936	1.017
	Frontal (m)	0.620	0.700	0.560	0.750	0.470	0.670	0.570	0.810	0.590	0.670	0.660	0.660	0.730	0.580	0.550	0.650	0.730	0.690	0.550	0.630	0.603	0.681
	Total (m)	0.989	1.262	1.252	1.134	1.345	1.212	1.048	1.264	1.152	1.297	1.029	1.240	1.136	1.235	1.115	1.151	1.025	1.118	1.133	1.364	1.122	1.228
Stride Velocity	(m/s)	1.445	1.456	1.294	1.332	1.679	1.513	1.185	1.485	1.354	1.318	1.143	1.457	1.449	1.254	1.261	1.302	1.098	1.314	1.386	1.514	1.329	1.394
Blade Time on Ice (s)	Weight Acceptance	0.867	2.736	2.085	4.187	3.603	5.622	4.954	6.973	6.389	8.341	7.774	9.909	9.242	11.277	10.577	12.879	11.978	14.314	13.413	15.732	7.088	9.197
	Propulsion	1.551	3.603	3.053	5.038	4.404	6.423	5.839	7.824	7.240	9.325	8.675	10.760	10.026	12.262	11.461	13.763	12.912	15.165	14.230	16.633	7.939	10.080
	Total	0.684	0.867	0.968	0.851	0.801	0.801	0.885	0.851	0.851	0.984	0.901	0.851	0.784	0.985	0.884	0.884	0.934	0.851	0.817	0.901	0.851	0.883

Subject Two Kinematics (11mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	18.000	5.800	15.400	8.200	18.100	13.300	15.700	13.400	17.300	13.800	14.600	13.400	14.400	13.300	13.500	12.100	16.700	15.800	16.300	12.400	16.000	12.150
(D/P)	Propulsion	-1.800	0.500	5.400	13.700	0.800	3.600	2.200	8.100	0.100	8.400	4.500	14.200	2.600	11.100	0.500	16.500	-1.900	3.700	3.900	13.700	1.630	9.350
Ankle ROM		16.200	6.300	20.800	21.900	18.900	16.900	17.900	21.500	17.400	22.200	19.100	27.600	17.000	24.400	14.000	28.600	14.800	19.500	20.200	26.100	17.630	21.500
Ankle Angular Velocity	(Deg/s)	19.804	8.583	24.471	29.161	23.133	21.556	22.347	25.294	20.447	28.944	21.606	35.204	19.976	31.122	18.253	38.965	17.051	23.381	24.725	33.291	21.181	27.550
Knee Flexion	Weight Acceptance	69.600	57.300	69.700	58.700	70.500	61.800	65.600	60.200	68.700	61.300	67.300	62.300	70.000	60.400	65.300	64.900	72.500	65.700	68.700	64.700	68.790	61.730
	Propulsion	18.800	23.300	29.500	12.300	25.500	21.800	22.000	16.300	20.400	14.800	18.600	13.100	13.700	10.000	21.900	10.100	26.900	22.300	13.000	8.800	21.030	15.280
Knee Extension (ROM)		50.800	34.000	40.200	46.400	45.000	40.000	43.600	43.900	48.300	46.500	48.700	49.200	56.300	50.400	43.400	54.800	45.600	43.400	55.700	55.900	47.760	46.450
Knee Angular Velocity	(Deg/s)	62.103	46.322	47.294	61.784	55.080	51.020	54.432	51.647	56.757	60.626	55.090	62.755	66.157	64.286	56.584	74.659	52.535	52.038	68.176	71.301	57.421	59.644
Hip Flexion	Weight Acceptance	80.500	76.000	78.700	77.000	79.100	73.300	84.600	65.800	81.800	65.700	82.200	73.100	79.800	74.900	90.500	74.600	81.800	76.900	80.200	76.000	81.920	73.330
	Propulsion	22.400	10.400	24.700	14.500	16.100	17.200	18.300	15.500	22.500	10.400	25.700	17.900	24.200	16.800	17.700	18.800	19.200	11.800	29.600	20.300	22.040	15.360
Hip Extension ROM		58.100	65.600	54.000	62.500	63.000	56.100	66.300	50.300	59.300	55.300	56.500	55.200	55.600	58.100	72.800	55.800	62.600	65.100	50.600	55.700	59.880	57.970
Hip Angular Velocity	(Deg/s)	71.027	89.373	63.529	83.222	77.111	71.556	82.772	59.176	69.683	72.099	63.914	70.408	65.335	74.107	94.915	76.022	72.120	78.058	61.934	71.046	72.234	74.507
Hip Abduction/Adduction	Weight Acceptance	-2.300	-3.900	-2.100	-4.400	-4.200	-2.800	-2.600	-4.500	-4.100	-2.500	-4.300	-4.200	-6.400	-4.800	-1.300	-1.000	-1.200	-6.200	-7.000	-1.000	-3.550	-3.530
(Abd/Add)	Propulsion	32.600	29.200	33.000	29.500	34.500	31.000	29.100	34.200	32.800	31.000	35.200	27.900	34.800	33.300	32.100	34.700	31.300	30.000	33.000	34.100	32.840	31.490
Hip Abduction ROM		34.900	33.100	35.100	33.900	38.700	33.800	31.700	38.700	36.900	33.500	39.500	32.100	41.200	38.100	33.400	35.700	32.500	36.200	40.000	35.100	36.390	35.020
Hip Angular Velocity	(Deg/s)	42.665	45.095	41.294	45.140	47.368	43.112	39.576	45.529	43.361	43.677	44.683	40.944	48.414	48.597	43.546	48.638	37.442	43.405	48.960	44.770	43.731	44.891
Stride Length	Sagittal (m)	0.940	1.190	0.770	1.090	1.070	0.950	1.040	0.840	0.940	1.100	0.670	0.900	1.070	0.950	0.990	1.020	0.940	0.860	0.920	1.140	0.935	1.004
	Frontal (m)	0.660	0.710	0.710	0.790	0.720	0.740	0.740	0.760	0.680	0.740	0.670	0.750	0.800	0.780	0.730	0.730	0.620	0.740	0.770	0.760	0.710	0.750
	Total (m)	1.149	1.386	1.047	1.346	1.290	1.204	1.276	1.133	1.160	1.326	0.948	1.172	1.336	1.229	1.230	1.254	1.126	1.135	1.200	1.370	1.176	1.255
Stride Velocity	(m/s)	1.404	1.888	1.232	1.793	1.579	1.536	1.594	1.333	1.363	1.728	1.072	1.494	1.570	1.568	1.604	1.709	1.297	1.360	1.468	1.748	1.418	1.616
Blade Time on Ice (s)	Weight Acceptance	4.337	5.238	5.689	6.506	7.090	7.774	8.458	9.109	9.776	10.510	11.144	11.795	12.612	13.146	14.047	14.481	15.348	15.749	16.783	17.117	10.528	11.143
	Propulsion	5.155	5.972	6.539	7.257	7.907	8.558	9.259	9.959	10.627	11.277	12.028	12.579	13.463	13.930	14.814	15.215	16.216	16.583	17.600	17.901	11.361	11.923
	Total	0.818	0.734	0.850	0.751	0.817	0.784	0.801	0.850	0.851	0.767	0.884	0.784	0.851	0.784	0.767	0.734	0.868	0.834	0.817	0.784	0.832	0.781

Subject Two Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	15.600	11.600	18.200	11.400	18.700	17.600	14.200	11.500	17.300	13.400	18.600	17.200	16.400	15.300	16.500	13.600	18.900	15.300	16.300	14.400	17.070	14.130
(D/P)	Propulsion	-3.600	7.100	5.400	6.100	5.100	13.600	7.200	3.200	6.900	6.500	4.000	9.400	0.700	13.600	-4.900	10.000	5.600	11.400	9.800	8.000	3.620	8.890
Ankle ROM		12.000	18.700	23.600	17.500	23.800	31.200	21.400	14.700	24.200	19.900	22.600	26.600	17.100	28.900	11.600	23.600	24.500	26.700	26.100	22.400	20.690	23.020
Ankle Angular Velocity	(Deg/s)	18.927	26.081	34.503	25.585	29.713	41.545	31.287	22.039	35.380	25.945	29.427	36.240	23.816	36.862	16.156	30.729	29.376	34.766	34.029	29.205	28.261	30.900
Knee Flexion	Weight Acceptance	67.900	68.300	70.300	69.200	72.200	68.300	62.600	63.400	70.400	68.400	72.600	68.800	67.900	68.300	68.800	66.400	69.300	67.800	70.300	67.200	69.230	67.610
	Propulsion	23.000	19.300	13.400	19.800	30.500	17.500	22.900	23.700	19.700	18.100	16.000	17.100	21.100	11.300	29.900	14.200	20.600	12.700	20.200	16.800	21.730	17.050
Knee Extension (ROM)		44.900	49.000	56.900	49.400	41.700	50.800	39.700	39.700	50.700	50.300	56.600	51.700	46.800	57.000	38.900	52.200	48.700	55.100	50.100	50.400	47.500	50.560
Knee Angular Velocity	(Deg/s)	70.820	68.340	83.187	72.222	52.060	67.643	58.041	59.520	74.123	65.580	73.698	70.436	65.181	72.704	54.178	67.969	58.393	71.745	65.319	65.711	65.500	68.187
Hip Flexion	Weight Acceptance	82.000	78.700	79.300	77.600	74.400	73.500	74.700	74.700	83.100	73.900	80.300	79.600	80.800	81.800	76.200	77.100	75.700	78.800	73.400	79.900	77.990	77.560
	Propulsion	25.500	17.400	27.800	27.300	16.400	20.600	23.600	13.800	21.400	11.400	17.900	11.200	26.800	16.800	25.700	15.900	15.400	14.400	22.200	16.700	22.270	16.550
Hip Extension ROM		56.500	61.300	51.500	50.300	58.000	52.900	51.100	60.900	61.700	62.500	62.400	68.400	54.000	65.000	50.500	61.200	60.300	64.400	51.200	63.200	55.720	61.010
Hip Angular Velocity	(Deg/s)	89.117	85.495	75.292	73.538	72.409	70.439	74.708	91.304	90.205	81.486	81.250	93.188	75.209	82.908	70.334	79.687	72.302	83.854	66.754	82.399	76.758	82.430
Hip Abduction/Adduction	Weight Acceptance	-3.200	-4.900	-2.300	-6.300	-2.200	-5.200	-1.900	-2.900	-2.200	-4.400	-3.100	-6.200	-0.600	-8.200	-2.700	-3.300	-5.600	-3.700	-3.300	-2.800	-2.710	-4.790
(Abd/Add)	Propulsion	32.700	36.400	34.900	32.500	33.900	36.100	34.200	36.500	35.200	36.100	28.300	34.000	35.800	36.100	33.900	32.100	31.800	37.400	29.000	39.000	32.970	35.620
Hip Abduction ROM		35.900	41.300	37.200	38.800	36.100	41.300	36.100	39.400	37.400	40.500	31.400	40.200	36.400	44.300	36.600	35.400	37.400	41.100	32.300	41.800	35.680	40.410
Hip Angular Velocity	(Deg/s)	56.625	57.601	54.386	56.725	45.069	54.993	52.778	59.070	54.678	52.803	40.885	54.768	50.696	56.505	50.975	46.094	44.844	53.516	42.112	54.498	49.305	54.657
Stride Length	Sagittal (m)	1.100	1.000	0.830	0.940	0.850	1.170	0.940	1.150	1.040	1.110	1.010	0.970	1.030	0.960	0.900	1.110	0.850	1.010	0.860	0.880	0.941	1.030
	Frontal (m)	0.770	0.740	0.720	0.740	0.690	0.720	0.660	0.780	0.700	0.780	0.740	0.780	0.650	0.850	0.670	0.770	0.740	0.700	0.670	0.780	0.701	0.764
	Total (m)	1.343	1.244	1.099	1.196	1.095	1.374	1.149	1.390	1.254	1.357	1.252	1.245	1.218	1.282	1.122	1.351	1.127	1.229	1.090	1.176	1.175	1.284
Stride Velocity	(m/s)	2.118	1.735	1.606	1.749	1.367	1.829	1.679	2.083	1.833	1.769	1.630	1.696	1.696	1.635	1.563	1.759	1.351	1.600	1.421	1.533	1.627	1.739
Blade Time on Ice (s)	Weight Acceptance	2.152	5.572	3.269	6.840	4.437	8.041	5.739	9.309	6.906	10.477	8.074	11.778	9.342	13.046	10.543	14.347	11.745	15.648	13.113	16.950	7.532	11.201
	Propulsion	2.786	6.289	3.953	7.524	5.238	8.792	6.423	9.976	7.590	11.244	8.842	12.512	10.060	13.830	11.261	15.115	12.579	16.416	13.880	17.717	8.261	11.942
	Total	0.634	0.717	0.684	0.684	0.801	0.751	0.684	0.667	0.684	0.767	0.768	0.734	0.718	0.784	0.718	0.768	0.834	0.768	0.767	0.767	0.729	0.741

Subject Two Kinematics (15mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	17.600	11.100	18.000	14.300	18.500	10.300	19.400	12.000	17.200	12.300	16.900	13.600	15.700	14.500	17.900	18.800	16.100	18.900	15.100	14.700	17.240	14.050
(D/P)	Propulsion	13.400	6.600	-1.500	12.300	-2.400	3.500	-2.100	13.900	8.500	11.600	4.300	14.500	13.000	15.000	0.300	5.300	1.500	3.500	0.100	17.400	3.510	10.360
Ankle ROM		31.000	17.700	16.500	26.600	16.100	13.800	17.300	25.900	25.700	23.900	21.200	28.100	28.700	29.500	18.200	24.100	17.600	22.400	15.200	32.100	20.750	24.410
Ankle Angular Velocity	(Deg/s)	46.477	25.250	21.046	37.946	22.455	20.175	26.575	37.865	35.794	30.485	28.267	35.081	36.607	40.191	26.608	33.612	24.513	32.749	21.199	40.944	28.954	33.430
Knee Flexion	Weight Acceptance	72.200	60.200	72.900	65.300	69.200	68.300	73.700	66.200	72.700	69.300	71.700	70.300	74.200	68.000	71.700	71.900	73.300	74.800	74.900	74.500	72.650	68.880
	Propulsion	18.500	17.400	22.400	12.700	28.800	13.100	21.200	9.600	17.900	18.200	18.300	11.200	8.800	6.800	22.900	20.800	23.200	14.000	27.200	12.100	20.920	13.590
Knee Extension (ROM)		53.700	42.800	50.500	52.600	40.400	55.200	52.500	56.600	54.800	51.100	53.400	59.100	65.400	61.200	48.800	51.100	50.100	60.800	47.700	62.400	51.730	55.290
Knee Angular Velocity	(Deg/s)	80.510	61.056	64.413	75.036	56.346	80.702	80.645	82.749	76.323	65.179	71.200	73.783	83.418	83.379	71.345	71.269	69.777	88.889	66.527	79.592	72.050	76.163
Hip Flexion	Weight Acceptance	82.100	68.100	80.100	77.800	79.000	76.900	81.600	84.200	81.800	83.600	78.900	75.400	80.100	77.100	78.500	82.000	81.600	84.900	83.200	85.300	80.690	79.530
	Propulsion	23.200	20.600	14.500	18.600	16.100	19.500	19.500	22.800	17.700	17.900	18.900	19.800	22.900	14.100	20.100	18.100	18.000	22.000	17.400	20.200	18.830	19.360
Hip Extension ROM		58.900	47.500	65.600	59.200	62.900	57.400	62.100	61.400	64.100	65.700	60.000	55.600	57.200	63.000	58.400	63.900	63.600	62.900	65.800	65.100	61.860	60.170
Hip Angular Velocity	(Deg/s)	88.306	67.760	83.673	84.451	87.727	83.918	95.392	89.766	89.276	83.801	80.000	69.413	72.959	85.831	85.380	89.121	88.579	91.959	91.771	83.036	86.306	82.906
Hip Abduction/Adduction	Weight Acceptance	-2.600	-3.700	-4.900	-2.300	-4.000	-3.800	-3.700	-4.500	-5.600	-4.300	-4.100	-2.400	-4.600	-2.400	-4.700	-3.900	-1.600	-1.300	-1.500	-5.000	-3.730	-3.360
(Abd/Add)	Propulsion	31.300	33.200	38.900	31.400	33.900	31.200	34.300	32.300	35.600	32.700	34.300	32.800	33.400	33.200	33.900	34.000	33.200	38.600	36.500	34.900	34.530	33.430
Hip Abduction ROM		33.900	36.900	43.800	33.700	37.900	35.000	38.000	36.800	41.200	37.000	38.400	35.200	38.000	35.600	38.600	37.900	34.800	39.900	38.000	39.900	38.260	36.790
Hip Angular Velocity	(Deg/s)	50.825	52.639	55.867	48.074	52.859	51.170	58.372	53.801	57.382	47.194	51.200	43.945	48.469	48.501	56.433	52.859	48.468	58.333	52.999	50.893	53.287	50.741
Stride Length	Sagittal (m)	0.900	0.970	1.090	0.940	0.970	1.020	1.110	0.850	0.970	0.880	0.840	0.940	0.970	1.110	1.030	0.990	1.030	1.000	1.040	1.010	0.995	0.971
	Frontal (m)	0.640	0.660	0.670	0.650	0.630	0.690	0.640	0.750	0.590	0.810	0.710	0.790	0.690	0.680	0.660	0.670	0.570	0.760	0.630	0.720	0.643	0.718
	Total (m)	1.104	1.173	1.279	1.143	1.157	1.231	1.281	1.134	1.135	1.196	1.100	1.228	1.190	1.302	1.223	1.195	1.177	1.256	1.216	1.240	1.186	1.210
Stride Velocity	(m/s)	1.656	1.674	1.632	1.630	1.613	1.800	1.968	1.657	1.581	1.526	1.466	1.533	1.518	1.773	1.788	1.667	1.640	1.836	1.696	1.582	1.656	1.668
Blade Time on Ice (s)	Weight Acceptance	4.821	7.674	5.939	8.825	7.207	10.010	8.408	11.177	9.542	12.345	10.744	13.630	11.945	14.914	13.213	16.116	14.347	17.283	15.515	18.451	10.168	13.043
	Propulsion	5.488	8.375	6.723	9.526	7.924	10.694	9.059	11.861	10.260	13.129	11.494	14.431	12.729	15.648	13.897	16.833	15.065	17.967	16.232	19.235	10.887	13.770
	Total	0.667	0.701	0.784	0.701	0.717	0.684	0.651	0.684	0.718	0.784	0.750	0.801	0.784	0.734	0.684	0.717	0.718	0.684	0.717	0.784	0.719	0.727

Subject Two Kinematics (18mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	16.200	12.000	16.100	16.000	14.800	17.200	14.800	17.100	15.100	13.500	17.300	12.100	16.200	14.400	13.200	13.900	19.200	16.700	17.000	12.000	15.990	14.490
(D/P)	Propulsion	1.500	5.000	4.100	11.700	7.700	6.100	-4.500	5.700	-4.200	11.100	1.100	3.700	7.200	8.700	0.500	16.400	11.000	11.100	1.800	18.100	2.620	9.760
Ankle ROM		17.700	17.000	20.200	27.700	22.500	23.300	10.300	22.800	10.900	24.600	18.400	15.800	23.400	23.100	13.700	30.300	30.200	27.800	18.800	30.100	18.610	24.250
Ankle Angular Velocity	(Deg/s)	25.877	26.154	29.532	39.515	35.489	33.238	16.694	30.400	15.202	37.846	28.264	25.608	35.030	35.484	19.107	46.615	47.709	35.459	28.923	45.060	28.183	35.538
Knee Flexion	Weight Acceptance	69.300	70.000	74.100	71.600	73.500	71.400	73.200	76.600	72.000	71.300	74.600	71.000	72.500	71.800	74.500	69.700	72.100	72.300	73.400	71.300	72.920	71.700
	Propulsion	29.100	18.500	15.300	8.000	11.600	15.600	27.000	16.900	21.500	13.800	24.700	19.900	21.100	10.100	22.100	7.700	19.500	11.700	18.500	11.200	21.040	13.340
Knee Extension (ROM)		40.200	51.500	58.800	63.600	61.900	55.800	46.200	59.700	50.500	57.500	49.900	51.100	51.400	61.700	52.400	62.000	52.600	60.600	54.900	60.100	51.880	58.360
Knee Angular Velocity	(Deg/s)	58.772	79.231	85.965	90.728	97.634	79.601	74.878	79.600	70.432	88.462	76.651	82.820	76.946	94.777	73.082	95.385	83.096	77.296	84.462	89.970	78.192	85.787
Hip Flexion	Weight Acceptance	76.500	79.700	77.400	84.200	80.100	81.200	82.700	83.800	82.100	85.400	78.100	81.400	82.700	82.600	79.600	84.100	81.600	84.800	82.900	86.000	80.370	83.320
	Propulsion	22.300	16.900	28.200	15.100	21.100	15.400	20.800	22.000	25.100	15.900	23.300	18.500	15.400	13.300	26.300	24.500	17.400	15.100	16.900	13.900	21.680	17.060
Hip Extension ROM		54.200	62.800	49.200	69.100	59.000	65.800	61.900	61.800	57.000	69.500	54.800	62.900	67.300	69.300	53.300	59.600	64.200	69.700	66.000	72.100	58.690	66.260
Hip Angular Velocity	(Deg/s)	79.240	96.615	71.930	98.573	93.060	93.866	100.324	82.400	79.498	106.923	84.178	101.945	100.749	106.452	74.338	91.692	101.422	88.903	101.538	107.934	88.628	97.530
Hip Abduction/Adduction	Weight Acceptance	-4.400	-1.400	-3.300	-7.000	-2.900	-6.900	-4.200	-2.400	-2.400	-3.100	-5.300	-8.400	-1.200	-10.900	-1.300	-4.800	-3.600	-1.500	-2.900	-7.800	-3.150	-5.420
(Abd/Add)	Propulsion	33.200	37.000	34.700	35.100	26.600	33.600	33.700	34.400	32.800	38.700	31.500	35.100	32.800	37.000	31.900	34.100	34.300	37.900	35.100	38.300	32.660	36.120
Hip Abduction ROM		37.600	38.400	38.000	42.100	29.500	40.500	37.900	36.800	35.200	41.800	36.800	43.500	34.000	47.900	33.200	38.900	37.900	39.400	38.000	46.100	35.810	41.540
Hip Angular Velocity	(Deg/s)	54.971	59.077	55.556	60.057	46.530	57.775	61.426	49.067	49.093	64.308	56.528	70.502	50.898	73.579	46.304	59.846	59.874	50.255	58.462	69.012	53.964	61.348
Stride Length	Sagittal (m)	0.950	0.970	0.990	0.970	1.040	1.010	0.980	1.150	1.010	1.220	1.050	1.190	1.100	1.050	1.010	1.160	1.080	1.210	1.050	1.080	1.026	1.101
	Frontal (m)	0.710	0.780	0.600	0.900	0.680	0.850	0.720	0.850	0.620	0.750	0.700	0.740	0.690	0.760	0.630	0.760	0.670	0.820	0.690	0.660	0.671	0.787
	Total (m)	1.186	1.245	1.158	1.323	1.243	1.320	1.216	1.430	1.185	1.432	1.262	1.401	1.298	1.296	1.190	1.387	1.271	1.462	1.256	1.266	1.227	1.356
Stride Velocity	(m/s)	1.734	1.915	1.692	1.888	1.960	1.883	1.971	1.907	1.653	2.203	1.938	2.271	1.944	1.991	1.660	2.134	2.008	1.864	1.933	1.895	1.849	1.995
Blade Time on Ice (s)	Weight Acceptance	8.975	7.574	10.110	8.708	11.261	9.926	12.345	11.111	13.413	12.379	14.614	13.513	15.715	14.614	16.850	15.749	18.018	16.850	19.119	18.084	14.042	12.851
	Propulsion	9.659	8.224	10.794	9.409	11.895	10.627	12.962	11.861	14.130	13.029	15.265	14.130	16.383	15.265	17.567	16.399	18.651	17.634	19.769	18.752	14.708	13.533
	Total	0.684	0.650	0.684	0.701	0.634	0.701	0.617	0.750	0.717	0.650	0.651	0.617	0.668	0.651	0.717	0.650	0.633	0.784	0.650	0.668	0.666	0.682

Subject Three Kinematics (8mph)

Variable	Stride Number	1 Own	1 Mako	2 Own	2 Mako	3 Own	3 Mako	4 Own	4 Mako	5 Own	5 Mako	6 Own	6 Mako	7 Own	7 Mako	8 Own	8 Mako	9 Own	9 Mako	10 Own	10 Mako	Average Own	Average Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	11.200	10.800	4.200	10.400	10.400	14.200	11.500	13.300	13.700	9.900	15.200	10.700	11.100	8.900	12.100	10.900	15.700	13.100	17.200	11.100	12.230	11.330
(D/P)	Propulsion	8.100	8.100	11.500	12.000	6.200	6.700	0.800	4.700	-7.200	8.500	-4.500	13.400	-4.500	6.200	-4.600	6.300	-3.100	15.500	21.400	11.800	2.410	9.320
Ankle ROM		19.300	18.900	15.700	22.400	16.600	20.900	12.300	18.000	6.500	18.400	10.700	24.100	6.600	15.100	7.500	17.200	12.600	28.600	38.600	22.900	14.640	20.650
Ankle Angular Velocity	(Deg/s)	18.363	18.261	16.219	18.651	16.583	20.213	11.896	16.854	6.385	18.382	10.863	24.492	6.593	16.449	7.622	16.896	11.624	28.122	39.188	22.517	14.534	20.084
Knee Flexion	Weight Acceptance	86.200	71.300	71.500	74.800	81.800	73.200	78.100	79.400	77.100	72.800	78.800	78.900	78.400	74.300	79.500	76.400	78.700	81.100	80.000	75.600	79.010	75.780
	Propulsion	33.000	14.300	32.700	8.900	32.700	12.800	27.500	16.300	17.400	13.600	27.500	6.900	25.600	19.500	26.400	13.900	16.400	6.600	1.300	9.000	24.050	12.180
Knee Extension (ROM)		53.200	57.000	38.800	65.900	49.100	60.400	50.600	63.100	59.700	59.200	51.300	72.000	52.800	54.800	53.100	62.500	62.300	74.500	78.700	66.600	54.960	63.600
Knee Angular Velocity	(Deg/s)	50.618	55.072	40.083	54.871	49.051	58.414	48.936	59.082	58.644	59.141	52.081	73.171	52.747	59.695	53.963	61.395	57.472	73.255	79.898	65.487	54.350	61.958
Hip Flexion	Weight Acceptance	85.800	79.000	80.300	83.200	81.500	79.000	83.900	82.400	83.100	80.000	80.300	79.700	80.100	80.100	81.600	82.200	78.100	79.600	82.400	79.400	81.710	80.460
	Propulsion	37.300	21.700	29.600	29.200	20.500	30.900	28.000	27.800	21.300	29.400	39.500	28.100	27.100	28.900	33.500	33.000	31.400	31.400	28.300	25.000	29.650	28.540
Hip Extension ROM		48.500	57.300	50.700	54.000	61.000	48.100	55.900	54.600	61.800	50.600	40.800	51.600	53.000	51.200	48.100	49.200	46.700	48.200	54.100	54.400	52.060	51.920
Hip Angular Velocity	(Deg/s)	46.147	55.362	52.376	44.963	60.939	46.518	54.062	51.124	60.707	50.549	41.421	52.439	52.947	55.773	48.882	48.330	43.081	47.394	54.924	53.491	51.549	50.594
Hip Abduction/Adduction	Weight Acceptance	-7.300	-14.000	-11.500	-11.000	-5.200	-3.800	-16.100	-13.900	-20.200	-10.600	-17.000	-10.900	-18.000	-15.500	19.200	-15.300	-16.800	-16.600	-15.800	-16.400	-10.870	-12.800
(Abd/Add)	Propulsion	36.300	32.700	35.000	34.700	31.400	36.200	34.500	36.300	34.600	41.200	33.800	37.400	32.900	37.200	36.000	34.700	36.200	37.600	38.400	33.200	34.910	36.120
Hip Abduction ROM		43.600	46.700	46.500	45.700	36.600	40.000	50.600	50.200	54.800	51.800	50.800	48.300	50.900	52.700	16.800	50.000	53.000	54.200	54.200	49.600	45.780	48.920
Hip Angular Velocity	(Deg/s)	41.484	45.121	48.037	38.052	36.563	38.685	48.936	47.004	53.831	51.748	51.574	49.085	50.849	57.407	17.073	49.116	48.893	53.294	55.025	48.771	45.227	47.828
Stride Length	Sagittal (m)	0.650	0.970	1.180	0.610	0.850	0.900	0.830	0.740	0.910	0.740	0.560	0.800	1.120	0.890	0.810	0.610	0.900	0.710	0.860	0.820	0.867	0.779
	Frontal (m)	0.610	0.790	0.660	0.760	0.590	0.670	0.680	0.810	0.690	0.870	0.590	0.880	0.650	0.870	0.600	0.770	0.590	0.810	0.650	0.910	0.631	0.814
	Total (m)	0.891	1.251	1.352	0.975	1.035	1.122	1.073	1.097	1.142	1.142	0.813	1.189	1.295	1.245	1.008	0.982	1.076	1.077	1.078	1.225	1.076	1.131
Stride Velocity	(m/s)	0.848	1.209	1.397	0.811	1.034	1.085	1.038	1.027	1.122	1.141	0.826	1.209	1.294	1.356	1.024	0.965	0.993	1.059	1.094	1.204	1.067	1.107
Blade Time on Ice (s)	Weight Acceptance	3.069	8.541	4.704	10.076	6.206	11.728	7.741	13.246	9.292	14.848	10.860	16.383	12.445	17.917	13.980	19.335	15.482	20.854	17.083	22.389	10.086	15.532
	Propulsion	4.12	9.576	5.672	11.277	7.207	12.762	8.775	14.314	10.310	15.849	11.845	17.367	13.446	18.835	14.964	20.353	16.566	21.871	18.068	23.406	11.097	16.561
	Total	1.051	1.035	0.968	1.201	1.001	1.034	1.034	1.068	1.018	1.001	0.985	0.984	1.001	0.918	0.984	1.018	1.084	1.017	0.985	1.017	1.011	1.029

Subject Three Kinematics (11mph)

Variable	Stride Number	1 Own	1 Mako	2 Own	2 Mako	3 Own	3 Mako	4 Own	4 Mako	5 Own	5 Mako	6 Own	6 Mako	7 Own	7 Mako	8 Own	8 Mako	9 Own	9 Mako	10 Own	10 Mako	Average Own	Average Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	16.100	10.400	12.500	14.300	15.200	11.000	14.400	12.700	12.200	11.600	17.500	8.000	15.900	12.200	18.200	10.800	16.000	11.500	16.100	13.800	15.410	11.630
(D/P)	Propulsion	-2.100	6.300	-2.800	13.800	-5.500	2.100	1.100	16.900	0.500	11.000	1.400	14.900	1.200	15.700	1.300	10.800	-3.700	15.300	6.000	8.200	-0.260	11.500
Ankle ROM		14.000	16.700	9.700	28.100	9.700	13.100	15.500	29.600	12.700	22.600	18.900	22.900	17.100	27.900	19.500	21.600	12.300	26.800	22.100	22.000	15.150	23.130
Ankle Angular Velocity	(Deg/s)	15.251	19.240	10.200	28.557	9.381	15.092	16.299	25.762	13.597	27.662	20.236	31.199	19.322	36.328	21.265	22.314	12.934	28.181	22.854	25.882	16.134	26.022
Knee Flexion	Weight Acceptance	84.800	76.000	80.100	79.300	82.600	78.800	78.600	77.200	85.300	84.300	79.100	71.200	84.800	82.100	81.400	79.100	83.700	76.300	80.900	78.800	82.130	78.310
	Propulsion	17.100	19.100	20.000	8.700	23.400	22.400	14.600	7.500	20.700	17.100	24.000	8.000	15.700	16.100	23.900	17.000	17.000	12.900	26.600	20.900	20.300	14.970
Knee Extension (ROM)		67.700	56.900	60.100	70.600	59.200	56.400	64.000	69.700	64.600	67.200	55.100	63.200	69.100	66.000	57.500	62.100	66.700	63.400	54.300	57.900	61.830	63.340
Knee Angular Velocity	(Deg/s)	73.747	65.553	63.197	71.748	57.253	64.977	67.298	60.661	69.165	82.252	58.994	86.104	78.079	85.937	62.704	64.153	70.137	66.667	56.153	68.118	65.673	71.617
Hip Flexion	Weight Acceptance	82.600	80.700	82.400	78.100	80.100	79.000	79.400	79.000	86.500	83.600	78.500	83.800	87.200	85.600	81.500	82.300	79.400	75.900	80.200	81.000	81.780	80.900
	Propulsion	31.800	29.200	31.700	47.300	16.100	28.300	31.600	37.800	28.000	42.000	24.900	21.800	38.700	10.200	33.100	45.200	28.200	33.700	32.200	24.300	29.630	31.980
Hip Extension ROM		50.800	51.500	50.700	30.800	64.000	50.700	47.800	41.200	58.500	41.600	53.600	62.000	48.500	75.400	48.400	37.100	51.200	42.200	48.000	56.700	52.150	48.920
Hip Angular Velocity	(Deg/s)	55.338	59.332	53.312	31.301	61.896	58.410	50.263	35.857	62.634	50.918	57.388	84.469	54.802	98.177	52.781	38.326	53.838	44.374	49.638	66.706	55.189	56.787
Hip Abduction/Adduction	Weight Acceptance	-12.600	-21.200	-23.300	-18.300	-15.700	-23.900	-9.500	-14.200	-12.000	-15.200	-18.700	-15.800	-14.300	-10.300	-18.400	-17.700	-17.400	-14.800	-25.400	-20.600	-16.730	-17.200
(Abd/Add)	Propulsion	29.000	31.000	34.500	33.100	35.600	33.800	32.300	37.000	34.000	34.400	36.200	38.300	31.000	37.400	35.400	36.400	38.200	34.500	36.700	44.300	34.290	36.020
Hip Abduction ROM		41.600	52.200	57.800	51.400	51.300	57.700	41.800	51.200	46.000	49.600	54.900	54.100	45.300	47.700	53.800	54.100	55.600	49.300	62.100	64.900	51.020	53.220
Hip Angular Velocity	(Deg/s)	45.316	60.138	60.778	52.236	49.613	66.475	43.954	44.560	49.251	60.710	58.779	73.706	51.186	62.109	58.670	55.888	58.465	51.840	64.219	76.353	54.023	60.402
Stride Length	Sagittal (m)	0.680	0.570	0.710	0.550	0.940	0.690	0.880	0.650	0.880	0.560	1.130	1.020	0.870	1.000	0.880	0.610	0.840	0.860	0.960	0.870	0.877	0.738
	Frontal (m)	0.640	0.840	0.810	0.950	0.720	0.850	0.760	0.850	0.690	0.920	0.770	0.830	0.690	0.780	0.790	0.820	0.760	0.850	0.790	0.840	0.742	0.853
	Total (m)	0.934	1.015	1.077	1.098	1.184	1.095	1.163	1.070	1.118	1.077	1.367	1.315	1.110	1.268	1.183	1.022	1.133	1.209	1.243	1.209	1.151	1.138
Stride Velocity	(m/s)	1.017	1.170	1.133	1.116	1.145	1.261	1.223	0.931	1.197	1.318	1.464	1.792	1.255	1.651	1.290	1.056	1.191	1.271	1.286	1.423	1.220	1.299
Blade Time on Ice (s)	Weight Acceptance	4.771	9.442	6.222	10.777	7.674	12.228	9.242	15.580	10.744	14.948	12.212	16.399	13.646	17.550	15.048	18.835	16.466	20.286	17.951	21.705	11.398	15.775
	Propulsion	5.689	10.310	7.173	11.761	8.708	13.096	10.193	14.431	11.678	15.765	13.146	17.133	14.531	18.318	15.965	19.803	17.417	21.237	18.918	22.555	12.342	16.441
	Total	0.918	0.868	0.951	0.984	1.034	0.868	0.951	1.149	0.934	0.817	0.934	0.734	0.885	0.768	0.917	0.968	0.951	0.951	0.967	0.850	0.944	0.896

Subject Three Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	19.000	5.700	11.000	6.900	11.300	10.200	13.200	14.200	13.000	12.100	16.500	16.500	17.800	13.700	15.900	12.800	16.600	12.300	12.900	8.600	14.720	11.300
(D/P)	Propulsion	3.900	0.800	0.800	7.300	2.900	12.400	2.600	12.900	2.900	13.500	-4.800	7.900	2.300	6.100	5.500	15.600	4.000	8.700	-4.500	10.500	1.560	9.570
Ankle ROM		22.900	6.500	11.800	14.200	14.200	22.600	15.800	27.100	15.900	25.600	11.700	24.400	20.100	19.800	21.400	28.400	20.600	21.000	8.400	19.100	16.280	20.870
Ankle Angular Velocity	(Deg/s)	26.382	7.353	13.348	15.485	15.203	24.197	17.536	27.996	20.703	27.409	15.254	27.602	25.638	22.373	26.717	31.521	26.276	22.876	9.689	20.084	19.675	22.690
Knee Flexion	Weight Acceptance	84.200	73.800	81.500	70.900	78.600	76.000	78.700	78.400	80.100	77.600	84.400	78.600	79.500	81.400	82.800	80.300	84.300	77.600	80.100	75.200	81.420	76.980
	Propulsion	27.800	23.800	23.300	18.600	24.600	9.400	28.700	4.300	25.200	5.900	32.100	10.700	24.500	19.400	24.400	14.700	20.800	15.000	33.100	11.000	26.450	13.280
Knee Extension (ROM)		56.400	50.000	58.200	52.300	54.000	66.600	50.000	74.100	54.900	71.700	52.300	67.900	55.000	62.000	58.400	65.600	63.500	62.600	47.000	64.200	54.970	63.700
Knee Angular Velocity	(Deg/s)	64.977	56.561	65.837	57.034	57.816	71.306	55.494	76.550	71.484	76.767	68.188	76.810	70.153	70.056	72.909	72.808	80.995	68.192	54.210	67.508	66.206	69.359
Hip Flexion	Weight Acceptance	84.400	84.200	78.700	80.500	83.400	77.700	82.700	81.100	81.900	83.100	84.300	82.700	79.400	84.800	80.400	82.200	84.800	80.900	78.400	83.500	81.840	82.070
	Propulsion	29.100	21.800	32.300	24.700	29.000	26.800	29.700	28.600	20.100	40.400	22.900	38.700	30.000	37.700	19.500	24.500	34.700	27.800	29.800	37.100	27.710	30.810
Hip Extension ROM		55.300	62.400	46.400	55.800	54.400	50.900	53.000	52.500	61.800	42.700	61.400	44.000	49.400	47.100	60.900	57.700	50.100	53.100	48.600	46.400	54.130	51.260
Hip Angular Velocity	(Deg/s)	63.710	70.588	52.489	60.851	58.244	54.497	58.824	54.236	80.469	45.717	80.052	49.774	63.010	53.220	76.030	64.040	63.903	57.843	56.055	48.791	65.279	55.956
Hip Abduction/Adduction	Weight Acceptance	-17.900	18.200	-20.800	6.900	-15.500	-13.800	-18.400	-14.200	-19.400	-0.700	-18.500	-15.500	-22.800	-16.000	-25.300	-12.500	25.200	-16.100	-19.200	-17.700	-15.260	-8.140
(Abd/Add)	Propulsion	34.000	28.500	39.400	24.200	34.500	38.300	37.300	40.400	35.100	38.700	39.200	32.400	37.800	35.900	34.900	40.200	34.200	38.000	37.800	39.000	36.420	35.560
Hip Abduction ROM		51.900	10.300	60.200	17.300	50.000	52.100	55.700	54.600	54.500	39.400	57.700	47.900	60.600	51.900	60.200	52.700	9.000	54.100	57.000	56.700	51.680	43.700
Hip Angular Velocity	(Deg/s)	59.793	11.652	68.100	18.866	53.533	55.782	61.820	56.405	70.964	42.184	75.228	54.186	77.296	58.644	75.156	58.491	11.480	58.932	65.744	59.621	61.911	47.476
Stride Length	Sagittal (m)	0.730	1.110	0.650	0.930	0.970	0.950	0.830	0.970	1.030	1.050	0.860	0.780	0.920	0.920	0.910	1.000	0.760	0.930	0.790	0.820	0.845	0.946
	Frontal (m)	0.780	0.810	0.740	0.770	0.750	0.790	0.800	0.670	0.730	0.760	0.730	0.730	0.710	0.720	0.720	0.720	0.690	0.800	0.720	0.780	0.737	0.755
	Total (m)	1.068	1.374	0.985	1.207	1.226	1.236	1.153	1.179	1.262	1.296	1.128	1.068	1.162	1.168	1.160	1.232	1.026	1.227	1.069	1.132	1.124	1.212
Stride Velocity	(m/s)	1.231	1.554	1.114	1.317	1.313	1.323	1.279	1.218	1.644	1.388	1.471	1.209	1.482	1.320	1.449	1.368	1.309	1.336	1.233	1.190	1.352	1.322
Blade Time on Ice (s)	Weight Acceptance	1.968	8.041	3.336	9.409	4.738	10.844	6.172	12.278	24.991	13.713	26.226	15.148	27.460	16.549	28.695	17.951	29.963	19.352	31.231	20.754	18.478	14.404
	Propulsion	2.836	8.925	4.220	10.326	5.672	11.778	7.073	13.246	25.759	14.647	26.993	16.032	28.244	17.434	29.496	18.852	30.747	20.270	32.098	21.705	19.314	15.322
	Total	0.868	0.884	0.884	0.917	0.934	0.934	0.901	0.968	0.768	0.934	0.767	0.884	0.784	0.885	0.801	0.901	0.784	0.918	0.867	0.951	0.836	0.918

Subject Three Kinematics (15mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	13.000	13.500	11.800	15.100	15.500	11.000	18.000	11.800	10.100	8.200	15.000	13.600	17.500	13.400	20.600	11.400	13.700	9.200	16.700	16.100	15.190	12.330
(D/P)	Propulsion	-0.300	11.100	2.200	9.800	-1.500	11.300	6.400	8.800	1.200	4.600	2.000	7.200	0.400	14.100	-1.400	17.200	2.100	14.200	7.000	6.200	1.810	10.450
Ankle ROM		12.700	24.600	14.000	24.900	14.000	22.300	24.400	20.600	11.300	12.800	17.000	20.800	17.900	27.500	19.200	28.600	15.800	23.400	23.700	22.300	17.000	22.780
Ankle Angular Velocity	(Deg/s)	14.631	26.310	16.148	25.305	16.451	23.449	26.609	23.303	13.278	13.943	19.976	20.432	20.646	30.522	22.562	31.743	18.588	28.641	27.882	23.037	19.677	24.669
Knee Flexion	Weight Acceptance	79.900	78.900	81.300	78.000	90.100	72.900	83.200	78.500	84.900	80.000	83.800	80.500	84.800	79.000	83.100	77.300	87.600	81.000	85.000	75.500	84.370	78.160
	Propulsion	21.900	8.900	24.900	8.700	21.000	3.100	16.000	5.700	23.700	15.900	26.100	13.700	25.900	6.600	19.100	3.500	26.700	0.400	15.300	19.700	22.060	8.620
Knee Extension (ROM)		58.000	70.000	56.400	69.300	69.100	69.800	67.200	72.800	61.200	64.100	57.700	66.800	58.900	72.400	64.000	73.800	60.900	80.600	69.700	55.800	62.310	69.540
Knee Angular Velocity	(Deg/s)	66.820	74.866	65.052	70.427	81.199	73.396	73.282	82.353	71.915	69.826	67.803	65.619	67.935	80.355	75.206	81.909	71.647	98.654	82.000	57.645	72.286	75.505
Hip Flexion	Weight Acceptance	80.000	80.200	83.000	78.800	89.100	79.500	81.300	82.800	90.500	86.900	83.400	79.000	80.700	81.700	84.800	77.500	83.600	82.400	80.500	79.900	83.690	80.870
	Propulsion	29.500	16.200	26.200	13.900	21.400	18.300	20.200	22.300	33.000	20.300	38.000	35.200	34.700	17.900	37.200	22.200	33.900	19.300	33.100	27.300	30.720	21.290
Hip Extension ROM		50.500	64.000	56.800	64.900	67.700	61.200	61.100	60.500	57.500	66.600	45.400	43.800	46.000	63.800	47.600	55.300	49.700	63.100	47.400	52.600	52.970	59.580
Hip Angular Velocity	(Deg/s)	58.180	68.449	65.513	65.955	79.553	64.353	66.630	68.439	67.568	72.549	53.349	43.026	53.057	70.810	55.934	61.376	58.471	77.234	55.765	54.339	61.402	64.653
Hip Abduction/Adduction	Weight Acceptance	-19.700	-14.700	-21.200	-22.200	-26.900	-14.700	-27.500	-21.000	-28.800	-9.100	-28.400	-9.700	-24.100	15.400	-19.900	-14.700	-27.700	-16.900	-20.400	-12.700	-24.460	-12.030
(Abd/Add)	Propulsion	33.700	35.700	38.300	39.500	38.100	35.100	39.000	34.000	40.800	34.800	43.400	37.400	37.900	39.300	38.500	34.600	33.400	39.700	36.500	42.200	37.960	37.230
Hip Abduction ROM		53.400	50.400	59.500	61.700	65.000	49.800	66.500	55.000	69.600	43.900	71.800	47.100	62.000	23.900	58.400	49.300	61.100	56.600	56.900	54.900	62.420	49.260
Hip Angular Velocity	(Deg/s)	61.521	53.904	68.627	62.703	76.381	52.366	72.519	62.217	81.786	47.821	84.371	46.267	71.511	26.526	68.625	54.717	71.882	69.278	66.941	56.715	72.417	53.251
Stride Length	Sagittal (m)	1.000	0.940	0.970	1.080	0.860	1.210	0.860	0.940	0.990	0.940	0.870	1.070	0.930	0.830	0.860	0.940	0.690	0.970	0.920	0.980	0.895	0.990
	Frontal (m)	0.730	0.840	0.740	0.810	0.820	0.770	0.830	0.800	0.870	0.810	0.910	0.810	0.860	0.850	0.740	0.880	0.860	0.710	0.810	0.880	0.817	0.816
	Total (m)	1.238	1.261	1.220	1.350	1.188	1.434	1.195	1.234	1.318	1.241	1.259	1.342	1.267	1.188	1.135	1.288	1.103	1.202	1.226	1.317	1.215	1.286
Stride Velocity	(m/s)	1.426	1.348	1.407	1.372	1.396	1.508	1.303	1.396	1.549	1.352	1.479	1.318	1.461	1.319	1.333	1.429	1.297	1.471	1.442	1.361	1.409	1.387
Blade Time on Ice (s)	Weight Acceptance	5.705	4.804	7.090	6.239	8.508	7.741	9.843	9.242	11.277	10.710	12.645	12.145	14.014	13.646	15.348	15.098	16.750	16.533	18.118	17.884	11.930	11.404
	Propulsion	6.573	5.739	7.957	7.223	9.359	8.692	10.760	10.126	12.128	11.628	13.496	13.163	14.881	14.547	16.199	15.999	17.600	17.350	18.968	18.852	12.792	12.332
	Total	0.868	0.935	0.867	0.984	0.851	0.951	0.917	0.884	0.851	0.918	0.851	1.018	0.867	0.901	0.851	0.901	0.850	0.817	0.850	0.968	0.862	0.928

Subject Three Kinematics (18mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	21.300	11.600	16.600	12.900	19.500	10.100	17.400	11.700	11.500	15.700	16.000	10.700	17.400	13.600	12.300	14.500	16.100	12.800	10.200	13.900	15.830	12.750
(D/P)	Propulsion	-3.400	10.700	8.700	11.400	6.600	7.300	5.800	6.700	8.900	4.700	1.700	10.400	1.000	7.300	0.800	8.800	2.700	11.200	2.100	5.200	3.490	8.370
Ankle ROM		17.900	22.300	25.300	24.300	26.100	17.400	23.200	18.400	20.400	20.400	17.700	21.100	18.400	20.900	13.100	23.300	18.800	24.000	12.300	19.100	19.320	21.120
Ankle Angular Velocity	(Deg/s)	21.909	23.876	34.469	29.137	34.029	22.194	29.554	21.198	23.972	23.077	20.023	26.342	24.533	26.092	13.775	27.938	25.033	31.291	19.401	24.362	24.670	25.551
Knee Flexion	Weight Acceptance	83.200	81.400	89.100	81.600	93.800	79.900	94.200	77.700	86.500	84.300	91.100	82.600	81.600	85.400	86.700	82.100	84.800	85.100	81.900	80.100	87.290	82.020
	Propulsion	21.900	13.000	17.800	9.400	16.300	12.100	17.400	14.000	14.900	20.700	20.000	9.000	19.900	16.200	24.700	12.100	29.800	13.700	24.200	21.900	20.690	14.210
Knee Extension (ROM)		61.300	68.400	71.300	72.200	77.500	67.800	76.800	63.700	71.600	63.600	71.100	73.600	61.700	69.200	62.000	70.000	55.000	71.400	57.700	58.200	66.600	67.810
Knee Angular Velocity	(Deg/s)	75.031	73.233	97.139	86.571	101.043	86.480	97.834	73.387	84.136	71.946	80.430	91.885	82.267	86.392	65.195	83.933	73.236	93.090	91.009	74.235	84.732	82.115
Hip Flexion	Weight Acceptance	78.000	82.700	81.400	84.600	89.600	85.200	90.700	86.000	88.800	86.300	89.300	86.700	80.900	91.400	83.800	88.500	81.800	87.700	78.100	81.200	84.240	86.030
	Propulsion	25.400	33.000	33.900	15.100	24.800	19.900	26.100	19.700	30.400	16.900	28.700	32.200	21.900	19.500	29.600	22.900	20.500	16.900	24.000	22.100	26.530	21.820
Hip Extension ROM		52.600	49.700	47.500	69.500	64.800	65.300	64.600	66.300	58.400	69.400	60.600	54.500	59.000	71.900	54.200	65.600	61.300	70.800	54.100	59.100	57.710	64.210
Hip Angular Velocity	(Deg/s)	64.382	53.212	64.714	83.333	84.485	83.291	82.293	76.382	68.625	78.507	68.552	68.040	78.667	89.763	56.993	78.657	81.625	92.308	85.331	75.383	73.567	77.888
Hip Abduction/Adduction	Weight Acceptance	-24.600	-22.300	-22.500	-27.900	-24.600	-17.600	-25.400	-26.000	-26.500	-19.800	-21.400	-19.300	-19.300	14.600	-26.300	-13.500	-19.900	-25.200	-19.800	-18.500	-23.030	-17.550
(Abd/Add)	Propulsion	35.600	42.600	35.500	36.100	34.100	37.200	36.600	34.700	33.700	34.900	34.400	37.300	35.100	40.200	33.600	41.200	31.700	35.100	32.600	41.900	34.290	38.120
Hip Abduction ROM		60.200	64.900	58.000	64.000	58.700	54.800	62.000	60.700	60.200	54.700	55.800	56.600	54.400	25.600	59.900	54.700	51.600	60.300	52.400	60.400	57.320	55.670
Hip Angular Velocity	(Deg/s)	73.684	69.486	79.019	76.739	76.532	69.898	78.981	69.931	70.740	61.878	63.122	70.662	72.533	31.960	62.986	65.588	68.708	78.618	82.650	77.041	72.896	67.180
Stride Length	Sagittal (m)	0.770	0.790	0.710	0.970	1.060	0.970	1.050	0.970	1.100	0.930	0.960	0.950	1.210	1.000	1.090	0.820	1.020	1.010	1.140	1.140	1.011	0.955
	Frontal (m)	0.82	0.840	0.9	0.910	0.95	0.980	0.87	0.910	0.96	1.000	0.86	0.880	0.92	0.940	0.9	0.850	0.83	0.840	0.82	0.910	0.883	0.906
	Total (m)	1.125	1.153	1.146	1.330	1.423	1.379	1.364	1.330	1.460	1.366	1.289	1.295	1.520	1.372	1.414	1.181	1.315	1.314	1.404	1.459	1.346	1.318
Stride Velocity	(m/s)	1.377	1.235	1.562	1.595	1.856	1.759	1.737	1.532	1.716	1.545	1.458	1.617	2.027	1.713	1.486	1.416	1.751	1.713	2.215	1.861	1.718	1.598
Blade Time on Ice (s)	Weight Acceptance	4.404	4.654	5.755	6.122	7.007	7.457	8.274	8.758	9.609	10.076	10.977	11.494	30.230	12.829	31.464	14.097	48.281	15.465	49.516	16.716	20.552	10.767
	Propulsion	5.221	5.588	6.489	6.956	7.774	8.241	9.059	9.626	10.460	10.960	11.861	12.295	30.980	13.630	32.415	14.931	49.032	16.232	50.150	17.500	21.344	11.596
	Total	0.817	0.934	0.734	0.834	0.767	0.784	0.785	0.868	0.851	0.884	0.884	0.801	0.750	0.801	0.951	0.834	0.751	0.767	0.634	0.784	0.792	0.829

Subject Four Kinematics (8mph)

Variable	Stride Number	1 Own	1 Mako	2 Own	2 Mako	3 Own	3 Mako	4 Own	4 Mako	5 Own	5 Mako	6 Own	6 Mako	7 Own	7 Mako	8 Own	8 Mako	9 Own	9 Mako	10 Own	10 Mako	Average Own	Average Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	18.100	19.500	19.700	19.000	20.600	21.000	22.500	19.900	23.200	21.500	22.200	16.900	18.700	17.100	22.400	20.100	21.200	22.400	21.800	20.100	21.040	19.750
(D/P)	Propulsion	-7.400	8.300	0.400	5.100	-3.500	6.800	-13.900	5.000	1.200	7.800	-8.600	6.200	-6.200	4.500	3.400	2.000	-11.300	5.500	4.300	0.400	-4.160	5.160
Ankle ROM		10.700	27.800	20.100	24.100	17.100	27.800	8.600	24.900	24.400	29.300	13.600	23.100	12.500	21.600	25.800	22.100	9.900	27.900	26.100	20.500	16.880	24.910
Ankle Angular Velocity	(Deg/s)	12.341	37.017	25.638	30.087	20.094	34.707	8.884	31.086	28.111	39.015	16.626	29.464	13.631	27.000	29.758	28.814	10.410	38.011	26.074	24.551	19.157	31.975
Knee Flexion	Weight Acceptance	72.000	70.000	73.500	77.200	68.800	73.400	73.000	75.300	75.100	71.200	74.600	74.700	74.700	75.800	71.700	70.500	74.100	73.400	77.500	78.300	73.500	73.980
	Propulsion	36.700	23.800	32.600	26.800	27.000	25.400	38.000	29.300	25.500	26.900	42.300	26.000	38.400	26.300	32.000	34.400	40.600	29.100	38.500	32.500	35.160	28.050
Knee Extension (ROM)		35.300	46.200	40.900	50.400	41.800	48.000	35.000	46.000	49.600	44.300	32.300	48.700	36.300	49.500	39.700	36.100	33.500	44.300	39.000	45.800	38.340	45.930
Knee Angular Velocity	(Deg/s)	40.715	61.518	52.168	62.921	49.119	59.925	36.157	57.428	57.143	58.988	39.487	62.117	39.586	61.875	45.790	47.066	35.226	60.354	38.961	54.850	43.435	58.704
Hip Flexion	Weight Acceptance	74.700	68.100	79.200	73.200	76.500	71.300	72.400	78.700	73.300	68.400	71.000	71.700	71.600	75.300	82.400	70.300	71.900	77.800	79.000	78.800	75.200	73.360
	Propulsion	46.700	25.500	35.500	29.700	26.000	28.900	34.100	26.800	30.800	25.100	48.100	26.800	37.500	23.900	36.100	34.400	37.100	24.700	28.900	28.700	36.080	27.450
Hip Extension ROM		28.000	42.600	43.700	43.500	50.500	42.400	38.300	51.900	42.500	43.300	22.900	44.900	34.100	51.400	46.300	35.900	34.800	53.100	50.100	50.100	39.120	45.910
Hip Angular Velocity	(Deg/s)	32.295	56.724	55.740	54.307	59.342	52.934	39.566	64.794	48.963	57.656	27.995	57.270	37.186	64.250	53.403	46.806	36.593	72.343	50.050	60.000	44.113	58.709
Hip Abduction/Adduction	Weight Acceptance	-4.700	-3.900	-5.100	-1.500	-2.900	-1.100	-1.500	-1.700	-3.700	-1.700	-2.100	-1.000	-1.000	-2.400	-6.000	-0.900	-0.600	-1.200	-5.500	-2.800	-3.310	-1.820
(Abd/Add)	Propulsion	30.500	29.700	34.100	31.500	33.200	30.500	32.800	30.300	30.000	28.300	32.200	29.000	34.200	30.400	35.000	31.700	37.800	29.400	35.800	32.800	33.560	30.360
Hip Abduction ROM		35.200	33.600	39.200	33.000	36.100	31.600	34.300	32.000	33.700	30.000	34.300	30.000	35.200	32.800	41.000	32.600	38.400	30.600	41.300	35.600	36.870	32.180
Hip Angular Velocity	(Deg/s)	40.600	44.740	50.000	41.199	42.421	39.451	35.434	39.950	38.825	39.947	41.932	38.265	38.386	41.000	47.290	42.503	40.379	41.689	41.259	42.635	41.652	41.138
Stride Length	Sagittal (m)	0.870	0.980	1.000	0.800	0.910	0.820	0.820	0.920	1.100	0.880	0.610	0.850	0.970	0.880	0.920	0.850	0.920	0.930	0.980	0.650	0.910	0.856
	Frontal (m)	0.740	0.720	0.880	0.710	0.590	0.680	0.670	0.720	0.710	0.570	0.630	0.690	0.700	0.710	0.700	0.700	0.650	0.610	0.750	0.780	0.702	0.689
	Total (m)	1.142	1.216	1.332	1.070	1.085	1.065	1.059	1.168	1.309	1.048	0.877	1.095	1.196	1.131	1.156	1.101	1.126	1.112	1.234	1.015	1.152	1.102
Stride Velocity	(m/s)	1.317	1.619	1.699	1.335	1.274	1.330	1.094	1.458	1.508	1.396	1.072	1.396	1.304	1.413	1.333	1.436	1.184	1.515	1.233	1.216	1.302	1.412
Blade Time on Ice (s)	Weight Acceptance	11.044	5.872	12.612	7.223	13.997	8.575	15.515	9.993	17.183	11.361	18.718	12.712	20.220	14.114	21.805	15.532	23.323	16.933	24.891	18.284	17.931	12.060
	Propulsion	11.911	6.623	13.396	8.024	14.848	9.376	16.483	10.794	18.051	12.112	19.536	13.496	21.137	14.914	22.672	16.299	24.274	17.667	25.892	19.119	18.820	12.842
	Total	0.867	0.751	0.784	0.801	0.851	0.801	0.968	0.801	0.868	0.751	0.818	0.784	0.917	0.8	0.867	0.767	0.951	0.734	1.001	0.835	0.889	0.783

Subject Four Kinematics (11mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	20.700	22.500	20.100	18.900	19.400	21.100	25.200	19.800	15.600	20.100	18.500	19.400	18.900	21.100	16.000	19.100	11.300	21.900	18.600	21.000	18.430	20.490
(D/P)	Propulsion	-7.300	11.000	5.800	4.900	13.900	9.000	10.800	8.800	6.100	6.900	7.900	5.900	2.800	5.500	-5.200	7.200	0.000	4.700	-8.000	14.400	2.680	7.830
Ankle ROM		13.400	33.500	25.900	23.800	33.300	30.100	36.000	28.600	21.700	27.000	26.400	25.300	21.700	26.600	10.800	26.300	11.300	26.600	10.600	35.400	21.110	28.320
Ankle Angular Velocity	(Deg/s)	17.471	48.977	33.036	31.691	42.474	41.008	45.918	45.110	28.292	35.952	31.655	32.986	25.988	37.946	13.776	34.289	14.413	40.923	13.233	51.754	26.626	40.064
Knee Flexion	Weight Acceptance	75.300	72.900	75.000	76.000	73.600	74.500	73.200	77.300	72.800	76.700	78.300	76.500	74.800	75.700	77.200	78.500	74.300	70.900	75.100	77.400	74.960	75.640
	Propulsion	29.600	16.400	36.100	32.600	27.700	23.200	36.900	19.100	30.600	26.500	29.800	31.300	32.100	25.800	31.800	23.300	32.400	24.700	33.800	28.000	32.080	25.090
Knee Extension (ROM)		45.700	56.500	38.900	43.400	45.900	51.300	36.300	58.200	42.200	50.200	48.500	45.200	42.700	49.900	45.400	55.200	41.900	46.200	41.300	49.400	42.880	50.550
Knee Angular Velocity	(Deg/s)	59.583	82.602	49.617	57.790	58.546	69.891	46.301	91.798	55.020	66.844	58.153	58.931	51.138	71.184	57.908	71.969	53.444	71.077	51.561	72.222	54.127	71.431
Hip Flexion	Weight Acceptance	74.500	69.500	75.500	75.900	76.300	80.600	74.300	73.200	80.000	76.400	76.800	72.800	75.700	72.000	76.700	78.300	76.300	68.000	77.900	76.200	76.400	74.290
	Propulsion	38.900	23.100	41.100	32.400	41.300	28.500	37.500	21.700	29.900	28.300	35.100	32.500	33.900	21.700	31.400	27.000	37.500	27.400	36.700	30.400	36.330	27.300
Hip Extension ROM		35.600	46.400	34.400	43.500	35.000	52.100	36.800	51.500	50.100	48.100	41.700	40.300	41.800	50.300	45.300	51.300	38.800	40.600	41.200	45.800	40.070	46.990
Hip Angular Velocity	(Deg/s)	46.415	67.836	43.878	57.923	44.643	70.981	46.939	81.230	65.319	64.048	50.000	52.542	50.060	71.755	57.781	66.884	49.490	62.462	51.436	66.959	50.596	66.262
Hip Abduction/Adduction	Weight Acceptance	-3.700	-0.900	-7.800	-6.800	-2.300	-5.000	-4.300	-2.800	-2.300	-3.300	-2.300	-2.400	-5.000	-3.600	-4.500	-5.600	-2.000	-3.100	-1.900	-0.800	-3.610	-3.430
(Abd/Add)	Propulsion	29.200	31.300	31.400	33.300	32.500	33.300	30.700	29.400	31.000	30.600	33.800	32.000	36.700	28.200	30.400	33.000	37.300	33.400	30.600	33.200	32.360	31.770
Hip Abduction ROM		32.900	32.200	39.200	40.100	34.800	38.300	35.000	32.200	33.300	33.900	36.100	34.400	41.700	31.800	34.900	38.600	39.300	36.500	32.500	34.000	35.970	35.200
Hip Angular Velocity	(Deg/s)	42.894	47.076	50.000	53.395	44.388	52.180	44.643	50.789	43.416	45.140	43.285	44.850	49.940	45.364	44.515	50.326	50.128	56.154	40.574	49.708	45.378	49.498
Stride Length	Sagittal (m)	1.030	1.080	1.060	0.840	0.920	1.080	0.980	1.190	1.080	0.910	1.030	0.900	1.010	1.020	1.040	1.030	0.950	0.810	0.910	0.890	1.001	0.975
	Frontal (m)	0.670	0.620	0.780	0.780	0.850	0.770	0.780	0.590	0.760	0.780	0.810	0.750	0.760	0.710	0.730	0.750	0.640	0.820	0.800	0.770	0.758	0.734
	Total (m)	1.229	1.245	1.316	1.146	1.253	1.326	1.253	1.328	1.321	1.199	1.310	1.172	1.264	1.243	1.271	1.274	1.145	1.153	1.212	1.177	1.257	1.226
Stride Velocity	(m/s)	1.602	1.821	1.679	1.526	1.598	1.807	1.598	2.095	1.722	1.596	1.571	1.527	1.514	1.773	1.621	1.661	1.461	1.773	1.513	1.721	1.588	1.730
Blade Time on Ice (s)	Weight Acceptance	4.254	5.021	5.605	6.272	7.007	7.590	8.408	8.858	9.843	10.043	11.211	11.361	12.645	12.712	14.080	13.997	15.515	15.382	16.933	16.666	10.550	10.790
	Propulsion	5.021	5.705	6.389	7.023	7.791	8.324	9.192	9.492	10.610	10.794	12.045	12.128	13.480	13.413	14.864	14.764	16.299	16.032	17.734	17.350	11.343	11.503
	Total	0.767	0.684	0.784	0.751	0.784	0.734	0.784	0.634	0.767	0.751	0.834	0.767	0.835	0.701	0.784	0.767	0.784	0.650	0.801	0.684	0.792	0.712

Subject Four Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	15.900	16.400	18.900	27.400	15.400	18.500	16.300	16.200	16.300	21.200	17.200	22.000	14.700	20.600	13.000	22.000	16.900	18.900	15.700	22.600	16.030	20.580
(D/P)	Propulsion	-17.400	7.400	-5.800	1.100	7.900	8.300	-9.300	7.900	-10.200	6.000	-3.100	9.300	-2.000	3.100	-15.900	9.900	-4.000	9.900	1.400	4.000	-5.840	6.690
Ankle ROM		-1.500	23.800	13.100	28.500	23.300	26.800	7.000	24.100	6.100	27.200	14.100	31.300	12.700	23.700	-2.900	31.900	12.900	28.800	17.100	26.600	10.190	27.270
Ankle Angular Velocity	(Deg/s)	-2.366	34.795	17.443	41.667	35.791	43.366	9.537	37.077	8.123	44.084	18.775	48.080	17.302	38.350	-3.867	47.826	17.992	45.426	25.000	38.889	14.373	41.956
Knee Flexion	Weight Acceptance	72.800	75.700	77.500	77.600	75.400	72.500	76.900	79.000	74.300	77.600	74.000	77.900	76.100	73.900	76.100	82.100	75.200	76.000	74.000	86.100	75.230	77.840
	Propulsion	41.100	26.500	29.500	29.800	31.600	25.300	36.000	20.700	35.400	24.100	26.800	33.900	26.200	28.600	39.600	27.000	31.200	21.800	30.500	28.200	32.790	26.590
Knee Extension (ROM)		31.700	49.200	48.000	47.800	43.800	47.200	40.900	58.300	38.900	53.500	47.200	44.000	49.900	45.300	36.500	55.100	44.000	54.200	43.500	57.900	42.440	51.250
Knee Angular Velocity	(Deg/s)	50.000	71.930	63.915	69.883	67.281	76.375	55.722	89.692	51.798	86.710	62.850	67.588	67.984	73.301	48.667	82.609	61.367	85.489	63.596	84.649	59.318	78.823
Hip Flexion	Weight Acceptance	76.400	69.100	76.400	68.700	79.400	70.200	78.300	80.400	76.300	69.200	72.600	66.100	79.200	61.500	76.900	76.500	74.500	70.300	76.500	79.000	76.650	71.100
	Propulsion	34.800	37.400	27.900	23.000	25.500	27.700	37.800	23.400	38.800	26.400	27.100	26.400	23.200	34.500	26.200	25.300	28.700	26.000	25.900	30.100	29.590	28.020
Hip Extension ROM		41.600	31.700	48.500	45.700	53.900	42.500	40.500	57.000	37.500	42.800	45.500	39.700	56.000	27.000	50.700	51.200	45.800	44.300	50.600	48.900	47.060	43.080
Hip Angular Velocity	(Deg/s)	65.615	46.345	64.581	66.813	82.796	68.770	55.177	87.692	49.933	69.368	60.586	60.983	76.294	43.689	67.600	76.762	63.877	69.874	73.977	71.491	66.044	66.179
Hip Abduction/Adduction	Weight Acceptance	-0.600	-4.500	-0.700	-1.200	-2.300	-2.600	-2.500	-1.800	-0.600	-0.600	-1.300	-1.500	-0.800	-1.500	-1.600	-3.100	-1.200	-2.800	-0.900	-1.800	-1.250	-2.140
(Abd/Add)	Propulsion	28.800	34.600	29.400	32.400	35.300	29.300	37.300	30.200	33.200	36.400	33.200	30.300	29.900	35.400	33.400	31.200	33.900	36.700	34.000	37.900	32.840	33.440
Hip Abduction ROM		29.400	39.100	30.100	33.600	37.600	31.900	39.800	32.000	33.800	37.000	34.500	31.800	30.700	36.900	35.000	34.300	35.100	39.500	34.900	39.700	34.090	35.580
Hip Angular Velocity	(Deg/s)	46.372	57.164	40.080	49.123	57.757	51.618	54.223	49.231	45.007	59.968	45.939	48.848	41.826	59.709	46.667	51.424	48.954	62.303	51.023	58.041	47.785	54.743
Stride Length	Sagittal (m)	1.070	1.210	1.230	1.040	1.190	1.100	0.870	1.140	0.920	1.010	1.260	0.860	1.190	0.970	0.970	1.040	0.940	1.010	1.020	0.880	1.066	1.026
	Frontal (m)	0.720	0.990	0.720	0.690	0.830	0.850	0.840	0.740	0.650	0.740	0.750	0.790	0.760	0.920	0.810	0.840	0.860	0.950	0.800	0.800	0.774	0.831
	Total (m)	1.290	1.563	1.425	1.248	1.451	1.390	1.209	1.359	1.126	1.252	1.466	1.168	1.412	1.337	1.264	1.337	1.274	1.387	1.296	1.189	1.321	1.323
Stride Velocity	(m/s)	2.034	2.286	1.898	1.825	2.229	2.249	1.648	2.091	1.500	2.029	1.952	1.794	1.924	2.163	1.685	2.004	1.777	2.187	1.895	1.739	1.854	2.037
Blade Time on Ice (s)	Weight Acceptance	11.728	7.807	12.946	9.009	14.280	10.176	15.498	11.311	16.816	12.479	18.151	13.613	19.452	14.814	20.754	15.949	22.055	17.150	23.323	18.318	17.500	13.063
	Propulsion	12.362	8.491	13.697	9.693	14.931	10.794	16.232	11.961	17.567	13.096	18.902	14.264	20.186	15.432	21.504	16.616	22.772	17.784	24.007	19.002	18.216	13.713
	Total	0.634	0.684	0.751	0.684	0.651	0.618	0.734	0.650	0.751	0.617	0.751	0.651	0.734	0.618	0.750	0.667	0.717	0.634	0.684	0.684	0.716	0.651

Subject Four Kinematics (15mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	21.100	17.600	16.000	20.200	20.700	23.800	23.900	22.000	19.000	21.700	20.300	24.300	21.900	19.300	22.500	24.400	13.300	21.300	23.700	23.200	20.240	21.780
(D/P)	Propulsion	4.700	7.900	5.300	11.600	3.000	12.100	2.200	14.800	-16.500	2.700	-7.700	7.200	2.100	10.400	-5.200	10.700	-3.400	9.100	0.700	11.900	-1.480	9.840
Ankle ROM		25.800	25.500	21.300	31.800	23.700	35.900	26.100	36.800	2.500	24.400	12.600	31.500	24.000	29.700	17.300	35.100	9.900	30.400	24.400	35.100	18.760	31.620
Ankle Angular Velocity	(Deg/s)	39.692	43.664	35.500	51.540	40.582	55.146	40.092	64.903	3.655	41.781	19.355	52.500	36.866	49.418	25.292	56.888	15.615	49.191	37.538	56.796	29.419	52.183
Knee Flexion	Weight Acceptance	83.700	80.000	71.700	80.600	77.100	84.900	86.200	79.100	77.100	79.700	78.700	84.800	78.000	82.000	78.700	79.600	79.100	86.000	83.300	85.400	79.360	82.210
	Propulsion	23.100	23.000	30.800	21.500	29.100	13.400	29.500	11.400	38.700	19.800	35.000	21.600	26.900	18.400	30.600	15.900	33.500	23.000	30.500	20.400	30.770	18.840
Knee Extension (ROM)		60.600	57.000	40.900	59.100	48.000	71.500	56.700	67.700	38.400	59.900	43.700	63.200	51.100	63.600	48.100	63.700	45.600	63.000	52.800	65.000	48.590	63.370
Knee Angular Velocity	(Deg/s)	93.231	97.603	68.167	95.786	82.192	109.831	87.097	119.400	56.140	102.568	67.127	105.333	78.495	105.824	70.322	103.241	71.924	101.942	81.231	105.178	75.593	104.671
Hip Flexion	Weight Acceptance	74.900	72.800	73.100	76.000	77.000	77.300	80.900	69.500	76.600	65.100	76.600	74.600	75.700	72.300	73.800	73.900	82.900	84.800	77.800	78.400	76.930	74.470
	Propulsion	26.600	26.800	25.300	20.200	31.600	18.500	33.700	21.600	31.500	29.100	25.300	28.400	36.500	19.400	28.300	25.900	34.000	22.800	29.800	17.800	30.260	23.050
Hip Extension ROM		48.300	46.000	47.800	55.800	45.400	58.800	47.200	47.900	45.100	36.000	51.300	46.200	39.200	52.900	45.500	48.000	48.900	62.000	48.000	60.600	46.670	51.420
Hip Angular Velocity	(Deg/s)	74.308	78.767	79.667	90.438	77.740	90.323	72.504	84.480	65.936	61.644	78.802	77.000	60.215	88.020	66.520	77.796	77.129	100.324	73.846	98.058	72.667	84.685
Hip Abduction/Adduction	Weight Acceptance	1.600	-1.700	-0.100	-1.800	-3.500	-2.600	-2.400	-3.200	-1.500	-2.300	-1.700	-1.300	-1.500	-3.900	-2.400	-6.200	-7.700	-2.900	-0.900	-1.200	-2.010	-2.710
(Abd/Add)	Propulsion	32.000	35.500	38.100	29.700	36.700	31.800	32.600	31.100	39.000	36.700	36.000	36.100	32.400	31.000	35.800	33.400	33.200	36.800	36.300	34.900	35.210	33.700
Hip Abduction ROM		30.400	37.200	38.200	31.500	40.200	34.400	35.000	34.300	40.500	39.000	37.700	37.400	33.900	34.900	38.200	39.600	40.900	39.700	37.200	36.100	37.220	36.410
Hip Angular Velocity	(Deg/s)	46.769	63.699	63.667	51.053	68.836	52.842	53.763	60.494	59.211	66.781	57.911	62.333	52.074	58.070	55.848	64.182	64.511	64.239	57.231	58.414	57.982	60.211
Stride Length	Sagittal (m)	1.180	0.910	1.110	1.020	1.000	1.030	0.770	0.990	0.890	0.900	1.030	0.950	0.820	1.100	0.970	1.020	1.020	1.000	1.050	1.070	0.984	0.999
	Frontal (m)	0.680	0.800	0.790	0.740	0.810	0.900	0.710	0.770	0.800	0.890	0.810	0.740	0.710	0.790	0.760	0.810	0.810	0.890	0.860	0.770	0.774	0.810
	Total (m)	1.362	1.212	1.362	1.260	1.287	1.368	1.047	1.254	1.197	1.266	1.310	1.204	1.085	1.354	1.232	1.302	1.302	1.339	1.357	1.318	1.254	1.288
Stride Velocity	(m/s)	2.095	2.075	2.271	2.042	2.204	2.101	1.609	2.212	1.750	2.167	2.013	2.007	1.666	2.253	1.802	2.111	2.054	2.166	2.088	2.133	1.955	2.127
Blade Time on Ice (s)	Weight Acceptance	1.101	5.305	2.302	6.406	3.470	7.540	4.604	8.758	5.772	9.876	6.973	10.994	8.141	12.145	9.309	13.313	10.527	14.447	11.678	15.598	6.388	10.438
	Propulsion	1.751	5.889	2.902	7.023	4.054	8.191	5.255	9.325	6.456	10.460	7.624	11.594	8.792	12.746	9.993	13.930	11.161	15.065	12.328	16.216	7.032	11.044
	Total	0.650	0.584	0.600	0.617	0.584	0.651	0.651	0.567	0.684	0.584	0.651	0.600	0.651	0.601	0.684	0.617	0.634	0.618	0.650	0.618	0.644	0.606

Subject Four Kinematics (18mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	17.300	18.600	18.500	20.800	21.700	18.300	20.900	17.600	17.600	22.500	21.900	16.000	22.800	22.700	20.200	21.800	17.200	19.500	18.600	16.700	19.670	19.450
(D/P)	Propulsion	1.100	15.400	-11.700	0.400	6.300	4.800	7.400	9.800	11.700	13.700	0.100	7.500	2.400	3.100	-6.700	11.000	0.700	8.900	8.100	10.100	1.940	8.470
Ankle ROM		18.400	34.000	6.800	21.200	28.000	23.100	28.300	27.400	29.300	36.200	22.000	23.500	25.200	25.800	13.500	32.800	17.900	28.400	26.700	26.800	21.610	27.920
Ankle Angular Velocity	(Deg/s)	28.264	55.105	9.264	35.333	40.936	41.924	48.459	48.325	39.015	63.845	31.384	44.007	39.748	44.178	23.116	57.746	26.170	47.333	43.274	45.890	32.963	48.369
Knee Flexion	Weight Acceptance	71.400	87.000	73.100	84.000	34.200	86.600	74.400	80.100	75.700	83.300	79.600	84.300	79.000	82.800	86.200	91.000	82.400	88.100	86.800	84.100	74.280	85.130
	Propulsion	34.700	20.000	30.200	32.500	29.900	23.600	28.400	18.600	20.400	25.800	29.900	22.400	27.100	26.100	39.300	20.400	28.300	24.700	26.200	25.400	29.440	23.950
Knee Extension (ROM)		36.700	67.000	42.900	51.500	4.300	63.000	46.000	61.500	55.300	57.500	49.700	61.900	51.900	56.700	46.900	70.600	54.100	63.400	60.600	58.700	44.840	61.180
Knee Angular Velocity	(Deg/s)	56.375	108.590	58.447	85.833	6.287	114.338	78.767	108.466	73.635	101.411	70.899	115.918	81.861	97.089	80.308	124.296	79.094	105.667	98.217	100.514	68.389	106.212
Hip Flexion	Weight Acceptance	78.700	84.500	75.900	79.200	79.800	84.900	78.800	78.000	77.600	80.200	79.500	82.800	77.300	84.700	78.000	84.700	78.100	81.000	82.000	84.200	78.570	82.420
	Propulsion	37.200	22.900	29.600	26.600	39.900	19.700	26.600	28.100	33.500	21.400	28.300	25.100	21.300	20.500	23.500	26.600	23.900	26.100	31.000	20.600	29.480	23.760
Hip Extension ROM		41.500	61.600	46.300	52.600	39.900	65.200	52.200	49.900	44.100	58.800	51.200	57.700	56.000	64.200	54.500	58.100	54.200	54.900	51.000	63.600	49.090	58.660
Hip Angular Velocity	(Deg/s)	63.748	99.838	63.079	87.667	58.333	118.330	89.384	88.007	58.722	103.704	73.039	108.052	88.328	109.932	93.322	102.289	79.240	91.500	82.658	108.904	74.985	101.822
Hip Abduction/Adduction	Weight Acceptance	-1.000	-1.100	-3.200	-3.200	-4.600	-0.600	-3.600	-2.200	-1.200	-0.800	-2.900	-1.700	-4.100	4.000	-0.300	3.500	-3.500	-2.500	-3.300	-0.200	-2.770	-0.480
(Abd/Add)	Propulsion	35.100	36.000	33.100	35.200	36.900	32.200	39.700	34.000	32.500	36.900	35.300	35.600	32.700	35.300	30.300	36.800	37.000	37.900	36.200	36.100	34.880	35.600
Hip Abduction ROM		36.100	37.100	36.300	38.400	41.500	32.800	43.300	36.200	33.700	37.700	38.200	37.300	36.800	31.300	30.600	33.300	40.500	40.400	39.500	36.300	37.650	36.080
Hip Angular Velocity	(Deg/s)	55.453	60.130	49.455	64.000	60.673	59.528	74.144	63.845	44.874	66.490	54.494	69.850	58.044	53.596	52.397	58.627	59.211	67.333	64.019	62.158	57.276	62.556
Stride Length	Sagittal (m)	1.100	1.110	0.820	1.140	0.780	1.150	1.200	1.000	0.960	0.970	1.250	1.170	1.180	1.010	1.120	1.010	1.110	0.950	1.180	1.040	1.070	1.055
	Frontal (m)	0.830	0.740	0.740	0.750	0.800	0.790	0.640	0.890	0.780	0.630	0.760	0.850	0.790	0.780	0.880	0.820	0.750	0.880	0.740	0.710	0.771	0.784
	Total (m)	1.378	1.334	1.105	1.365	1.117	1.395	1.360	1.339	1.237	1.157	1.463	1.446	1.420	1.276	1.424	1.301	1.340	1.295	1.393	1.259	1.324	1.317
Stride Velocity	(m/s)	2.117	2.162	1.505	2.274	1.634	2.532	2.329	2.361	1.647	2.040	2.087	2.708	2.240	2.185	2.439	2.290	1.959	2.158	2.257	2.156	2.021	2.287
Blade Time on Ice (s)	Weight Acceptance	15.148	10.010	16.383	11.161	17.650	12.278	18.918	13.313	20.153	14.414	21.504	15.498	22.722	16.516	23.890	17.600	25.025	18.702	26.259	19.836	20.765	14.933
	Propulsion	15.799	10.627	17.117	11.761	18.334	12.829	19.502	13.880	20.904	14.981	22.205	16.032	23.356	17.100	24.474	18.168	25.709	19.302	26.876	20.420	21.428	15.510
	Total	0.651	0.617	0.734	0.600	0.684	0.551	0.584	0.567	0.751	0.567	0.701	0.534	0.634	0.584	0.584	0.568	0.684	0.600	0.617	0.584	0.662	0.577

Subject Five Kinematics (8mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	12.700	9.300	8.600	14.200	8.700	12.300	9.900	16.100	9.300	10.100	7.300	12.200	11.800	11.200	10.600	13.700	9.600	13.300	10.600	14.700	9.910	12.710
(D/P)	Propulsion	1.100	1.600	-3.500	0.800	-3.300	-6.600	-1.200	3.200	-8.900	-7.200	-1.000	-5.600	-11.700	0.900	-14.600	-7.000	-8.400	3.400	-3.300	5.500	-5.480	-1.100
Ankle ROM		13.800	10.900	5.100	15.000	5.400	5.700	8.700	19.300	0.400	2.900	6.300	6.600	0.100	12.100	-4.000	6.700	1.200	16.700	7.300	20.200	4.430	11.610
Ankle Angular Velocity	(Deg/s)	14.271	18.136	5.993	19.973	6.102	8.131	10.636	33.048	0.480	4.462	8.036	8.418	0.125	18.615	-4.706	10.030	1.754	25.037	9.720	28.134	5.241	17.399
Knee Flexion	Weight Acceptance	69.200	66.400	65.300	67.800	68.800	65.000	70.100	64.500	68.800	67.300	66.100	61.700	71.600	61.900	65.600	64.800	64.500	62.700	68.600	62.000	67.860	64.410
	Propulsion	27.800	33.100	29.500	41.500	28.600	33.100	36.800	22.600	40.500	50.000	32.200	39.000	42.700	31.400	47.100	42.300	41.100	36.000	37.300	31.800	36.360	36.080
Knee Extension (ROM)		41.400	33.300	35.800	26.300	40.200	31.900	33.300	41.900	28.300	17.300	33.900	22.700	28.900	30.500	18.500	22.500	23.400	26.700	31.300	30.200	31.500	28.330
Knee Angular Velocity	(Deg/s)	42.813	55.408	42.068	35.020	45.424	45.506	40.709	71.747	33.933	26.615	43.240	28.954	36.080	46.923	21.765	33.683	34.211	40.030	41.678	42.061	38.192	42.595
Hip Flexion	Weight Acceptance	80.300	84.200	83.000	79.100	82.700	82.300	86.100	74.800	82.400	88.700	87.100	82.100	86.900	74.200	84.900	73.600	91.100	70.900	81.100	72.100	84.560	78.200
	Propulsion	40.900	36.200	39.400	38.300	43.700	30.900	48.600	20.500	46.400	44.500	39.300	37.300	38.900	25.500	51.100	30.500	45.100	27.700	47.000	29.000	44.040	32.040
Hip Extension ROM		39.400	48.000	43.600	40.800	39.000	51.400	37.500	54.300	36.000	44.200	47.800	44.800	48.000	48.700	33.800	43.100	46.000	43.200	34.100	43.100	40.520	46.160
Hip Angular Velocity	(Deg/s)	40.745	79.867	51.234	54.328	44.068	73.324	45.844	92.979	43.165	68.000	60.969	57.143	59.925	74.923	39.765	64.521	67.251	64.768	45.406	60.028	49.837	68.988
Hip Abduction/Adduction	Weight Acceptance	0.000	4.700	-0.900	1.900	-0.800	6.500	-6.000	-1.800	-6.700	3.600	-0.800	4.300	-2.300	-1.900	-1.800	-0.800	-5.400	3.000	-3.400	-0.200	-2.810	1.930
(Abd/Add)	Propulsion	30.100	24.300	31.200	17.800	30.100	20.900	19.500	21.100	30.700	22.400	24.700	16.300	18.000	23.400	25.300	18.500	24.000	20.800	26.800	23.600	26.040	20.910
Hip Abduction ROM		30.100	19.600	32.100	15.900	30.900	14.400	25.500	22.900	37.400	18.800	25.500	12.000	20.300	25.300	27.100	19.300	29.400	17.800	30.200	23.800	28.850	18.980
Hip Angular Velocity	(Deg/s)	31.127	32.612	37.720	21.172	34.915	20.542	31.174	39.212	44.844	28.923	32.526	15.306	25.343	38.923	31.882	28.892	42.982	26.687	40.213	33.148	35.273	28.542
Stride Length	Sagittal (m)	0.770	0.980	1.190	0.840	1.010	0.920	0.980	0.940	0.980	0.660	1.200	1.140	1.090	1.170	1.020	0.870	1.300	1.010	1.040	0.910	1.058	0.944
	Frontal (m)	0.650	0.430	0.680	0.410	0.550	0.400	0.480	0.570	0.660	0.280	0.520	0.280	0.400	0.510	0.360	0.490	0.510	0.480	0.510	0.480	0.532	0.433
	Total (m)	1.008	1.070	1.371	0.935	1.150	1.003	1.091	1.099	1.182	0.717	1.308	1.174	1.161	1.276	1.082	0.998	1.396	1.118	1.158	1.029	1.191	1.042
Stride Velocity	(m/s)	1.042	1.781	1.611	1.245	1.299	1.431	1.334	1.882	1.417	1.103	1.668	1.497	1.450	1.964	1.273	1.495	2.042	1.677	1.542	1.433	1.468	1.551
Blade Time on Ice (s)	Weight Acceptance	4.888	11.494	6.306	12.545	7.640	13.780	9.075	14.964	10.360	16.116	11.745	17.217	13.079	18.435	14.381	19.552	15.682	20.687	16.883	21.821	11.004	16.661
	Propulsion	5.855	12.095	7.157	13.296	8.525	14.481	9.893	15.548	11.194	16.766	12.529	18.001	13.880	19.085	15.231	20.220	16.366	21.354	17.634	22.539	11.826	17.339
	Total	0.967	0.601	0.851	0.751	0.885	0.701	0.818	0.584	0.834	0.650	0.784	0.784	0.801	0.650	0.850	0.668	0.684	0.667	0.751	0.718	0.823	0.677

Subject Five Kinematics (11mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	12.500	12.100	8.800	11.100	16.400	12.400	5.700	8.300	10.500	13.800	10.700	11.600	12.600	15.700	12.500	15.700	15.200	14.600	11.500	10.600	11.640	12.590
(D/P)	Propulsion	-5.500	0.400	-0.700	-2.400	-2.700	5.700	-2.200	0.200	-5.700	1.000	-1.900	7.100	-4.700	0.500	-1.800	5.700	1.900	5.200	6.000	4.400	-1.730	2.780
Ankle ROM		7.000	12.500	8.100	8.700	13.700	18.100	3.500	8.500	4.800	14.800	8.800	18.700	7.900	16.200	10.700	21.400	17.100	19.800	17.500	15.000	9.910	15.370
Ankle Angular Velocity	(Deg/s)	10.495	17.832	11.555	13.385	18.242	24.659	5.376	12.744	6.695	23.344	12.256	26.676	10.763	23.110	15.264	29.847	23.297	27.577	23.302	23.659	13.725	22.283
Knee Flexion	Weight Acceptance	66.100	65.200	64.900	67.000	74.300	63.400	65.900	63.400	69.500	65.200	70.000	68.300	68.200	66.800	70.100	65.600	70.300	64.200	67.600	61.900	68.690	65.100
	Propulsion	30.500	30.500	34.800	27.800	37.300	35.000	26.600	30.300	34.400	33.200	30.300	28.100	32.100	33.000	34.200	25.400	34.000	38.000	35.400	26.200	32.960	30.750
Knee Extension (ROM)		35.600	34.700	30.100	39.200	37.000	28.400	39.300	33.100	35.100	32.000	39.700	40.200	36.100	33.800	35.900	40.200	36.300	26.200	32.200	35.700	35.730	34.350
Knee Angular Velocity	(Deg/s)	53.373	49.501	42.939	60.308	49.268	38.692	60.369	49.625	48.954	50.473	55.292	57.347	49.183	48.217	51.213	56.067	49.455	36.490	42.876	56.309	50.292	50.303
Hip Flexion	Weight Acceptance	88.600	78.500	83.500	80.200	82.200	80.900	86.900	88.700	81.900	84.500	79.300	86.300	85.200	77.800	88.400	78.100	81.500	78.100	85.500	79.500	84.300	81.260
	Propulsion	29.800	28.400	37.500	33.700	37.700	37.400	33.200	26.100	35.400	24.900	32.600	25.200	44.900	30.600	37.600	34.900	43.800	28.400	41.100	29.900	37.360	29.950
Hip Extension ROM		58.800	50.100	46.000	46.500	44.500	43.500	53.700	62.600	46.500	59.600	46.700	61.100	40.300	47.200	50.800	43.200	37.700	49.700	44.400	49.600	46.940	51.310
Hip Angular Velocity	(Deg/s)	88.156	71.469	65.621	71.538	59.254	59.264	82.488	93.853	64.854	94.006	65.042	87.161	54.905	67.332	72.468	60.251	51.362	69.220	59.121	78.233	66.327	75.233
Hip Abduction/Adduction	Weight Acceptance	-0.200	1.800	-2.600	2.600	-1.200	-0.500	0.600	-2.400	-1.300	3.100	-1.700	-0.400	-1.200	0.000	-0.600	-0.500	-1.800	-1.500	-1.300	6.600	-1.130	0.880
(Abd/Add)	Propulsion	32.100	27.200	30.000	24.400	27.400	25.300	31.600	25.100	29.000	29.400	30.200	24.800	30.700	25.800	28.100	25.900	25.200	30.800	29.800	32.500	29.410	27.120
Hip Abduction ROM		32.300	25.400	32.600	21.800	28.600	25.800	31.000	27.500	30.300	26.300	31.900	25.200	31.900	25.800	28.700	26.400	27.000	32.300	31.100	25.900	30.540	26.240
Hip Angular Velocity	(Deg/s)	48.426	36.234	46.505	33.538	38.083	35.150	47.619	41.229	42.259	41.483	44.429	35.949	43.460	36.805	40.942	36.820	36.785	44.986	41.411	40.852	42.992	38.305
Stride Length	Sagittal (m)	1.290	1.130	1.120	0.870	1.140	0.890	1.240	1.110	1.120	1.020	1.060	1.170	0.980	1.080	0.940	0.990	0.970	1.180	1.060	0.930	1.092	1.037
	Frontal (m)	0.600	0.570	0.620	0.630	0.630	0.600	0.640	0.620	0.630	0.530	0.670	0.580	0.650	0.580	0.600	0.570	0.610	0.630	0.640	0.660	0.629	0.597
	Total (m)	1.423	1.266	1.280	1.074	1.302	1.073	1.395	1.271	1.285	1.149	1.254	1.306	1.176	1.226	1.115	1.142	1.146	1.338	1.238	1.140	1.262	1.199
Stride Velocity	(m/s)	2.133	1.805	1.826	1.653	1.734	1.462	2.144	1.906	1.792	1.813	1.747	1.863	1.602	1.749	1.591	1.593	1.561	1.863	1.649	1.799	1.778	1.751
Blade Time on Ice (s)	Weight Acceptance	24.424	5.338	25.558	6.523	26.659	7.674	27.894	8.875	29.029	10.060	30.196	11.144	31.381	12.312	32.615	13.480	33.800	14.647	35.001	15.882	29.656	10.594
	Propulsion	25.091	6.039	26.259	7.173	27.410	8.408	28.545	9.542	29.746	10.694	30.914	11.845	32.115	13.013	33.316	14.197	34.534	15.365	35.752	16.516	30.368	11.279
	Total	0.667	0.701	0.701	0.650	0.751	0.734	0.651	0.667	0.717	0.634	0.718	0.701	0.734	0.701	0.701	0.717	0.734	0.718	0.751	0.634	0.713	0.686

Subject Five Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	14.700	12.100	11.400	11.800	12.600	12.200	11.100	13.300	7.600	13.200	11.800	10.600	10.700	15.300	13.200	12.000	12.100	12.500	10.500	10.700	11.570	12.370
(D/P)	Propulsion	7.800	1.200	0.100	4.300	-1.900	2.200	5.100	3.900	-0.100	2.500	-3.300	4.700	6.400	2.500	4.000	4.600	-4.500	2.000	3.500	3.800	1.710	3.170
Ankle ROM		22.500	13.300	11.500	16.100	10.700	14.400	16.200	17.200	7.500	15.700	8.500	15.300	17.100	17.800	17.200	16.600	7.600	14.500	14.000	14.500	13.280	15.540
Ankle Angular Velocity	(Deg/s)	32.895	19.940	15.668	24.138	14.923	20.571	23.143	25.749	11.830	22.397	11.855	21.339	27.715	26.023	27.129	24.850	11.111	20.685	20.468	19.755	19.674	22.545
Knee Flexion	Weight Acceptance	73.700	66.100	65.000	67.300	65.900	64.600	66.900	65.800	69.200	66.100	68.900	65.100	69.200	68.600	73.000	63.900	70.600	66.700	69.600	66.200	69.200	66.040
	Propulsion	27.500	27.100	28.500	31.500	34.300	30.900	39.000	32.100	29.300	27.700	30.200	28.100	26.500	28.300	26.300	28.300	28.400	29.300	32.400	29.500	30.240	29.280
Knee Extension (ROM)		46.200	39.000	36.500	35.800	31.600	33.700	27.900	33.700	39.900	38.400	38.700	37.000	42.700	40.300	46.700	35.600	42.200	37.400	37.200	36.700	38.960	36.760
Knee Angular Velocity	(Deg/s)	67.544	58.471	49.728	53.673	44.073	48.143	39.857	50.449	62.934	54.779	53.975	51.604	69.206	58.918	73.659	53.293	61.696	53.352	54.386	50.000	57.706	53.268
Hip Flexion	Weight Acceptance	83.800	81.000	85.400	82.900	91.000	79.700	92.300	85.600	77.800	81.100	84.600	82.300	83.000	81.000	84.200	81.600	89.000	83.400	91.200	82.500	86.230	82.110
	Propulsion	34.000	31.400	30.400	25.700	23.200	26.700	27.100	23.600	35.500	28.700	31.500	26.200	32.500	28.900	26.600	27.900	29.600	25.000	34.800	32.200	30.520	27.630
Hip Extension ROM		49.800	49.600	55.000	57.200	67.800	53.000	65.200	62.000	42.300	52.400	53.100	56.100	50.500	52.100	57.600	53.700	59.400	58.400	56.400	50.300	55.710	54.480
Hip Angular Velocity	(Deg/s)	72.807	74.363	74.932	85.757	94.561	75.714	93.143	92.814	66.719	74.750	74.059	78.243	81.848	76.170	90.852	80.389	86.842	83.310	82.456	68.529	81.822	79.004
Hip Abduction/Adduction	Weight Acceptance	-3.700	0.000	0.500	-1.000	-2.500	-0.300	-5.900	-4.200	-5.000	-3.300	0.200	-5.900	-4.900	-7.200	-0.300	-3.700	-2.900	-7.000	-2.300	-3.800	-2.680	-3.640
(Abd/Add)	Propulsion	37.700	30.100	29.700	25.600	34.800	27.000	31.800	29.900	29.600	29.300	30.200	25.700	33.200	28.100	33.900	31.000	35.100	34.700	33.100	32.500	32.910	29.390
Hip Abduction ROM		41.400	30.100	29.200	26.600	37.300	27.300	37.700	34.100	34.600	32.600	30.000	31.600	38.100	35.300	34.200	34.700	38.000	41.700	35.400	36.300	35.590	33.030
Hip Angular Velocity	(Deg/s)	60.526	45.127	39.782	39.880	52.022	39.000	53.857	51.048	54.574	46.505	41.841	44.073	61.750	51.608	53.943	51.946	55.556	59.486	51.754	49.455	52.561	47.813
Stride Length	Sagittal (m)	0.980	1.020	1.230	1.070	1.290	1.050	1.270	1.040	0.960	1.080	1.190	1.170	1.170	1.170	1.070	1.160	1.240	1.040	0.990	1.030	1.139	1.083
	Frontal (m)	0.690	0.670	0.700	0.670	0.730	0.640	0.730	0.600	0.700	0.610	0.790	0.680	0.700	0.580	0.670	0.640	0.750	0.640	0.670	0.750	0.713	0.648
	Total (m)	1.199	1.220	1.415	1.262	1.482	1.230	1.465	1.201	1.188	1.240	1.428	1.353	1.363	1.306	1.262	1.325	1.449	1.221	1.195	1.274	1.345	1.263
Stride Velocity	(m/s)	1.752	1.830	1.928	1.893	2.067	1.757	2.093	1.797	1.874	1.769	1.992	1.887	2.210	1.909	1.991	1.983	2.119	1.742	1.748	1.736	1.977	1.830
Blade Time on Ice (s)	Weight Acceptance	13.079	6.239	14.214	7.374	15.415	8.475	16.583	9.642	17.801	10.777	18.852	11.945	20.070	13.113	21.221	14.280	22.288	15.415	23.506	16.583	18.303	11.384
	Propulsion	13.763	6.906	14.948	8.041	16.132	9.175	17.283	10.310	18.435	11.478	19.569	12.662	20.687	13.797	21.855	14.948	22.972	16.116	24.190	17.317	18.983	12.075
	Total	0.684	0.667	0.734	0.667	0.717	0.700	0.700	0.668	0.634	0.701	0.717	0.717	0.617	0.684	0.634	0.668	0.684	0.701	0.684	0.734	0.681	0.691

Subject Five Kinematics (15mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	9.400	9.300	8.400	9.200	11.200	11.300	11.200	11.600	11.100	13.800	11.800	10.300	15.100	11.000	11.700	12.600	10.700	18.500	14.600	16.700	11.520	12.430
(D/P)	Propulsion	-4.400	7.800	-5.400	2.900	2.600	2.000	-5.200	3.800	-3.100	2.400	-4.800	2.600	4.500	4.800	3.800	2.300	1.800	4.400	-0.800	6.800	-1.100	3.980
Ankle ROM		5.000	17.100	3.000	12.100	13.800	13.300	6.000	15.400	8.000	16.200	7.000	12.900	19.600	15.800	15.500	14.900	12.500	22.900	13.800	23.500	10.420	16.410
Ankle Angular Velocity	(Deg/s)	8.091	26.972	4.862	19.611	20.690	20.978	8.357	23.656	11.158	24.288	9.763	21.500	26.099	23.653	21.618	21.784	19.231	32.668	18.375	32.016	14.824	24.712
Knee Flexion	Weight Acceptance	67.300	63.500	70.600	63.800	69.000	60.900	73.800	63.400	70.100	65.300	72.800	64.800	74.000	63.900	71.600	65.000	73.000	68.300	76.000	70.700	71.820	64.960
	Propulsion	40.400	29.400	32.600	30.400	32.700	26.400	36.000	27.200	30.900	27.000	33.200	30.300	31.100	25.400	27.700	29.200	36.500	26.800	37.900	24.000	33.900	27.610
Knee Extension (ROM)		65.372	46.372	52.836	49.271	49.025	41.640	50.139	41.782	43.096	40.480	46.304	50.500	41.411	38.024	38.633	42.690	56.154	38.231	50.466	32.698	49.344	42.169
Knee Angular Velocity	(Deg/s)	105.780	73.142	85.634	79.855	73.501	65.679	69.832	64.181	60.106	60.689	64.580	84.167	55.142	56.922	53.882	62.412	86.391	54.538	67.198	44.547	72.205	64.613
Hip Flexion	Weight Acceptance	84.100	85.700	94.300	83.100	84.800	79.700	88.900	79.300	87.900	78.600	85.900	80.100	87.900	80.600	90.600	77.600	89.100	80.200	92.400	81.600	88.590	80.650
	Propulsion	27.000	35.300	36.100	31.400	44.900	28.200	42.200	33.700	30.200	30.100	28.600	25.500	31.500	28.800	24.400	31.100	33.700	28.800	35.400	31.600	33.400	30.450
Hip Extension ROM		57.100	50.400	58.200	51.700	39.900	51.500	46.700	45.600	57.700	48.500	57.300	54.600	56.400	51.800	66.200	46.500	55.400	51.400	57.000	50.000	55.190	50.200
Hip Angular Velocity	(Deg/s)	92.395	79.495	94.327	83.793	59.820	81.230	65.042	70.046	80.474	72.714	79.916	91.000	75.100	77.545	92.329	67.982	85.231	73.324	75.899	68.120	80.053	76.525
Hip Abduction/Adduction	Weight Acceptance	-5.800	-1.100	4.900	-3.400	-3.600	-2.000	-5.100	-4.900	-4.600	-2.400	-5.300	-6.200	-3.000	-3.800	-5.300	-4.800	-8.900	-5.600	-6.200	-1.900	-4.290	-3.610
(Abd/Add)	Propulsion	31.800	29.100	26.400	30.700	28.300	30.600	23.100	32.500	28.500	32.000	29.500	31.500	27.700	30.900	24.700	30.600	27.200	31.200	26.600	32.900	27.380	31.200
Hip Abduction ROM		37.600	30.200	21.500	34.100	31.900	32.600	28.200	37.400	33.100	34.400	34.800	37.700	30.700	34.700	30.000	35.400	36.100	36.800	32.800	34.800	31.670	34.810
Hip Angular Velocity	(Deg/s)	60.841	47.634	34.846	55.267	47.826	51.420	39.276	57.450	46.165	51.574	48.536	62.833	40.879	51.946	41.841	51.754	55.538	52.496	43.675	47.411	45.942	52.979
Stride Length	Sagittal (m)	1.300	1.140	1.160	1.280	0.880	1.210	1.240	1.110	1.200	1.290	0.940	1.170	1.070	1.230	1.050	1.120	1.160	1.090	1.090	1.120	1.109	1.176
	Frontal (m)	0.680	0.620	0.840	0.680	0.740	0.630	0.810	0.590	0.820	0.630	0.800	0.640	0.760	0.670	0.820	0.750	0.830	0.640	0.790	0.720	0.789	0.657
	Total (m)	1.467	1.298	1.432	1.449	1.150	1.364	1.481	1.257	1.453	1.436	1.234	1.334	1.312	1.401	1.332	1.348	1.426	1.264	1.346	1.331	1.364	1.348
Stride Velocity	(m/s)	2.374	2.047	2.321	2.349	1.724	2.152	2.063	1.931	2.027	2.152	1.722	2.223	1.748	2.097	1.858	1.971	2.194	1.803	1.793	1.814	1.982	2.054
Blade Time on Ice (s)	Weight Acceptance	19.919	18.952	20.987	20.053	21.988	21.121	25.358	22.188	26.526	23.256	27.694	24.391	28.828	25.458	30.030	26.559	31.231	27.677	32.332	28.795	26.489	23.845
	Propulsion	20.537	19.586	21.604	20.670	22.655	21.755	26.076	22.839	27.243	23.923	28.411	24.991	29.579	26.126	30.747	27.243	31.881	28.378	33.083	29.529	27.182	24.504
	Total	0.618	0.634	0.617	0.617	0.667	0.634	0.718	0.651	0.717	0.667	0.717	0.600	0.751	0.668	0.717	0.684	0.650	0.701	0.751	0.734	0.692	0.659

Subject Five Kinematics (18mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	14.500	9.600	9.700	10.200	11.300	11.800	10.330	14.500	11.600	13.000	15.000	13.500	15.900	10.500	13.700	12.700	14.400	15.900	10.700	9.100	12.713	12.080
(D/P)	Propulsion	-4.200	7.300	-0.300	4.600	-3.200	8.600	5.200	6.300	-6.200	1.300	-2.100	5.800	-1.300	7.300	-7.300	4.400	-5.800	3.400	-3.000	6.000	-2.820	5.500
Ankle ROM		10.300	16.900	9.400	14.800	8.100	20.400	15.530	20.800	5.400	14.300	12.900	19.300	14.600	17.800	6.400	17.100	8.600	19.300	7.700	15.100	9.893	17.580
Ankle Angular Velocity	(Deg/s)	14.365	28.120	14.439	22.769	13.128	30.585	23.856	31.184	10.112	20.906	20.908	27.532	23.625	23.177	8.719	26.308	12.573	25.699	12.460	22.076	15.418	25.836
Knee Flexion	Weight Acceptance	77.400	69.200	74.800	70.900	72.800	68.500	75.800	67.900	76.100	70.300	78.600	68.000	75.700	70.100	79.700	71.000	75.400	76.300	74.400	71.900	76.070	70.410
	Propulsion	40.500	30.900	32.400	25.100	32.100	23.300	32.500	21.400	41.900	27.500	40.400	25.900	34.400	24.500	35.400	24.800	36.200	28.700	33.300	26.800	35.910	25.890
Knee Extension (ROM)		36.900	38.300	42.400	45.800	40.700	45.200	43.300	46.500	34.200	42.800	38.200	42.100	41.300	45.600	44.300	46.200	39.200	47.600	41.100	45.100	40.160	44.520
Knee Angular Velocity	(Deg/s)	51.464	63.727	65.131	70.462	65.964	67.766	66.513	69.715	64.045	62.573	61.912	60.057	66.828	59.375	60.354	71.077	57.310	63.382	66.505	65.936	62.603	65.407
Hip Flexion	Weight Acceptance	79.700	83.600	86.600	84.600	90.700	81.700	86.900	81.900	88.900	87.300	90.800	85.500	90.900	83.300	82.300	86.400	85.200	83.400	91.300	87.800	87.330	84.550
	Propulsion	37.400	29.300	30.900	27.300	23.000	24.600	41.800	24.000	34.500	31.900	34.500	25.900	30.900	22.300	44.700	28.000	38.800	34.500	30.600	40.500	34.710	28.830
Hip Extension ROM		42.300	54.300	55.700	57.300	67.700	57.100	45.100	57.900	54.400	55.400	56.300	59.600	60.000	61.000	37.600	58.400	46.400	48.900	60.700	47.300	52.620	55.720
Hip Angular Velocity	(Deg/s)	58.996	90.349	85.561	88.154	109.724	85.607	69.278	86.807	101.873	80.994	91.248	85.021	97.087	79.427	51.226	89.846	67.836	65.113	98.220	69.152	83.105	82.047
Hip Abduction/Adduction	Weight Acceptance	-2.600	-2.200	-4.000	-3.900	-6.000	-2.300	-2.700	-5.000	-5.000	-4.300	-4.500	-5.400	-1.800	-4.200	-2.000	-0.600	-4.700	-5.200	-2.000	-4.400	-3.530	-3.750
(Abd/Add)	Propulsion	32.300	29.700	29.800	32.900	30.400	33.000	31.900	32.100	28.700	33.300	35.200	31.900	36.000	34.700	32.000	31.500	30.700	30.700	27.300	29.700	31.430	31.950
Hip Abduction ROM		34.900	31.900	33.800	36.800	36.400	35.300	34.600	37.100	33.700	37.600	39.700	37.300	37.800	38.900	34.000	32.100	35.400	35.900	29.300	34.100	34.960	35.700
Hip Angular Velocity	(Deg/s)	48.675	53.078	51.920	56.615	58.995	52.924	53.149	55.622	63.109	54.971	64.344	53.210	61.165	50.651	46.322	49.385	51.754	47.803	47.411	49.854	54.684	52.411
Stride Length	Sagittal (m)	1.100	1.090	1.300	1.170	1.260	1.180	0.960	1.290	1.110	1.150	1.230	1.210	1.210	1.310	0.930	1.230	1.060	1.160	1.200	1.240	1.136	1.203
	Frontal (m)	0.740	0.680	0.740	0.740	0.760	0.740	0.730	0.710	0.760	0.770	0.720	0.780	0.700	0.760	0.750	0.820	0.770	0.710	0.690	0.610	0.736	0.732
	Total (m)	1.326	1.285	1.496	1.384	1.471	1.393	1.206	1.472	1.345	1.384	1.425	1.440	1.398	1.514	1.195	1.478	1.310	1.360	1.384	1.382	1.356	1.409
Stride Velocity	(m/s)	1.849	2.138	2.298	2.130	2.385	2.088	1.853	2.208	2.519	2.023	2.310	2.054	2.262	1.972	1.628	2.274	1.915	1.811	2.240	2.020	2.126	2.072
Blade Time on Ice (s)	Weight Acceptance	9.843	11.711	10.977	12.746	12.045	13.847	13.079	14.948	14.230	16.049	15.215	17.183	16.282	18.251	17.267	19.486	18.418	20.553	19.552	21.721	14.691	16.650
	Propulsion	10.560	12.312	11.628	13.396	12.662	14.514	13.730	15.615	14.764	16.733	15.832	17.884	16.900	19.019	18.001	20.136	19.102	21.304	20.170	22.405	15.335	17.332
	Total	0.717	0.601	0.651	0.650	0.617	0.667	0.651	0.667	0.534	0.684	0.617	0.701	0.618	0.768	0.734	0.650	0.684	0.751	0.618	0.684	0.644	0.682

Subject Six Kinematics (8mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	10.600	0.800	6.200	2.800	3.100	0.800	2.900	5.200	8.300	0.100	6.800	4.900	5.400	2.500	5.200	2.100	3.900	8.100	4.700	2.800	5.710	3.010
(D/P)	Propulsion	-1.400	1.100	-4.500	5.900	-0.900	7.800	1.300	3.800	-7.000	3.000	-5.300	12.500	-2.400	16.700	-8.200	1.900	5.500	4.700	2.800	6.700	-2.010	6.410
Ankle ROM		9.200	1.900	1.700	8.700	2.200	8.600	4.200	9.000	1.300	3.100	1.500	17.400	3.000	19.200	-3.000	4.000	9.400	12.800	7.500	9.500	3.700	9.420
Ankle Angular Velocity	(Deg/s)	12.267	2.710	2.368	12.134	2.929	12.268	6.287	11.719	1.658	4.324	2.044	25.439	4.178	27.389	-4.498	5.326	11.506	17.044	10.218	13.231	4.896	13.158
Knee Flexion	Weight Acceptance	56.500	47.100	48.000	45.900	50.800	41.400	47.900	55.000	55.800	45.500	50.500	52.600	47.100	46.800	47.000	44.900	51.900	51.900	49.400	48.700	50.490	47.980
	Propulsion	14.300	17.400	23.300	16.500	15.700	13.500	17.300	15.500	21.700	21.600	30.900	16.500	19.900	5.700	17.700	24.100	15.800	18.500	13.600	23.700	19.020	17.300
Knee Extension (ROM)		42.200	29.700	24.700	29.400	35.100	27.900	30.600	39.500	34.100	23.900	19.600	36.100	27.200	41.100	29.300	20.800	36.100	33.400	35.800	25.000	31.470	30.680
Knee Angular Velocity	(Deg/s)	56.267	42.368	34.401	41.004	46.738	39.800	45.808	51.432	43.495	33.333	26.703	52.778	37.883	58.631	43.928	27.696	44.186	44.474	48.774	34.819	42.818	42.634
Hip Flexion	Weight Acceptance	66.400	70.600	62.900	75.900	69.500	74.600	68.100	72.300	68.400	70.200	66.300	70.100	65.400	67.100	66.700	71.900	67.500	75.100	70.500	72.000	67.170	71.980
	Propulsion	17.700	19.600	13.600	23.000	19.800	22.400	9.200	27.400	16.700	32.500	21.100	23.000	19.100	20.200	22.300	17.700	16.400	25.000	13.500	28.300	16.940	23.910
Hip Extension ROM		48.700	51.000	49.300	52.900	49.700	52.200	58.900	44.900	51.700	37.700	45.200	47.100	46.300	46.900	44.400	54.200	51.100	50.100	57.000	43.700	50.230	48.070
Hip Angular Velocity	(Deg/s)	64.933	72.753	68.663	73.780	66.178	74.465	88.174	58.464	65.944	52.580	61.580	68.860	64.485	66.904	66.567	72.170	62.546	66.711	77.657	60.864	68.673	66.755
Hip Abduction/Adduction	Weight Acceptance	-2.800	-7.300	-2.800	-5.500	-4.900	-4.700	-3.100	-7.000	-3.200	-8.100	-0.500	-1.800	-3.900	-4.800	-1.200	-7.600	-0.800	-3.400	-5.100	-3.100	-2.830	-5.330
(Abd/Add)	Propulsion	17.900	20.900	19.700	22.000	17.500	15.900	22.200	14.500	20.500	22.000	23.400	21.700	19.900	18.100	25.500	19.400	23.200	23.500	21.600	25.400	21.140	20.340
Hip Abduction ROM		20.700	28.200	22.500	27.500	22.400	20.600	25.300	21.500	23.700	30.100	23.900	23.500	23.800	22.900	26.700	27.000	24.000	26.900	26.700	28.500	23.970	25.670
Hip Angular Velocity	(Deg/s)	27.600	40.228	31.337	38.354	29.827	29.387	37.874	27.995	30.230	41.980	32.561	34.357	33.148	32.668	40.030	35.952	29.376	35.819	36.376	39.694	32.836	35.643
Stride Length	Sagittal (m)	0.980	1.030	1.030	1.050	1.180	0.910	1.070	1.040	1.010	0.880	1.040	0.920	1.020	0.990	0.990	1.020	1.080	0.970	1.030	1.020	1.043	0.983
	Frontal (m)	0.410	0.510	0.400	0.490	0.500	0.410	0.440	0.380	0.400	0.530	0.420	0.440	0.450	0.380	0.470	0.450	0.450	0.450	0.400	0.470	0.434	0.451
	Total (m)	1.062	1.149	1.105	1.159	1.282	0.998	1.157	1.107	1.086	1.027	1.122	1.020	1.115	1.060	1.096	1.115	1.170	1.069	1.105	1.123	1.130	1.083
Stride Velocity	(m/s)	1.416	1.640	1.539	1.616	1.706	1.424	1.732	1.442	1.386	1.433	1.528	1.491	1.553	1.513	1.643	1.484	1.432	1.424	1.505	1.564	1.544	1.503
Blade Time on Ice (s)	Weight Acceptance	7.107	4.671	8.341	5.839	9.509	7.023	10.710	8.174	11.845	9.409	13.063	10.577	14.280	11.761	15.415	12.946	16.583	14.180	17.851	15.448	12.470	10.003
	Propulsion	7.857	5.372	9.059	6.556	10.260	7.724	11.378	8.942	12.629	10.126	13.797	11.261	14.998	12.462	16.082	13.697	17.400	14.931	18.585	16.166	13.205	10.724
	Total	0.750	0.701	0.718	0.717	0.751	0.701	0.668	0.768	0.784	0.717	0.734	0.684	0.718	0.701	0.667	0.751	0.817	0.751	0.734	0.718	0.734	0.721

Subject Six Kinematics (11mph)

Variable	Stride Number	1 Own	1 Mako	2 Own	2 Mako	3 Own	3 Mako	4 Own	4 Mako	5 Own	5 Mako	6 Own	6 Mako	7 Own	7 Mako	8 Own	8 Mako	9 Own	9 Mako	10 Own	10 Mako	Average Own	Average Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	8.100	3.300	15.700	7.700	6.600	3.100	7.600	5.200	5.100	7.000	10.200	6.200	8.000	2.200	5.800	5.900	7.600	7.700	-4.000	4.500	7.070	5.280
(D/P)	Propulsion	-7.200	3.700	-5.400	3.300	-13.200	4.500	-1.400	4.400	2.000	8.700	0.500	-13.000	-12.100	2.500	-15.300	2.700	-6.600	7.500	-9.800	9.000	-6.850	3.330
Ankle ROM		0.900	7.000	10.300	11.000	-6.600	7.600	6.200	9.600	7.100	15.700	10.700	-6.800	-4.100	4.700	-9.500	8.600	1.000	15.200	-13.800	13.500	0.220	8.610
Ankle Angular Velocity	(Deg/s)	1.498	11.986	15.058	15.320	-12.000	13.793	9.538	14.747	11.507	25.446	16.462	-12.734	-6.467	8.048	-14.593	13.565	1.538	26.027	-22.366	20.240	0.018	13.644
Knee Flexion	Weight Acceptance	59.100	45.500	55.900	56.600	53.500	48.800	59.600	49.100	55.300	55.000	59.100	52.800	49.200	49.800	52.000	51.500	53.200	54.800	51.600	52.700	54.850	51.660
	Propulsion	17.800	24.800	18.900	27.100	19.600	18.900	15.300	21.100	15.500	23.500	17.200	29.400	23.500	19.000	25.700	18.600	17.600	14.200	21.100	18.600	19.220	21.520
Knee Extension (ROM)		41.300	20.700	37.000	29.500	33.900	29.900	44.300	28.000	39.800	31.500	41.900	23.400	25.700	30.800	26.300	32.900	35.600	40.600	30.500	34.100	35.630	30.140
Knee Angular Velocity	(Deg/s)	68.719	35.445	54.094	41.086	61.636	54.265	68.154	43.011	64.506	51.053	64.462	43.820	40.536	52.740	40.399	51.893	54.769	69.521	49.433	51.124	56.671	49.396
Hip Flexion	Weight Acceptance	78.400	78.800	62.900	73.400	74.000	72.800	76.300	86.400	74.000	77.600	74.600	78.900	70.100	81.900	75.800	80.000	72.600	82.200	70.900	75.800	72.960	78.780
	Propulsion	22.800	42.600	19.000	32.900	23.200	40.100	19.400	29.400	23.000	36.500	25.000	30.500	25.300	27.800	28.000	28.000	27.800	25.100	27.800	34.700	24.130	32.760
Hip Extension ROM		55.600	36.200	43.900	40.500	50.800	32.700	56.900	57.000	51.000	41.100	49.600	48.400	44.800	54.100	47.800	52.000	44.800	57.100	43.100	41.100	48.830	46.020
Hip Angular Velocity	(Deg/s)	92.512	61.986	64.181	56.407	92.364	59.347	87.538	87.558	82.658	66.613	76.308	90.637	70.662	92.637	73.425	82.019	68.923	97.774	69.854	61.619	77.843	75.660
Hip Abduction/Adduction	Weight Acceptance	-2.800	-3.500	-1.800	-5.200	0.200	-4.200	-3.700	-1.400	0.600	-2.500	-2.700	2.500	-2.800	-1.000	-2.200	-1.200	-2.100	-1.900	-2.700	-3.000	-2.000	-2.140
(Abd/Add)	Propulsion	17.800	21.500	20.500	15.700	20.400	20.500	21.500	19.900	22.400	16.500	14.700	17.000	21.000	21.500	19.100	16.500	19.800	16.100	16.500	24.300	19.370	18.950
Hip Abduction ROM		20.600	25.000	22.300	20.900	20.200	24.700	25.200	21.300	21.800	19.000	17.400	14.500	23.800	22.500	21.300	17.700	21.900	18.000	19.200	27.300	21.370	21.090
Hip Angular Velocity	(Deg/s)	34.276	42.808	32.602	29.109	36.727	44.828	38.769	32.719	35.332	30.794	26.769	27.154	37.539	38.527	32.719	27.918	33.692	30.822	31.118	40.930	33.955	34.561
Stride Length	Sagittal (m)	0.960	0.920	0.950	0.880	0.880	1.070	1.120	1.000	0.990	1.050	0.940	1.060	0.890	1.110	1.000	1.110	0.730	1.120	0.820	0.910	0.928	1.023
	Frontal (m)	0.490	0.530	0.480	0.550	0.460	0.550	0.510	0.540	0.510	0.490	0.440	0.410	0.480	0.480	0.550	0.430	0.530	0.530	0.430	0.560	0.488	0.507
	Total (m)	1.078	1.062	1.064	1.038	0.993	1.203	1.231	1.136	1.114	1.159	1.038	1.137	1.011	1.209	1.141	1.190	0.902	1.239	0.926	1.069	1.050	1.144
Stride Velocity	(m/s)	1.793	1.818	1.556	1.445	1.805	2.183	1.893	1.746	1.805	1.878	1.597	2.128	1.595	2.071	1.753	1.878	1.388	2.122	1.501	1.602	1.669	1.887
Blade Time on Ice (s)	Weight Acceptance	3.236	6.206	4.204	7.207	5.305	8.341	6.306	9.275	7.340	10.310	8.375	11.294	9.409	12.278	10.443	13.213	11.478	14.247	12.512	15.248	7.861	10.762
	Propulsion	3.837	6.790	4.888	7.925	5.855	8.892	6.956	9.926	7.957	10.927	9.025	11.828	10.043	12.862	11.094	13.847	12.128	14.831	13.129	15.915	8.491	11.374
	Total	0.601	0.584	0.684	0.718	0.55	0.551	0.65	0.651	0.617	0.617	0.65	0.534	0.634	0.584	0.651	0.634	0.65	0.584	0.617	0.667	0.630	0.612

Subject Six Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	7.200	8.500	13.000	5.900	4.900	9.500	4.600	4.900	0.600	4.600	5.600	6.400	8.000	5.400	8.000	8.400	7.700	7.000	3.400	1.600	6.300	6.220
(D/P)	Propulsion	-6.300	-0.600	2.500	4.800	-2.100	5.500	-9.100	11.300	3.600	0.700	-2.600	10.200	-2.400	0.500	-3.600	14.100	1.700	1.400	1.000	0.400	-1.730	4.830
Ankle ROM		0.900	7.900	15.500	10.700	2.800	15.000	-4.500	16.200	4.200	5.300	3.000	16.600	5.600	5.900	4.400	22.500	9.400	8.400	4.400	2.000	4.570	11.050
Ankle Angular Velocity	(Deg/s)	1.585	15.280	25.833	20.696	4.795	27.223	-7.500	32.335	6.807	8.819	4.087	29.277	8.833	10.406	6.940	40.909	14.826	14.815	6.769	3.868	7.298	20.363
Knee Flexion	Weight Acceptance	54.500	56.200	56.000	56.000	48.200	60.100	50.100	50.800	53.800	54.700	50.700	53.700	56.100	53.200	56.700	58.500	59.100	57.100	52.700	46.800	53.790	54.710
	Propulsion	17.500	21.900	22.100	21.500	19.700	18.800	15.800	28.700	11.500	18.300	20.200	19.000	15.800	21.400	18.700	16.700	18.500	16.000	17.700	21.500	17.750	20.380
Knee Extension (ROM)		37.000	34.300	33.900	34.500	28.500	41.300	34.300	22.100	42.300	36.400	30.500	34.700	40.300	31.800	38.000	41.800	40.600	41.100	35.000	25.300	36.040	34.330
Knee Angular Velocity	(Deg/s)	65.141	66.344	56.500	66.731	48.801	74.955	57.167	44.112	68.558	60.566	41.553	61.199	63.565	56.085	59.937	76.000	64.038	72.487	53.846	48.936	57.911	62.741
Hip Flexion	Weight Acceptance	69.700	68.700	67.700	71.000	71.000	67.800	73.500	73.100	79.900	75.000	64.900	71.500	70.300	74.400	71.300	75.500	73.400	73.500	68.300	76.800	71.000	72.730
	Propulsion	21.600	28.800	20.700	21.100	27.200	23.800	25.100	26.800	22.500	26.300	25.400	32.400	22.100	18.800	22.800	23.700	20.800	23.100	22.500	22.600	23.070	24.740
Hip Extension ROM		48.100	39.900	47.000	49.900	43.800	44.000	48.400	46.300	57.400	48.700	39.500	39.100	48.200	55.600	48.500	51.800	52.600	50.400	45.800	54.200	47.930	47.990
Hip Angular Velocity	(Deg/s)	84.683	77.176	78.333	96.518	75.000	79.855	80.667	92.415	93.031	81.032	53.815	68.959	76.025	98.060	76.498	94.182	82.965	88.889	70.462	104.836	77.148	88.192
Hip Abduction/Adduction	Weight Acceptance	-3.800	-3.800	-2.000	-0.800	-0.600	-3.900	-4.300	-2.100	-4.500	-4.600	-4.200	-4.300	-5.000	-3.200	-2.200	-6.300	-5.600	-2.000	-1.000	-6.500	-3.320	-3.750
(Abd/Add)	Propulsion	23.700	21.900	24.800	23.100	20.000	17.800	21.900	23.800	27.400	22.200	20.000	21.600	22.600	24.700	23.800	22.900	20.200	20.600	23.000	26.700	22.740	22.530
Hip Abduction ROM		27.500	25.700	26.800	23.900	20.600	21.700	26.200	25.900	31.900	26.800	24.200	25.900	27.600	27.900	26.000	29.200	25.800	22.600	24.000	33.200	26.060	26.280
Hip Angular Velocity	(Deg/s)	48.415	49.710	44.667	46.228	35.274	39.383	43.667	51.697	51.702	44.592	32.970	45.679	43.533	49.206	41.009	53.091	40.694	39.859	36.923	64.217	41.885	48.366
Stride Length	Sagittal (m)	0.920	0.900	0.810	0.960	1.000	1.070	0.900	0.890	0.800	1.020	0.740	0.910	0.920	1.090	0.800	0.900	0.780	1.000	0.800	0.960	0.847	0.970
	Frontal (m)	0.540	0.470	0.590	0.450	0.440	0.500	0.560	0.490	0.630	0.560	0.630	0.510	0.610	0.500	0.620	0.570	0.590	0.460	0.530	0.590	0.574	0.510
	Total (m)	1.067	1.015	1.002	1.060	1.093	1.181	1.060	1.016	1.018	1.164	0.972	1.043	1.104	1.199	1.012	1.065	0.978	1.101	0.960	1.127	1.027	1.097
Stride Velocity	(m/s)	1.878	1.964	1.670	2.051	1.871	2.143	1.767	2.028	1.650	1.936	1.324	1.840	1.741	2.115	1.596	1.937	1.543	1.941	1.476	2.180	1.652	2.013
Blade Time on Ice (s)	Weight Acceptance	6.539	7.140	7.474	8.041	8.475	8.975	9.476	9.926	10.510	10.810	11.544	11.828	12.679	12.779	13.730	13.747	14.764	14.714	15.849	15.699	11.104	11.366
	Propulsion	7.107	7.657	8.074	8.558	9.059	9.526	10.076	10.427	11.127	11.411	12.278	12.395	13.313	13.346	14.364	14.297	15.398	15.281	16.499	16.216	11.730	11.911
	Total	0.568	0.517	0.600	0.517	0.584	0.551	0.600	0.501	0.617	0.601	0.734	0.567	0.634	0.567	0.634	0.550	0.634	0.567	0.650	0.517	0.626	0.546

Subject Six Kinematics (15mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	7.300	7.900	8.100	8.300	5.800	6.400	8.900	10.600	10.700	8.100	11.500	8.400	10.800	8.000	9.300	4.300	5.800	7.400	13.100	5.700	9.130	7.510
(D/P)	Propulsion	-1.600	2.200	5.500	1.300	-2.500	4.900	-2.600	4.700	-1.300	7.300	-2.700	4.500	-5.300	2.800	-1.600	6.000	-5.300	2.900	-1.500	4.800	-1.890	4.140
Ankle ROM		5.700	10.100	13.600	9.600	3.300	11.300	6.300	15.300	9.400	15.400	8.800	12.900	5.500	10.800	7.700	10.300	0.500	10.300	11.600	10.500	7.240	11.650
Ankle Angular Velocity	(Deg/s)	9.238	18.330	20.891	18.569	5.660	20.508	10.211	29.594	14.439	27.160	14.239	22.127	8.462	19.601	11.828	18.166	0.789	19.288	16.959	19.663	11.272	21.301
Knee Flexion	Weight Acceptance	55.500	57.900	63.700	56.600	58.300	59.000	68.600	59.400	62.400	53.300	61.300	56.400	62.900	56.600	61.300	52.100	57.700	57.100	62.900	58.200	61.460	56.660
	Propulsion	20.300	26.100	22.000	26.700	21.200	22.600	17.500	16.700	21.000	27.200	25.400	18.400	22.000	17.900	24.100	19.900	22.900	24.700	23.500	21.600	21.990	22.180
Knee Extension (ROM)		35.200	31.800	41.700	29.900	37.100	36.400	51.100	42.700	41.400	26.100	35.900	38.000	40.900	38.700	37.200	32.200	34.800	32.400	39.400	36.600	39.470	34.480
Knee Angular Velocity	(Deg/s)	57.050	57.713	64.055	57.834	63.636	66.062	82.820	82.592	63.594	46.032	58.091	65.180	62.923	70.236	57.143	56.790	54.890	60.674	57.602	68.539	62.180	63.165
Hip Flexion	Weight Acceptance	71.200	74.600	75.200	71.700	78.500	73.500	80.300	73.200	76.000	74.600	74.100	77.900	76.600	76.600	77.700	75.900	78.300	76.500	76.600	74.200	76.450	74.870
	Propulsion	18.600	24.500	19.200	24.900	20.500	28.900	19.800	22.000	21.800	25.800	20.300	29.700	20.000	25.600	21.300	27.900	20.800	22.200	23.800	24.800	20.610	25.630
Hip Extension ROM		52.600	50.100	56.000	46.800	58.000	44.600	60.500	51.200	54.200	48.800	53.800	48.200	56.600	51.000	56.400	48.000	57.500	54.300	52.800	49.400	55.840	49.240
Hip Angular Velocity	(Deg/s)	85.251	90.926	86.022	90.522	99.485	80.944	98.055	99.033	83.257	86.067	87.055	82.676	87.077	92.559	86.636	84.656	90.694	101.685	77.193	92.509	88.072	90.158
Hip Abduction/Adduction	Weight Acceptance	-1.500	-1.900	-1.400	-3.200	-3.200	-5.000	-2.400	-4.100	-1.800	-3.200	-1.600	-3.900	-1.800	-7.500	-1.800	-6.100	-1.800	-3.200	-2.600	-4.800	-1.990	-4.290
(Abd/Add)	Propulsion	16.000	19.300	25.100	19.400	24.400	23.400	21.800	25.500	22.400	21.000	21.900	24.000	23.000	25.300	24.100	26.700	22.800	20.100	24.200	23.100	22.570	22.780
Hip Abduction ROM		17.500	21.200	26.500	22.600	27.600	28.400	24.200	29.600	24.200	24.200	23.500	27.900	24.800	32.800	25.900	32.800	24.600	23.300	26.800	27.900	24.560	27.070
Hip Angular Velocity	(Deg/s)	28.363	38.475	40.707	43.714	47.341	51.543	39.222	57.253	37.174	42.681	38.026	47.856	38.154	59.528	39.785	57.848	38.801	43.633	39.181	52.247	38.675	49.478
Stride Length	Sagittal (m)	0.940	1.000	1.010	1.090	1.030	0.980	1.000	1.010	0.920	1.010	0.940	1.000	0.930	0.880	0.960	0.930	0.930	1.070	0.930	1.030	0.959	1.000
	Frontal (m)	0.580	0.440	0.560	0.460	0.620	0.500	0.530	0.510	0.550	0.500	0.560	0.480	0.540	0.540	0.580	0.560	0.590	0.490	0.620	0.500	0.573	0.498
	Total (m)	1.105	1.093	1.155	1.183	1.202	1.100	1.132	1.131	1.072	1.127	1.094	1.109	1.075	1.032	1.122	1.086	1.101	1.177	1.118	1.145	1.118	1.118
Stride Velocity	(m/s)	1.790	1.983	1.774	2.288	2.062	1.997	1.834	2.189	1.646	1.988	1.770	1.903	1.654	1.874	1.723	1.915	1.737	2.204	1.634	2.144	1.763	2.048
Blade Time on Ice (s)	Weight Acceptance	10.610	6.439	11.644	7.374	12.746	8.274	13.780	9.209	14.814	10.076	15.915	11.011	16.950	11.978	18.051	12.879	19.119	13.763	20.153	14.714	15.378	10.572
	Propulsion	11.227	6.990	12.295	7.891	13.329	8.825	14.397	9.726	15.465	10.643	16.533	11.594	17.600	12.529	18.702	13.446	19.753	14.297	20.837	15.248	16.014	11.119
	Total	0.617	0.551	0.651	0.517	0.583	0.551	0.617	0.517	0.651	0.567	0.618	0.583	0.650	0.551	0.651	0.567	0.634	0.534	0.684	0.534	0.636	0.547

Subject Six Kinematics (18mph)

Variable	Stride Number	1 Own	1 Mako	2 Own	2 Mako	3 Own	3 Mako	4 Own	4 Mako	5 Own	5 Mako	6 Own	6 Mako	7 Own	7 Mako	8 Own	8 Mako	9 Own	9 Mako	10 Own	10 Mako	Average Own	Average Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	5.900	3.700	7.200	4.600	6.700	5.200	9.000	4.200	6.600	2.800	8.000	5.800	5.300	6.100	13.300	7.000	7.800	6.400	9.400	6.000	7.920	5.180
(D/P)	Propulsion	5.900	7.300	1.900	10.100	3.000	5.700	1.900	8.000	2.000	5.400	2.700	7.100	1.800	8.800	0.100	5.400	5.100	2.500	4.900	3.400	2.930	6.370
Ankle ROM		11.800	11.000	9.100	14.700	9.700	10.900	10.900	12.200	8.600	8.200	10.700	12.900	7.100	14.900	13.400	12.400	12.900	8.900	14.300	9.400	10.850	11.550
Ankle Angular Velocity	(Deg/s)	23.600	21.956	16.021	26.679	16.140	19.818	22.521	29.257	14.751	14.882	17.804	22.751	13.733	29.741	24.319	25.620	24.952	18.388	23.139	16.096	19.698	22.519
Knee Flexion	Weight Acceptance	65.300	52.100	59.900	55.500	57.100	54.500	61.400	55.700	56.900	53.300	59.300	55.900	58.600	50.300	61.600	55.800	59.200	56.200	57.700	53.300	59.700	54.260
	Propulsion	18.900	18.500	23.700	15.100	15.600	15.800	19.700	16.100	20.900	18.600	20.900	16.200	29.200	11.000	19.200	21.300	26.900	28.200	20.100	19.400	21.510	18.020
Knee Extension (ROM)		46.400	33.600	36.200	40.400	41.500	38.700	41.700	39.600	36.000	34.700	38.400	39.700	29.400	39.300	42.400	34.500	32.300	28.000	37.600	33.900	38.190	36.240
Knee Angular Velocity	(Deg/s)	92.800	67.066	63.732	73.321	69.052	70.364	86.157	94.964	61.750	62.976	63.894	70.018	56.867	78.443	76.951	71.281	62.476	57.851	60.841	58.048	69.452	70.433
Hip Flexion	Weight Acceptance	85.600	80.400	81.000	79.800	74.300	74.400	86.700	80.200	75.800	79.800	76.500	73.800	80.000	71.600	76.300	70.400	81.900	78.300	78.500	73.200	79.660	76.190
	Propulsion	22.900	23.100	30.000	24.600	29.500	22.600	32.100	16.500	30.200	25.600	25.000	23.900	28.100	24.700	32.400	23.100	36.900	24.700	29.700	23.300	29.680	23.210
Hip Extension ROM		62.700	57.300	51.000	55.200	44.800	51.800	54.600	63.700	45.600	54.200	51.500	49.900	51.900	46.900	43.900	47.300	45.000	53.600	48.800	49.900	49.980	52.980
Hip Angular Velocity	(Deg/s)	125.400	114.371	89.789	100.181	74.542	94.182	112.810	152.758	78.216	98.367	85.691	88.007	100.387	93.613	79.673	97.727	87.041	110.744	78.964	85.445	91.251	103.540
Hip Abduction/Adduction	Weight Acceptance	-2.900	-2.200	-3.500	-7.600	-3.700	-6.500	-3.100	-6.900	-2.600	-3.800	-3.900	-8.000	-1.100	-5.400	-1.900	-7.100	-3.800	-3.800	-2.700	-5.700	-2.920	-5.700
(Abd/Add)	Propulsion	21.100	22.000	22.100	22.700	23.500	21.300	25.000	21.500	25.500	19.600	24.500	24.400	21.000	22.500	25.100	19.500	21.200	20.200	24.700	24.000	23.370	21.770
Hip Abduction ROM		24.000	24.200	25.600	30.300	27.200	27.800	28.100	28.400	28.100	23.400	28.400	32.400	22.100	27.900	27.000	26.600	25.000	24.000	27.400	29.700	26.290	27.470
Hip Angular Velocity	(Deg/s)	48.000	48.303	45.070	54.991	45.258	50.545	58.058	68.106	48.199	42.468	47.255	57.143	42.747	55.689	49.002	54.959	48.356	49.587	44.337	50.856	47.628	53.265
Stride Length	Sagittal (m)	1.020	1.110	0.790	0.910	0.910	1.120	0.970	1.210	0.900	0.900	0.930	1.010	0.890	1.050	0.820	1.060	0.770	0.960	0.920	0.920	0.892	1.025
	Frontal (m)	0.620	0.560	0.620	0.510	0.530	0.680	0.570	0.540	0.570	0.510	0.560	0.620	0.490	0.590	0.590	0.590	0.640	0.540	0.600	0.620	0.579	0.576
	Total (m)	1.194	1.243	1.004	1.043	1.053	1.310	1.125	1.325	1.065	1.034	1.086	1.185	1.016	1.204	1.010	1.213	1.001	1.101	1.098	1.109	1.065	1.177
Stride Velocity	(m/s)	2.387	2.482	1.768	1.893	1.752	2.382	2.325	3.178	1.827	1.877	1.806	2.090	1.965	2.404	1.833	2.506	1.937	2.276	1.777	1.900	1.938	2.299
Blade Time on Ice (s)	Weight Acceptance	7.724	3.069	8.591	3.903	9.542	4.838	10.510	5.739	11.378	6.506	12.345	7.407	13.313	8.324	14.147	9.209	15.048	10.076	15.915	10.910	11.851	6.998
	Propulsion	8.224	3.570	9.159	4.454	10.143	5.388	10.994	6.156	11.961	7.057	12.946	7.974	13.830	8.825	14.698	9.693	15.565	10.560	16.533	11.494	12.405	7.517
	Total	0.500	0.501	0.568	0.551	0.601	0.550	0.484	0.417	0.583	0.551	0.601	0.567	0.517	0.501	0.551	0.484	0.517	0.484	0.618	0.584	0.554	0.519

Subject Seven Kinematics (8mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	3.000	4.200	3.500	5.000	6.900	6.900	3.300	9.100	6.900	5.600	3.200	7.100	4.300	5.600	3.100	7.800	3.400	9.500	2.900	9.600	4.050	7.040
(D/P)	Propulsion	7.600	5.600	7.100	16.000	1.800	11.200	7.800	9.300	1.000	5.800	-2.200	6.400	6.000	9.000	5.900	7.200	4.600	10.100	6.800	9.100	4.640	8.970
Ankle ROM		10.600	9.800	10.600	21.000	8.700	18.100	11.100	18.400	7.900	11.400	1.000	13.500	10.300	14.600	9.000	15.000	8.000	19.600	9.700	18.700	8.690	16.010
Ankle Angular Velocity	(Deg/s)	14.115	11.303	14.115	24.677	11.853	24.133	12.092	22.521	10.519	16.667	1.276	17.219	13.429	19.035	12.000	19.133	9.401	27.336	12.933	27.339	11.173	20.936
Knee Flexion	Weight Acceptance	38.900	53.900	48.300	46.500	51.300	57.700	46.900	51.200	50.400	51.200	49.900	59.200	49.100	54.400	40.800	58.700	51.400	52.600	47.900	54.500	47.490	53.990
	Propulsion	13.500	11.500	15.700	10.600	14.700	14.500	15.300	13.100	15.300	14.900	17.800	13.700	17.500	18.300	23.400	13.100	19.200	18.200	22.400	15.600	17.480	14.350
Knee Extension (ROM)		25.400	42.400	32.600	35.900	36.600	43.200	31.600	38.100	35.100	36.300	32.100	45.500	31.600	36.100	17.400	45.600	32.200	34.400	25.500	38.900	30.010	39.640
Knee Angular Velocity	(Deg/s)	33.822	48.904	43.409	42.186	49.864	57.600	34.423	46.634	46.738	53.070	40.944	58.036	41.199	47.066	23.200	58.163	37.838	47.978	34.000	56.871	38.544	51.651
Hip Flexion	Weight Acceptance	55.700	67.600	72.700	59.200	66.100	70.700	71.000	65.000	75.500	70.300	74.300	72.400	67.000	70.000	67.200	71.100	68.700	63.900	64.500	69.400	68.270	67.960
	Propulsion	24.100	20.900	28.700	24.800	27.800	24.500	24.500	27.800	29.300	22.400	27.400	29.100	28.400	27.700	29.600	25.600	25.200	23.600	27.300	30.800	27.230	25.720
Hip Extension ROM		31.600	46.700	44.000	34.400	38.300	46.200	46.500	37.200	46.200	47.900	46.900	43.300	38.600	42.300	37.600	45.500	43.500	40.300	37.200	38.600	41.040	42.240
Hip Angular Velocity	(Deg/s)	42.077	53.864	58.589	40.423	52.180	61.600	50.654	45.532	61.518	70.029	59.821	55.230	50.326	55.150	50.133	58.036	51.116	56.206	49.600	56.433	52.601	55.250
Hip Abduction/Adduction	Weight Acceptance	-3.900	-9.400	-5.800	-9.600	-10.300	-7.500	-7.800	-6.600	-3.200	-7.700	-8.000	-5.800	-2.600	-4.100	-3.500	-0.500	-9.000	-3.100	-7.000	-0.400	-6.110	-5.470
(Abd/Add)	Propulsion	18.700	19.600	18.400	19.100	17.600	25.000	16.800	29.200	19.600	28.900	19.800	20.400	18.200	22.900	17.600	22.000	19.600	16.000	19.800	21.400	18.610	22.450
Hip Abduction ROM		22.600	29.000	24.200	28.700	27.900	32.500	24.600	35.800	22.800	36.600	27.800	26.200	20.800	27.000	21.100	22.500	28.600	19.100	26.800	21.800	24.720	27.920
Hip Angular Velocity	(Deg/s)	30.093	33.449	32.224	33.725	38.011	43.333	26.797	43.819	30.360	53.509	35.459	33.418	27.119	35.202	28.133	28.699	33.608	26.639	35.733	31.871	31.754	36.366
Stride Length	Sagittal (m)	1.150	0.810	0.920	0.880	0.910	0.770	1.040	0.840	0.750	0.920	0.730	0.710	0.920	0.710	0.860	0.890	0.820	0.960	1.000	0.770	0.910	0.826
	Frontal (m)	0.590	0.680	0.510	0.570	0.450	0.550	0.580	0.550	0.620	0.600	0.570	0.640	0.640	0.620	0.630	0.540	0.610	0.460	0.650	0.520	0.585	0.573
	Total (m)	1.293	1.058	1.052	1.048	1.015	0.946	1.191	1.004	0.973	1.098	0.926	0.956	1.121	0.943	1.066	1.041	1.022	1.065	1.193	0.929	1.085	1.009
Stride Velocity	(m/s)	1.721	1.220	1.401	1.232	1.383	1.262	1.297	1.229	1.296	1.606	1.181	1.219	1.461	1.229	1.421	1.328	1.201	1.485	1.590	1.358	1.395	1.317
Blade Time on Ice (s)	Weight Acceptance	3.303	4.454	4.604	5.839	5.939	7.207	7.240	8.508	8.675	9.876	9.976	11.144	11.311	12.462	12.579	13.747	13.813	15.115	15.215	16.349	9.266	10.470
	Propulsion	4.054	5.321	5.355	6.690	6.673	7.957	8.158	9.325	9.426	10.560	10.760	11.928	12.078	13.229	13.329	14.531	14.664	15.832	15.965	17.033	10.046	11.241
	Total	0.751	0.867	0.751	0.851	0.734	0.750	0.918	0.817	0.751	0.684	0.784	0.784	0.767	0.767	0.750	0.784	0.851	0.717	0.750	0.684	0.781	0.771

Subject Seven Kinematics (11mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	4.800	8.100	5.700	8.300	10.000	6.700	2.900	7.700	6.200	8.700	8.800	8.200	8.700	10.500	7.600	6.900	6.900	3.500	6.400	10.400	6.800	7.900
(D/P)	Propulsion	7.100	9.700	11.200	9.900	13.000	8.300	4.900	13.600	6.100	14.900	10.700	10.200	4.700	13.500	6.200	8.300	11.600	8.400	3.300	8.600	7.880	10.540
Ankle ROM		11.900	17.800	16.900	18.200	23.000	15.000	7.800	21.300	12.300	23.600	19.500	18.400	13.400	24.000	13.800	15.200	18.500	11.900	9.700	19.000	14.680	18.440
Ankle Angular Velocity	(Deg/s)	17.398	27.343	23.570	25.963	40.564	25.000	10.879	33.649	17.155	34.503	27.817	28.264	17.471	35.088	20.175	21.199	9.241	16.574	15.300	27.778	19.957	27.536
Knee Flexion	Weight Acceptance	48.300	53.200	50.700	53.000	55.400	47.200	42.900	57.300	56.000	56.000	56.300	57.400	58.100	58.900	57.800	62.300	55.200	52.600	52.300	59.900	53.300	55.780
	Propulsion	10.400	16.000	18.000	11.000	17.300	14.100	14.500	11.500	11.700	16.200	13.700	17.400	15.700	13.900	16.000	10.100	9.100	20.100	10.400	9.500	13.680	13.980
Knee Extension (ROM)		37.900	37.200	32.700	42.000	38.100	33.100	28.400	45.800	44.300	39.800	42.600	40.000	42.400	45.000	41.800	52.200	46.100	32.500	41.900	50.400	39.620	41.800
Knee Angular Velocity	(Deg/s)	55.409	57.143	45.607	59.914	67.196	55.167	39.609	72.354	61.785	58.187	60.770	61.444	55.280	65.789	61.111	72.803	23.027	45.265	66.088	73.684	53.588	62.175
Hip Flexion	Weight Acceptance	66.900	73.500	69.300	67.600	74.600	63.600	64.700	63.100	73.900	69.500	75.300	73.800	75.100	74.000	70.800	75.200	72.300	75.000	66.900	76.200	70.980	71.150
	Propulsion	31.600	27.600	19.500	24.500	26.400	21.900	30.800	23.900	30.100	22.500	31.400	20.800	30.600	26.200	30.500	20.500	24.800	21.400	27.200	28.500	28.290	23.780
Hip Extension ROM		35.300	45.900	49.800	43.100	48.200	41.700	33.900	39.200	43.800	47.000	43.900	53.000	44.500	47.800	40.300	54.700	47.500	53.600	39.700	47.700	42.690	47.370
Hip Angular Velocity	(Deg/s)	51.608	70.507	69.456	61.484	85.009	69.500	47.280	61.927	61.088	68.713	62.625	81.413	58.018	69.883	58.918	76.290	23.726	74.652	62.618	69.737	58.035	70.411
Hip Abduction/Adduction	Weight Acceptance	-3.100	-6.900	-4.700	-8.100	-3.800	-6.100	-5.800	-2.900	-7.200	-3.200	-3.700	-7.000	-7.100	-11.700	-3.100	-12.100	-4.300	-9.700	-2.800	-11.500	-4.560	-7.920
(Abd/Add)	Propulsion	21.900	21.500	16.900	20.600	19.300	20.000	20.700	21.600	21.400	19.300	23.200	20.900	21.000	19.900	21.100	23.500	22.800	23.100	22.300	22.600	21.060	21.300
Hip Abduction ROM		25.000	28.400	21.600	28.700	23.100	26.100	26.500	24.500	28.600	22.500	26.900	27.900	28.100	31.600	24.200	35.600	27.100	32.800	25.100	34.100	25.620	29.220
Hip Angular Velocity	(Deg/s)	36.550	43.625	30.126	40.942	40.741	43.500	36.960	38.705	39.888	32.895	38.374	42.857	36.636	46.199	35.380	49.651	13.536	45.682	39.590	49.854	34.778	43.391
Stride Length	Sagittal (m)	0.770	0.850	1.170	0.910	1.050	0.990	0.860	0.880	0.830	0.900	0.850	0.900	0.820	0.760	0.830	0.760	0.750	0.920	0.770	0.760	0.870	0.863
	Frontal (m)	0.630	0.570	0.490	0.580	0.360	0.590	0.610	0.550	0.630	0.560	0.590	0.630	0.720	0.620	0.610	0.680	0.760	0.580	0.650	0.810	0.605	0.617
	Total (m)	0.995	1.023	1.268	1.079	1.110	1.152	1.054	1.038	1.042	1.060	1.035	1.099	1.091	0.981	1.030	1.020	1.068	1.088	1.008	1.111	1.070	1.065
Stride Velocity	(m/s)	1.455	1.572	1.769	1.539	1.958	1.921	1.471	1.639	1.453	1.550	1.476	1.688	1.423	1.434	1.506	1.422	0.533	1.515	1.589	1.624	1.463	1.590
Blade Time on Ice (s)	Weight Acceptance	6.773	6.439	7.941	7.607	9.075	8.842	10.110	10.010	11.311	11.161	12.512	12.362	13.747	13.580	15.048	14.831	16.249	16.082	18.768	17.317	12.153	11.823
	Propulsion	7.457	7.090	8.658	8.308	9.642	9.442	10.827	10.643	12.028	11.845	13.213	13.013	14.514	14.264	15.732	15.548	18.251	16.800	19.402	18.001	12.972	12.495
	Total	0.684	0.651	0.717	0.701	0.567	0.600	0.717	0.633	0.717	0.684	0.701	0.651	0.767	0.684	0.684	0.717	2.002	0.718	0.634	0.684	0.819	0.672

Subject Seven Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	6.500	6.100	9.500	8.400	5.900	11.400	4.000	8.100	7.300	10.000	7.500	6.800	4.800	10.800	8.200	8.300	5.500	10.100	6.400	12.500	6.560	9.250
(D/P)	Propulsion	0.600	8.600	0.400	11.500	13.200	13.800	2.500	13.700	12.100	10.000	15.500	8.500	-0.200	9.800	-5.000	5.400	10.000	9.100	6.800	6.400	5.590	9.680
Ankle ROM		7.100	14.700	9.900	19.900	19.100	25.200	6.500	21.800	19.400	20.000	23.000	15.300	4.600	20.600	3.200	13.700	15.500	19.200	13.200	18.900	12.150	18.930
Ankle Angular Velocity	(Deg/s)	11.199	22.006	16.500	30.615	27.924	41.930	10.833	34.385	29.042	31.546	38.270	24.757	7.890	30.117	4.678	22.204	21.618	30.332	21.963	26.323	18.992	29.422
Knee Flexion	Weight Acceptance	56.400	59.400	56.700	55.800	61.000	58.200	55.100	60.600	57.200	65.600	61.500	60.000	56.600	65.500	60.000	59.500	53.100	65.700	53.100	65.400	57.070	61.570
	Propulsion	19.600	14.000	12.000	17.900	11.800	9.800	14.800	16.000	10.600	8.100	14.900	12.000	15.700	11.200	9.800	14.300	14.100	11.400	18.300	11.800	14.160	12.650
Knee Extension (ROM)		36.800	45.400	44.700	37.900	49.200	48.400	40.300	44.600	46.600	57.500	46.600	48.000	40.900	54.300	50.200	45.200	39.000	54.300	34.800	53.600	42.910	48.920
Knee Angular Velocity	(Deg/s)	58.044	67.964	74.500	58.308	71.930	80.532	67.167	70.347	69.760	90.694	77.537	77.670	70.154	79.386	73.392	73.258	54.393	85.782	57.903	74.652	67.478	75.859
Hip Flexion	Weight Acceptance	79.700	73.400	73.200	74.500	84.300	66.700	79.000	74.500	75.100	74.100	79.800	73.500	73.800	76.400	77.400	73.300	75.800	78.500	70.800	68.200	76.890	73.310
	Propulsion	21.900	26.200	25.400	23.000	28.200	20.400	25.600	29.400	30.000	28.000	28.000	30.100	22.500	26.100	34.500	17.000	28.500	25.600	22.700	32.000	26.730	25.780
Hip Extension ROM		57.800	47.200	47.800	51.500	56.100	46.300	53.400	45.100	45.100	46.100	51.800	43.400	51.300	50.300	42.900	56.300	47.300	52.900	48.100	36.200	50.160	47.530
Hip Angular Velocity	(Deg/s)	91.167	70.659	79.667	79.231	82.018	77.038	89.000	71.136	67.515	72.713	86.190	70.227	87.993	73.538	62.719	91.248	65.969	83.570	80.033	50.418	79.227	73.978
Hip Abduction/Adduction	Weight Acceptance	-6.900	-6.900	-8.500	-11.200	-6.900	-10.000	-6.200	-5.800	-5.600	-12.600	-2.900	-6.700	-8.400	-4.600	-5.400	-6.600	-7.600	-4.200	-5.700	-3.300	-6.410	-7.190
(Abd/Add)	Propulsion	22.300	20.400	18.700	23.000	24.400	24.500	24.700	27.200	22.500	26.300	22.900	25.500	24.500	22.700	23.300	26.300	23.500	24.700	24.500	23.600	23.130	24.420
Hip Abduction ROM		29.200	27.300	27.200	34.200	31.300	34.500	30.900	33.000	28.100	38.900	25.800	32.200	32.900	27.300	28.700	32.900	31.100	28.900	30.200	26.900	29.540	31.610
Hip Angular Velocity	(Deg/s)	46.057	40.868	45.333	52.615	45.760	57.404	51.500	52.050	42.066	61.356	42.928	52.104	56.432	39.912	41.959	53.323	43.375	45.656	50.250	37.465	46.566	49.275
Stride Length	Sagittal (m)	1.080	0.790	1.020	0.990	0.860	0.800	1.010	0.940	0.870	0.770	0.900	0.890	0.720	0.890	0.910	0.920	0.950	0.700	0.870	0.880	0.919	0.857
	Frontal (m)	0.590	0.610	0.670	0.690	0.560	0.740	0.650	0.590	0.580	0.700	0.610	0.620	0.700	0.720	0.650	0.650	0.630	0.720	0.590	0.580	0.623	0.662
	Total (m)	1.231	0.998	1.220	1.207	1.026	1.090	1.201	1.110	1.046	1.041	1.087	1.085	1.004	1.145	1.118	1.126	1.140	1.004	1.051	1.054	1.112	1.086
Stride Velocity	(m/s)	1.941	1.494	2.034	1.857	1.500	1.813	2.002	1.751	1.565	1.641	1.809	1.755	1.722	1.674	1.635	1.826	1.590	1.586	1.749	1.468	1.755	1.686
Blade Time on Ice (s)	Weight Acceptance	4.604	19.602	5.739	20.754	6.840	21.921	8.008	23.006	9.075	24.124	10.243	25.291	11.378	26.393	12.445	27.577	13.613	28.712	14.814	29.829	9.676	24.721
	Propulsion	5.238	20.270	6.339	21.404	7.524	22.522	8.608	23.640	9.743	24.758	10.844	25.909	11.961	27.077	13.129	28.194	14.330	29.345	15.415	30.547	10.313	25.367
	Total	0.634	0.668	0.600	0.650	0.684	0.601	0.600	0.634	0.668	0.634	0.601	0.618	0.583	0.684	0.684	0.617	0.717	0.633	0.601	0.718	0.637	0.646

Subject Seven Kinematics (15mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	7.000	11.000	8.900	8.500	5.400	7.200	5.500	7.800	10.800	8.800	7.600	8.600	9.900	10.600	7.200	13.500	13.000	10.300	7.300	12.900	8.260	9.920
(D/P)	Propulsion	1.200	10.100	11.700	16.100	7.900	12.300	11.200	11.200	12.500	4.900	11.000	11.600	8.800	7.700	9.000	14.200	9.600	10.000	10.800	5.300	9.370	10.340
Ankle ROM		8.200	21.100	20.600	24.600	13.300	19.500	16.700	19.000	23.300	13.700	18.600	20.200	18.700	18.300	16.200	27.700	22.600	20.300	18.100	18.200	17.630	20.260
Ankle Angular Velocity	(Deg/s)	14.041	32.412	34.276	39.870	19.444	32.446	28.596	30.794	35.791	19.081	25.905	29.532	28.036	28.864	23.143	35.332	34.769	27.074	27.136	27.957	27.114	30.336
Knee Flexion	Weight Acceptance	55.300	61.100	62.000	58.200	57.400	51.300	56.100	61.100	60.100	64.800	60.100	62.700	63.900	54.100	61.600	64.300	64.100	56.900	56.800	63.600	59.740	59.810
	Propulsion	11.500	11.400	11.600	10.100	14.100	11.700	11.600	13.900	14.300	10.900	10.400	9.500	12.100	15.300	13.200	5.100	9.100	8.400	7.700	15.000	11.560	11.130
Knee Extension (ROM)		43.800	49.700	50.400	48.100	43.300	39.600	44.500	47.200	45.800	53.900	49.700	53.200	51.800	38.800	48.400	59.200	55.000	48.500	49.100	48.600	48.180	48.680
Knee Angular Velocity	(Deg/s)	75.000	76.344	83.860	77.958	63.304	65.890	76.199	76.499	70.353	75.070	69.220	77.778	77.661	61.199	69.143	75.510	84.615	64.684	73.613	74.654	74.297	72.559
Hip Flexion	Weight Acceptance	73.000	77.000	82.600	75.000	71.900	65.800	76.900	71.100	74.400	73.100	78.400	75.300	77.800	60.100	78.500	73.100	78.900	70.200	72.200	77.100	76.460	71.780
	Propulsion	31.400	23.800	23.700	27.800	29.900	24.500	23.100	26.200	26.500	29.100	25.300	23.800	30.000	25.400	35.500	32.300	29.000	36.900	31.300	26.100	28.570	27.590
Hip Extension ROM		41.600	53.200	58.900	47.200	42.000	41.300	53.800	44.900	47.900	44.000	53.100	51.500	47.800	34.700	43.000	40.800	49.900	33.300	40.900	51.000	47.890	44.190
Hip Angular Velocity	(Deg/s)	71.233	81.720	98.003	76.499	61.404	68.719	92.123	72.771	73.579	61.281	73.955	75.292	71.664	54.732	61.429	52.041	76.769	44.412	61.319	78.341	74.148	66.581
Hip Abduction/Adduction	Weight Acceptance	-6.100	-7.700	-8.000	-8.000	-9.100	-12.600	-8.900	-7.100	-6.400	-7.500	-10.600	-5.700	-6.200	-3.900	-12.900	-13.200	-5.500	-11.100	-6.700	-10.800	-8.040	-8.760
(Abd/Add)	Propulsion	20.100	23.700	21.500	25.200	18.800	27.400	21.900	26.100	21.600	27.300	25.300	24.400	25.000	22.700	22.200	26.700	27.900	29.400	23.900	25.500	22.820	25.840
Hip Abduction ROM		26.200	31.400	29.500	33.200	27.900	40.000	30.800	33.200	28.000	34.800	35.900	30.100	31.200	26.600	35.100	39.900	33.400	40.500	30.600	36.300	30.860	34.600
Hip Angular Velocity	(Deg/s)	44.863	48.233	49.085	53.809	40.789	66.556	52.740	53.809	43.011	48.468	50.000	44.006	46.777	41.956	50.143	50.893	51.385	54.014	45.877	55.760	47.467	51.750
Stride Length	Sagittal (m)	0.960	0.990	0.910	0.970	0.920	0.920	0.890	8.200	0.890	0.760	0.970	1.000	0.850	0.810	0.800	0.820	0.770	0.830	0.800	0.880	0.876	1.618
	Frontal (m)	0.540	0.680	0.630	0.710	0.690	0.700	0.580	0.720	0.640	0.690	0.650	0.770	0.720	0.710	0.660	0.820	0.640	0.870	0.660	0.760	0.641	0.743
	Total (m)	1.101	1.201	1.107	1.202	1.150	1.156	1.062	8.232	1.096	1.026	1.168	1.262	1.114	1.077	1.037	1.160	1.001	1.202	1.037	1.163	1.087	1.868
Stride Velocity	(m/s)	1.886	1.845	1.842	1.948	1.681	1.924	1.819	13.341	1.684	1.430	1.626	1.845	1.670	1.699	1.482	1.479	1.540	1.604	1.555	1.786	1.679	2.890
Blade Time on Ice (s)	Weight Acceptance	5.071	12.912	6.139	14.047	7.207	15.181	8.441	16.266	9.509	17.350	10.643	18.551	11.845	19.753	13.013	20.887	14.214	22.122	15.315	23.356	10.140	18.043
	Propulsion	5.655	13.563	6.740	14.664	7.891	15.782	9.025	16.883	10.160	18.068	11.361	19.235	12.512	20.387	13.713	21.671	14.864	22.872	15.982	24.007	10.790	18.713
	Total	0.584	0.651	0.601	0.617	0.684	0.601	0.584	0.617	0.651	0.718	0.718	0.684	0.667	0.634	0.700	0.784	0.650	0.750	0.667	0.651	0.651	0.671

Subject Seven Kinematics (18mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	11.100	10.800	6.600	11.700	6.300	10.100	12.700	8.200	10.400	7.900	10.200	11.400	11.600	10.600	12.300	11.700	8.300	12.800	13.000	12.000	10.250	10.720
(D/P)	Propulsion	14.600	5.800	11.400	12.100	13.900	3.200	7.700	16.400	3.600	15.200	3.400	11.600	12.500	10.200	-6.800	10.500	5.200	4.100	6.300	10.300	7.180	9.940
Ankle ROM		25.700	16.600	18.000	23.800	20.200	13.300	20.400	24.600	14.000	23.100	13.600	23.000	24.100	20.800	5.500	22.200	13.500	16.900	19.300	22.300	17.430	20.660
Ankle Angular Velocity	(Deg/s)	44.007	27.667	30.000	37.539	29.532	20.978	33.063	36.826	21.505	33.772	22.667	37.217	38.013	32.000	9.418	35.016	21.293	27.391	30.442	32.602	27.994	32.101
Knee Flexion	Weight Acceptance	66.300	70.700	59.500	64.000	56.100	62.000	68.900	62.800	64.300	59.600	60.900	66.000	57.400	58.200	68.100	68.700	66.800	66.400	63.400	65.800	63.170	64.420
	Propulsion	7.700	12.900	12.000	6.900	16.600	14.700	11.300	15.900	12.900	5.100	8.900	6.400	8.700	13.700	14.300	9.300	10.200	13.000	8.200	12.300	11.080	11.020
Knee Extension (ROM)		58.600	57.800	47.500	57.100	39.500	47.300	57.600	46.900	51.400	54.500	52.000	59.600	48.700	44.500	53.800	59.400	56.600	53.400	55.200	53.500	52.090	53.400
Knee Angular Velocity	(Deg/s)	100.342	96.333	79.167	90.063	57.749	74.606	93.355	70.210	78.955	79.678	86.667	96.440	76.814	68.462	92.123	93.691	89.274	86.548	87.066	78.216	84.151	83.425
Hip Flexion	Weight Acceptance	81.000	80.900	76.400	81.600	77.100	76.400	79.400	80.800	80.600	76.900	78.400	81.900	73.900	75.500	81.200	82.200	88.300	83.900	78.000	82.600	79.430	80.270
	Propulsion	29.000	26.200	36.300	24.600	27.600	22.500	27.700	26.400	30.900	28.800	29.100	32.200	24.400	33.000	28.100	30.200	25.700	26.100	28.300	29.600	28.710	27.960
Hip Extension ROM		52.000	54.700	40.100	57.000	49.500	53.900	51.700	54.400	49.700	48.100	49.300	49.700	49.500	42.500	53.100	52.000	62.600	57.800	49.700	53.000	50.720	52.310
Hip Angular Velocity	(Deg/s)	89.041	91.167	66.833	89.905	72.368	85.016	83.793	81.437	76.344	70.322	82.167	80.421	78.076	65.385	90.925	82.019	98.738	93.679	78.391	77.485	81.668	81.684
Hip Abduction/Adduction	Weight Acceptance	-6.100	-10.800	-4.800	-6.300	-4.200	-6.200	-8.500	-7.900	-11.900	-9.300	-9.100	-2.300	-13.900	-10.400	-6.600	-8.300	-8.500	-7.300	-9.400	-6.900	-8.300	-7.570
(Abd/Add)	Propulsion	26.300	27.100	25.200	25.200	26.000	25.600	26.600	24.500	28.600	25.600	28.400	27.600	24.700	24.500	21.600	23.300	29.000	22.400	27.200	29.500	26.360	25.530
Hip Abduction ROM		32.400	37.900	30.000	31.500	30.200	31.800	35.100	32.400	40.500	34.900	37.500	29.900	38.600	34.900	28.200	31.600	37.500	29.700	36.600	36.400	34.660	33.100
Hip Angular Velocity	(Deg/s)	55.479	63.167	50.000	49.685	44.152	50.158	56.888	48.503	62.212	51.023	62.500	48.382	60.883	53.692	48.288	49.842	59.148	48.136	57.729	53.216	55.728	51.580
Stride Length	Sagittal (m)	0.870	0.870	0.850	0.800	0.920	1.000	0.850	0.710	0.830	0.750	0.860	0.800	0.970	0.870	0.820	0.930	0.840	0.910	0.870	0.890	0.868	0.853
	Frontal (m)	0.680	0.800	0.680	0.720	0.680	0.740	0.730	0.750	0.760	0.750	0.810	0.700	0.690	0.720	0.710	0.640	0.680	0.720	0.830	0.700	0.725	0.724
	Total (m)	1.104	1.182	1.089	1.076	1.144	1.244	1.120	1.033	1.125	1.061	1.181	1.063	1.190	1.129	1.085	1.129	1.081	1.160	1.202	1.132	1.132	1.121
Stride Velocity	(m/s)	1.891	1.970	1.814	1.698	1.673	1.962	1.816	1.546	1.729	1.551	1.969	1.720	1.878	1.737	1.857	1.781	1.705	1.881	1.897	1.655	1.823	1.750
Blade Time on Ice (s)	Weight Acceptance	5.839	10.110	6.890	11.177	7.941	12.278	9.109	13.346	10.176	14.481	11.311	15.648	12.379	16.750	13.513	17.901	14.564	19.035	15.665	20.120	10.739	15.085
	Propulsion	6.423	10.710	7.490	11.811	8.625	12.912	9.726	14.014	10.827	15.165	11.911	16.266	13.013	17.400	14.097	18.535	15.198	19.652	16.299	20.804	11.361	15.727
	Total	0.584	0.600	0.600	0.634	0.684	0.634	0.617	0.668	0.651	0.684	0.600	0.618	0.634	0.650	0.584	0.634	0.634	0.617	0.634	0.684	0.622	0.642

Subject Eight Kinematics (8mph)

Variable	Stride Number	1 Own	1 Mako	2 Own	2 Mako	3 Own	3 Mako	4 Own	4 Mako	5 Own	5 Mako	6 Own	6 Mako	7 Own	7 Mako	8 Own	8 Mako	9 Own	9 Mako	10 Own	10 Mako	Average Own	Average Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	9.400	6.500	10.200	8.100	10.100	6.700	9.500	9.400	6.300	10.300	8.800	8.100	9.700	6.600	6.700	14.800	6.800	9.500	11.100	10.000	8.860	9.000
(D/P)	Propulsion	4.300	2.900	-6.700	3.600	-0.600	1.000	-2.200	3.500	-0.700	3.700	-0.300	1.700	-4.400	1.700	-2.100	5.400	-0.200	0.100	-1.700	5.100	-1.460	2.870
Ankle ROM		13.700	9.400	3.500	11.700	9.500	7.700	7.300	12.900	5.600	14.000	8.500	9.800	5.300	8.300	4.600	20.200	6.600	9.600	9.400	15.100	7.400	11.870
Ankle Angular Velocity	(Deg/s)	21.077	14.072	5.376	17.972	14.593	11.257	10.673	20.347	8.396	23.973	12.427	15.457	8.141	13.091	6.562	32.739	10.154	15.559	14.093	24.473	11.149	18.894
Knee Flexion	Weight Acceptance	62.100	50.200	58.800	53.600	61.200	50.700	59.500	56.100	57.200	59.600	58.400	55.800	58.300	56.800	58.600	61.400	56.800	60.300	58.700	57.700	58.960	56.220
	Propulsion	13.300	14.400	14.900	15.900	11.400	16.200	16.900	14.500	17.900	16.900	13.400	16.400	20.500	15.800	14.600	15.100	19.400	15.100	17.300	14.000	15.960	15.430
Knee Extension (ROM)		48.800	35.800	43.900	37.700	49.800	34.500	42.600	41.600	39.300	42.700	45.000	39.400	37.800	41.000	44.000	46.300	37.400	45.200	41.400	43.700	43.000	40.790
Knee Angular Velocity	(Deg/s)	75.077	53.593	67.435	57.911	76.498	50.439	62.281	65.615	58.921	73.116	65.789	62.145	58.065	64.669	62.767	75.041	57.538	73.258	62.069	70.827	64.644	64.661
Hip Flexion	Weight Acceptance	71.400	61.800	70.100	60.200	71.600	66.700	67.200	56.100	71.800	64.500	71.800	65.200	65.700	68.700	71.100	64.000	75.100	68.800	63.400	61.300	69.920	63.730
	Propulsion	20.700	13.700	18.300	10.400	18.900	14.600	18.000	64.600	18.800	11.700	16.800	13.900	23.800	19.200	19.400	16.900	20.500	16.700	21.400	14.500	19.660	19.620
Hip Extension ROM		50.700	48.100	51.800	49.800	52.700	52.100	49.200	-8.500	53.000	52.800	55.000	51.300	41.900	49.500	51.700	47.100	54.600	52.100	42.000	46.800	50.260	44.110
Hip Angular Velocity	(Deg/s)	78.000	72.006	79.570	76.498	80.952	76.170	71.930	-13.407	79.460	90.411	80.409	80.915	64.363	78.076	73.752	76.337	84.000	84.441	62.969	75.851	75.540	69.730
Hip Abduction/Adduction	Weight Acceptance	-2.000	-4.600	-2.400	-5.600	-2.000	-1.400	-0.900	-5.000	-2.300	-3.100	-4.500	-3.200	-3.700	-3.200	-3.900	-1.400	-3.400	-4.200	-7.100	-3.200	-3.220	-3.490
(Abd/Add)	Propulsion	24.500	15.600	24.100	19.500	23.500	19.400	25.300	16.900	16.800	14.900	24.400	14.200	23.100	16.700	20.500	17.500	17.200	16.600	18.800	12.000	21.820	16.330
Hip Abduction ROM		26.500	20.200	26.500	25.100	25.500	20.800	26.200	21.900	19.100	18.000	28.900	17.400	26.800	19.900	24.400	18.900	20.600	20.800	25.900	15.200	25.040	19.820
Hip Angular Velocity	(Deg/s)	40.769	30.240	40.707	38.556	39.171	30.409	38.304	34.543	28.636	30.822	42.251	27.445	41.167	31.388	34.807	30.632	31.692	33.712	38.831	24.635	37.634	31.238
Stride Length	Sagittal (m)	0.93	0.920	0.99	0.930	0.87	1.040	0.900	0.990	0.930	1.050	0.870	1.040	0.920	0.930	1.050	0.900	0.940	0.970	0.940	1.090	0.934	0.986
	Frontal (m)	0.540	0.490	0.540	0.500	0.520	0.500	0.510	0.480	0.500	0.530	0.620	0.420	0.550	0.470	0.550	0.510	0.510	0.470	0.510	0.460	0.535	0.483
	Total (m)	1.075	1.042	1.128	1.056	1.014	1.154	1.034	1.100	1.056	1.176	1.068	1.122	1.072	1.042	1.185	1.034	1.069	1.078	1.069	1.183	1.077	1.099
Stride Velocity	(m/s)	1.654	1.560	1.732	1.622	1.557	1.687	1.512	1.735	1.583	2.014	1.562	1.769	1.646	1.644	1.691	1.677	1.645	1.747	1.603	1.917	1.619	1.737
Blade Time on Ice (s)	Weight Acceptance	6.006	12.028	7.140	13.179	8.274	14.280	9.442	15.398	10.660	16.549	11.811	17.584	12.979	18.685	14.130	19.786	15.315	20.887	16.416	21.988	11.217	17.036
	Propulsion	6.656	12.696	7.791	13.830	8.925	14.964	10.126	16.032	11.327	17.133	12.495	18.218	13.630	19.319	14.831	20.403	15.965	21.504	17.083	22.605	11.883	17.670
	Total	0.650	0.668	0.651	0.651	0.651	0.684	0.684	0.634	0.667	0.584	0.684	0.634	0.651	0.634	0.701	0.617	0.650	0.617	0.667	0.617	0.666	0.634

Subject Eight Kinematics (11mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	10.300	8.200	11.500	10.300	11.600	12.300	11.600	9.900	9.300	8.200	12.300	16.400	9.100	15.600	15.100	10.000	8.800	11.300	10.300	8.300	10.990	11.050
(D/P)	Propulsion	-8.200	0.500	-10.200	7.400	-9.800	2.300	-10.100	11.200	-7.100	0.400	5.000	0.500	3.000	8.200	-6.000	5.900	-6.200	1.000	-6.000	4.100	-5.560	4.150
Ankle ROM		2.100	8.700	1.300	17.700	1.800	14.600	1.500	21.100	2.200	8.600	17.300	16.900	12.100	23.800	9.100	15.900	2.600	12.300	4.300	12.400	5.430	15.200
Ankle Angular Velocity	(Deg/s)	3.596	15.344	2.434	31.162	3.169	26.545	2.809	36.130	3.767	15.608	32.397	30.672	20.167	43.194	17.041	28.857	4.869	24.551	7.584	21.233	9.783	27.330
Knee Flexion	Weight Acceptance	57.300	57.500	60.600	61.100	62.400	64.400	59.400	63.200	58.800	57.100	61.600	65.100	62.400	58.500	66.000	59.100	58.600	62.200	64.500	55.900	61.160	60.410
	Propulsion	16.800	13.400	22.400	9.100	20.200	11.400	21.300	7.900	24.400	8.400	15.100	8.400	17.000	11.600	20.300	10.100	17.000	7.000	17.200	12.600	19.170	9.990
Knee Extension (ROM)		40.500	44.100	38.200	52.000	42.200	53.000	38.100	55.300	34.400	48.700	46.500	56.700	45.400	46.900	45.700	49.000	41.600	55.200	47.300	43.300	41.990	50.420
Knee Angular Velocity	(Deg/s)	69.349	77.778	71.536	91.549	74.296	96.364	71.348	94.692	58.904	88.385	87.079	102.904	75.667	85.118	85.581	88.929	77.903	110.180	83.422	74.144	75.508	91.004
Hip Flexion	Weight Acceptance	69.500	66.400	75.100	74.600	72.800	73.000	74.400	68.200	71.800	67.100	75.600	76.800	70.200	57.400	74.500	68.400	68.100	72.800	77.400	67.300	72.940	69.200
	Propulsion	14.800	9.000	17.200	12.400	22.000	12.200	16.500	15.700	25.000	19.400	21.600	20.500	15.600	19.100	14.900	14.800	20.300	17.800	18.700	14.600	18.660	15.550
Hip Extension ROM		54.700	57.400	57.900	62.200	50.800	60.800	57.900	52.500	46.800	47.700	54.000	56.300	54.600	38.300	59.600	53.600	47.800	55.000	58.700	52.700	54.280	53.650
Hip Angular Velocity	(Deg/s)	93.664	101.235	108.427	109.507	89.437	110.545	108.427	89.897	80.137	86.570	101.124	102.178	91.000	69.510	111.610	97.278	89.513	109.780	103.527	90.240	97.687	96.674
Hip Abduction/Adduction	Weight Acceptance	6.200	-0.400	-4.600	-0.300	-4.200	-4.000	-5.800	-3.700	-5.300	-3.900	-3.400	-9.000	-3.900	-5.900	-2.800	-5.700	-2.800	-7.900	-4.300	-6.800	-3.090	-4.760
(Abd/Add)	Propulsion	19.500	16.500	23.300	23.300	21.500	19.100	22.600	22.900	22.200	15.600	26.900	18.800	26.700	18.500	18.600	18.000	19.800	25.100	18.200	21.600	21.930	19.940
Hip Abduction ROM		13.300	16.900	27.900	23.600	25.700	23.100	28.400	26.600	27.500	19.500	30.300	27.800	30.600	24.400	21.400	23.700	22.600	33.000	22.500	28.400	25.020	24.700
Hip Angular Velocity	(Deg/s)	22.774	29.806	52.247	41.549	45.246	42.000	53.184	45.548	47.089	35.390	56.742	50.454	51.000	44.283	40.075	43.013	42.322	65.868	39.683	48.630	45.036	44.654
Stride Length	Sagittal (m)	1.250	1.110	1.030	1.160	1.130	1.080	1.020	1.050	0.920	0.990	0.880	1.040	0.820	1.030	1.100	1.200	1.070	1.160	0.840	1.200	1.006	1.102
	Frontal (m)	0.510	0.410	0.510	0.490	0.540	0.560	0.510	0.550	0.500	0.540	0.550	0.540	0.570	0.520	0.530	0.530	0.490	0.550	0.490	0.530	0.520	0.522
	Total (m)	1.350	1.183	1.149	1.259	1.252	1.217	1.140	1.185	1.047	1.128	1.038	1.172	0.999	1.154	1.221	1.312	1.177	1.284	0.972	1.312	1.135	1.221
Stride Velocity	(m/s)	2.312	2.087	2.152	2.217	2.205	2.212	2.136	2.030	1.793	2.047	1.943	2.127	1.664	2.094	2.287	2.381	2.204	2.562	1.715	2.246	2.041	2.200
Blade Time on Ice (s)	Weight Acceptance	9.509	13.113	10.543	14.130	11.544	15.165	12.545	16.149	13.513	17.183	14.597	18.251	15.582	19.252	16.616	20.253	17.617	21.304	18.618	22.255	14.068	17.706
	Propulsion	10.093	13.680	11.077	14.698	12.112	15.715	13.079	16.733	14.097	17.734	15.131	18.802	16.182	19.803	17.150	20.804	18.151	21.805	19.185	22.839	14.626	18.261
	Total	0.584	0.567	0.534	0.568	0.568	0.550	0.534	0.584	0.584	0.551	0.534	0.551	0.600	0.551	0.534	0.551	0.534	0.501	0.567	0.584	0.557	0.556

Subject Eight Kinematics (14mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	7.900	6.900	14.500	13.000	9.400	13.000	12.800	14.200	10.400	11.400	10.300	10.100	9.100	15.800	14.600	11.300	14.400	12.700	8.800	11.000	11.220	11.940
(D/P)	Propulsion	-7.100	3.700	-2.300	4.200	-0.400	4.100	-3.100	5.300	-2.100	4.200	-5.500	3.500	-5.200	9.700	-11.000	1.100	-0.300	2.700	-6.000	11.200	-4.300	4.970
Ankle ROM		0.800	10.600	12.200	17.200	9.000	17.100	9.700	19.500	8.300	15.600	4.800	13.600	3.900	25.500	3.600	12.400	14.100	15.400	2.800	22.200	6.920	16.910
Ankle Angular Velocity	(Deg/s)	1.653	21.901	25.207	33.269	16.364	33.012	18.762	40.289	15.543	31.138	9.917	26.306	8.333	47.842	6.742	25.673	26.404	30.739	5.091	45.868	13.402	33.604
Knee Flexion	Weight Acceptance	65.900	65.700	66.100	69.000	65.800	67.900	58.300	63.700	58.800	57.000	58.000	59.700	57.200	64.900	64.300	68.700	58.900	65.600	68.200	65.300	62.150	64.750
	Propulsion	16.500	14.800	16.800	17.400	13.200	9.300	19.400	10.400	11.700	7.100	8.700	13.900	9.000	7.100	14.600	9.900	16.500	9.600	12.100	8.700	13.850	10.820
Knee Extension (ROM)		49.400	50.900	49.300	51.600	52.600	58.600	38.900	53.300	47.100	49.900	49.300	45.800	48.200	57.800	49.700	58.800	42.400	56.000	56.100	56.600	48.300	53.930
Knee Angular Velocity	(Deg/s)	102.066	105.165	101.860	99.807	95.636	113.127	75.242	110.124	88.202	99.601	101.860	88.588	102.991	108.443	93.071	121.739	79.401	111.776	102.000	116.942	94.233	107.531
Hip Flexion	Weight Acceptance	76.300	84.800	73.700	74.900	78.000	76.300	67.600	75.600	72.400	75.000	71.300	73.100	65.900	74.500	77.000	77.900	74.300	75.900	81.100	81.300	73.760	76.930
	Propulsion	19.600	19.600	18.000	16.000	22.800	19.700	21.000	18.500	20.900	21.100	22.800	18.100	21.500	18.600	27.500	17.800	22.300	19.000	24.000	20.900	22.040	18.930
Hip Extension ROM		56.700	65.200	55.700	58.900	55.200	56.600	46.600	57.100	51.500	53.900	48.500	55.000	44.400	55.900	49.500	60.100	52.000	56.900	57.100	60.400	51.720	58.000
Hip Angular Velocity	(Deg/s)	117.149	134.711	115.083	113.926	100.364	109.266	90.135	117.975	96.442	107.585	100.207	106.383	94.872	104.878	92.697	124.431	97.378	113.573	103.818	124.793	100.814	115.752
Hip Abduction/Adduction	Weight Acceptance	-2.500	-5.800	-2.500	-7.400	-4.500	-4.800	-6.800	-3.200	-7.500	-3.500	-5.800	-3.800	-3.000	-5.600	-3.100	-2.100	-7.200	-9.200	-2.400	-5.300	-4.530	-5.070
(Abd/Add)	Propulsion	17.100	21.400	16.800	17.400	20.800	21.500	21.400	21.500	21.100	21.800	21.400	17.300	22.400	20.300	19.600	22.200	25.800	22.200	21.400	20.400	20.780	20.600
Hip Abduction ROM		19.600	27.200	19.300	24.800	25.300	26.300	28.200	24.700	28.600	25.300	27.200	21.100	25.400	25.900	22.700	24.300	33.000	31.400	23.800	25.700	25.310	25.670
Hip Angular Velocity	(Deg/s)	40.496	56.198	39.876	47.969	46.000	50.772	54.545	51.033	53.558	50.499	56.198	40.812	54.274	48.593	42.509	50.311	61.798	62.675	43.273	53.099	49.253	51.196
Stride Length	Sagittal (m)	1.030	1.160	1.010	1.130	0.910	1.140	0.940	1.190	0.900	1.040	0.990	1.110	0.930	1.070	0.860	1.160	1.060	1.090	0.730	1.090	0.936	1.118
	Frontal (m)	0.470	0.500	0.530	0.540	0.490	0.510	0.580	0.440	0.580	0.490	0.530	0.520	0.500	0.440	0.570	0.490	0.570	0.430	0.490	0.500	0.531	0.486
	Total (m)	1.132	1.263	1.141	1.252	1.034	1.249	1.105	1.269	1.071	1.150	1.123	1.226	1.056	1.157	1.032	1.259	1.204	1.172	0.879	1.199	1.077	1.220
Stride Velocity	(m/s)	2.339	2.610	2.357	2.422	1.879	2.411	2.136	2.621	2.005	2.295	2.320	2.371	2.256	2.171	1.932	2.607	2.254	2.339	1.599	2.478	2.108	2.432
Blade Time on Ice (s)	Weight Acceptance	9.576	14.447	10.510	15.365	11.411	16.282	12.412	17.283	13.346	18.184	14.314	19.119	15.281	20.070	16.199	21.021	17.150	21.921	18.118	22.822	13.832	18.651
	Propulsion	10.060	14.931	10.994	15.882	11.961	16.800	12.929	17.767	13.880	18.685	14.798	19.636	15.749	20.603	16.733	21.504	17.684	22.422	18.668	23.306	14.346	19.154
	Total	0.484	0.484	0.484	0.517	0.550	0.518	0.517	0.484	0.534	0.501	0.484	0.517	0.468	0.533	0.534	0.483	0.534	0.501	0.550	0.484	0.514	0.502

Subject Eight Kinematics (15mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	8.000	11.000	14.200	10.100	14.600	10.900	14.900	14.000	10.500	11.300	6.500	13.100	9.400	11.000	12.200	9.900	16.800	7.900	9.800	10.200	11.690	10.940)40
(D/P)	Propulsion	-1.400	-0.900	-1.400	14.300	4.000	4.700	-1.100	7.300	-4.200	11.100	-5.600	11.500	-13.900	6.800	3.900	9.000	-3.300	5.700	-4.800	7.500	-2.780	7.700 '00
Ankle ROM		6.600	10.100	12.800	24.400	18.600	15.600	13.800	21.300	6.300	22.400	0.900	24.600	-4.500	17.800	16.100	18.900	13.500	13.600	5.000	17.700	8.910	18.640 ;40
Ankle Angular Velocity	(Deg/s)	11.301	20.911	23.273	44.283	31.849	29.213	25.843	39.888	11.111	43.327	1.737	46.067	-8.704	35.600	29.273	39.130	27.000	26.306	9.074	36.570	16.176	36.130 .30
Knee Flexion	Weight Acceptance	62.900	66.700	68.100	65.100	66.800	64.500	63.700	65.100	67.900	70.300	49.600	66.300	60.300	63.700	63.100	63.000	65.600	61.800	58.800	54.800	62.680	64.130 .30
	Propulsion	11.000	10.300	8.800	7.800	7.800	12.600	9.300	12.900	8.600	6.700	12.300	7.800	17.400	6.200	12.000	5.200	9.300	7.200	14.000	5.400	11.050	8.210 !10
Knee Extension (ROM)		51.900	56.400	59.300	57.300	59.000	51.900	54.400	52.200	59.300	63.600	37.300	58.500	42.900	57.500	51.100	57.800	56.300	54.600	44.800	49.400	51.630	55.920)20
Knee Angular Velocity	(Deg/s)	88.870	116.770	107.818	103.993	101.027	97.191	101.873	97.753	104.586	123.017	72.008	109.551	82.979	115.000	92.909	119.669	112.600	105.609	81.307	102.066	94.598	109.062)62
Hip Flexion	Weight Acceptance	84.600	82.700	82.900	78.300	80.300	79.600	78.200	78.600	81.100	82.700	64.500	81.400	69.500	78.500	72.000	80.300	75.100	76.400	73.200	75.200	76.140	79.370 i70
	Propulsion	20.800	18.500	25.900	18.800	25.000	16.900	21.300	12.500	20.600	14.000	21.300	16.500	15.100	16.200	25.700	22.200	21.400	19.900	19.100	15.800	21.620	17.130 .30
Hip Extension ROM		63.800	64.200	57.000	59.500	55.300	62.700	56.900	66.100	60.500	68.700	43.200	64.900	54.400	62.300	46.300	58.100	53.700	56.500	54.100	59.400	54.520	62.240 !40
Hip Angular Velocity	(Deg/s)	109.247	132.919	103.636	107.985	94.692	117.416	106.554	123.783	106.702	132.882	83.398	121.536	105.222	124.600	84.182	120.290	107.400	109.284	98.185	122.727	99.922	121.342 i42
Hip Abduction/Adduction	Weight Acceptance	-5.700	-6.000	-6.400	-5.200	-3.200	-6.200	-8.500	-6.800	-7.600	-7.000	-5.000	-6.000	-7.100	-6.500	-5.200	-7.900	-3.800	-8.600	-7.000	-4.200	-5.950	-6.440 l40
(Abd/Add)	Propulsion	21.100	16.700	21.100	20.100	25.800	21.400	22.500	21.500	24.400	21.700	26.600	21.700	18.700	22.100	23.700	19.900	24.300	20.300	22.300	20.000	23.050	20.540 ;40
Hip Abduction ROM		26.800	22.700	27.500	25.300	29.000	27.600	31.000	28.300	32.000	28.700	31.600	27.700	25.800	28.600	28.900	27.800	28.100	28.900	29.300	24.200	29.000	26.980 l80
Hip Angular Velocity	(Deg/s)	45.890	46.998	50.000	45.917	49.658	51.685	58.052	52.996	56.437	55.513	61.004	51.873	49.903	57.200	52.545	57.557	56.200	55.899	53.176	50.000	53.287	52.564 ;64
Stride Length	Sagittal (m)	1.040	1.210	0.930	1.140	0.970	1.180	1.020	1.230	0.850	1.150	1.070	1.140	1.040	1.100	1.010	1.070	1.020	1.150	1.020	1.010	0.997	1.138 .38
	Frontal (m)	0.550	0.500	0.600	0.500	0.530	0.570	0.580	0.480	0.480	0.530	0.560	0.530	0.450	0.500	0.520	0.500	0.560	0.500	0.530	0.490	0.536	0.510 :10
	Total (m)	1.176	1.309	1.107	1.245	1.105	1.310	1.173	1.320	0.976	1.266	1.208	1.257	1.133	1.208	1.136	1.181	1.164	1.254	1.149	1.123	1.133	1.247 !47
Stride Velocity	(m/s)	2.015	2.711	2.012	2.259	1.893	2.454	2.197	2.473	1.722	2.449	2.331	2.354	2.192	2.417	2.065	2.445	2.327	2.426	2.086	2.319	2.084	2.431 l31
Blade Time on Ice (s)	Weight Acceptance	5.772	14.114	6.740	14.981	7.707	15.915	8.658	16.850	9.576	17.767	10.543	18.685	11.478	19.586	12.379	20.487	13.380	21.388	14.280	22.305	10.051	18.208 !08
	Propulsion	6.356	14.597	7.290	15.532	8.291	16.449	9.192	17.384	10.143	18.284	11.061	19.219	11.995	20.086	12.929	20.970	13.880	21.905	14.831	22.789	10.597	18.722 '22
	Total	0.584	0.483	0.550	0.551	0.584	0.534	0.534	0.534	0.567	0.517	0.518	0.534	0.517	0.500	0.550	0.483	0.500	0.517	0.551	0.484	0.546	0.514 ;14

Subject Eight Kinematics (18mph)

Variable	Stride Number	1		2		3		4		5		6		7		8		9		10		Average	
		Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako	Own	Mako
Ankle Dorsi/Plantarflexion	Weight Acceptance	9.100	13.400	10.800	13.600	10.100	13.700	7.900	12.900	10.900	11.700	4.100	10.900	11.500	12.900	14.400	12.500	15.700	12.900	12.100	11.400	10.660	12.590
(D/P)	Propulsion	1.500	7.200	-6.400	7.400	-5.800	4.700	-7.300	9.400	-4.500	5.600	-1.800	13.100	-4.800	9.100	-3.800	9.900	-2.300	7.000	-4.600	1.900	-3.980	7.530
Ankle ROM		10.600	20.600	4.400	21.000	4.300	18.400	0.600	22.300	6.400	17.300	2.300	24.000	6.700	22.000	10.600	22.400	13.400	19.900	7.500	13.300	6.680	20.120
Ankle Angular Velocity	(Deg/s)	21.901	47.465	8.782	52.369	8.317	42.494	1.161	49.446	12.379	35.744	4.600	49.689	13.373	43.912	22.698	44.800	25.869	42.612	15.000	25.676	13.408	43.421
Knee Flexion	Weight Acceptance	67.800	72.300	65.400	69.900	63.300	71.900	54.600	66.600	60.800	68.900	57.800	67.500	63.000	70.600	60.100	66.600	66.600	67.800	67.100	67.500	62.650	68.960
	Propulsion	9.300	8.100	5.400	6.000	4.900	6.500	10.800	12.200	11.000	11.000	10.400	8.300	9.900	2.900	-2.300	4.900	6.900	9.700	14.800	8.200	8.110	7.780
Knee Extension (ROM)		58.500	64.200	60.000	63.900	58.400	65.400	43.800	54.400	49.800	57.900	47.400	59.200	53.100	67.700	62.400	61.700	59.700	58.100	52.300	59.300	54.540	61.180
Knee Angular Velocity	(Deg/s)	120.868	147.926	119.760	159.352	112.959	151.039	84.720	120.621	96.325	119.628	94.800	122.567	105.988	135.130	133.619	123.400	115.251	124.411	104.600	114.479	108.889	131.855
Hip Flexion	Weight Acceptance	81.600	86.400	84.300	80.500	80.500	82.700	75.500	80.800	76.100	82.400	78.000	82.700	76.700	86.800	74.700	76.900	79.600	84.700	83.400	89.800	79.040	83.370
	Propulsion	16.900	21.100	20.900	19.700	25.500	18.900	18.800	21.200	28.900	20.500	16.700	22.500	18.600	15.600	16.300	17.800	24.200	19.800	15.200	14.400	20.200	19.150
Hip Extension ROM		64.700	65.300	63.400	60.800	55.000	63.800	56.700	59.600	47.200	61.900	61.300	60.200	58.100	71.200	58.400	59.100	55.400	64.900	68.200	75.400	58.840	64.220
Hip Angular Velocity	(Deg/s)	133.678	150.461	126.547	151.621	106.383	147.344	109.671	132.151	91.296	127.893	122.600	124.638	115.968	142.116	125.054	118.200	106.950	138.972	136.400	145.560	117.455	137.895
Hip Abduction/Adduction	Weight Acceptance	-3.700	-4.700	-2.000	-3.300	-5.300	-1.200	-6.800	-2.700	-3.100	-6.200	-10.300	-4.900	-9.200	-3.700	-7.600	-5.800	-9.100	-1.700	-7.800	-8.400	-6.490	-4.260
(Abd/Add)	Propulsion	27.800	23.100	26.600	20.500	21.300	20.000	23.900	18.600	28.300	19.800	24.300	24.100	23.600	24.800	22.200	24.200	26.200	22.100	25.300	24.400	24.950	22.160
Hip Abduction ROM		31.500	27.800	28.600	23.800	26.600	21.200	30.700	21.300	31.400	26.000	34.600	29.000	32.800	28.500	29.800	30.000	35.300	23.800	33.100	32.800	31.440	26.420
Hip Angular Velocity	(Deg/s)	65.083	64.055	57.086	59.352	51.451	48.961	59.381	47.228	60.735	53.719	69.200	60.041	65.469	56.886	63.812	60.000	68.147	50.964	66.200	63.320	62.656	56.453
Stride Length	Sagittal (m)	1.180	1.230	1.190	1.210	1.010	1.210	1.050	1.130	0.930	1.010	1.090	1.000	0.950	1.060	1.000	1.070	1.100	1.040	1.120	1.070	1.062	1.103
	Frontal (m)	0.470	0.500	0.500	0.540	0.460	0.490	0.500	0.450	0.500	0.640	0.550	0.570	0.510	0.620	0.530	0.620	0.530	0.570	0.540	0.640	0.509	0.564
	Total (m)	1.270	1.328	1.291	1.325	1.110	1.305	1.163	1.216	1.056	1.196	1.221	1.151	1.078	1.228	1.132	1.237	1.221	1.186	1.243	1.247	1.178	1.242
Stride Velocity	(m/s)	2.624	3.059	2.576	3.304	2.147	3.015	2.249	2.697	2.042	2.470	2.442	2.383	2.152	2.451	2.423	2.473	2.357	2.540	2.487	2.407	2.350	2.680
Blade Time on Ice (s)	Weight Acceptance	7.707	14.781	8.541	15.615	9.376	16.383	10.243	17.183	11.111	17.984	12.012	18.852	12.879	19.719	13.797	20.587	14.647	21.454	15.582	22.288	11.590	18.485
	Propulsion	8.191	15.215	9.042	16.016	9.893	16.816	10.760	17.634	11.628	18.468	12.512	19.335	13.380	20.220	14.264	21.087	15.165	21.921	16.082	22.806	12.092	18.952
	Total	0.484	0.434	0.501	0.401	0.517	0.433	0.517	0.451	0.517	0.484	0.500	0.483	0.501	0.501	0.467	0.500	0.518	0.467	0.500	0.518	0.502	0.467

APPENDIX I

Endless Ice Skating Treadmill

Machine Footprint	
Height (To skating surface)	30
Length (Including platform)	138
Width (Including platform)	124

Platform & Track	
Belt Drive Type	Chain roller
Hand Support Rail	Yes: Fixed Bar
Platform Puck Deck	Yes: small
Platform Skater Capacity	2
Safety Shut Off – Manual	Hand held
Safety Shut Off - Automatic	Yes
Slat Care	Glycerin
Slat Colour	White
Slat Composition	Polyethlene
Slat Thickness	0.5
Slat Width	2.5
Track Effective Length	96
Track Effective Width	87
Track Incline Positive Degree	30
Track Incline Negative Degree	0
Track Noise Level	Quiet
Track Speed Maximum MPH	20
Track Speed Minimum	1.6
Track Speed Reverse MPH	0

Appendix J
Means and Standard Errors of Variables Measured

Mean comparisons between two skate designs while treadmill skating (* p< 0.05)

Measured	Skate	Mean	Std. Error
Plantar flexion (degrees)	Traditional	13.535*	1.943
	Mako	19.708*	1.979
Plantar flexion angular velocity (degrees/s)	Traditional	19.409*	2.476
	Mako	29.246*	3.001
Knee extension (degrees)	Traditional	45.374	2.560
	Mako	48.153	3.614
Knee extension angular velocity (degrees/s)	Traditional	65.990	3.521
	Mako	71.860	5.165
Hip extension (degrees)	Traditional	50.256*	1.817
	Mako	51.976*	1.816
Hip extension angular velocity (degrees)	Traditional	73.178*	4.422
	Mako	78.597*	5.040
Hip abduction (degrees/s)	Traditional	34.111	3.162
	Mako	33.253	2.845
Hip abduction angular velocity (degrees/s)	Traditional	48.318	2.187
	Mako	49.064	1.538
Sagittal stride length (meter)	Traditional	.937	.041
	Mako	.991	.030
Stride width (meter)	Traditional	.648	.031
	Mako	.660	.042
Stride length (meter)	Traditional	1.147*	.039
	Mako	1.203*	.025
Stride velocity (meter/s)	Traditional	1.667*	.080
	Mako	1.819*	.099
Skate time on treadmill (seconds)	Traditional	.708	.034
	Mako	.683	.042

Mean range of motion comparisons between treadmill speeds

Measure	Speed (m/s)	Mean	Std. Error
Plantar flexion (degrees)	3.33	13.359	1.783
	5.00	16.143	2.353
	6.66	16.579	1.856
	6.71	18.541	2.058
	8.05	18.485	1.814
Knee extension (degrees)	3.33	39.552	3.374
	5.00	44.889	3.247
	6.66	46.528	2.658
	6.71	51.043	2.992
	8.05	51.806	3.267
Hip extension (degrees)	3.33	47.216	2.058
	5.00	49.306	1.805
	6.66	50.794	1.863
	6.71	52.742	1.971
	8.05	55.521	1.914
Hip abduction (degrees/s)	3.33	30.052	2.866
	5.00	32.267	3.366
	6.66	33.808	2.501
	6.71	35.773	3.225
	8.05	36.510	3.176
Sagittal stride length (meter)	3.33	.907	.035
	5.00	.941	.036
	6.66	.962	.033
	6.71	1.008	.056
	8.05	1.002	.040
Stride width (meter)	3.33	.572	.037
	5.00	.646	.038
	6.66	.660	.036
	6.71	.688	.040
	8.05	.702	.040
Stride length (meter)	3.33	1.082	.030
	5.00	1.151	.027
	6.66	1.173	.037
	6.71	1.238	.050
	8.05	1.230	.042

Mean angular and linear velocity comparisons between treadmill speeds

Measure	Speed (m/s)	Mean	Std. Error
Plantar flexion angular velocity (degrees/s)	3.33	16.699	1.832
	5.00	21.518	2.930
	6.66	24.991	2.559
	6.71	28.598	3.106
	8.05	29.831	2.762
Knee extension angular velocity (degrees/s)	3.33	49.585	2.931
	5.00	62.808	3.718
	6.66	70.918	4.814
	6.71	77.134	4.513
	8.05	84.179	5.882
Hip extension angular velocity (degrees/s)	3.33	60.103	2.921
	5.00	70.264	4.592
	6.66	78.041	5.099
	6.71	80.039	5.675
	8.05	90.990	5.795
Hip abduction angular velocity (degrees/s)	3.33	37.227	1.691
	5.00	44.298	2.403
	6.66	50.622	1.081
	6.71	53.327	2.071
	8.05	57.981	2.104
Stride velocity (meter/s)	3.33	1.372	.073
	5.00	1.637	.091
	6.66	1.798	.095
	6.71	1.902	.110
	8.05	2.005	.097
Skate time on treadmill (seconds)	3.33	.789	.042
	5.00	.727	.039
	6.66	.668	.039
	6.71	.668	.040
	8.05	.627	.034