5-2014

Factors affecting the coefficient of friction of soccer goalie gloves 2014

Candice Hofmann

Factors Affecting the Coefficient of Friction
of Soccer Goalie Gloves

by

Candice Hofmann

Submitted in Partial Fulfillment of the
Requirements for the Master of Science in Exercise Science Degree

Kinesiology Department

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

May 2014

Approved:

Date	Thesis Advisor
Date	Committee Member
Date	Committee Member
Date	Associate Dean, School of Professional Studies

ABSTRACT

The purpose of this study was to compare the coefficients of static friction of five different pairs of soccer goalie gloves with one soccer ball and to compare the effects of four different glove conditions on the coefficients of static friction. Specifically, the coefficients of static friction were determined and compared for one size 5 soccer ball (Select) with five different pairs of goalie gloves (Nike Vapor Grip 3, Select 88, Uhlsport Aqua, Uhlsport Soft and Uhlsport Hard) and four different glove conditions (new, wet, saliva and dirty).

Surrogate wooden fingers were inserted into each glove and the glove was placed on a flattened surface of a soccer ball that was secured to a Bertec force platform. A ten, twenty or thirty pound load was placed on top of the glove and a pulling force was applied to the wrist of the glove. The magnitude of the pulling force was slowly increased until the glove began to slide. The forces exerted by the glove on the ball surface were measured by the force platform. The analog force platform signal was amplified and then converted to digital form at a sampling rate of 600 Hz. The digital data were then input to the Peak Motus 32 version 6.1 motion analysis software that computed the normal contact force and friction force. The maximum friction force just prior to glove movement and the corresponding normal contact force were used to compute the coefficient of static friction between the glove and ball. Five trials were completed for each load. This procedure was completed for each of the five glove types and each of the four conditions. Separate multiple linear regression models were employed to determine if the coefficients of friction for the four glove conditions were statistically different from one another. Load and trial number were also included in these models. The coefficients of friction for brand new gloves were significantly different from the other three conditions. The coefficients of friction for glove in saliva, wet or dirty conditions were not significantly different from one another. Separate multiple linear regression models were employed to determine if the coefficients of friction for the five glove models were statistically different from one another. Again, load and trial number were also included in the models. For the new condition, the Nike Vapor Grip 3 and Select 88 gloves had the highest coefficients of friction and were significantly different from the rest. For the saliva condition, the Uhlsport Aqua and Uhlsport Soft gloves had the highest coefficients of friction and were significantly different from the rest. For the wet conditions, the Uhlsport Soft and Uhlsport Hard gloves had the highest coefficients of friction and were significantly different from the rest. For the dirty condition, the Select 88 glove had the highest coefficients of friction and was significantly different from the rest. These results show that different soccer goalie glove brands and models as well as different conditions all have significantly influence the coefficient of friction between the ball and glove. Soccer goalkeepers should be aware that there are differences in goalie glove brands and differences in how those brands react to different conditions.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Goalie gloves are an important part of a soccer goalkeeper's kit. Goalie gloves increase friction and decrease impact force thus enabling the goalie to safely and effectively handle, control and stop shots. Most contemporary goalie gloves are made of a latex foam material with good gripping ability. Goalie gloves also form a protective covering of the hand to help prevent injuries due to shot impact force. Knowledge of the physical characteristics of a goalie glove and how these characteristics change under different conditions would help a goalie choose the best glove for the specific conditions of a game.

Statement of the Problem

Goalkeepers are always looking for ways to enhance their ability to grip the ball and improve their ability to perform their game tasks. However, little literature in the public domain describes the grip characteristics of goalie gloves. This information may be useful to a goalkeeper when choosing which goalie gloves to use for each different game condition.

Purpose of the Study

The purpose of this study was to compare the coefficients of static friction of five different pairs of soccer goalie gloves with one soccer ball and to compare the effects of four different glove conditions on the coefficients of static friction. Specifically, the coefficients of static friction were determined and compared for one size 5 soccer ball (Select) with five different pairs of goalie gloves (Nike Vapor Grip 3, Select 88, Uhlsport

Aqua, Uhlsport Soft and Uhlsport Hard) and four different glove conditions (new, wet, saliva and dirty).

Hypotheses

The coefficients of friction of new gloves with the ball surface will be significantly different than the coefficients of friction of the gloves for each of the other conditions (wet, saliva, and dirty). However, the coefficients of friction of the gloves for the wet, saliva, and dirty conditions will not be significant different from one another. Also, the coefficients of friction for the five different pairs of gloves will not be significantly different from each other for any of the five glove conditions.

Delimitations

This study was delimited by the following:

1. Only five different pairs of goalie gloves were used: Nike Vapor Grip 3, Select 88, Uhlsport Aqua, Uhlsport Soft, and Uhlsport Hard.
2. Only size 8 gloves were used.
3. Only one soccer ball was used, a Select size 5.
4. Only four different glove conditions were examined: new, wet, saliva, and dirty.
5. The saliva condition was produced by spraying a commercial artificial saliva solution, biotène®, onto the contact surface of the glove.

Limitations

The number of goalie gloves used limited this study. For each glove brand and model, only one pair of gloves was used. Therefore, the same glove was used for two different conditions. For every brand and model of a pair of gloves the left glove was used for the new and saliva condition and the right glove was used for the wet and dirty condition.

Assumptions

Each soccer goalie glove tested was assumed to have uniform material properties throughout the contact surfaces of the glove's palm and fingers.

The force platform used to measure the friction and normal contact forces was assumed to be accurate and reliable.

Definition of Terms

Anterior-Posterior Force – The horizontal force exerted by the glove on the force platform along the same line of action of the pulling force that is exerted on the glove.

Coefficient of Dynamic Friction – The ratio of the friction force measured during movement between two surfaces and the normal contact force.

Coefficient of Friction – A measure of the difficulty with which the surface of one material will slide over another material. Coefficient of friction is the ratio of friction force to normal contact force.

Coefficient of Static Friction – The ratio of the friction force required to initiate movement between two surfaces in contact and the normal contact force.

Friction – The component of a contact force that acts parallel to the two contacting surfaces.

Force Platform - An instrument that measures the reaction forces generated by an object in contact with the force platform. Also referred to as force plate.

Goalie Glove – A piece of equipment worn on the hands and typically made of a latex foam. Goalie gloves are used by a soccer goalie to help catch a soccer ball in a soccer game.

Goalkeeper – A player in soccer that is assigned to protect their team's goal in order to limit the number of goals the other team can score. Also referred to as a goalie.

Ground Reaction Force – The force exerted by the ground on a body in contact with it.

Normal Contact Force – That component of a contact force that acts perpendicular to the two contacting surfaces.

Significance of the Study

In the game of soccer the goalkeepers have the difficult task of keeping a shot out of the goal in whatever way they can while trying to stay safe and avoid injuries. If manipulation of the coefficient of friction of the goalkeepers gloves can occur then the goalkeeper's glove stickiness will increase. This will enable the goalkeeper to be able to perform the job better by having a more efficient way to catch the ball. Finding a way to increase the goalkeeper's ability to catch a ball, while not affecting the other aspects of their game, would be very beneficial. This would give the goalkeepers a better opportunity to complete more difficult plays and secure the ball better which will increase their effectiveness in their position as well keep them out of potentially dangerous situations.

Soccer goalie glove manufacturers have started to create different gloves for different game conditions, such as wet or dry games. However, no research has been found that evaluates the performance of these condition specific gloves. Information gleaned from such research would help a soccer goalie in choose suitable gloves for the game conditions encountered. This would benefit both the manufacturer and the goalkeeper. The manufacturer would be able to show that their goalie glove is the more appropriate glove to be used in a specific condition. A manufacturer would also be able to use the information to make different models of gloves in order to work better for a specific condition. This would create more glove options and in turn a goalkeeper would be inclined to purchase different models for different situations.

CHAPTER 2

REVIEW OF LITERATURE

In the world of sports many athletes wear gloves. Receivers in American Football, use gloves to help them to catch a pass. Hockey goalies use a glove to stop the puck. Baseball players use gloves to catch the ball. Soccer goalies use gloves to stop a shot. The gloves used in these sports have specific purposes, yet little research has been published that describes sport gloves' abilities to perform their sport specific job. Many patents have been submitted for soccer goalie gloves that describe methods to manipulate and improve the friction of the gripping surface. Improved friction will improve the goalkeeper's ability to catch the soccer ball (Kobe & Levitt, 2003; Spitzer, 1998). However, not much research has been done on the manipulation of conditions that could affect the gloves' coefficient of friction.

Importance of Goalie Glove Coefficient of Friction

Little information regarding the friction characteristics of soccer goalie gloves is available in the public domain. However, soccer goalie glove patents clearly indicate the importance of the friction of the gloves. In one soccer goalie glove patent, the inventor described a bonding substance that was slow drying in air that would be applied to the gloves (Montero, 1992). The spray was intended to enable the goalie gloves latex foam material to have a higher coefficient of friction for a longer duration of time (Montero, 1992). Montero also proposed that when gloves are in a warehouse or packaged for shipping, the latex foam front of the glove should have a covering over it in order to prevent dust or other particles from sticking to the surface before use. He determined that this would maintain the glove's coefficient of friction for a longer duration because the latex foam glove would be covered and not exposed to air prior to use (Montero, 1992). Another patent indicated that increasing latex foam thickness would decrease the force of the impact of a shot but that would not decrease the coefficient of friction of the gloves, nor reduce the mobility or use of a goalie's hands within the gloves, would be most beneficial for improved ability (Spitzer, 1998). Both Montero and Spitzer knew and understood the importance of the coefficient of friction of the gloves during the catching phase of the game. They understood that it was important to maximize the amount of friction in order to make the ball easier to catch. However, even though the inventors of these particular gloves knew that the friction was important in the success of the catch, there is still little information or data on how to manipulate and improve that coefficient of friction.

Friction Testing of Hands and Gloves

One sport that has examined the effects of glove friction on performance is wheelchair rugby. Wheelchair rugby has started to become a popular sport and the player's hands are very important (Lutgendorf, et al., 2009). Lutgendorf, Mason, van der Woude, and Goosey-Tolfrey (2009) wanted to determine if the gloves most commonly used by the players made a difference in the players' ability to perform game tasks. They examined a bare hand and three types of gloves: National Football League receiver gloves, multipurpose gloves and building gloves. The researchers determined if different types of gloves or no gloves affected a player's ability to accelerate their wheelchair, catch or throw a ball, and control the directional movement of the chair. This research is interesting in that it tested many different types of gloves. This study is relevant in that it shows gloves can have an impact of the ability of an athlete to perform game tasks. So it is important to test soccer goalie gloves to see if different conditions affect a goalkeeper's ability to catch the ball.

Tomlinson, Lewis, Ball, Yoxall, and Carré (2009) examined the effect of finger-ball friction on the handling performance of rugby balls. Friction was measured using a custom-made finger friction rig (known in the study as the bespoke finger friction rig). The rig was used to measure the coefficient of friction for different ball and finger conditions (Tomlinson et al., 2009). This was an easy way to determine a coefficient of friction. However, they also field tested some of the types of balls and finger conditions by having a participant catch and throw the rugby ball in a "real life" situations that were not controlled. Tomlinson et al. (2009) also used high speed video in order to breakdown and evaluate where the friction loss was occurring. The high speed videos revealed that, although the different conditions didn't seem to affect catching ability or throwing accuracy, the fingers slipped in the different conditions and thus decreased the amount of spin imparted to the ball. This was an interesting evaluation of friction and the use of high-speed video might be an interesting addition to the research on goalie glove friction to see where on the hand the coefficient of the glove friction is affected.

Shih, Vasarhelyi, Dubrowski, and Carnahan (2001) investigated latex gloves used in hospitals and how double layering or even triple layering in order to avoid germs can affect the usefulness of the gloves. The researchers measured many characteristics including friction. Using a weighted object, the participants were instructed to reach for this object or "grip" and pick it up with their index finger and thumbs (Shih et al., 2001). Wearing no glove, one glove, two gloves or three gloves, the participants followed the instructions. The coefficient of friction was determined by how much force the participant needed to apply to the grip at the moment of the object slipping (Shih et al., 2001). The bare hand had the highest coefficient of friction compared to the different numbers of gloves (Shih et al., 2001). Only dry conditions were used in the study.

Lewis, Menardi, Yoxall, and Langley (2007) explored the use of gloves to open packaging. The researchers understood the importance of finger friction in everyday life, but realized the minimal research done, and therefore created a study in order to measure friction. They built a friction rig that consisted of two load cells to measure the normal and friction forces and these in turn were used to calculate the coefficient of friction. They tested bare hand, as well as a nitrile kitchen glove and a latex glove. The participant was instructed to apply a twenty newton force at a thirty degree angle and then to slide the finger across the friction rig (Lewis et al., 2007). This test was conducted under dry, slightly wetted, and oil contaminated conditions (Lewis et al., 2007). The results showed that the rubber glove had the best coefficient of friction during the dry states while the bare hand and latex glove performed best under slightly damp conditions. The lowest coefficients of friction were measured for the oil conditions (Lewis et al., 2007). These results showed that there is a change in glove friction based on the conditions the gloves are exposed to and therefore can be applicable to goalie gloves.

Force Platform Testing

The research that involved friction testing of gloves described many methods for measuring friction (Lewis et al., 2007; Lutgendorf, et al., 2009; Shih et al., 2001; Tomlinson et al., 2009) . Many tests were used with different gloves on different surfaces and with different machines. The most relevant friction measurement method was described by Fuss, Niegl, and Tan (2004) in their investigation of rock climbing and the friction between the hand and different surfaces under different conditions. The researchers tested the different hand conditions and surfaces on a Kistler force platform (Fuss et al., 2004). Different surfaces were mounted to the platform and different conditions were applied to the hands. Friction force was measured for each condition and surface combination (Fuss et al., 2004). First they applied a normal force and then a tangential force, and upon slippage the hand was released. Prior to release and after release the values were recorded and a coefficient of both static and dynamic friction were found (Fuss et al., 2004). This method seems appropriate for the measurement of friction in this proposed study for the different conditions on a pair of goalie gloves.

Other methods of using force platforms to measure friction have been reported in the literature. Leppävuori, Karras, Rusko, and Viitasalo (1993) used a 2.2 meter long force platform inserted under snow in order to measure forces applied by cross country skiers. Llewellyn and Nevola (1992) measured friction conditions and the ability to walk when the coefficient of friction underfoot was varied. This study was interesting because the application of the different condition was applied to the floor (force platform) instead of to the object in contact with the floor (Llewellyn & Nevola, 1992). Changing the condition of the platform is interesting and perhaps a different and feasible way to test the different conditions of the gloves. However in this study, it is the condition of goalie gloves that is of interest and not the condition of contacting surface. Therefore, the conditions should be applied to the glove itself and not to the platform.

Reliability, Validity and Calibration of Force Platforms

Force platforms have been used to measure forces in research on a variety of topics including steadiness, postural control, gait, etc. However, some have questioned the reliability and validity of force platform use. Goldie, Evans and Bach, (1989 & 1992) used steadiness and postural control in order to test the validity and reliability of the force values they acquired using a force platform. For the steadiness study, test-retest reliability was used to examine the reliability of the force platform (Goldie et al., 1992). The force platform was found to be an acceptable measure of steadiness within this study. These researchers completed another study to test the reliability of force platform data for describing postural control (Goldie et al., 1989). They defined steadiness as the ability to keep the body as motionless as possible (Goldie et al., 1989). The researchers compared the force platform to a commonly accepted measure of steadiness, center of pressure excursion (Goldie et al., 1989). They found that the force plate measurements were a more reliable and accurate way of measuring steadiness than the center of pressure calculations (Goldie et al., 1989). These studies by Goldie et al. (1989 & 1992) show that the force platform, if used properly, can produce reliable and valid results.

Friction and Injury

Research has also been done in sport in order to see if friction plays a role in injury. Heidt et al., (1996) studied the differences between friction and torsional resistance in athletic shoe-turf surface interfaces. They studied how the use of different shoes on different surfaces affects the friction between the shoe and that surface. Different shoes were placed onto a prosthetic foot and used for all testing. A load was then applied to the foot and translational and rotational forces were applied to the surface

(Heidt et al., 1996). The results of these tests showed that either excessive friction or minimal friction was produced when the shoes were tested on surfaces they were not designed for (Heidt et al., 1996). Injuries could occur due to this because the athlete could slip and fall or they could get stuck in turf and twist a knee if they are not equipped with the proper footwear. Being properly equipped for the given game situation or condition can be applicable to the effectiveness of goalie gloves. A goalie does not want to manipulate glove friction so much that it ends up hindering, hurting or negatively affecting their ability to perform game tasks. So the researcher needs to be aware of the range in which the equipment, in this case goalie gloves, performs effectively and efficiently.

CHAPTER 3

RESEARCH BRIEF

No research was found on the mechanical properties of soccer goalie gloves. A soccer goalie may be more effective and safer if the goalie knows what the coefficient of friction is between a goalie glove and soccer ball, and if the goalie understands how game conditions affect this coefficient of friction. The coefficient of friction of a goalie glove is important because it can influence whether or not a goalkeeper is able to catch a shot during a game. This not only influences the goalie's effectiveness in the game but the goalie's safety as well.

The purpose of this study was to compare the coefficients of static friction of five different pairs of soccer goalie gloves with one soccer ball and to compare the effects of four different glove conditions on the coefficients of static friction. Specifically, the coefficients of static friction were determined and compared for one size five soccer ball (Select) with five different pairs of goalie gloves (Nike Vapor Grip 3, Select 88, Uhlsport Aqua, Uhlsport Soft, and Uhlsport Hard) and four different glove conditions (new, wet, saliva and dirty). A force platform was used to determine the coefficient of static friction between the glove and ball surface for each of the five gloves in each of the four conditions. The coefficients of static friction were then statistically analyzed to determine which glove conditions significantly differed from one glove to the other.

The results of this study revealed differences between the glove coefficients of friction for the conditions of the glove surface and for the different gloves. The results can be used to better inform goalkeepers on the optimal condition their gloves should be in as well as the gloves that work better in certain conditions. This information could also help manufacturers better design soccer goalie gloves to improve the goalkeeper's quality of play.

Methods

Experimental set up. A force platform (Bertec #K00606 Type 4060-10, 40 cm wide x 60 cm long) was used to measure the normal contact force and friction force between the glove and ball surface for each of the five gloves in each of the four conditions under three different loads. The analog signals from the force platform were first amplified and then converted to digital form at a sampling rate of 600 Hz. The digital data were then input to the Peak Motus 32 version 6.1 motion analysis software that computed the normal contact force and friction force.

A Select Club Viking size 5 soccer ball was deconstructed by cutting the seams that connected each hexagonal panel of the ball to its adjacent panels. Fourteen hexagonal panels from the cut up soccer ball were trimmed and flattened. Command Strips™ were glued to the inner surface of each hexagonal panel as shown in Figure 1. The hexagonal panels were then firmly attached to the force platform surface using the adhesive sides of the Command Strips™ to form a flat soccer ball surface on the force platform as shown in Figure 2.

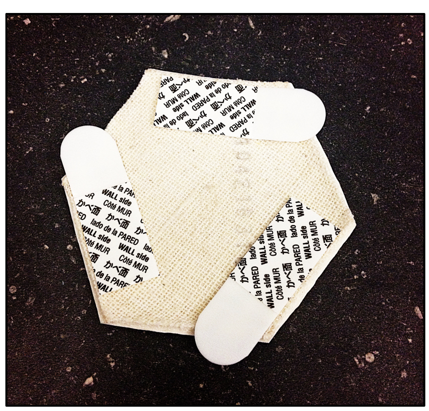


Figure 1. Command Strips™ glued to the inner surface of a soccer ball panel.

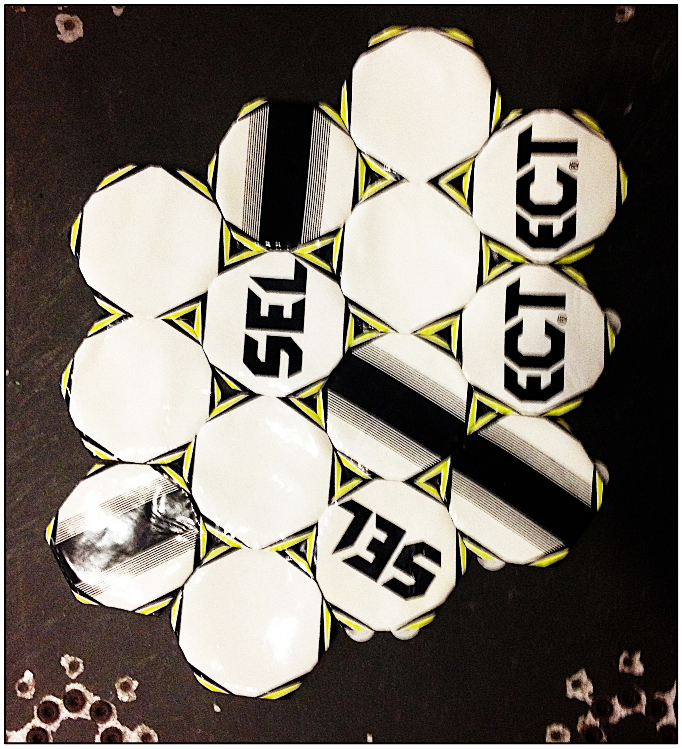


Figure 2. Fourteen hexagonal soccer ball panels affixed to the force platform with the adhesive side of the Command Strips™.

When performing a catch a goalkeeper uses their fingers and not their palms in order to catch a ball because the fingers are able to absorb some of the impact unlike the palm. Since the glove friction tests occurred on a flat surface, it was important that the finger contact area of the gloves be the primary contact surface of the gloves during the friction test. The goalie's fingers were simulated using articulated wooden fingers. The wooden fingers were detached from an artist's wooden hand mannequin. The surrogate fingers were placed inside the finger sleeves of the goalie gloves during the friction tests to insure that the glove contact on the force platform was mainly from the fingers, the main points of contact during a catch (See Figure 3). When the force was applied downward on the top surface of the glove it created a vertical load on the fingers and not the palm. Therefore, only the fingers supported the load because no other part of the glove had a rigid supporting object within it.

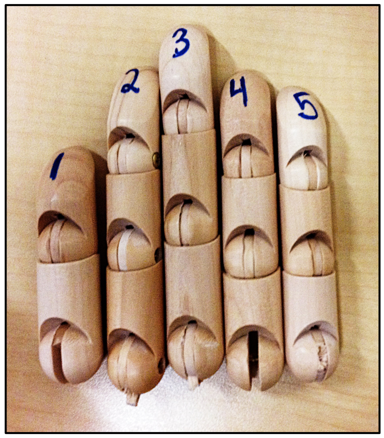


Figure 3. Surrogate wooden fingers.

In order to measure the friction force created between the soccer goalie glove and soccer ball surface, the goalie glove had to be pulled horizontally across the soccer ball surface. A pulling apparatus was created to apply a pulling force to the glove. The wrist cuff of the glove was wrapped and secured around a wooden truncated cone that simulated the wrist. This surrogate wrist was then attached to a rope and pulley system. A pulling force was applied via a rope tied to a carabineer that was clipped to an eyebolt attached to the surrogate wrist. The rope then passed through a 2.5 cm diameter pulley attached to a rigid wooden frame. The direction of pull of the rope was not perfectly horizontal. The rope pulled at an angle of approximately 16 degrees above horizontal, so that the wooden surrogate wrist did not contact the ball panels or force platform. The pulley redirected the rope upward at an angle of approximately 30 degrees to another 2.5 cm diameter pulley that redirected the rope downward to its terminal attachment on the handle of a 13 liter bucket. The pulleys were attached to a 91.4 cm x 58.4 cm x 121.9 cm rigid wooden frame made of plywood and dimensional lumber. The bucket was used to hold sand whose weight created the pulling force on the glove. The sand was funneled into the bucket to control the magnitude and rate of increase of the pulling force on the glove. In order to ensure that the direction of the rope and the direction of the pulling force remained the same for all trials, the position of the rope and pulley system frame was marked on the floor so that if any movement of the frame occurred between trials, the frame could be repositioned to its original position. The complete pulling apparatus is shown in Figures 4, 5, and 6.

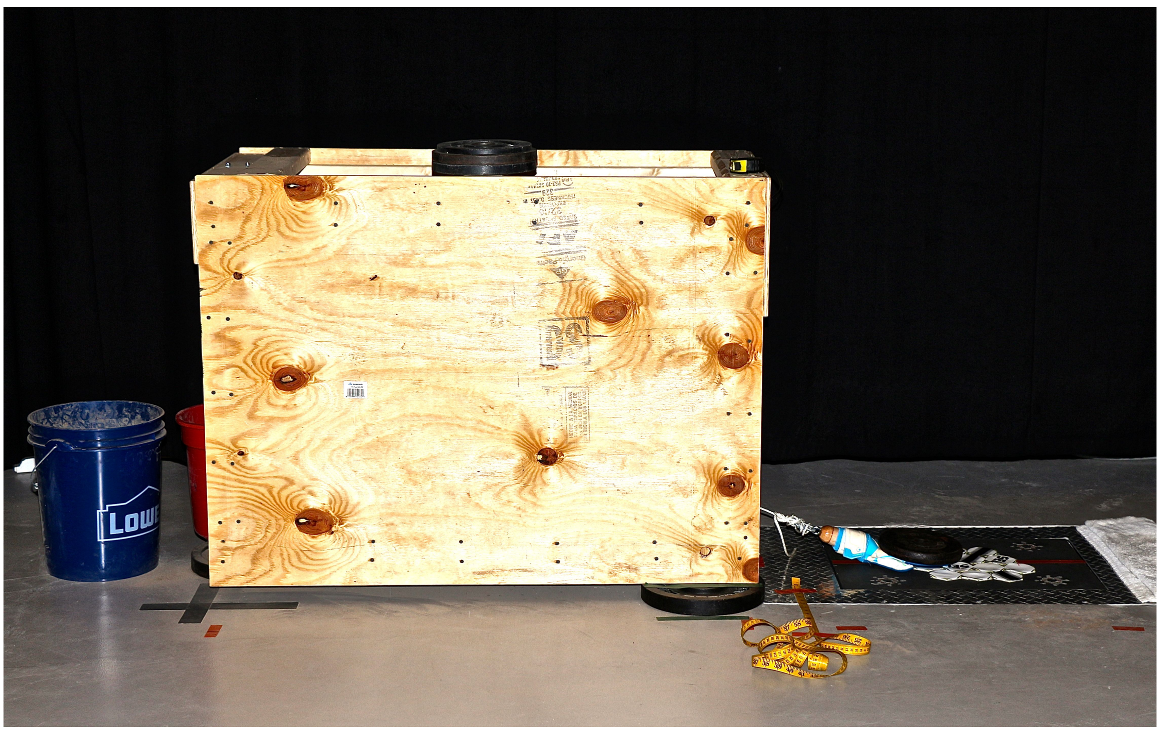


Figure 4. Side view of the pulling apparatus.

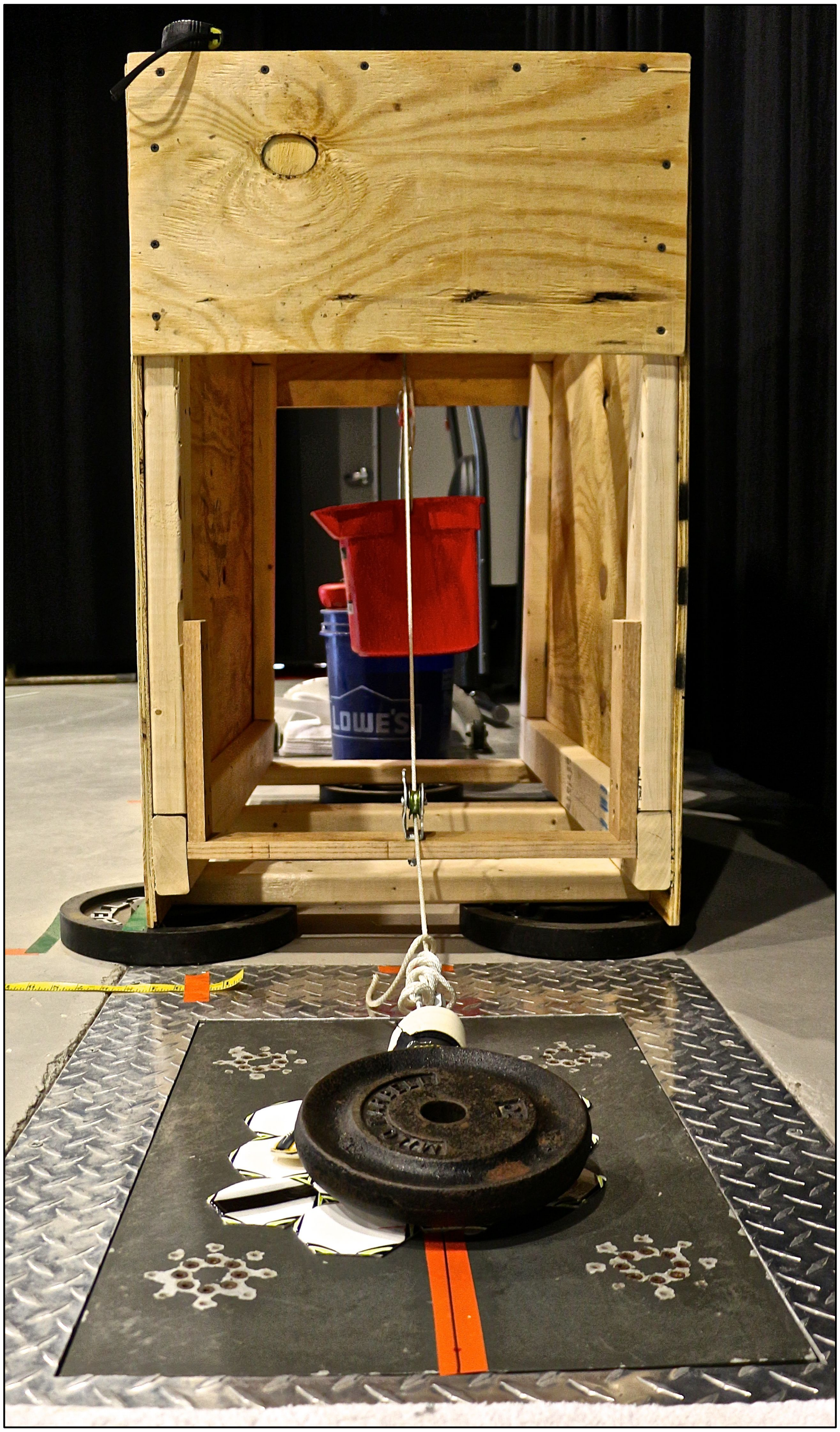


Figure 5. Front view of the pulling apparatus.

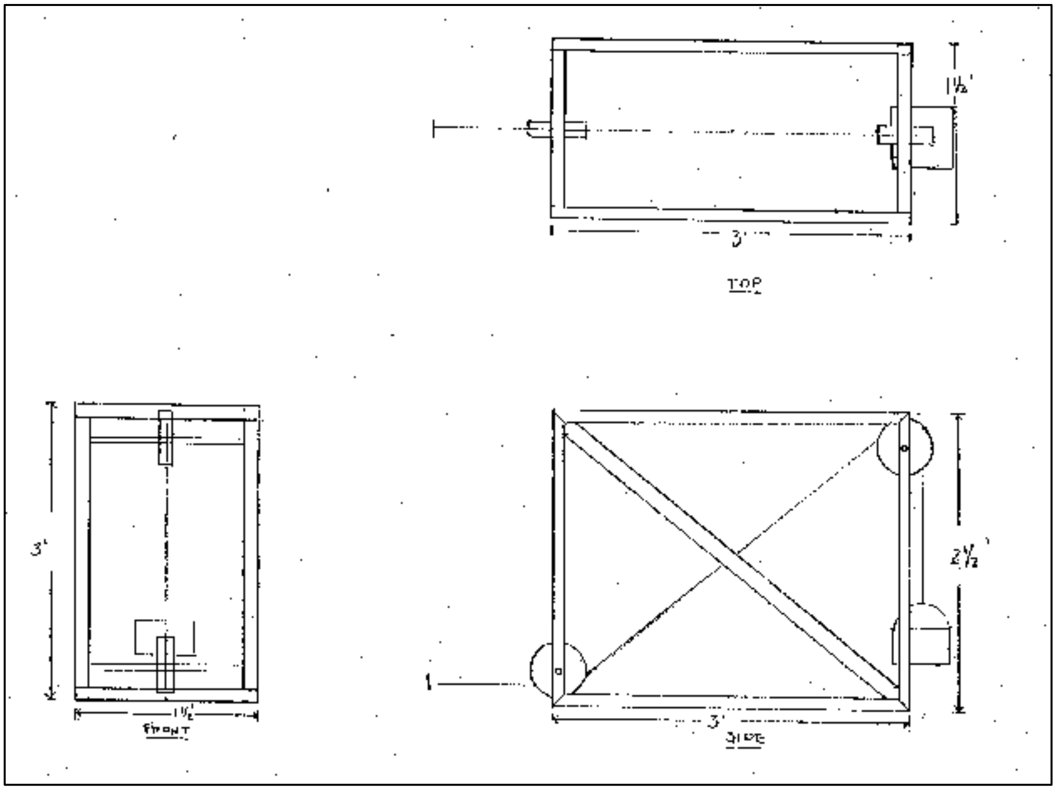


Figure 6. Orthogonal drawing of the pulling apparatus.

A vertical load was applied to the goalie glove by placing weight lifting plates on the glove. To determine if the glove reacts differently when different loads are applied to it, all the conditions were tested with three different vertical loads. Three ten-pound (44.6 N) weight plates placed on the goalie glove individually or in combination to apply a 10, 20 or 30 pound (44.6 N, 89.2 N, or 133.8 N) vertical load on the glove.

A commercially available mouth spray made by biotène® and comparable to saliva was used to simulate the saliva condition.

Testing order. For each condition the Uhlsport Aqua glove was tested first, then the Uhlsport Hard glove, the Uhlsport Soft glove, the Nike Vapor Grip 3 glove and the Select 88 glove. The glove conditions were tested in the following order. New gloves were tested first, one glove model at a time and the left glove was used from each pair of gloves for this condition. The saliva conditioned gloves were tested second. Again, the left glove was used from each pair of gloves for this condition. The wet conditioned gloves were tested third. The right glove was used from each pair of gloves for this condition. Finally, the dirty conditioned gloves were tested last. After the right glove had dried from the wet condition, the right glove was again used from each pair of gloves for this condition. For each glove and each condition, the three different vertical loads (10, 20, and 30 pounds) were tested in random order. Five test trials were completed for each of the three loads. A total of three hundred trials were completed (5 gloves x 4 conditions x 3 loads x 5 trials per load = 300 trials).

Test procedures. The first trial of each condition began by first placing the wooden fingers inside the goalie glove's finger sleeves. The wooden truncated cone was then placed into the wrist section of the glove and the glove's wrist strap was tightly wrapped around the truncated cone to secure the glove. The glove was attached to the rope of the pulling apparatus by hooking the quick link carabineer through the eyebolt. After the glove was attached to the pulley system it was not removed until all trials for that condition and glove were completed.

For the new condition trials the following procedure were followed. First, the soccer ball surface attached to the force platform was wiped off with a towel. Within the 3D optical/analog data acquisition window of the Peak Motus program, manual offsets were taken to zero the output of the force platform while only the soccer ball panels were on the force platform. The glove was then placed on the soccer ball panels on the force platform and lined up so that the rope aligned with the two pulleys in the vertical plane parallel to the y-axis of the force platform. One, two, or three ten-pound (44.6 N) weight plates were placed on the top of the glove to create a 10, 20 or 30 pound (44.6 N, 89.2 N, or 133.8 N) vertical load on the glove. The weight plates' centers were placed over the middle knuckle of the glove's middle finger for each trial. The trial order for the three vertical loads on the gloves was randomly assigned using the Excel random number generation function. Weight plates equal to the load on the glove were placed in the bucket to produce an initial pulling force on the glove. Within the 3D optical/analog data acquisition window of the Peak Motus program, the record button was clicked. The recording time was set to 7.2 seconds with a 7 second pre-trigger time and a 0.2 second post-trigger time. Recording of the force data did not begin until after the trigger button was pushed. After the record button was clicked, sand was funneled into the bucket until the glove began to slip. When the glove slipped, the trigger button was pushed and the force data before and after the slip were recorded. Within the calculate window of the Peak Motus program, the digital data from the force platform were scaled and matched. The ground reaction forces were computed, and these ground reaction forces were then filtered. The maximum Y-axis force was recorded. This represented the maximum static friction force. The average Z-axis force was also recorded. This represented the normal contact force.

The saliva glove condition was tested next. The same steps were followed for the new glove condition with some additional steps to apply the condition to the glove. The left-handed gloves were used for this test as well. After manual offsets were taken and prior to the weights being applied to the top of the glove the artificial saliva was applied to the glove. The biotène® dry mouth spray was emptied into a spray bottle that would create a mist spray. The glove was held one foot away from the spray bottle and then two biotène® sprays were applied to the fingers and palm of the glove. A separate glove (not being used for the testing) was used to rub the artificial saliva into the glove. Then the glove was placed on the ball surface and the rest of the test was performed as before. The only other change to the steps was the amount of weight initially placed in the bucket. The gloves for this condition did not produce as much friction so the initial weight placed in the bucket was less than the load placed on the glove. The remaining steps of the procedure were the same as those for the new glove condition.

For the wet glove condition the five right-handed gloves were placed in a container of water and fully submerged in the water. Weights were placed on top of the gloves in order to keep them submerged. The gloves were submerged in the water for at least 12 hours. Each glove was only removed from the water just prior to that particular glove's trials. Therefore, some of the gloves were in the water longer than others. The assumption was made that after 12 hours the gloves were fully saturated and being left in the water longer was not going to change the amount of water the glove had absorbed. When the glove was removed from the water it was wrung out in order to create a situation in which a goalkeeper would create. During wet games goalies are always trying to get the water out of the latex by using a towel or the back of the glove or making a fist in order to get the water out of the latex which is why for the wet trial the gloves were rung out. After the glove was taken out of the water and wrung out, it was weighed to determine how much water was absorbed into the glove. After every five trials the glove was weighed again to make sure the glove weight was still in within 10% of the first weight taken. The gloves never fell outside of the 10% range so the gloves never had to be resubmerged in the water. The initial weight placed inside the bucket was determined in the same way as the saliva condition. The steps of the procedure for the wet trial were the same as those used in the saliva trials.

The last condition tested was the dirty glove condition. After the right-handed gloves had dried entirely from the wet condition they were used for the dirty condition. Prior to attaching the glove to the pulley system it was placed into a gallon sized Ziploc® bag and one teaspoon of playground sand was poured into the bag as well. This teaspoon of sand was rubbed into the fingers and palm of the glove until it was gone. Then one tablespoon of playground sand was dumped into the Ziploc® bag and prior to every trial the glove was placed into the bag and shaken five times in order to apply some more dirt particles by creating a dusty environment in the bag. The gloves were then removed from the bag and testing began. The other testing procedures used for the saliva condition were followed for these trials as well, with the exception of spraying the glove with artificial saliva.

Five trials were completed for each glove, condition, and load combination. This was smaller than the recommended sample size that was calculated using the G*Power 3.1 computer program. Using a power of .8, an effect size of .707 and a .05 error probability the G*Power program computed a minimum sample size of eight. Due to the limited number of gloves of each model, it was decided to limit the number of trials to five at each load to limit the wear of the gloves.

Analysis

The maximum Y-axis (friction) and average Z-axis (normal contact) forces for each trial were used to compute the coefficient of static friction by dividing the friction force by the normal contact force in an Excel program. Figure 7 shows how the maximum friction force was identified. The coefficients of static friction for all trials were analyzed using the STATA v.10 statistical software. Visual analysis of the data showed that the distributions of coefficient of friction were skewed. Therefore, the coefficient of friction data were transformed using a log function. Figure 8 shows the distribution of the coefficient of friction and the log coefficient of friction. Then separate multiple linear regression models were employed to determine if the different glove conditions were statistically different from one another. Each condition was binary (1/0) coded. Four multiple linear regression models were run, one for each condition as the reference group. These analyses adjusted the standard error to account for the clustering of each individual glove tested. The multiple linear regression models also included load and trial number. This accounted for the load placed on the glove as well as how many trials the glove was previously subjected to. Further, for each condition separate multiple linear regressions were used to determine if differences exists between glove models (binary coded), while also accounting for load and trial number.

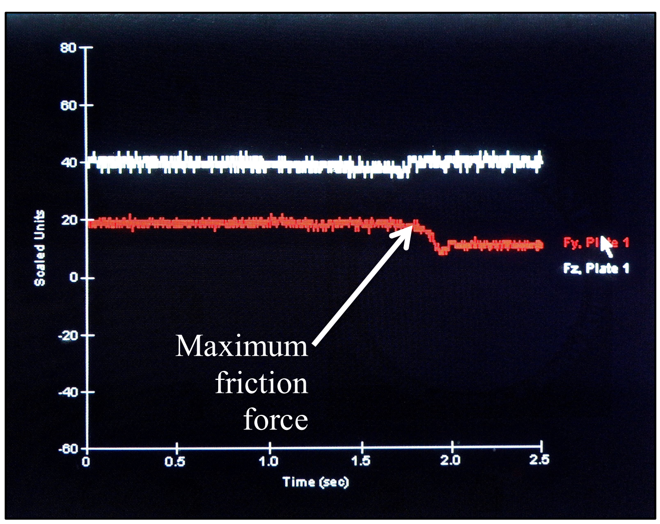


Figure 7. Point in the test where static friction becomes dynamic friction. Maximum friction value was used for static friction value.

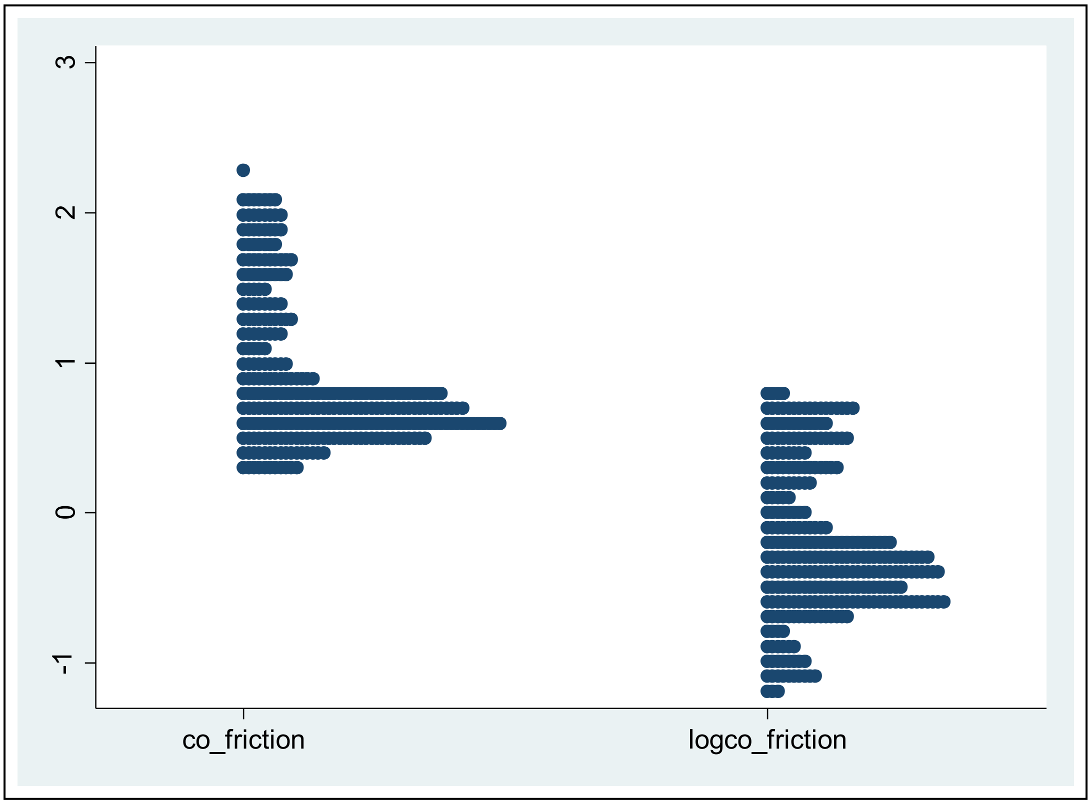


Figure 8. Distribution of the coefficient of friction data compared to the distribution of the log coefficient of friction data.

Results

When comparing the new condition coefficient of static friction to the rest of the conditions' coefficients of friction, it was found that the coefficient of static friction for brand new gloves were significantly different from the coefficients of static friction for other three conditions, F (5, 9) = 4.79, $p < .05$. Further, it was determined that for the different conditions, load had a significant effect on the coefficient of static friction but trial number did not. The adjusted R squared value was .27. This indicates that 27% of the variance in the gloves' coefficient of static friction based on condition is explained by this model, which is considered a medium effect. The beta weights and 95% confidence intervals are presented in Table 1. There were no significant differences in the coefficient of static friction between the wet, saliva, and dirty conditions.

Table 1
Multiple Linear Regression Analysis Summary for New Gloves compared to the Other Three Conditions (Saliva, Wet and Dirty) Clustered by Individual Glove

Variable	*B*		95% CI
Saliva	-0.72	**	[-1.097, -.323]
Wet	-0.864	*	[-1.508, -.221]
Dirty	-0.598	*	[-1.102, -.094]
Load	-0.0004		[-.013, .001]
Trial	-0.006		[-.005, .004]
Constant	0.476		[.079, .873]

Note. $R^2 = .27$: $F(5, 9) = 4.79$, $p < .05$
*$p < .05$; **$p < .01$

The means and standard deviations of the coefficient of static friction can be found in Table 2 for each glove model under different conditions. Then separate multiple linear regressions were performed to compare each glove's coefficient of static friction to the other four pairs of gloves coefficient of static friction based on the specific condition. For all multiple linear regressions run for the different glove pairs based on condition resulted in the same adjusted *R* squared values throughout all these analyses. For new condition the adjusted *R* squared value was .95, which means that this model explains 95% of the variance, which is a very large effect. For saliva, wet and dirty conditions the adjusted *R* squared values were .66, .90 and .77 respectively. This means that for this model the percent of variance explained are 66% for saliva, 90% for wet and 77% for the dirty condition, which are all very large effects.

Table 2
Means and Standard Deviations for the Coefficient of Friction Based on Glove Models and Conditions

	New		Saliva		Wet		Dirty	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Uhlsport Aqua	1.778	0.232	0.876	0.365	0.558	0.048	0.670	0.188
Uhlsport Hard	0.755	0.072	0.363	0.184	0.795	0.099	0.764	0.077
Uhlsport Soft	1.318	0.217	0.885	0.207	0.835	0.110	0.583	0.067
Nike Vapor Grip 3	1.890	0.226	0.629	0.084	0.398	0.070	0.769	0.348
Select 88	1.829	0.188	0.603	0.089	0.349	0.029	1.416	0.141

The coefficient of static friction for the Uhlsport Aqua glove in the new condition was significantly different from the coefficients of static friction of the Nike Vapor Grip 3, Uhlsport Hard, and Uhlsport Soft gloves, F (6, 68) = 220.40, $p < .05$, but not significantly different from the coefficient of static friction for the Select 88 glove. Load and trial number were both significant as well. For the saliva condition, the coefficient of static friction for the Uhlsport Aqua glove was found to be significantly different from the coefficients of static friction for the Nike Vapor Grip 3, Uhlsport Hard, and Select 88 gloves, F (6, 68) = 24.82, $p < .05$, but not significantly different from the coefficient of static friction for the Uhlsport Soft glove. Load and trial number were also significant. The wet condition showed that Uhlsport Aqua glove had a statistically significant different coefficient of static friction from all of the other pairs of gloves' coefficients of static friction, F (6, 68) = 120.58, $p < .05$ and load was found to be significant but trial number was not. For the last condition it was found that the Uhlsport Aqua glove's coefficient of static friction was significantly different from the coefficients of static friction of the Uhlsport Hard and Select 88 gloves, F (6, 68) = 41.99, $p < .05$, when dirt was applied to the gloves. For the dirty condition, load and trial number were also both significant. Table 3 presents all the beta weights and 95% confidence intervals for this glove.

The coefficient of static friction for the Uhlsport Hard glove in the new condition showed that it was significantly different from the coefficients of static friction for all the other pairs of gloves, $F(6, 68) = 220.40$, $p < .05$. Load and trial number were both significant as well. For the saliva condition, the coefficient of static friction for the Uhlsport Hard glove was found to be significantly different from the coefficients of static friction for the Uhlsport Aqua and Uhlsport Soft gloves, $F(6, 68) = 24.82$, $p < .05$, but not significantly different from the coefficients of static friction for the Nike Vapor Grip 3 and Select 88 gloves. Load and trial number were also significant. The wet condition showed that the coefficient of static friction for the Uhlsport Hard glove was significantly different from the coefficients of static friction for the Uhlsport Aqua, Nike Vapor Grip 3, and Select 88 gloves, $F(6, 68) = 120.58$, $p < .05$ and load was found to be significant but trial number was not. For the wet condition, the coefficient of static friction for the Uhlsport Hard glove was not significantly different from the coefficient of static friction for the Uhlsport Soft glove. For the last condition it was found that the coefficient of static friction for the Uhlsport Hard glove was significantly different from the coefficients of static friction for the Uhlsport Aqua, Uhlsport Soft, and Select 88 gloves, $F(6, 68) = 41.99$, $p < .05$, when dirt was applied to the gloves. It was not significantly different from the coefficient of static friction for the Nike Vapor Grip 3 glove. For the dirty condition, load and trial number were also both significant. Beta weights and 95% confidence intervals are presented in Table 4.

Table 3

Multiple Linear Regression Analysis of Uhlsport Aqua Gloves Compared to the Four Other Pairs of Glove Models Based on Condition

	New			Saliva			Wet			Dirty		
Variable	*B*		95% CI	*B*		95% CI	*B*		95% CI	*B*		95% CI
Uhlsport Hard	-0.841	**	[-.904, -.778]	-0.269	**	[-.39, -.148]	0.35	**	[.267, .434]	0.153	*	[.022, .284]
Uhlsport Soft	-0.292	**	[-.355, -.229]	0.052		[-.069, .173]	0.399	**	[.316, .483]	-0.119		[-.250, .012]
Nike Vapor Grip 3	0.074	*	[.011, .137]	-0.272	**	[-.393, -.148]	-0.347	**	[-.431, -.264]	0.087		[-.044, .218]
Select 88	0.043		[-.02, .106]	-0.315	**	[-0.436, -.195]	-0.47	**	[-.553, -.386]	0.77	**	[.638, .901]
Load	-0.011	**	[-.014, -.009]	-0.017	**	[-.022, -.012]	-0.005	**	[-.009, -.002]	0.009	**	[.004, .014]
Trial#	0.001	*	[.000, .003]	-0.024	**	[-.033, -.015]	-0.001		[-.007, .005]	-0.018	**	[-.028, -.009]
Constant	0.77	**	[.703, .837]	0.691	**	[.453, .928]	-0.472	**	[-.569, -.376]	-0.191		[-.461, .08]

Note: R^2 for New = .95; *F (*6,68) = 220.40, Saliva = .69; F (6,68) = 24.82, Wet = .91; F (6,68) = 120.58, Dirty = .79; F (6,68) = 41.99

$*p < .05$; $**p < .01$

Table 4

Multiple Linear Regression Analysis of Uhlsport Hard Gloves Compared to the Four Other Pairs of Glove Models Based on Condition

	New			Saliva			Wet			Dirty		
Variable	*B*		95% CI	*B*		95% CI	*B*		95% CI	*B*		95% CI
Uhlsport. Aqua	0.841	**	[.778, .904]	0.269	**	[.148, .39]	-0.35	**	[-.434, -.267]	-0.153	*	[-.284, -.022]
Uhlsport Soft	0.549	**	[.487, .611]	0.321	**	[.200, .442]	0.049		[-.034, .133]	-0.272	**	[-.403, -.141]
Nike Vapor Grip 3	0.915	**	[.853, .977]	-0.004		[-.124, .117]	-0.697	**	[-.781, -.614]	-0.066		[-.197, .066]
Select 88	0.884	**	[.822, .946]	-0.047		[-.167, .074]	-0.82	**	[-.903, -.737]	0.617	**	[.486, .748]
Load	-0.011	**	[-.014, -.009]	-0.017	**	[-.022, -.012]	-0.005	**	[-.009, -.002]	0.009	**	[.004, .014]
Trial#	0.001	*	[.000, .003]	-0.024	**	[-.033, -.015]	-0.001		[-.007, .005]	-0.018	**	[-.028, -.009]
Constant	-0.071	*	[-.136, -.006]	0.422	**	[.184, .659]	-0.122	*	[-.219, -.026]	-0.038		[-.309, .232]

Note: R^2 for New = .95; *F (*6,68) = 220.40, Saliva = .69; F (6,68) = 24.82, Wet = .91; F (6,68) = 120.58, Dirty = .79; F (6,68) = 41.99

$*p < .05$; $**p < .01$

The coefficient of static friction for the Uhlsport Soft glove in the new condition was significantly different from coefficients of static friction for all of the other gloves tested, F (6, 68) = 220.40, $p < .05$. Load and trial number were also both significant. For the saliva condition, coefficient of static friction for the Uhlsport Soft glove was significantly different from the coefficients of static friction for the Nike Vapor Grip 3, Uhlsport Hard and Select 88 gloves, F (6, 68) = 24.82, $p < .05$, but not significantly different from the coefficient of static friction for the Uhlsport Aqua glove. Load and trial number were significant as well. The coefficient of static friction for the Uhlsport Soft glove in the wet condition was significantly different from the coefficients of static friction for the Uhlsport Aqua, Nike Vapor Grip 3 and Select 88 gloves, F (6, 68) = 120.58, $p < .05$, but not from the coefficient of static friction for the Uhlsport Hard glove. Also load was found to be significant but trial number was not. For the last condition, the coefficient of static friction for the Uhlsport Soft glove was significantly different from the coefficient of static friction for the Uhlsport Hard, Nike Vapor Grip 3, and Select 88 gloves, F (6, 68) = 41.99, $p < .05$, when dirt was applied to the gloves. It was not significantly different from the coefficient of static friction for the Uhlsport Aqua glove, however. For the dirty condition, load and trial number were also both significant. Table 5 displays the beta weights and 95% confidence intervals for the Uhlsport Soft glove.

The coefficient of static friction for the Nike Vapor Grip 3 glove in the new condition was significantly different from the coefficient of static friction for the Uhlsport Aqua, Uhlsport Hard, and Uhlsport Soft gloves, F (6, 68) = 220.40, $p < .05$, but not significantly different from the coefficient of static friction for the Select 88 glove. Load and trial number were both significant as well. For the saliva condition, the coefficient of static friction for the Nike Vapor Grip 3 glove was significantly different from the coefficients of static friction for the Uhlsport Aqua, and Uhlsport Soft gloves, F (6, 68) = 24.82, p <.05, but not significantly different from the coefficients of static friction for the Uhlsport Hard and Select 88 gloves. Load and trial number were also significant. For the wet condition, the coefficient of static friction for the Nike Vapor Grip 3 glove was significantly different from the coefficients of static friction for the all of the other pairs of gloves, F (6, 68) = 120.58, p < .05 and load was found to be significant but trial number was not. For the last condition, the coefficient of static friction for the Nike Vapor Grip 3 glove was significantly different from the coefficients of static friction for the Uhlsport Soft and Select 88 gloves, F (6, 68) = 41.99, p < .05, when dirt was applied to the gloves, but not for the Uhlsport Aqua and Uhlsport Hard gloves. For the dirty condition, load and trial number were also both significant. For this glove the beta weights and 95% confidence interval are displayed in Table 6.

Table 5
Multiple Linear Regression Analysis of Uhlsport Soft Gloves Compared to the Four Other Pairs of Glove Models Based on Condition

	New			Saliva			Wet			Dirty		
Variable	*B*		95% CI	*B*		95% CI	*B*		95% CI	*B*		95% CI
Uhlsport Aqua	0.292	**	[.229, .355]	-0.052		[-.173, .069]	-0.399	**	[-.483, -.316]	0.119		[-.012, .250]
Uhlsport Hard	-0.549	**	[-.611, -.487]	-0.321	**	[-.442, -.200]	-0.049		[-.133, .034]	0.272	**	[.141, .403]
Nike Vapor Grip 3	0.366	**	[.304, .428]	-0.324	**	[-.445, -.204]	-0.747	**	[-.830, -.663]	0.206	**	[.075, .337]
Select 88	0.335	**	[.273, .397]	-0.367	**	[-.488, -.247]	-0.869	**	[-.953, -.786]	0.889	**	[.758, 1.02]
Load	-0.011	**	[-.014, -.009]	-0.017	**	[-.022, -.012]	-0.005	**	[-.009, -.002]	0.009	**	[.004, .014]
Trial#	0.001	*	[.000, .003]	-0.024	**	[-.033, -.015]	-0.001		[-.007, .005]	-0.018	**	[-.028, -.009]
Constant	0.478	**	[.412, .543]	0.743	**	[.505, .980]	-0.073		[-.17, .024]	-0.31	*	[-.580, -.039]

Note: R^2 for New = .95; *F* (6,68) = 220.40, Saliva = .69; F (6,68) = 24.82, Wet = .91; F (6,68) = 120.58, Dirty = .79; F (6,68) = 41.99
**p* < .05; ***p* < .01

Table 6
Multiple Linear Regression Analysis of Nike Vapor Grip 3 Gloves Compared to the Four Other Pairs of Glove Models Based on Condition

	New			Saliva			Wet			Dirty		
Variable	*B*		95% CI	*B*		95% CI	*B*		95% CI	*B*		95% CI
Uhlsport Aqua	-0.074	*	[-.137, -.011]	0.272	**	[.152, .393]	0.35	**	[.264, .431]	-0.087		[-.218, .044]
Uhl. Hard	-0.915	**	[-.977, -.853]	0.004		[-.117, .124]	0.697	**	[.614, .781]	0.066		[-.065, .197]
Uhl. Soft	-0.366	**	[-.428, -.304]	0.324	**	[.204, .445]	0.747	**	[.663, .830]	-0.206	**	[-.337, -.075]
Select 88	-0.031		[-.093, .031]	-0.043		[-.164, .078]	-0.123	**	[-.206, -.002]	0.683	**	[.551, .814]
Load	-0.011	**	[-.014, -.009]	-0.017	**	[-.022, -.012]	-0.005	**	[-.009, -.002]	0.009	**	[.004, .014]
Trial#	0.001	*	[.000, .003]	-0.024	**	[-.033, -.015]	-0.001		[-.007, .005]	-0.018	**	[-.028, -.009]
Constant	0.844	**	[.779, .909]	0.418	**	[.181, .656]	-0.82	**	[-.917, -.723]	-0.104		[-.374, .167]

Note: R^2 for New = .95; *F* (6,68) = 220.40, Saliva = .69; F (6,68) = 24.82, Wet = .91; F (6,68) = 120.58, Dirty = .79; F (6,68) = 41.99
**p* < .05; ***p* < .01

The last regression analysis compared the coefficient of static friction for the Select 88 glove to those of all the other pairs of gloves. In the new condition, it was significantly different from the coefficients of static friction for the Uhlsport Hard and Uhlsport Soft gloves, F (6, 68) = 220.40, $p < .05$, but not significantly different from the coefficients of static friction for the Uhlsport Aqua and Nike Vapor Grip 3 gloves. Load and trial number were both significant as well. For the saliva condition, the coefficient of static friction for the Select 88 glove was significantly different from the coefficients of static friction for the Uhlsport Aqua and Uhlsport Soft gloves, F (6, 68) = 24.82, $p < .05$, but not significantly different from the coefficients of static friction for the Uhlsport Hard or Nike Vapor Grip 3 gloves. Load and trial number were also significant. In the wet condition, the coefficient of static friction for the Select 88 glove was significantly different from the coefficients of static friction for all of the other pairs of gloves, F (6, 68) = 120.58, $p < .05$ and load was found to be significant but trial number was not. For the last condition the coefficient of static friction for the Select 88 glove was again significantly different from the coefficients of static friction for all the other pairs of gloves, F (6, 68) = 41.99, $p < .05$. For the dirty condition, load and trial number were also both significant. Table 7 presents the beta weights and 95% confidence interval for the Select 88 model glove.

Table 7

Multiple Linear Regression Analysis of Select 88 Gloves Compared to the Four Other Pairs of Glove Models Based on Condition

	New			Saliva			Wet			Dirty		
Variable	*B*		95% CI	*B*		95% CI	*B*		95% CI	*B*		95% CI
Uhl. Aqua	-0.043		[-.106, .02]	0.0315	**	[.195, .436]	0.47	**	[.386, .553]	-0.77	**	[-.901, -.638]
Uhl. Hard	-0.884	**	[-.946, -.822]	0.047		[-.074, .167]	0.82	**	[.737, .903]	-0.617	**	[-.748, -.486]
Uhl. Soft	-0.335	**	[-.397, -.273]	0.367	**	[.247, .488]	0.869	**	[.786, .953]	-0.889	**	[-1.02, -.758]
Nike Vapor Grip 3	0.031		[-.031, .093]	0.043		[-.078, .164]	0.123	**	[.039, .206]	-0.683	**	[-.814, .551]
Load	-0.011	**	[-.014, -.009]	-0.017	**	[-.022, -.012]	-0.005	**	[-.009, -.002]	0.009	**	[.004, .014]
Trial#	0.001	*	[.000, .003]	-0.024	**	[-.033, -.015]	-0.001		[-.007, .005]	-0.018	**	[-.028, -.009]
Constant	0.813	**	[.747, .878]	0.375	**	[.138, .613]	-0.942	**	[-1.039, -.846]	0.579	**	[.308, .849]

Note: R^2 for New = .95; *F* (6,68) = 220.40, Saliva = .69; F (6,68) = 24.82, Wet = .91; F (6,68) = 120.58, Dirty = .79; F (6,68) = 41.99

*$p < .05$; **$p < .01$

Discussion

The hypotheses that the three other conditions would be statistically significant from new but not significantly different from each other was found to be true. The hypothesis that the glove brand and types would not be significantly different from one another based on condition was determined to be false. Therefore, it is important to understand that the conditions played in and the brand and model of glove a goalkeeper uses can affect the coefficient of friction and the goalkeeper's ability to perform game tasks.

Therefore, it can be said that the best condition for glove to use is a new condition. The surprising condition was the saliva condition. It is a very common practice for goalkeepers to spit in their gloves because they believe it is helping improve the "stickiness" of them. In this study however, the results did not show this. The unexpected result could be because artificial saliva was used in the study and a controlled amount of the saliva was applied to each glove. Another reason for the unexpected result is that the artificial saliva was applied to relatively new gloves. Typically, goalie's spit on their gloves when the latex is worn down and not fresh. The saliva puts moisture back into the latex material after it is in a dirty state. The results of this study also show that dirty gloves have a lower coefficient of friction than the new gloves. So further testing should look into applying saliva to a dirty glove to see if it improves the coefficient of friction in that specific case.

The new Nike Vapor Grip 3 and Select 88 gloves had the highest coefficients of friction. The Uhlsport Aqua glove was close in comparison to the Select 88 glove but it was not close to the Nike Vapor Grip 3 model. The Uhlsport Soft glove was in fourth with the Nike Vapor Grip 3, Select 88 and Uhlsport Aqua gloves all having significantly higher coefficients of friction. The Uhlsport Hard glove had the lowest coefficient of friction and its coefficient of friction was significantly different than the rest.

For the saliva condition, the best gloves were the Uhlsport Aqua and Uhlsport Soft gloves. The Uhlsport Hard, Nike Vapor Grip 3 and Select 88 gloves all had significantly lower coefficients of friction than the aforementioned gloves.

The wet condition was interesting because there was a glove made specifically for wet conditions. The results showed that the specific glove, the Uhlsport Aqua, had one of the lower coefficients of friction for the wet condition. The gloves that had the larger coefficients of friction for this condition were the Uhlsport Soft and the Uhlsport Hard gloves. These two gloves both had significantly larger coefficients of friction than the other three gloves for the wet condition. The third glove, the Uhlsport Aqua, which is the condition specific glove, had a coefficient of friction significantly less than the two other Uhlsport gloves but significantly greater than the Nike Vapor Grip 3 and Select 88 gloves for the wet condition. It is interesting to compare the two conditions that deal with a wet material. Saliva and wet conditions showed different results for which glove performed better in the different conditions. Specifically the Uhlsport Aqua glove was rated among the best for saliva but was in the middle for wet. Since this glove was made for wet conditions it is interesting that it performed well under some saturation with the saliva condition but not as well under the total saturation condition.

The last condition evaluated was the dirty condition. The Select 88 glove model had the highest coefficient of friction when dirty and was significantly different from the rest of the models. The lowest the coefficient of friction in the dirty condition was for the Uhlsport Soft and Uhlsport Aqua gloves, with Nike Vapor Grip 3 and Uhlsport Hard gloves being in the middle.

This study shows that the different model gloves do differ in their coefficient of friction based on what condition they are subjected to. It is important to note however that there was one glove model that had consistent coefficient of friction values across all of the conditions. The specific model was the Uhlsport Hard glove. This glove had very consistent coefficients of friction across all conditions. This glove model was made for hard ground surfaces, like turf, and was created in order to withstand the harder surfaces ripping apart the latex. Therefore the latex was much thinner and rougher than the other gloves in the study. However, it could be said that because of this it was not as vulnerable to the different conditions. It did not take in as much water in the wet condition as the other gloves and the saliva and dirt may not have adhered as much because it was a rougher material. So even though the Uhlsport Hard glove didn’t have the highest coefficient of friction in the new condition it is appealing because it is a consistent coefficient of friction across all conditions. A goalkeeper would feel comfortable in a pair of gloves knowing what to expect from them no matter what the conditions and these gloves seemed to have that consistency.

The other factors observed in this study were the load and trial number. In most cases both significant affected the coefficient of friction and therefore should be addressed. It was no surprise that trial number had some significantly affected the coefficient of friction of the gloves because the latex of the gloves deteriorates over time. This was one of the reasons for the study, to see if there was a glove that can last longer or work better. The interesting significant variable was the load variable. It was assumed that the coefficients of frictions for the different loads would result in a linear relationship or if not a linear relationship at least one in which the greater the load applied the higher the coefficient of friction. Neither of these turned out to be true. Instead, the relationship was the smaller the load on the glove the larger the coefficient of friction. This may be a result of the compression of the latex foam itself. Goalie gloves' latex is more of a foam-like material; it is porous, spongy and typically 3-4 mm thick. So given this knowledge it would seem that when more load is applied to the top of the glove the more compressed the latex foam material becomes. The more compressed the glove is the less porous and spongy it is and potentially the more flat and slippery it becomes. Given this knowledge however that the coefficient is less when more force is applied needs to be further researched because the loads applied in this study were much less than the peak force applied by a well kicked ball to a goalie's glove in a game.

Conclusion

This study demonstrated that there are good reasons to test the mechanical characteristics of soccer goalie gloves. Different brand models and different conditions do have significant influences on the coefficients of friction of soccer goalie gloves. This study also showed that even though certain glove models may be marketed as made for a specific condition that might not be the best glove for that condition. In the end there is still much more research to be done on this topic. There are many different conditions that could be tested such as cold temperatures or hot and humid conditions. There are also hundreds of other glove brands and models that could be tested as well. It would also be interesting to test game used gloves versus gloves conditioned in a controlled manner in order to test a real dirty or “used” glove and how actual saliva acts when applied to that condition. A few questions were answered by this study but some unexpected results give rise to other questions. In any case, goalkeepers need to be aware that there are differences in glove brands and models, and differences in how those glove brands and models react to different conditions. The more knowledge goalies have about their equipment the better their ability to perform their game tasks and the more successful they will be.

REFERENCE LIST

Cappello, A., Lenzi, D., & Chiari, L. (2004). Periodical in-situ re-calibration of force platforms: a new method for the robust estimation of the calibration matrix. *Medical & Biological Engineering & Computing, 42*, 350-355.

Fuss, F. K., Niegl, G., & Tan, A. M. (2004). Friction between hand and different surfaces under different conditions and its implication for sport climbing. *The engineering of sport*, *5*, 269–275.

Goldie, P.A., Evans, O.M., & Bach, T.M. (1989). Force Platform Measures for Evaluating Postural Control: Reliability and Validity. *American Congress of Rehabilitation Medicine, 70*, 510-517.

Goldie, P.A., Evans, O.M., & Bach, T.M. (1992). Steadiness in One-Legged Stance: Development of a Reliable Force-Platform Testing Procedure. *American Congress of Rehabilitation Medicine, 73*, 348-354.

Heidt, R. S., Dormer, S. G., Cawley, P. W., Scranton, P. E., Losse, G., & Howard, M. (1996). Differences in friction and torsional resistance in athletic shoe-turf surface interfaces. *The American journal of sports medicine*, *24*(6), 834–842.

Kobe, J. J., & Levitt, L. (2003, August 26). Friction control article for wet and dry applications. Google Patents.

Leppävuori, A. P., Karras, M., Rusko, H., & Viitasalo, J. T. (1993). A New Method of Measuring 3-D Ground Reaction Forces Under the Ski During Skiing on Snow. *Journal of Applied Biomechanics*, *9*(4), 315–328.

Lewis, R., Menardi, C., Yoxall, A., & Langley, J. (2007). Finger friction: Grip and opening packaging. *Wear*, *263*(7–12), 1124–1132. Retrieved from http://www.sciencedirect.com/science/article/pii/S0043164807003080

Llewellyn, M. G. A., & Nevola, V. R. (1992). Strategies for walking on low-friction surfaces. *Proceedings of the Fifth International Conference on Environmental Ergonomics, Maastricht, The Netherlands* (Vol. 156).

Lutgendorf, M., Mason, B., van der Woude, L., & Goosey-Tolfrey, V. L. (2009). Effect of glove type on wheelchair rugby sports performance. *Sports Technology*, *2*(3-4), 121–128. doi:10.1002/jst.103

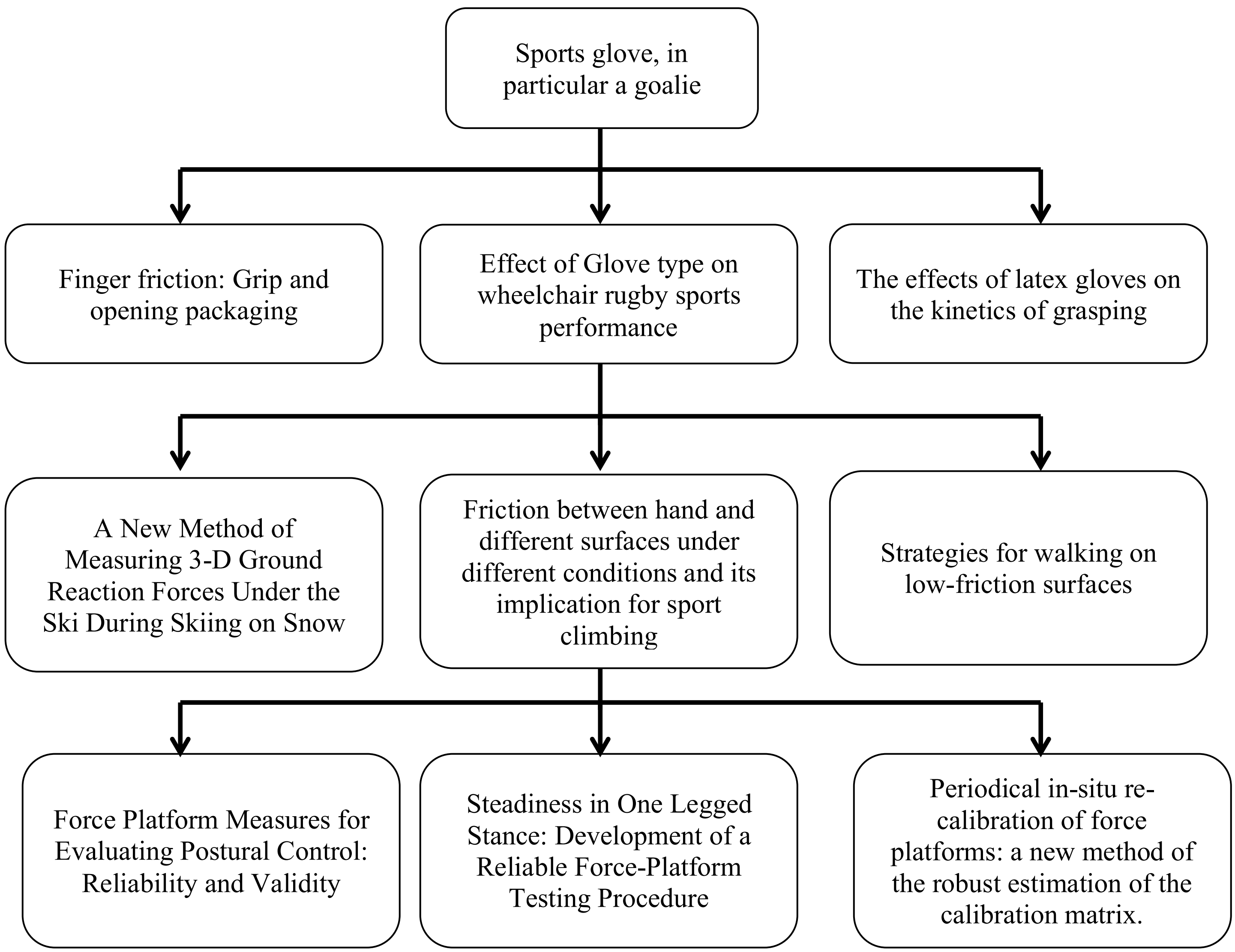
Montero, J. (1992, August 11). Sports glove, in particular for goalies. Google Patents.

Shih, R. H., Vasarhelyi, E. M., Dubrowski, A., & Carnahan, H. (2001). The effects of latex gloves on the kinetics of grasping. *International Journal of Industrial Ergonomics*, *28*(5), 265–273.

Spitzer, T. (1998, September 22). Sports glove, in particular a goalie glove. Google Patents.

Tomlinson, S., Lewis, R., Ball, S., Yoxall, A., & Carré, M. (2009). Understanding the effect of finger–ball friction on the handling performance of rugby balls. *Sports Engineering*, *11*(3), 109–118. doi:10.1007/s12283-009-0014-7

APPENDIX A
LITERATURE REVIEW MAP



APPENDIX B
STATISTICS

Condition Analysis

```
. regress logcoeff bi_con_spit bi_con_wet bi_con_dirt trial# load, vce(cluster
glove_id)

Linear regression                                      Number of obs =     300
                                                       F(  5,     9) =    4.79
                                                       Prob > F      =  0.0206
                                                       R-squared     =  0.2725
                                                       Root MSE      =  .54754

                              (Std. Err. adjusted for 10 clusters in glove_id)
------------------------------------------------------------------------------
             |               Robust
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 bi_con_spit |  -.7097235   .1709907    -4.15   0.002    -1.096531   -.3229156
  bi_con_wet |  -.8643204   .2845436    -3.04   0.014    -1.508003   -.2206381
 bi_con_dirt |  -.5977091   .2228004    -2.68   0.025    -1.101719   -.0936995
      trial# |  -.0004044   .0019962    -0.20   0.844    -.0049203    .0041114
        load |  -.0058434   .0031634    -1.85   0.098    -.0129996    .0013128
       _cons |   .4755999   .1755019     2.71   0.024      .078587    .8726128
```

```
. regress logcoeff  bi_con_new   bi_con_wet bi_con_dirt trial# load,
vce(cluster glove_id)

Linear regression                                      Number of obs =     300
                                                       F(  5,     9) =    4.79
                                                       Prob > F      =  0.0206
                                                       R-squared     =  0.2725
                                                       Root MSE      =  .54754

                              (Std. Err. adjusted for 10 clusters in glove_id)
------------------------------------------------------------------------------
             |               Robust
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  bi_con_new |   .7097235   .1709907     4.15   0.002     .3229156    1.096531
  bi_con_wet |   -.154597   .2552402    -0.61   0.560    -.7319904    .4227964
 bi_con_dirt |   .1120144   .1644162     0.68   0.513    -.2599209    .4839496
      trial# |  -.0004044   .0019962    -0.20   0.844    -.0049203    .0041114
        load |  -.0058434   .0031634    -1.85   0.098    -.0129996    .0013128
       _cons |  -.2341236   .0888636    -2.63   0.027    -.4351471      -.0331
------------------------------------------------------------------------------

. regress logcoeff  bi_con_new  bi_con_spit  bi_con_dirt trial# load,
vce(cluster glove_id)

Linear regression                                      Number of obs =     300
                                                       F(  5,     9) =    4.79
                                                       Prob > F      =  0.0206
                                                       R-squared     =  0.2725
                                                       Root MSE      =  .54754

                              (Std. Err. adjusted for 10 clusters in glove_id)
------------------------------------------------------------------------------
             |               Robust
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

```
  bi_con_new |   .8643204   .2845436     3.04   0.014     .2206381    1.508003
 bi_con_spit |    .154597   .2552402     0.61   0.560    -.4227964    .7319904
 bi_con_dirt |   .2666114    .361328     0.74   0.479    -.5507694    1.083992
      trial# |  -.0004044   .0019962    -0.20   0.844    -.0049203    .0041114
        load |  -.0058434   .0031634    -1.85   0.098    -.0129996    .0013128
       _cons |  -.3887205   .2398787    -1.62   0.140    -.9313638    .1539227
------------------------------------------------------------------------------

. regress logcoeff  bi_con_new  bi_con_spit bi_con_wet trial# load, vce(cluster
glove_id)

Linear regression                                      Number of obs =     300
                                                       F(  5,      9) =    4.79
                                                       Prob > F      =  0.0206
                                                       R-squared     =  0.2725
                                                       Root MSE      =  .54754

                              (Std. Err. adjusted for 10 clusters in glove_id)
------------------------------------------------------------------------------
             |               Robust
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  bi_con_new |   .5977091   .2228004     2.68   0.025     .0936995    1.101719
 bi_con_spit |  -.1120144   .1644162    -0.68   0.513    -.4839496    .2599209
  bi_con_wet |  -.2666114    .361328    -0.74   0.479    -1.083992    .5507694
      trial# |  -.0004044   .0019962    -0.20   0.844    -.0049203    .0041114
        load |  -.0058434   .0031634    -1.85   0.098    -.0129996    .0013128
       _cons |  -.1221092    .161773    -0.75   0.470    -.4880651    .2438468
------------------------------------------------------------------------------
```

Glove and Condition Descriptive Statistics

```
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 1, glove_brand = 1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    1.778213    .2316438   1.389525   2.113357

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 1, glove_brand = 2

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .7551048    .0723343   .6037362   .8683844

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 1, glove_brand = 3

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    1.317733    .2165264   1.008258    1.72328

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
```

```
-> condition = 1, glove_brand = 4

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    1.890838    .2256017   1.312856   2.294558

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 1, glove_brand = 5

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    1.828915    .1880244   1.462707   2.105218

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 2, glove_brand = 1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .8763756    .3630221   .5248253   1.646582

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 2, glove_brand = 2

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15     .648545    .1835201   .4505374   .9561043

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 2, glove_brand = 3

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .8845176    .2073783   .6306584   1.209903

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 2, glove_brand = 4

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .6294543    .0844196   .4711615    .765873

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 2, glove_brand = 5

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .6034779    .0886959   .4862955    .773231

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
```

```
-> condition = 3, glove_brand = 1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .5578411    .0481464   .4753684   .6348654

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 3, glove_brand = 2

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .7950364    .0994935   .5814256   .9444319

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 3, glove_brand = 3

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15     .835316    .1097238   .6870455     1.0453

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 3, glove_brand = 4

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .3979292     .069678   .3083322   .5826315

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 3, glove_brand = 5

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .3485838    .0290945   .3080324   .4083972

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 4, glove_brand = 1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .6702985    .1880703   .5260084   1.306939

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 4, glove_brand = 2

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .7642572    .0767375   .6327815   .9245935

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
```

```
-> condition = 4, glove_brand = 3

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .5827466    .0666509   .5074795   .7856044

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 4, glove_brand = 4

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    .7689717    .3479491    .483863   1.643864

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 4, glove_brand = 5

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      trial0 |        15    1.416386    .1405735   1.088679   1.627302
```

Glove Analysis Based on Condition

```
. by condition, sort : regress logcoeff     bi_brand_aqu bi_brand_hard
bi_brand_soft bi_brand_sel load trial#

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 1

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  220.40
       Model |  9.60899063     6  1.60149844           Prob > F      =  0.0000
    Residual |  .494114343    68  .007266387           R-squared     =  0.9511
-------------+------------------------------           Adj R-squared =  0.9468
       Total |   10.103105    74  .136528446           Root MSE      =  .08524

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_aqu |  -.0741616   .0315966    -2.35   0.022    -.1372117   -.0111114
bi_brand_h~d |  -.9150298   .0311264   -29.40   0.000    -.9771415   -.8529181
bi_brand_s~t |  -.3661134   .0311264   -11.76   0.000    -.4282251   -.3040017
bi_brand_sel |  -.0310478   .0311264    -1.00   0.322    -.0931595    .0310639
        load |  -.0112976   .0012159    -9.29   0.000     -.013724   -.0088712
      trial# |   .0014822   .0006789     2.18   0.032     .0001275    .0028369
       _cons |   .8438431   .0327233    25.79   0.000     .7785447    .9091415
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 2

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   24.82
       Model |   4.0901494     6  .681691566           Prob > F      =  0.0000
```

```
    Residual |  1.86781078    68  .027467806           R-squared     =  0.6865
-------------+------------------------------           Adj R-squared =  0.6588
       Total |  5.95796018    74  .080512975           Root MSE      =  .16573

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_aqu |    .272346   .0605176     4.50   0.000     .1515851    .3931069
bi_brand_h~d |   .0035135   .0605176     0.06   0.954    -.1172474    .1242744
bi_brand_s~t |   .3242854   .0605176     5.36   0.000     .2035245    .4450463
bi_brand_sel |  -.0431431   .0605176    -0.71   0.478     -.163904    .0776178
        load |  -.0169995   .0023447    -7.25   0.000    -.0216781   -.0123208
      trial# |   -.023919    .004431    -5.40   0.000    -.0327609   -.0150771
       _cons |   .4184317   .1190103     3.52   0.001     .1809504     .655913
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 3

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  120.58
       Model |  9.48532483     6  1.58088747           Prob > F      =  0.0000
    Residual |  .891529841    68  .013110733           R-squared     =  0.9141
-------------+------------------------------           Adj R-squared =  0.9065
       Total |  10.3768547    74  .140227766           Root MSE      =   .1145

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_aqu |   .3471912   .0418103     8.30   0.000     .2637601    .4306223
bi_brand_h~d |   .6973672   .0418103    16.68   0.000     .6139361    .7807982
bi_brand_s~t |   .7465893   .0418103    17.86   0.000     .6631582    .8300204
bi_brand_sel |  -.1226333   .0418103    -2.93   0.005    -.2060644   -.0392022
        load |  -.0053516   .0016313    -3.28   0.002    -.0086068   -.0020964
      trial# |  -.0009454   .0030828    -0.31   0.760    -.0070971    .0052062
       _cons |   -.819801   .0484983   -16.90   0.000    -.9165778   -.7230241
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 4

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   41.99
       Model |  8.16641622     6  1.36106937           Prob > F      =  0.0000
    Residual |  2.20435435    68  .032416976           R-squared     =  0.7874
-------------+------------------------------           Adj R-squared =  0.7687
       Total |  10.3707706    74  .140145548           Root MSE      =  .18005

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_aqu |  -.0870431   .0657439    -1.32   0.190    -.2182331    .0441468
bi_brand_h~d |   .0656989   .0657439     1.00   0.321    -.0654911    .1968888
bi_brand_s~t |  -.2061446   .0657439    -3.14   0.003    -.3373345   -.0749546
bi_brand_sel |   .6826011   .0657439    10.38   0.000     .5514112    .8137911
        load |   .0091987   .0025606     3.59   0.001      .004089    .0143083
      trial# |  -.0182399   .0048391    -3.77   0.000    -.0278962   -.0085835
       _cons |  -.1037572   .1355657    -0.77   0.447    -.3742743    .1667599
------------------------------------------------------------------------------
```

```
. by condition, sort : regress logcoeff   bi_brand_nike   bi_brand_hard
bi_brand_soft bi_brand_sel load trial#

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 1

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  220.40
       Model |  9.60899063     6  1.60149844           Prob > F      =  0.0000
    Residual |  .494114343    68  .007266387           R-squared     =  0.9511
-------------+------------------------------           Adj R-squared =  0.9468
       Total |   10.103105    74  .136528446           Root MSE      =  .08524

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .0741616   .0315966     2.35   0.022     .0111114    .1372117
bi_brand_h~d |  -.8408682   .0315966   -26.61   0.000    -.9039184   -.7778181
bi_brand_s~t |  -.2919518   .0315966    -9.24   0.000     -.355002   -.2289017
bi_brand_sel |   .0431138   .0315966     1.36   0.177    -.0199364    .1061639
        load |  -.0112976   .0012159    -9.29   0.000     -.013724   -.0088712
      trial# |   .0014822   .0006789     2.18   0.032     .0001275    .0028369
       _cons |   .7696816    .033538    22.95   0.000     .7027576    .8366056
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 2

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   24.82
       Model |   4.0901494     6  .681691566           Prob > F      =  0.0000
    Residual |  1.86781078    68  .027467806           R-squared     =  0.6865
-------------+------------------------------           Adj R-squared =  0.6588
       Total |  5.95796018    74  .080512975           Root MSE      =  .16573

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   -.272346   .0605176    -4.50   0.000    -.3931069   -.1515851
bi_brand_h~d |  -.2688325   .0605176    -4.44   0.000    -.3895934   -.1480716
bi_brand_s~t |   .0519394   .0605176     0.86   0.394    -.0688215    .1727003
bi_brand_sel |  -.3154891   .0605176    -5.21   0.000      -.43625   -.1947282
        load |  -.0169995   .0023447    -7.25   0.000    -.0216781   -.0123208
      trial# |   -.023919    .004431    -5.40   0.000    -.0327609   -.0150771
       _cons |   .6907777   .1190103     5.80   0.000     .4532964     .928259
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 3

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  120.58
       Model |  9.48532483     6  1.58088747           Prob > F      =  0.0000
    Residual |  .891529841    68  .013110733           R-squared     =  0.9141
-------------+------------------------------           Adj R-squared =  0.9065
```

```
       Total |  10.3768547    74  .140227766           Root MSE      =   .1145

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |  -.3471912   .0418103    -8.30   0.000    -.4306223   -.2637601
bi_brand_h~d |   .3501759   .0418103     8.38   0.000     .2667449     .433607
bi_brand_s~t |   .3993981   .0418103     9.55   0.000      .315967    .4828292
bi_brand_sel |  -.4698245   .0418103   -11.24   0.000    -.5532556   -.3863934
        load |  -.0053516   .0016313    -3.28   0.002    -.0086068   -.0020964
      trial# |  -.0009454   .0030828    -0.31   0.760    -.0070971    .0052062
       _cons |  -.4726098   .0484983    -9.74   0.000    -.5693866   -.3758329
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 4

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   41.99
       Model |  8.16641622     6  1.36106937           Prob > F      =  0.0000
    Residual |  2.20435435    68  .032416976           R-squared     =  0.7874
-------------+------------------------------           Adj R-squared =  0.7687
       Total |  10.3707706    74  .140145548           Root MSE      =  .18005

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .0870431   .0657439     1.32   0.190    -.0441468    .2182331
bi_brand_h~d |    .152742   .0657439     2.32   0.023      .021552     .283932
bi_brand_s~t |  -.1191014   .0657439    -1.81   0.074    -.2502914    .0120885
bi_brand_sel |   .7696443   .0657439    11.71   0.000     .6384543    .9008342
        load |   .0091987   .0025606     3.59   0.001      .004089    .0143083
      trial# |  -.0182399   .0048391    -3.77   0.000    -.0278962   -.0085835
       _cons |  -.1908003   .1355657    -1.41   0.164    -.4613174    .0797167
------------------------------------------------------------------------------


. by condition, sort : regress logcoeff   bi_brand_nike  bi_brand_aqu
bi_brand_soft bi_brand_sel load trial#

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 1

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  220.40
       Model |  9.60899063     6  1.60149844           Prob > F      =  0.0000
    Residual |  .494114343    68  .007266387           R-squared     =  0.9511
-------------+------------------------------           Adj R-squared =  0.9468
       Total |   10.103105    74  .136528446           Root MSE      =  .08524

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .9150298   .0311264    29.40   0.000     .8529181    .9771415
bi_brand_aqu |   .8408682   .0315966    26.61   0.000     .7778181    .9039184
bi_brand_s~t |   .5489164   .0311264    17.64   0.000     .4868047    .6110281
bi_brand_sel |    .883982   .0311264    28.40   0.000     .8218703    .9460937
        load |  -.0112976   .0012159    -9.29   0.000     -.013724   -.0088712
```

```
      trial# |   .0014822   .0006789     2.18   0.032     .0001275    .0028369
       _cons |  -.0711866   .0327233    -2.18   0.033    -.1364851   -.0058882
------------------------------------------------------------------------------

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 2

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   24.82
       Model |   4.0901494     6  .681691566           Prob > F      =  0.0000
    Residual |  1.86781078    68  .027467806           R-squared     =  0.6865
-------------+------------------------------           Adj R-squared =  0.6588
       Total |  5.95796018    74  .080512975           Root MSE      =  .16573

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |  -.0035135   .0605176    -0.06   0.954    -.1242744    .1172474
bi_brand_aqu |   .2688325   .0605176     4.44   0.000     .1480716    .3895934
bi_brand_s~t |   .3207719   .0605176     5.30   0.000      .200011    .4415327
bi_brand_sel |  -.0466566   .0605176    -0.77   0.443    -.1674175    .0741043
        load |  -.0169995   .0023447    -7.25   0.000    -.0216781   -.0123208
      trial# |   -.023919    .004431    -5.40   0.000    -.0327609   -.0150771
       _cons |   .4219452   .1190103     3.55   0.001     .1844639    .6594265
------------------------------------------------------------------------------

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 3

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  120.58
       Model |  9.48532483     6  1.58088747           Prob > F      =  0.0000
    Residual |  .891529841    68  .013110733           R-squared     =  0.9141
-------------+------------------------------           Adj R-squared =  0.9065
       Total |  10.3768547    74  .140227766           Root MSE      =   .1145

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |  -.6973672   .0418103   -16.68   0.000    -.7807982   -.6139361
bi_brand_aqu |  -.3501759   .0418103    -8.38   0.000     -.433607   -.2667449
bi_brand_s~t |   .0492221   .0418103     1.18   0.243    -.0342089    .1326532
bi_brand_sel |  -.8200005   .0418103   -19.61   0.000    -.9034315   -.7365694
        load |  -.0053516   .0016313    -3.28   0.002    -.0086068   -.0020964
      trial# |  -.0009454   .0030828    -0.31   0.760    -.0070971    .0052062
       _cons |  -.1224338   .0484983    -2.52   0.014    -.2192107   -.0256569
------------------------------------------------------------------------------

--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
---
-> condition = 4

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   41.99
       Model |  8.16641622     6  1.36106937           Prob > F      =  0.0000
    Residual |  2.20435435    68  .032416976           R-squared     =  0.7874
-------------+------------------------------           Adj R-squared =  0.7687
       Total |  10.3707706    74  .140145548           Root MSE      =  .18005
```

```
------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |  -.0656989   .0657439    -1.00   0.321    -.1968888    .0654911
bi_brand_aqu |   -.152742   .0657439    -2.32   0.023     -.283932   -.021552
bi_brand_s~t |  -.2718434   .0657439    -4.13   0.000    -.4030334   -.1406535
bi_brand_sel |   .6169023   .0657439     9.38   0.000     .4857123    .7480922
        load |   .0091987   .0025606     3.59   0.001      .004089    .0143083
      trial# |  -.0182399   .0048391    -3.77   0.000    -.0278962   -.0085835
       _cons |  -.0380583   .1355657    -0.28   0.780    -.3085754    .2324587
------------------------------------------------------------------------------

. by condition, sort : regress logcoeff   bi_brand_nike  bi_brand_aqu
bi_brand_hard  bi_brand_sel load trial#

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 1

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  220.40
       Model |  9.60899063     6  1.60149844           Prob > F      =  0.0000
    Residual |  .494114343    68  .007266387           R-squared     =  0.9511
-------------+------------------------------           Adj R-squared =  0.9468
       Total |   10.103105    74  .136528446           Root MSE      =  .08524

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .3661134   .0311264    11.76   0.000     .3040017    .4282251
bi_brand_aqu |   .2919518   .0315966     9.24   0.000     .2289017     .355002
bi_brand_h~d |  -.5489164   .0311264   -17.64   0.000    -.6110281   -.4868047
bi_brand_sel |   .3350656   .0311264    10.76   0.000     .2729539    .3971773
        load |  -.0112976   .0012159    -9.29   0.000     -.013724   -.0088712
      trial# |   .0014822   .0006789     2.18   0.032     .0001275    .0028369
       _cons |   .4777297   .0327233    14.60   0.000     .4124313    .5430281
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 2

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   24.82
       Model |   4.0901494     6  .681691566           Prob > F      =  0.0000
    Residual |  1.86781078    68  .027467806           R-squared     =  0.6865
-------------+------------------------------           Adj R-squared =  0.6588
       Total |  5.95796018    74  .080512975           Root MSE      =  .16573

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |  -.3242854   .0605176    -5.36   0.000    -.4450463   -.2035245
bi_brand_aqu |  -.0519394   .0605176    -0.86   0.394    -.1727003    .0688215
bi_brand_h~d |  -.3207719   .0605176    -5.30   0.000    -.4415327    -.200011
bi_brand_sel |  -.3674285   .0605176    -6.07   0.000    -.4881894   -.2466676
        load |  -.0169995   .0023447    -7.25   0.000    -.0216781   -.0123208
      trial# |   -.023919    .004431    -5.40   0.000    -.0327609   -.0150771
       _cons |   .7427171   .1190103     6.24   0.000     .5052358    .9801984
------------------------------------------------------------------------------
```

```
------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 3

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  120.58
       Model |  9.48532483     6  1.58088747           Prob > F      =  0.0000
    Residual |  .891529841    68  .013110733           R-squared     =  0.9141
-------------+------------------------------           Adj R-squared =  0.9065
       Total |  10.3768547    74  .140227766           Root MSE      =   .1145

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |  -.7465893   .0418103   -17.86   0.000    -.8300204   -.6631582
bi_brand_aqu |  -.3993981   .0418103    -9.55   0.000    -.4828292    -.315967
bi_brand_h~d |  -.0492221   .0418103    -1.18   0.243    -.1326532    .0342089
bi_brand_sel |  -.8692226   .0418103   -20.79   0.000    -.9526537   -.7857915
        load |  -.0053516   .0016313    -3.28   0.002    -.0086068   -.0020964
      trial# |  -.0009454   .0030828    -0.31   0.760    -.0070971    .0052062
       _cons |  -.0732117   .0484983    -1.51   0.136    -.1699885    .0235652
------------------------------------------------------------------------------

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 4

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   41.99
       Model |  8.16641622     6  1.36106937           Prob > F      =  0.0000
    Residual |  2.20435435    68  .032416976           R-squared     =  0.7874
-------------+------------------------------           Adj R-squared =  0.7687
       Total |  10.3707706    74  .140145548           Root MSE      =  .18005

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .2061446   .0657439     3.14   0.003     .0749546    .3373345
bi_brand_aqu |   .1191014   .0657439     1.81   0.074    -.0120885    .2502914
bi_brand_h~d |   .2718434   .0657439     4.13   0.000     .1406535    .4030334
bi_brand_sel |   .8887457   .0657439    13.52   0.000     .7575558    1.019936
        load |   .0091987   .0025606     3.59   0.001      .004089    .0143083
      trial# |  -.0182399   .0048391    -3.77   0.000    -.0278962   -.0085835
       _cons |  -.3099018   .1355657    -2.29   0.025    -.5804188   -.0393847
------------------------------------------------------------------------------



. by condition, sort : regress logcoeff   bi_brand_nike  bi_brand_aqu
bi_brand_hard bi_brand_soft   load trial#

------------------------------------------------------------------------------
------------------------------------------------------------------------------
---
-> condition = 1

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  220.40
       Model |  9.60899063     6  1.60149844           Prob > F      =  0.0000
```

```
    Residual |  .494114343    68  .007266387           R-squared     =  0.9511
-------------+------------------------------           Adj R-squared =  0.9468
       Total |   10.103105    74  .136528446           Root MSE      =  .08524

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .0310478   .0311264     1.00   0.322    -.0310639    .0931595
bi_brand_aqu |  -.0431138   .0315966    -1.36   0.177    -.1061639    .0199364
bi_brand_h~d |   -.883982   .0311264   -28.40   0.000    -.9460937   -.8218703
bi_brand_s~t |  -.3350656   .0311264   -10.76   0.000    -.3971773   -.2729539
        load |  -.0112976   .0012159    -9.29   0.000     -.013724   -.0088712
      trial# |   .0014822   .0006789     2.18   0.032     .0001275    .0028369
       _cons |   .8127953   .0327233    24.84   0.000     .7474969    .8780937
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 2

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   24.82
       Model |   4.0901494     6  .681691566           Prob > F      =  0.0000
    Residual |  1.86781078    68  .027467806           R-squared     =  0.6865
-------------+------------------------------           Adj R-squared =  0.6588
       Total |  5.95796018    74  .080512975           Root MSE      =  .16573

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .0431431   .0605176     0.71   0.478    -.0776178     .163904
bi_brand_aqu |   .3154891   .0605176     5.21   0.000     .1947282      .43625
bi_brand_h~d |   .0466566   .0605176     0.77   0.443    -.0741043    .1674175
bi_brand_s~t |   .3674285   .0605176     6.07   0.000     .2466676    .4881894
        load |  -.0169995   .0023447    -7.25   0.000    -.0216781   -.0123208
      trial# |   -.023919    .004431    -5.40   0.000    -.0327609   -.0150771
       _cons |   .3752886   .1190103     3.15   0.002     .1378073    .6127699
------------------------------------------------------------------------------

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 3

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =  120.58
       Model |  9.48532483     6  1.58088747           Prob > F      =  0.0000
    Residual |  .891529841    68  .013110733           R-squared     =  0.9141
-------------+------------------------------           Adj R-squared =  0.9065
       Total |  10.3768547    74  .140227766           Root MSE      =   .1145

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |   .1226333   .0418103     2.93   0.005     .0392022    .2060644
bi_brand_aqu |   .4698245   .0418103    11.24   0.000     .3863934    .5532556
bi_brand_h~d |   .8200005   .0418103    19.61   0.000     .7365694    .9034315
bi_brand_s~t |   .8692226   .0418103    20.79   0.000     .7857915    .9526537
        load |  -.0053516   .0016313    -3.28   0.002    -.0086068   -.0020964
      trial# |  -.0009454   .0030828    -0.31   0.760    -.0070971    .0052062
       _cons |  -.9424343   .0484983   -19.43   0.000    -1.039211   -.8456574
------------------------------------------------------------------------------
```

```
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
---
-> condition = 4

      Source |       SS       df       MS              Number of obs =      75
-------------+------------------------------           F(  6,    68) =   41.99
       Model |  8.16641622     6  1.36106937           Prob > F      =  0.0000
    Residual |  2.20435435    68  .032416976           R-squared     =  0.7874
-------------+------------------------------           Adj R-squared =  0.7687
       Total |  10.3707706    74  .140145548           Root MSE      =  .18005

------------------------------------------------------------------------------
    logcoeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bi_brand_n~e |  -.6826011   .0657439   -10.38   0.000    -.8137911   -.5514112
bi_brand_aqu |  -.7696443   .0657439   -11.71   0.000    -.9008342   -.6384543
bi_brand_h~d |  -.6169023   .0657439    -9.38   0.000    -.7480922   -.4857123
bi_brand_s~t |  -.8887457   .0657439   -13.52   0.000    -1.019936   -.7575558
        load |   .0091987   .0025606     3.59   0.001      .004089    .0143083
      trial# |  -.0182399   .0048391    -3.77   0.000    -.0278962   -.0085835
       _cons |    .578844   .1355657     4.27   0.000     .3083269     .849361
------------------------------------------------------------------------------
```