Evaluation of dual purpose softball gloves

by

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ABSTRACT

The aim of the present study was design and evaluate a multi-purpose softball glove that would increase player safety while eliminating the need for multiple types of gloves. The construction of the Dual Purpose Softball Glove is likened to that of a typical batting glove with added padding on the dorsal side and an elastic seam on the palm allowing the glove to be reversed and worn on both hands. The placement of the padding was determined by a force sensor test. The padding decreased the force felt from the ball, thereby decreasing likelihood of injury. A surveyed comparison of the Dual Purpose Softball Glove and user's preferred method of insert in softball gloves, showed that users prefer the Dual Purpose Softball glove to no mitigation, yet prefer batting gloves overall.

CHAPTER 1: INTRODUCTION & OVERVIEW

As a selected domain, softball is a sport similar to baseball with competitive equipment manufacturers and tradition as old as baseball. Yet, with competition comes innovation and advancement into new opportunities for both performance and protection.

The recommended process for designing sports equipment with a biomechanical focus is to create based on a user-centered design (McIntosh, 2012). User-centered design follows the iterative process of requirements gathering, designing, implementing, and evaluating. The most basic part of any user-centered design process is understanding your user (Dix, Finlay, Abowd, & Beale, 2004). Therefore, the prototype version of the Dual Purpose Softball Glove was developed based on requirement gathered through user surveys about existing products in order to find areas where current designs were strong or lacking. The prototype design used measured forces to direct padding location and material selection. A reversible design will allow users to utilize the advantages of two types of protectant gloves: a padded glove insert and batting gloves, without needing two pairs of gloves. These attributes will be discussed more in depth later in this paper.

The equipment used for the game includes a required softball glove used when on defense for catching and fielding balls, batting gloves used when on offense, and padding glove inserts used when on defense under the softball glove. Each of these designs has strengths. Softball gloves are a necessary piece of equipment used in softball while playing defense (Noren & Human Kinetics Organization, 2005). The softball glove comes with a rich history and tradition that is often handed down from generation to generation. Each softball glove is carefully selected by the player to match their position played, their personal style preferences and the overall feel of the softball glove. Quality and cost are key factors in the purchase of a

softball glove as well. However, it is difficult for some players to part ways with their old softball glove due to its sentimental value. A good softball glove is key to good defense. As Yogi Berra was quoted saying "… because good defense is so important, good gloves are also important" (Liberman, 2003). Because of the deep connection between players and their softball glove, when a softball glove gets old or worn out and can no longer fully perform its full function of protecting the hand from a hard, fast ball, many players decide to delay the purchase of a new one and keep their current glove. Due to this, players may turn to modifying other pieces of equipment, such as batting gloves, or wearing a padded glove insert to overcome the shortcomings of their current softball glove and to avoid parting ways. This can be a cheaper alternative to buying a new softball glove, as well as a way to provide extra padding and a better fit for the softball glove.

Currently available in the market are traditional batting gloves and padded softball glove inserts. The batting gloves protect the hand during batting. Padded gloves are used under the softball glove to protect both the hand from the impact of catching a ball and the softball glove from the sweats and oils of the hand. These gloves allow players to modify and personalize their softball playing experience.

Batting gloves are typically used as a form of protective equipment when batting on offense. Their original purpose is to protect the hand when batting from blisters and vibrations caused from hitting the ball with the bat. They are also used to acquire a better grip on the bat (Noren & Human Kinetics Organization, 2005). Other functions of the batting glove have evolved as its use spread throughout softball. Some players decide to wear their batting gloves while running the bases on offense to protect their hand while sliding or diving head first into the bases. Players also may use the batting glove inside their softball glove while on defense in the

field as an extra insert. However, the batting glove was only created to protect the hands when batting, not for other purposes. It provides very little extra protection without any padding or a material specifically used for force absorption.

Padded glove inserts are used under the softball glove as a form of protection and are used to reduce the impact and force of the ball while catching, typically using a padded foam to absorb impact of the ball. A thrown ball can reach an average velocity of 19.07 m/s (SD 1.61 m/s) when thrown overhand by female youth softball players with an average age of 13.74 years (Petranek & Barton, 2011). This force only increases with age and experience, reaching velocities of 31.3 m/s from professional softball pitches (Meyers, Brown, & Bloom, 2001). A standard 12 inch softball may only weigh between 0.177 and 0.198 kilograms, but these velocities can produce forces of almost 900 pounds force. These forces can cause a stinging pain or bruising if the ball is not caught correctly or if using an old softball glove with little to no padding.

Focusing on current glove designs, there are several variations of protectant softball glove inserts. These glove inserts feature different materials such as EvoShield™'s Gel-to-Shell technology™; extra padding to the palm and first two fingers, like Palm Guard®; added wrist protection, like Under Armour®; and some with a combination of all three aspects. All of the previously mentioned glove inserts try to reduce pressure and injuries by adding padding and cushions. However, for players interested in the extra protection a padded glove provides, there becomes the issue of using a thin batting glove, or having two different types of gloves: batting gloves and a padded insert. This is an inconvenient situation for players who need to switch between batting gloves and inserts each half-inning. The Dual Purpose Softball Glove (hereinafter referred to as the DPS glove) was created to eliminate the need of two separate

gloves --- batting gloves and protective padded inserts --- by combining them into one functioning product by using engineering and design principles. The DPS glove combines the features of both types of gloves into one design by making the glove reversible. The player is able to use both sides of the DPS glove by switching on which hand the glove is worn. One side has the leather-like material of a batting glove to be worn on offense and can be used as a pair. The other side has memory foam padding for catching protection like a glove insert to be worn on the non-dominant hand during defense.

The DPS glove was created using engineering methods for sports equipment design. Force testing determined the most critical locations for padding placement. Three different types of padding materials were qualitatively assessed for force attenuation and mitigation. Force mitigation is very important in the design of sports equipment. Any type of padding will decrease the force felt by the hand, but some have more desirable qualities than others, such as less rebound or bounce, durability, lightweight materials and greater force absorption (Harris & Spears, 2010). Creating a product that meets user expectations for performance and aesthetics is the greatest challenge any designer faces. In this case, emphasis was put on the functionality and performance of the prototype rather than the aesthetics. It takes both a biomechanical and user-centered approach to design injury preventing equipment (McIntosh, 2012).

The design of the DPS glove is founded on strong engineering design principles such as usability, intuitiveness, and functionality. Padding is how the glove insert functions as a piece of protectant sports equipment by mitigating force. It is expected that the strategically padded insert will be preferred to no mitigation. Using the well-known batting glove as a model increases intuitiveness; determining impact areas addresses the specific padding needs in order to create an effective piece of protective equipment. The strategically padded insert is expected to decrease

discomfort resulting from impact and therefore decrease the likelihood of cumulative trauma disorders compared to no mitigation. Yet, this does not mean that it will be readily accepted by players. It could be reasonably expected that players will prefer what they know and typically already use. The new style of glove may be deemed acceptable if it is determined to be more favorable compared to no insert glove. After surveying experienced softball players, the DPS was not rejected and therefore deemed satisfactory.

Chapter 2 presents the journal paper to be submitted to the Journal of Sports Science, discussing prototype creation and evaluation from user testing with softball players. Chapter 3 then reveals the conclusions from the study and recommendations for further research.

CHAPTER 2: THE EVALUATION OF DUAL PURPOSE SOFTBALL GLOVES

A paper to be submitted to the Journal of Sports Sciences

Heidi Laabs

1. Abstract

The aim of the present study was design and evaluate a multi-purpose softball glove that would increase player safety while eliminating the need for multiple types of gloves. The construction of the Dual Purpose Softball Glove is likened to that of a typical batting glove with added padding on the dorsal side and an elastic seam on the palm allowing the glove to be reversed and worn on both hands. The placement of the padding was determined by a force sensor test. The padding decreased the force felt from the ball, thereby decreasing likelihood of injury. A surveyed comparison of the Dual Purpose Softball Glove and user's preferred method of insert in softball gloves, showed that users prefer the Dual Purpose Softball glove to no mitigation, yet prefer batting gloves overall.

2. Introduction

Each spring, an estimated 7.8 million people try to find their bats, balls, and gloves to take part in one of the most popular team recreational sports in the United States—slow pitch softball (Association, 2012). Every year, the American Softball Association registers 3.5 million players in categories ranging from adult slow pitch to youth girls' fast pitch, which includes over 1.2 million girls each year (Committee, 2015).

As a consequence of its popularity, softball injuries are prevalent among all types of players and age groups. In a survey by Powell and Barber-Foss (2000), forearm and wrist injuries accounted for 22.9% of injuries in softball-playing high school athletes, the largest of any body category in this study (Powell & Barber-Foss, 2000). In another study by Meyers,

Brown, and Bloom (2001); 27% of injuries in NCAA softball players involved various hand, finger and thumb areas. In addition, they found that both age and experience seem to make a difference due to the correlation between a higher skill level and a diminished likelihood of injury. The study also found that 9% of injuries occurred during batting. When comparing fielding injuries caused during practicing at 25.5% and those occurring in a game situation with 26.9%, there is little difference (Powell & Barber-Foss, 2000). As the game evolved, so have the methods of protection and the equipment used.

Softball is a variable sport with both a fast pitch and slow pitch version. Both variants have competitive equipment manufacturers and tradition as old as baseball. Yet, with competition comes innovation and advancement into new opportunities for both performance and protection.

Softball gloves are a necessary piece of equipment used in softball while playing defense (Noren & Human Kinetics Organization, 2005). The softball glove comes with a rich history and tradition that is often handed down from generation to generation. Each softball glove is carefully selected by the player to match the position played, their personal style preferences and the overall feel of the softball glove. Quality and cost are key factors in the purchase of a softball glove as well. However, it is difficult for some players to part ways with their old softball glove due to its sentimental value. A good softball glove is key to good defense. As Yogi Berra was quoted saying "… because good defense is so important, good gloves are also important." (Liberman, 2003). Because of the deep connection between players and their softball glove, when a softball glove gets old or worn out and can no longer fully perform its full function of protecting the hand from a hard, fast ball, many players decide to prolong the purchase of a new one and keep their current glove. Due to this, players may turn to modifying other pieces of

equipment, such as batting gloves, or wearing a padded glove insert to overcome the shortcomings of their current softball glove and to avoid parting ways. This can be a cheaper alternative to buying a new softball glove, as well as a way to provide extra padding and a better fit for any softball glove.

Currently available in the market are traditional batting gloves and padded softball glove inserts. The batting gloves protect the hand during batting. Padded gloves are used under the softball glove to protect both the hand from the impact of catching a ball and the softball glove from the sweats and oils of the hand. These gloves allow players to modify and personalize their softball playing experience.

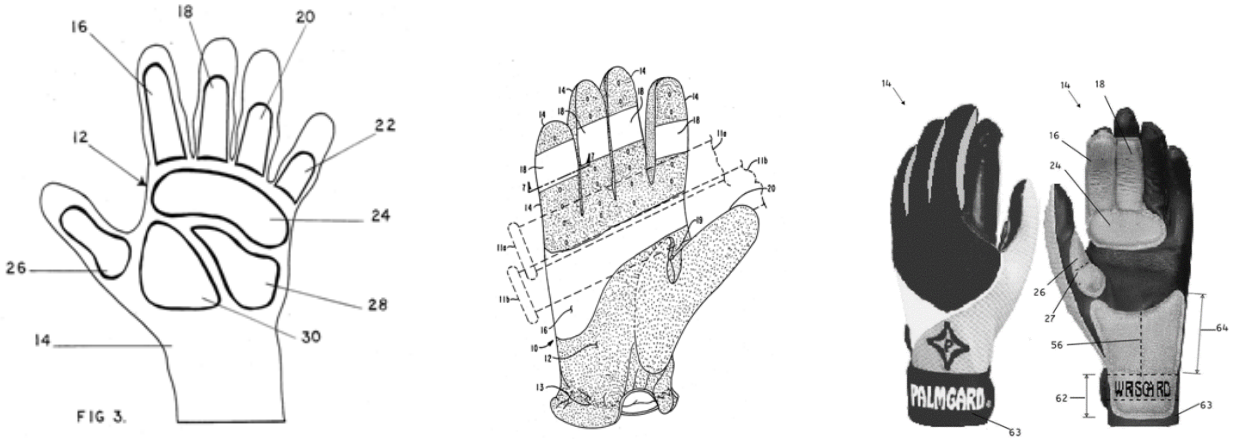
Batting gloves are typically used as a form of protective equipment when batting on offense. Their original purpose is to protect the hand when batting from blisters and vibrations caused from hitting the ball with the bat. They are also used to achieve a better grip on the bat (Noren & Human Kinetics Organization, 2005). Other functions of the batting glove have evolved as its use spread throughout softball. Some players decide to wear their batting gloves while running the bases on offense to protect their hand while sliding or diving head first into the bases. Players also may use the batting glove inside their softball glove while on defense in the field as an extra insert. However, the batting glove was only created to protect the hands when batting, not for other purposes. It provides very little extra protection without any padding or a material specifically used for force absorption.

Padded glove inserts are used under the softball glove as a form of protection and are used to reduce the impact and force of the ball while catching, typically using a padded foam to absorb impact of the ball. A thrown ball can reach an average velocity of 19.07 m/s (SD 1.61 m/s) when thrown overhand by female youth softball players (Petranek & Barton, 2011). This

force only increases with age and experience, reaching velocities of 31.3 m/s from professional softball pitches (Meyers et al., 2001). A standard 12 inch softball may only weigh between 0.177 and 0.198 kilograms, but these velocities can produce forces of almost 900 pounds force. These forces can cause a stinging pain or bruising if the ball is not caught correctly or if using an old softball glove with little to no padding.

Focusing on current glove designs, there are several variations of protectant softball glove inserts. These glove inserts feature different materials such as EvoShield™'s Gel-to-Shell technology™; extra padding to the palm and first two fingers, like Palm Guard®; added wrist protection, like Under Armour®; and some with a combination of all three aspects. Webster (1988) was one of the first to explore extra padding on batting gloves (Figure 1(a)). Cushions are located on the palm and the fingers and are covered by an outer layer of leather. Webster claimed that his inner glove with cushions would help protect the critical areas of the fingers and palm, affected during catching a ball, and it would reduce the incidence of injury during play. Johnson (1993) took a different approach to adding protective padding. Johnson's glove included pads located between the first and second phalangeal joints and a palm pad located across the metacarpophalangeal joints of the hand in order to encourage a proper grip of the bat by the batter, not focusing specifically on catching (Figure 1(b)). Johnson's glove introduced hook-and-loop fasteners, commonly referred to as "Velcro" fasteners, as a means of fastening the glove and securing it to the wrist. He recommended padding materials such as air, liquid, putty, or a gel to provide a release for the pressure and force on the hand. Webster (2013) modified existing designs and added wrist padding (Figure 1(c)). Webster's glove has a section of shock absorbing padding that extends one to three inches up the forearm, providing a shield for the

carpometacarpal joint of the hand and all five digits. This glove also has padding on the first two fingers and their base and on the thumb joint.



(a) U.S. Patent No. 4748690 (Webster, 1988)

(b) U.S. Patent No. 5218719 (Johnson, 1993)

(c) U.S. Patent No. 8839462 (Webster, 2013)

Figure 1: Sketches of glove inserts from patents

All of the above mentioned glove inserts try to reduce pressure and injuries by adding padding and cushions. However, for players interested in the extra protection a padded glove provides, there becomes the issue of using a thin batting glove, or having two different types of gloves: batting gloves and a padded insert. This is an inconvenient situation for players who need to switch between batting gloves and inserts each half-inning. The Dual Purpose Softball Glove (hereby referred to as DPS glove) was created to eliminate the need of two separate gloves --- batting gloves and protective padded inserts --- by combining them into one functioning product by using engineering, biomechanics and design principles. The DPS glove combines the features of both types of gloves into one design by making the glove reversible. The player is able to use both sides of the DPS glove by switching on which hand the glove is worn. One side has the leather-like material of a batting glove to be worn on offense and can be used as a pair. The other side has memory foam padding for catching protection like a glove insert to be worn on the non-dominant hand during defense.

The DPS glove was created using an engineering approach to sports equipment design using information gathering and analysis. Force testing determined the most critical locations for padding placement. Three different types of padding materials were qualitatively assessed for force attenuation and mitigation. Force mitigation is very important in the design of sports equipment. Any type of padding will decrease the force felt by the hand, but some have more desirable qualities than others, such as less rebound or bounce, durability, lightweight materials and greater force absorption (Harris & Spears, 2010). Creating a product that meets user expectations for performance and aesthetics is the greatest challenge any designer faces. It takes both a biomechanical and user-centered approach to design injury preventing equipment (McIntosh, 2012).

The design of the DPS glove is founded on strong engineering design principles such as usability, intuitiveness, and functionality. Padding is how the glove insert functions as a piece of protectant sports equipment by mitigating force. It is expected that the strategically padded insert will be preferred to no mitigation. Using the well-known batting glove as a model increases intuitiveness; determining impact areas addresses the specific padding needs in order to create an effective piece of protective equipment. The strategically padded insert is expected to decrease discomfort resulting from impact and therefore decrease the likelihood of cumulative trauma disorders compared to no mitigation. Yet, this does not mean that it will be readily accepted by players. It could be reasonably expected that players will prefer what they know and typically already use. The new style of glove may be deemed acceptable if it is determined to be more favorable compared to no insert glove. After surveying experienced softball players, the DPS was not rejected and therefore deemed satisfactory.

3. Methods

3.1 Participants

The initial background survey was completed by 16 female softball players ranging in age from 16 to 21 years. Participants had an average playing history of 12.6 years ± 2.8 years. All participants provided written informed consent before completing the surveys.

The testing of the DPS glove prototype was completed by 11 female softball players ranging in age from 18 to 21 years. Participants were self-screened for three or more years of competitive softball experience. All participants provided written informed consent and were informed of the risks before completing the study. The study was approved by the Institutional Review Board at Iowa State University and respected the principles of the Declaration of Helsinki.

3.2 Procedures

3.2.1 Background Survey

An initial survey (Appendix A) was sent out to softball players to gather background data on the typical use of gloves in softball. The survey asked the player's opinions of their current softball glove and their use of batting gloves. The survey provided insight on current areas where the gloves may be lacking, and aspects of the gloves that should remain as part of glove design. This information was used to create the requirements and guide the engineering design approach used to create a prototype glove.

3.2.2 Design Testing – Materials and Locations

Both repetition and force are key factors in the risk of musculoskeletal disorders. While there may be an interaction between force and repetition, lower forces create less risk than higher forces (Gallagher & Herberger, 2013). Therefore, when determining which material to use,

decreasing measured force of impact is imperative to mitigating risk of injury and increasing comfort. FlexComp® force sensors were used to determine the force of a ball dropped from 0.91 meters (1 yard) onto a piece of foam to measure the amount of force absorbed by the foam padding (Figure 2). Three different types of foam were analyzed: compressed Ethylene-vinyl acetate (EVA), Polyurethane foam, and Visco-elastic memory foam. Each material was tested N = 40 times.

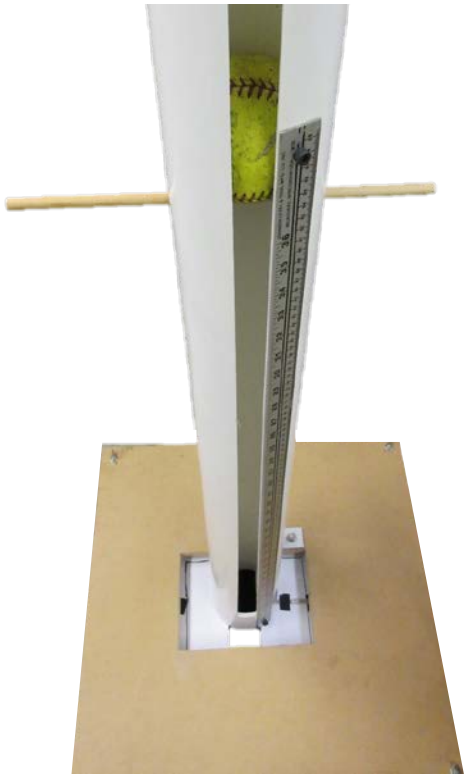


Figure 2: Drop Test apparatus

In order to test whether impact area can be used to dictate padding needs of protective equipment, a force test using FlexComp® force sensors was used. This was later used to determine the placement and amount of the padding used on the prototype DPS glove. The locations needing extra padding were determined using a FlexComp® force sensing device and Thought Technology's BioGraph Infinity software to extract the information. Figure 3 shows the locations of the force sensors. The batting glove with the force sensors was then placed inside of

a softball glove and used as an insert for a total of 27 catches. Each location was then compared to the other locations using a Paired t-Test. This was used to determine if a location was hit more than another.

Figure 3: Force sensors on hand during Catching Test

3.2.3 Participant User Feedback Testing

The goal of the user testing was to determine if the design would be preferred to no mitigation by experienced softball players. Participants were asked to use the DPS glove while performing typical softball drills. All participants were given time, approximately 20 minutes, to warm-up and stretch before performing the drills and were allowed to rest at any time. The warm-up consisted of jogging, stretching, and throwing progressions used in a typical practice to warm-up the arm. The softball drills are representative of typical tasks performed while playing softball. They included approximately five minutes of throwing and catching, fielding ground 5-10 balls, fielding 5-10 fly balls and hitting 15 balls. After using the DPS glove and their typical glove, participants were asked to evaluate their experience through surveys.

The surveys, (Appendix B) used a 1-7 Likert Scale to collect the participant's opinion on the comfort, range of motion, control, enjoyment, ease of use, natural feel, trust and durability of the DPS glove and their preferred glove. Participants were then asked to rank the DPS glove, a regular batting glove, and no insert glove, based on the usability, comfort, reliability, durability, trust, and personal preference of each (Appendix C).

3.2.4 Statistical Analysis

The Background Survey results were analyzed using numerical summary statistical techniques. The Padding Location Drop Test results were analyzed by a Paired t-test comparing each location to the other locations. The Padding Material Test results were analyzed using numerical descriptive measures of central tendency and variability.

The Prototype Survey results were analyzed using the Sign Test, which revealed little about the data, and the Paired t-test for a two-tailed t Distribution. These tests examined the user's preference of the gloves and the difference in these preferences. While the survey gathered discrete data, it is assumed that the t-test is robust enough for the analysis. The final ranking of each glove was analyzed based on the number of respondents who ranked it as first, second or third. JMP statistical software by SAS was used to evaluate the data.

4. Results

4.1 Background Survey

Based on the background survey, several things were noted. Most participants, 88%, used a batting glove while on offense during batting and running the bases. Meanwhile, 63% of all respondents used the batting glove as an insert with their softball glove, while only 53% did so in order to reduce the impact of the ball on the hand (Table 1 and Table 2). Some key aspects of softball gloves included size and quality of the product, showing how important fit and comfort are to players.

Table 1: Batting glove use among players

Batting Glove	Percent
Use a batting glove?	**88%**
Use when hitting?	81%
Use when running bases?	81%
Use as insert with softball glove?	63%

Table 2: Top reasons to wear a batting glove

Reason to Wear Batting Glove	Response
Avoid blisters	**87%**
Minimize vibrations	**87%**
Protect hands when sliding	67%
Make softball glove fit better	60%
Protect hand from ball impact	53%
Protect softball glove from sweat/oils	33%

Approximately 31% of respondents believe their softball glove is lacking in some way, including not having enough padding, difficultly to breaking in, and how quickly the glove wears out. While only 25% of respondents have modified their softball glove. The number of respondents who feel pain due to an old injury to the hand or wrist was 25%. Of those respondents, 100% reported feeling pain during or after playing softball due to their injuries. From this survey, a batting glove was chosen to be the basis of the prototype design with modifications to allow for reversibility. These requirements are shown in Table 3.

Table 3: Design Requirements for Batting Only, Fielding Only, and Both

Batting Only	***Fielding Only***	***Both***
Provide improved grip of bat	Allow for stable ball catching	Breathable materials
Shock absorption	Protect hand from force of ball	Flexible design
Lightweight materials	Fit hand in glove	Adjustable wrist strap
		Durable materials and design

4.2 Design Testing – Materials and Locations

The materials used for the padding were pre-selected based on their lightweight features, ability to reduce force felt by the hand, and flexibility of the material in an effort to maintain comfort. For these reasons a foam was selected over a gel or liquid option. Another key factor was the rebound of the ball. The padding should lessen the force transferred to the hand, but not allow the ball to bounce off. Each piece of padding tested was 0.5 cm thick and was tested N=40

times using the Drop Test apparatus shown in Figure 2. The results of the Drop Test (Figure 4) are represented by the average pound force and standard deviation.

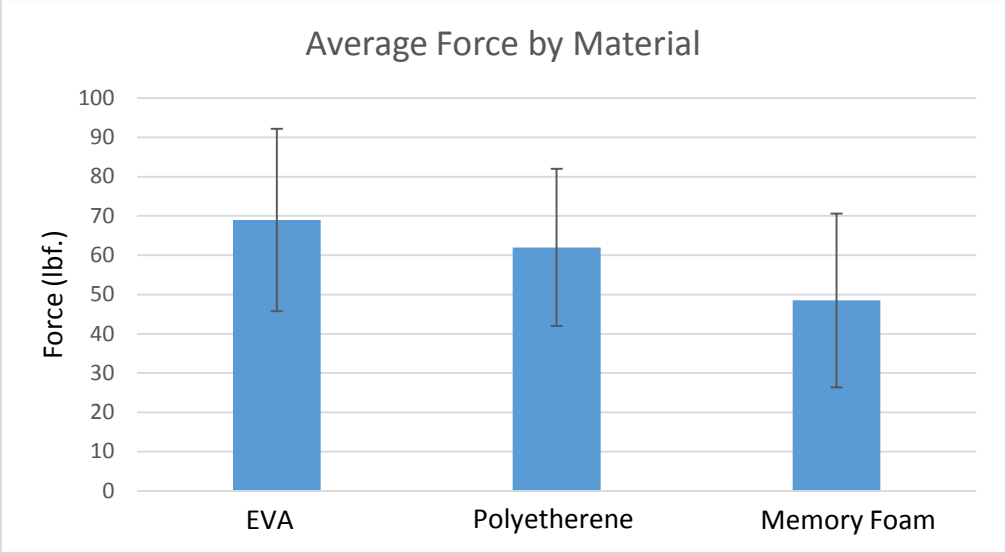


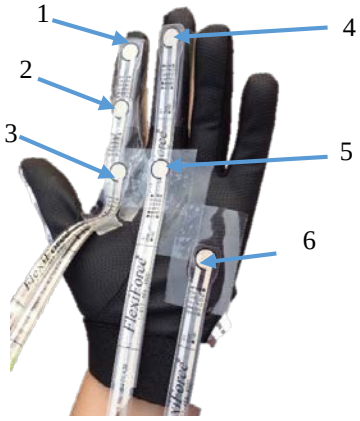
Figure 4: Average measured force by material with Standard Deviation

The location testing focused on the specific positions on the hand that receive the most force. Using a Paired t-test, the differences between each sample average were calculated by trial to determine which sensors had larger measured forces compared to the other sensors (Table 4).

Table 4: Paired t-Test Results for Location Testing

Difference between Sensor X & Sensor Y	t Statistic
1-2	-0.6883
1-3	0.3829
1-4	0.5931
1-5	-0.4012
1-6	0.3953
2-3	0.7488
2-4	0.7767
2-5	0.0522
2-6	0.7384
3-4	-0.1224
3-5	-0.5225
3-6	0.2820
4-5	-0.4852
4-6	0.1921
5-6	0.5545

The final rankings of each location are shown in Figure 5 in order of highest to lowest frequency from Sensor 2 to Sensor 6.



Ranking	Sensor Number
1st	2
2nd	5
3rd	1
4th	3
5th	4
6th	6

Figure 5: Rankings from Force Sensor Catching Test

4.3 Construction and Design

The model for the DPS glove was developed and modified based on the widely used batting glove. The batting glove design includes a leather palmar side for gripping the bat and protecting the hitter from both blisters and painful vibrations, resulting from hitting a ball, and a breathable mesh backside which allows for comfort and movement. Improvements made on the current design include a spandex liner added to the thumb joint to increase flexibility and allow players to reverse the glove. The DPS glove may be worn either offense or defense.

Based on the background survey, the following key aspects of a batting glove remained for the prototype: sturdy and durable leather palm, breathable and flexible mesh back, and adjustable wrist strap. In order to incorporate the padding onto the DPS glove, care was taken to keep the integrity of the batting glove's functionality by using stretchable LYCRA® fabric to attach the padding to the DPS glove. Sewing on the padding creates a durable bond, while using a stretch stich allows the material to expand without breaking the thread. The LYCRA® fabric also was added to the thumb seam on the palmar side to increase comfort when the DPS glove is worn on

the other hand. The added flexion around the thumb makes the DPS glove easier to wear while on defense.

Most manufactures do not state a specific reason for where they place their padding, other than vague generalizations to decrease impact or protect fingers. Performance can be improved if the specific locations of the forces were analyzed. The force sensor test determined the locations where force is most likely to occur, allowing for more precise padding locations and only placing extra padding where needed, as shown in Figure 5. The two locations, shown in Figure 6, received padding that was 0.75 cm thick, whereas the rest of the DPS glove had padding that was 0.50 cm thick. Thicker padding has better performance, compared to the regular thickness (Harris & Spears, 2010). The testing of the materials has proven that the addition of padding can decrease force, thereby also decreasing the likelihood of injury. The types of materials and locations were all chosen to decrease the most force felt by the hand and provide extra protection while playing on defense.

While playing offense, the DPS glove will be worn with the leather side on the palm and the padded side on the dorsal side (Figure 6). Leather, or synthetic leather, is a common material used in batting gloves. Leather provides the functionality of gripping the bat and providing some protection from both blisters and the vibration caused from hitting a ball with the bat. The leather is also a tough material that can withstand the abrasive forces of sliding head-first into a base in the event of a close play while running the bases. Continuing to use leather is an easy way to maintain the functional aspects of the offensive part of the game. The padding was specifically placed on each of the digits of the finger in order to maintain flexibility and allow the batter to grip the bat and flex the fingers.

Figure 6: Dual Purpose Softball Glove as worn on offense

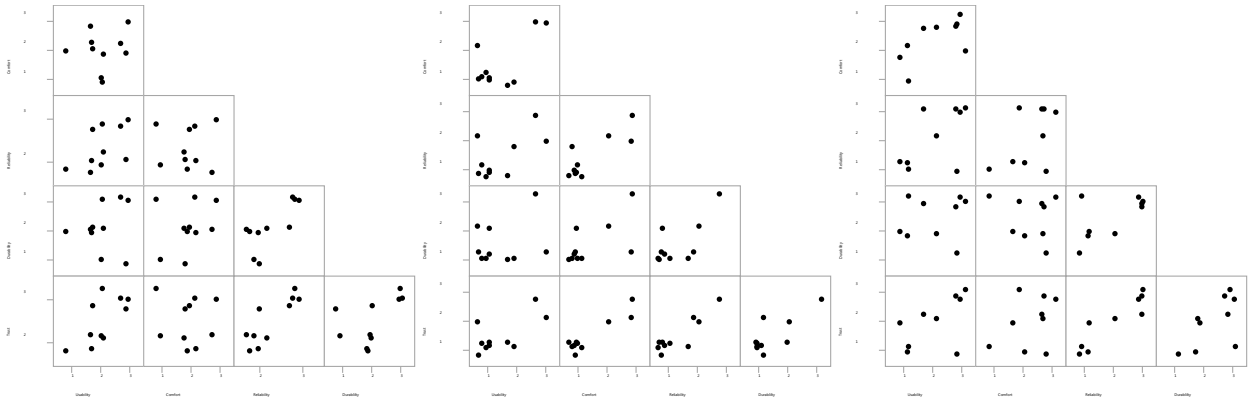
While playing defense, the DPS glove will be reversed and placed on the opposite hand (Figure 7). In this way, the padding is on the palmar side of the hand and the leather is on the dorsal side. The DPS glove will be placed inside the softball glove and used together. The DPS glove will maintain the functionality of helping to fit the hand inside the softball glove with added comfort. It will also provide extra padding to the hand inside of the softball glove. The added padding will protect the hand from the forces associated with catching softballs whether they are thrown or hit. Catching thrown balls can have just as much impact force and inconsistency in catching technique as fielding a hit line-drive softball or pop fly. The DPS glove provides the added protection, but still allows flexibility and functionality of all catching and fielding techniques.

Figure 7: Dual Purpose Softball Glove as worn during defense

4.4 Design Feedback Survey

4.4.1 Ranking of Glove Characteristics

The participant design feedback surveys asked each participant to rank the three glove options in order from one to three based on specific characteristics: comfort, reliability, durability, trust, and usability (Figure 8).



8a. Prototype Glove *8b. Batting Glove* *8c. No Insert Glove*

Figure 8: Scatter plot matrix of glove characteristics rankings

These plots also depict how the participants favored each glove. Figure 8 breaks down each characteristic by its ranking, “1” signifies that the glove was ranked first in that category, “2” signifies that it was ranked second, and “3” signifies that the glove was ranked third. Figure 8b shows that the batting glove was most often ranked first, while Figure 8a shows that the DPS glove was typically ranked second with Figure 8c showing that using no insert glove was often ranked third. However, the DPS glove was ranked second to the batting glove in five out of seven categories, tying for second in level of trust and falling in third when users ranked their personal preference during fielding. It may be expected that if one person has a strong preference toward one glove specifically, that glove will be ranked first in all categories, however this was not always the case. There was a large amount of variation with standard deviations ranging from 0.48 to 1.00 between the categories for each of the gloves.

4.4.2 Glove Usability Survey

For the glove usability survey, participants evaluated their experience with the three glove types. Table 5 shows a comparison between the DPS glove and the glove that the participant typically uses while playing softball. The two questions that showed the greatest difference were “What was your level of comfort with the glove?” which had a negative response to the DPS glove and “How easy was it to perform tasks?” which had a positive response to the DPS glove shown in Table 5. Based on the p values calculated, there is no statistical significance between the prototype DPS glove and the user’s preferred glove method.

Table 5: Preference Survey: Dual Purpose Softball Glove vs preferred glove

	Fielding		Hitting	
Question	**Paired t statistic**	**P value**	**Paired t statistic**	**P value**
What was your level of comfort with the glove?	-0.4129	0.6884	**-0.5462**	**0.5969**
What was your range of motion with the glove?	0.1043	0.9190	-0.2792	0.7858
How uncomfortable did the glove feel?	0.3936	0.7021	-0.2745	0.7593
Did you feel in control of the glove?	0.2175	0.8322	-0.3286	0.7492
Did you feel in control of your movements with the glove?	0.1669	0.8708	-0.3393	0.7414
What was your level of enjoyment?	-0.2716	0.7914	0.3563	0.7290
How easy was it to perform tasks?	0.4275	0.6781	**0.5671**	**0.5831**
How natural was the feel of the glove?	0.1400	0.8915	-0.3997	0.6978
How much do you trust the glove with reliable performance?	0.0000	1.0000	-0.4294	0.6767
How durable is the glove?	0.2029	0.8433	-0.2520	0.8061

5. Discussion

5.1 Background Survey

The background survey showed the most important aspects of softball gloves and batting gloves as well as their various uses. Through the survey, key aspects were identified to incorporate into the DPS glove such as the ability to keep the batting glove's current function and making it as comfortable and natural feeling as possible since respondents indicated that "feel" was an important aspect of choosing a softball glove. Since the most common use for a batting glove is during offense when batting or running the bases, the padding should not change its function and only add to the features.

5.2 Design Testing – Materials and Locations

Memory foam was selected as the material for the DPS prototype glove. This was based on its lightweight, flexible design and its ability to decrease the forces measured on impact. Memory foam had the smallest average measured force compared to the other options.

The force sensor test determined the locations where the greatest force is likely to occur. This allows for more precise padding locations and only placing extra padding where needed. Only placing extra padding where needed allows for more flexibility and range of motion, as well as less bulk when used as an insert inside of the softball glove.

5.3 Design Feedback Survey

The purpose of the feedback surveys was to determine how users would respond to the DPS glove and if they prefer the DPS glove over no force mitigation, or no insert glove. In order to determine if players will accept the new type of glove, participants were asked to rank the gloves based on various characteristics and overall preference.

After ranking the three different glove options: no insert glove, batting glove, DPS glove, the most preferred option was the batting glove, as was expected. The participant's personal

preference ranked the batting glove above or tied with the rankings of the DPS glove in all categories, which ranked above the alternative option, no insert glove. These rankings show that the DPS glove was ranked above using no insert glove, and therefore was not rejected by the participants. This data also supports the choice to use a batting glove as the basis for the design of the DPS glove and only adding features instead of completely redesigning a new glove.

There are several factors that may have had an influence on participant's opinions of the DPS glove. The DPS glove tested was a prototype, which may have had an influence on participant's preferences. User preference and equipment performance is affected by the manufacturing process, or in this case, the lack of a higher fidelity prototype (McIntosh, 2012). Another factor that may have had an influence was the age and experience of the participants. Apart from the softball glove itself, it is possible that not all players will require the same type of equipment. A study by McIntosh discusses the concept of designing sports equipment for specific demographics, such as general or recreational players and professional players (McIntosh, 2012). This idea can then be expanded to separate types of equipment for youth (under 18) or seniors (over 65). Experienced players typically have their own form of work-around for any design flaws and have developed habits based on what has worked for them in the past or suggestions from authorities such as a parental figure or a coach. Many younger players end up with a softball glove that is too large for them because their parents hope they will grow into their glove over time. This can lead to awkward, painful catches if the young player cannot adjust. If a younger, less experienced group were to try the DPS glove, they may be more receptive to a new design that decreases the sting from the hard ball. Typically older, more worn out softball gloves lack necessary padding to provide full protection of the fingers. Parents and players can see an insert, such as the DPS, as a cheaper alternative to buying multiple gloves or injury treatment.

5.4 Limitations, Assumptions, and Future Work

Some limitations of this study included a restricted number of participants and a limited participant demographic. With such a small sample of participants, only generalizations can be made from the data collected. A wider participant base would allow for more variety in experience levels and equipment preferences since different levels of play may lend players to use different types of equipment (McIntosh, 2012). There was also a limitation on the forces sensing equipment used for the study. The force sensors read a maximum of 100 pounds of force. This may have skewed averages lower than intended.

An assumption made during testing was that the participants would know how to use the equipment. It is important that the designer know if the equipment was used as it was intended (McIntosh, 2012). If the prototype was not used as intended, the data will be skewed from those who used the DPS glove incorrectly.

After testing the prototype with users, recommendations for improvement were made. The first recommendation is to add extra padding to the tips of the fingers, specifically on the index finger. Participants mentioned that there was still an occasional sting if the ball contacted with the softball glove in that location. Another recommendation was to make it more flexible when switching hands. This can be achieved by extending the thumb seam toward the index finger and adding more LYCRA® fabric.

6. Conclusions

The Dual Purpose Softball glove was created using engineering and user-centered design principles. It integrates current batting glove designs with padded glove insert designs into one functional product by allowing players to reverse the glove. Extra padding was placed on the locations with the most measured force. Padding decreased the measured force of impact, and

decreased force leads to a decrease in the likelihood of a cumulative trauma. While the traditions and deep sentiment revolving around gloves, both in softball and baseball, may make players wary of new products, the new DPS glove was not rejected by softball players. Overall, the new Dual Purpose Softball glove design was preferred to using no mitigation, but was not preferred to the batting gloves. It was expected that players would prefer what they already know and use over the DPS glove due to personal attachment, trust and comfort.

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CHAPTER 3: CONCLUSIONS

The Dual Purpose Softball glove was created using engineering and user-centered design principles. It integrates current batting glove designs with padded glove insert designs into one functional product by allowing players to reverse the glove. Extra padding was placed on the locations with the most measured force. Padding decreased the measured force of impact, and decreased force leads to a decrease in the likelihood of a cumulative trauma. Following user-centered design means the Dual Purpose Softball Glove is based off of requirements from experienced players.

While the traditions and deep sentiment revolving around gloves, both in softball and baseball, may make players wary of new products, the new DPS glove was not rejected by softball players. It was expected that players would prefer what they already know and use over the Dual Purpose Softball glove due to personal attachment, trust and comfort. Overall, the new Dual Purpose Softball glove design was preferred to using no mitigation, but was not preferred to the batting gloves. It was expected that players would prefer what they already know and use over the DPS glove due to personal attachment, trust and comfort.

It is recommended that further research investigate the long term effects of using the Dual Purpose Softball Glove and investigate if it changes the way players perform their tasks. It is also advised to research the acceptability of the Dual Purpose Softball Glove with younger or less experienced players who may not have fully developed proper form or technique. And finally, it is recommended to research the optimal combination of features and materials for a high fidelity prototype or final product.

APPENDIX A: SOFTBALL PLAYER GLOVE SURVEY

Softball Player Glove Survey

The following are definitions of the terminology used in this document.

Softball glove: This refers to the padded glove used to catch the ball and protect the hand.
Batting glove: This refers to the typically thinner glove used when batting for grip and support.

Gender: Male or Female
Age: _____
Years of Experience: _____
Playing Level (circle highest level achieved):

a. High School Junior Varsity (B Squad)
b. High School Varsity (A Squad)
c. College Club Team
d. Junior/Community Collegiate Team
e. NCAA (DI, DII, DIII) Collegiate Team
f. Professional/National Team

1. Do you use a batting glove? Yes No
   a. Do you use it while batting? Yes No
   b. Do you wear it while running the bases? Yes No
   c. Do you use it while wearing your softball glove? Yes No

2. What is your motivation for using a batting glove? Mark all that apply.

— To protect your hand from blisters when batting
— To protect your hand from vibrations when batting
— To fit your hand inside your softball glove
— To protect your hand from impact of balls when wearing in softball glove
— To protect your softball glove from sweat and oils
— To protect your hand while sliding
— Other while batting _____
— Other while base running _____
— Other while wearing softball glove _____

3. If you use a batting glove as an insert while wearing your softball glove, what does this accomplish for you?

4. What problems have you encountered when using a batting glove?

5. Have you ever made any modifications to your softball glove or batting glove? Yes No
   If yes, what are they?

6. Do you believe the current design of softball gloves lacks in any way? Yes No
   If yes, in what ways?

7. How did you decide which softball glove to purchase? Circle all that may apply **and** rank in order of importance.

— Glove buying guide (found either online or in the store)
— A sales associate at the store
— An “expert” (someone with extensive knowledge of the game)
— Based on feel of the glove (i.e. comfort, materials, size of the glove)
— Based on aesthetics (i.e. color coordination, overall glove appearance)
— Based on a brand you used in the past
— Based on a brand name

8. What are is the most important aspect of a softball glove? Rank in order of importance.

— The size (length)
— The brand
— The pocket shape and size
— The “fit” for a certain position
— The appearance of the glove
— The feel of the glove
— The quality of the product
— The ability to protect your hand
— Other: _____

9. Do you wear a batting glove in your softball glove? Yes No
   If yes, what is your primary motivation to do so?

10. Have you ever injured your catching hand or wrist? Yes No
    If no, skip to the next section. If yes:
    - 10.1 What was injured?
      a. Bone (broken or fractured): _____
      b. Tendon/Muscle (strain): _____
      c. Ligament (sprain): _____
      d. Other: _____
    - 10.2 Do you experience any pain during or after play? Yes No
    - 10.3 How long since your injury?
      a. <1 year
      b. 1-2 years
      c. 2-3 years
      d. 3-5 years
      e. 5+ years

11. What do you like about your softball glove?

12. What do you not like about your softball glove?

13. If you could change something about your softball glove what would it be?

14. Why did you purchase your specific glove?

15. What influenced your decision to buy?

APPENDIX B: PARTICIPANT GLOVE FEEDBACK SURVEY

Participant Glove Feedback
To be administered after using each type of glove.

Please answer the following questions. For each question a scale is given to indicate your level of agreement with the scale with 1 being “Low” or “Does not apply” and 7 being “High” or “All the time”

1. What was your level of comfort with the glove?

   Low---1—2—3—4—5—6—7---High
2. What was your range of motion with the glove?

   Low---1—2—3—4—5—6—7---High
3. How uncomfortable did the glove feel?

   Low---1—2—3—4—5—6—7---High
4. Did you feel in control of the glove?

   Low---1—2—3—4—5—6—7---High
5. Did you feel in control of your movements with the glove?

   Low---1—2—3—4—5—6—7---High
6. What was your level of enjoyment?

   Low---1—2—3—4—5—6—7---High
7. How easy was it to perform tasks?

   Low---1—2—3—4—5—6—7---High
8. How natural was the feel of the glove?

   Low---1—2—3—4—5—6—7---High
9. How much do you trust the glove with reliable performance?

   Low---1—2—3—4—5—6—7---High
10. How durable is the glove?

    Low---1—2—3—4—5—6—7---High

APPENDIX C: PARTICIPANT GLOVE RANKINGS SURVEY

Participant Glove Rankings

To be administered after using all types of gloves.

Please rank gloves according to the following categories:

Usability:

Easiest to use 1. _____
2. _____
3. _____
4. _____
Most difficult to use 5. _____

Comfort:

Most comfortable 1. _____
2. _____
3. _____
4. _____
Least comfortable 5. _____

Reliability:

Most reliable 1. _____
2. _____
3. _____
4. _____
Least reliable 5. _____

Durability:

Most durable 1. _____
2. _____
3. _____
4. _____
Least durable 5. _____

Trust:

Most trustworthy 1. _____
2. _____
3. _____
4. _____
Least trustworthy 5. _____

Personal Preference (Fielding):

Most preferred 1. _____
2. _____
3. _____
4. _____
Least preferred 5. _____

Personal Preference (Hitting):

Most preferred 1. _____
2. _____
3. _____
4. _____
Least preferred 5. _____