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Flux Guard:

An Exploration of Situational Rigidity

By:

Nicholas Miclette

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Fine Art in Industrial Design.

Department of Graduate Industrial Design

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Rochester, NY

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Abstract

In 2014 there was an estimated 15 million snowboarders worldwide. Like many extreme sports there is always the possibility of injury. Extensive research has shown snowboarders sustain more wrist injuries than any other sport in the world. In particular beginner or novice snowboarders are the most susceptible to injury and often times wear no protective gear when first learning. Although there has been research into the efficacy of upper extremity protection in snowboarding, a universal standard has yet to be developed to judge current wrist protection. Due to this fact my thesis explores innovative ways to reinvent the wrist guard through the lense of a designer concerned with the socio-ergonomic issues of current wrist guard protection. Throughout my thesis I'll be exploring ways that design can encourage wrist protection use with in the beginner snowboard community.

Keywords

Wrist Protection, 3D Printing, Industrial Design, Situational Rigidity, Injury Prevention.

Dedication

I'd like to start off by thanking all of my classmates for their support and idea's throughout my thesis. My classmates feedback was essential to my design process. I'd also like to thank my advisors Alex Lobos, Mindy Mahar, Shu Cheng, and Stan Rickel for constantly pushing and challenging me as a designer. Although Stan was not an "official" advisor his feedback and support was invaluable throughout the development of my thesis. A special thanks goes out to the Auburn family, first to Rick Auburn for connecting me with his incredible talented wife Natalie Auburn. Secondly to Natalie for all the amazing sewing she did for my prototypes and final concept models. A huge shout-out to the CIAS 3d print lab crew for always printing beautiful prototypes for me! Finally a thank you to my family and girlfriend for giving me the opportunity and support to pursue my passion for design.

Introduction

The snowboard community has seen exponential growth since its inception in the mid 1960's. Today *"there are an estimated 10–15 million riders worldwide and it is particularly popular among adolescents and younger adults."*¹ Research into improving protection gear in a sport with a higher than average risk of injury especially among beginners could lead to healthier long term riders. New developments in the area of wrist protection could also lead to less injuries in beginner snowboarders and even self proclaimed "intermediate" snowboarders. Wrist and upper extremity injuries account for *"35–40 % of all snowboard injuries."*² The wrist makes up a substantial portion of injuries and it's an injury that is very preventable. Studies have found that *"overall wearing wrist guards reduced the risk of a hand, wrist or forearm injury by 85%."*³

Researchers have also linked long term health complications such as damage to the growth plates and reduced functionality of the wrist and hand to wrist fractures in adolescent beginner riders. Interestingly the factors that most influenced injury were *"being 16 years of younger, being a beginner, and not wearing a wrist guard."*⁴ In interviews, snowboarders revealed the negative stigma surrounding wrist protection in the snowboard community. In one

¹ Michel, Frank I , Kai Uwe Schmitt, Richard M. Greenwald, Kelly Russel, Frank I. Simpson, David Schulz, and Mike Langran. "White Paper: functionality and efficacy of wrist protectors in snowboarding—towards a harmonized international standard." *Sports Engineering* 16, no. 4 (March 14, 2013): 197-210. Accessed April 24, 2017. doi:10.1007/s12283-013-0113-3 .

² Michel, Frank I , Kai Uwe Schmitt, Richard M. Greenwald, Kelly Russel, Frank I. Simpson, David Schulz, and Mike Langran. "White Paper: functionality and efficacy of wrist protectors in snowboarding—towards a harmonized international standard." *Sports Engineering* 16, no. 4 (March 14, 2013): 197-210. Accessed April 24, 2017. doi:10.1007/s12283-013-0113-3 .

³ 8. "Wrist Injuries and their Prevention During Snowboarding - Expert Treatments Sports Injury Products & Physiotherapy Advice." Expert Treatments - PhysioRoom.com. Accessed November 5, 2016. http://www.physioroom.com/experts/expertupdate/snowboarding_wrist_injury.php.

⁴ Michel, Frank I , Kai Uwe Schmitt, Richard M. Greenwald, Kelly Russel, Frank I. Simpson, David Schulz, and Mike Langran. "White Paper: functionality and efficacy of wrist protectors in snowboarding—towards a harmonized international standard." *Sports Engineering* 16, no. 4 (March 14, 2013): 197-210. Accessed April 24, 2017. doi:10.1007/s12283-013-0113-3

study researchers found that snowboarders believed that using a wrist guard would either not prevent a wrist fracture or would cause a wrist fracture were normally there wouldn't be one. Another study revealed rider's felt that current wrist guard designs were too "limiting" and "uncomfortable" to wear while riding. All this research points to several larger socio-ergonomic issues that I believe are key areas that need solving to further convince snowboarders that wrist protection is an effective solution. The first is addressing the negative incorrect stigmas surrounding wrist guards. The second is addressing the usability and functionality of current wrist guard designs. I believe many wrist guards to be unbalanced in their design. They either offer not enough protection or too little protection to the rider. By addressing the key points outlined above I believe the result will yield a wrist guard design that snowboarders will feel confident in and want to wear. A successful design could lead to preventing injuries which translates into healthier more confident snowboarders and less health care costs to families.

Problem Area

Addressing the problem of wrist protection in snowboarding is a multifaceted conversation. To understand the problem in general terms, we must look to injury biomechanics, psychology, sociology, and injury statistics. Trauma biomechanics are valuable for understanding how the body reacts to the external forces attributed to a wrist break/sprain. Studying biomechanics may also help in understanding which part of the wrist is most susceptible to injury. To understand how relevant a wrist injury is as a problem we must look to injury statistics. Statistics are valuable in understanding the problem on a national or even global level. Psychology is important in understanding how snowboarders react in the event of an injury. What does breaking a bone do for a beginners ambition to continue riding? What types of

physical or psychological events led to wrist injury? By understanding these types of questions, I might gain insight into how to prevent those events from occurring. Sociology and psychology are paired together because of their close influence over one another. By researching the sociological factors of wrist protection in the snowboarding community I may gain further insight into why snowboarders don't use them and the social stigmas associated with using them.

Injury Statistics

Before delving into the other four key areas of research discussed above. It's first important to understand how prevalent of an issue wrist injuries are in the snowboard community. The logical course of action was to research injury statistics. The very first statistic revealed that "*over 100,000 snowboarders injury their wrists a year.*"⁵ That's quite a large number when you consider two factors. The first is wrist injuries are season enders, and by that I mean there is no snowboarding for the rest of the season. The second factor is that based on other statistics almost half of those would be beginners or novices. For many beginners/novices this may just drive them away from the sport. With that statistics I felt confident that the problem area I was addressing was relevant.

The next studies I found first identified rising patterns of wrist injuries in snowboarders over skiers. "*Matsumoto and colleagues found that among injured snowboarders, 40% sustained upper extremity injuries, while only 19% of skiers did ($p < 0.0001$).*"⁶ This is not surprising due to fact that snowboards have less mobility on the mountain than skiers. Skiers have poles that

⁵ 12. "Most common snowboarding injuries." Tahoe Ski World. January 08, 2016. Accessed April 29, 2017. <http://www.tahoetskiworld.com/most-common-snowboarding-injuries/>.

⁶ Michel, Frank I, Kai Uwe Schmitt, Richard M. Greenwald, Kelly Russel, Frank I. Simpson, David Schulz, and Mike Langran. "White Paper: functionality and efficacy of wrist protectors in snowboarding—towards a harmonized international standard." *Sports Engineering* 16, no. 4 (March 14, 2013): 197-210. Accessed April 24, 2017. doi:10.1007/s12283-013-0113-3

also keep themselves from using their arms in the event of a fall. Snowboarders have both feet strapped into a snowboard, making the only mobile extremity their arms. Snowboarders are twice as likely to sustain an upper extremity injury as skiers. Naturally the next statistic revealed of those upper extremity injuries how many were wrist injuries. Interestingly the study found that *“An estimated 25% of snowboarding injuries occur to the wrist. Most are fractures of the forearm bone, just above the wrist joint. Others commonly involve a small wrist bone called the scaphoid.”*⁷ This statistic may prove useful in the design of the wrist guard as it’s referred to several common injury areas in snowboarding.

Within the same paper the authors also reveal a correlation between beginner/intermediate snowboarders and wrist injuries. *“The most common injury location among snowboarders was the wrist, 33.3% among first-day participants and 21.2% among all others.”*⁸ This statistic will make more sense once we’ve reached psychological and sociological factors involved in a wrist break. In summary research into injury statistics and has proven fruitful as it’s both verified the problem and inspired deeper research into why the wrist is the most common injury.

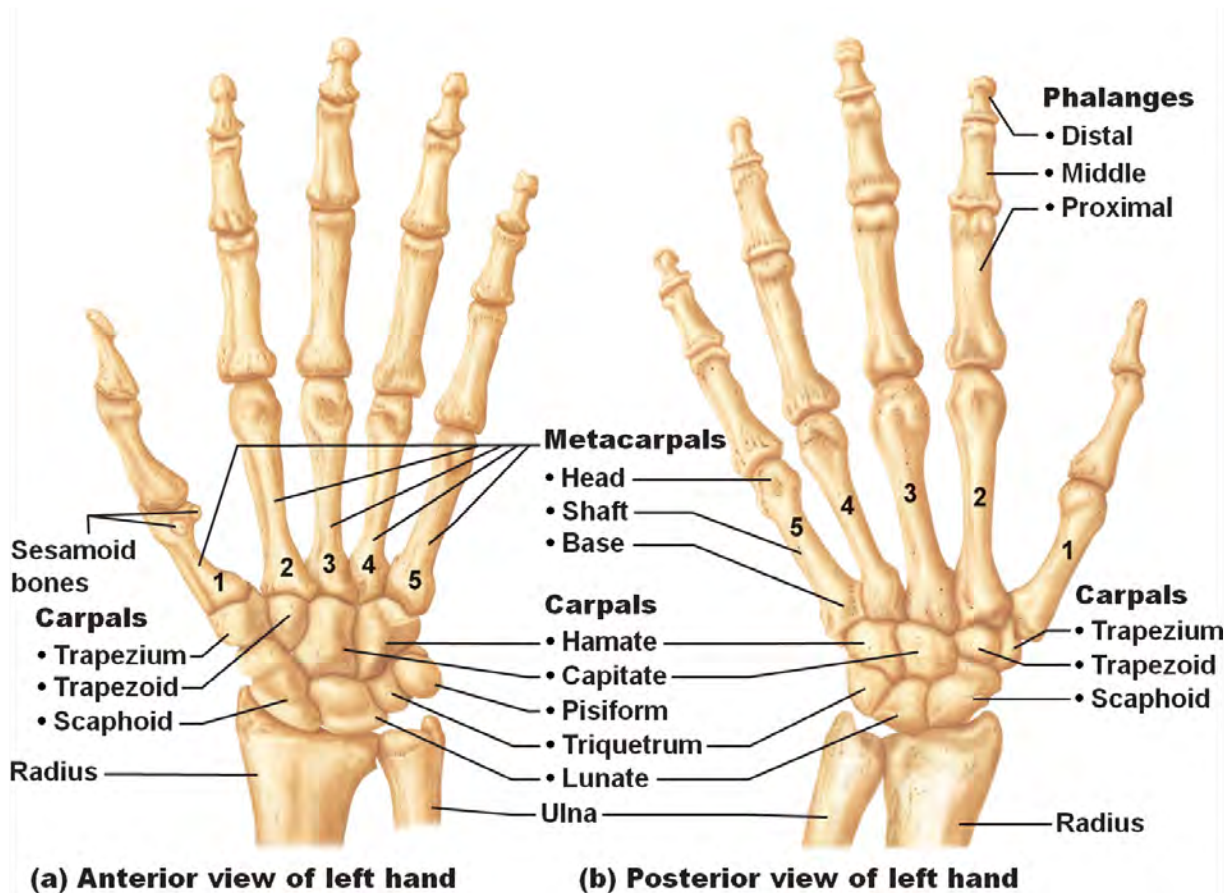
Biomechanics

To understand how the wrist breaks we must first understand how it works. Logically human biology would be the first place to start, it can give a firm foundation of understanding

⁷Pfeiffer, Ronald P., and Brent C. Mangus. Concepts of Athletic Training. Sudbury, Ma.: Jones and Bartlett Publishers, 2002.

⁸ Michel, Frank I , Kai Uwe Schmitt, Richard M. Greenwald, Kelly Russel, Frank I. Simpson, David Schulz, and Mike Langran. "White Paper: functionality and efficacy of wrist protectors in snowboarding—towards a harmonized international standard." *Sports Engineering* 16, no. 4 (March 14, 2013): 197-210. Accessed April 24, 2017. doi:10.1007/s12283-013-0113-3

from which to delve to deeper from. Below we can see a standard view of the parts that make up the wrist.



For the purposes of my research I thought it was best to focus on first understanding the bone structure and how that related to the mechanics of the wrist. With this chart in mind I started researching into the biomechanics of the wrist. My research revealed that “Overall, the wrist ligaments have properties similar to those of other joint systems. The palmar capsular ligaments, such as the radioscaphocapitate and the long radiolunate ligaments, are typical viscoelastic structures, generally failing at approximately 100 newtons (N). The intrinsic (interosseous) ligaments between the bones of the proximal carpal row are much stronger, requiring up to 300 N to fail. The strain at failure of these ligaments is much greater than that of

the capsular ligaments, exceeding 50% compared with 10-35%, respectively. On the other end of the spectrum is the radioscapolunate ligament, shown histologically to be a neurovascular pedicle with little collagen organized in a ligamentous fashion. Distraction testing has shown it to be quite weak, failing at less than 50 N.”⁹ Understanding how these forces relate to a wrist fall could be helpful in stress testing whatever design I come up with. Along these lines my research led me to a study that had done “Both analytical and experimental studies of force transmission across the wrist, positioned in a neutral position and in neutral forearm rotation, show that approximately 80% of the force is transmitted across the radiocarpal joint and the remaining 20% across the ulnocarpal joint. With ulnar deviation of the wrist, ulnocarpal force transmission has been shown to increase to 28%, while radiocarpal forces increase to 87% during radial deviation. Wrist palmar flexion and dorsiflexion exert only modest effects on force transmission distribution across the wrist.”¹⁰

This last statistic was particularly interesting because in the event of a wrist injury snowboards use flexion dorsiflexion during falls. Meaning when testing my solution I can test it from a static position. Following an analysis of the biomechanics of the wrist I looked next to biomechanics violent cousin trauma biomechanics.

Trauma Biomechanics

Trauma Biomechanics are very similar to normal biomechanics but differs in their study of the human body. Trauma biomechanics are focused on how the body reacts under stressed situations,

⁹ . Berger, Richard A., M.D. "The Anatomy and Basic Biomechanics of the Wrist Joint." *Journal of Hand Therapy* 9, no. 2 (June 1996): 84-93. Accessed October 15, 2016. doi:[https://doi.org/10.1016/S0894-1130\(96\)80066-4](https://doi.org/10.1016/S0894-1130(96)80066-4) .

¹⁰ . Berger, Richard A., M.D. "The Anatomy and Basic Biomechanics of the Wrist Joint." *Journal of Hand Therapy* 9, no. 2 (June 1996): 84-93. Accessed October 15, 2016. doi:[https://doi.org/10.1016/S0894-1130\(96\)80066-4](https://doi.org/10.1016/S0894-1130(96)80066-4) .

where biomechanics focused on how the body reacts under normal everyday use. From researching into biomechanics several key pieces of information were revealed. The first study focuses on how much force the different parts of the wrist could withstand. Researchers revealed that when *“Addressing the influence of the impact direction showed the forearm to be 21 % stronger in supinated position (91 Nm) than in a pronated position (75 Nm).”*¹¹ This is very relevant to my wrist injury research as the majority of wrist injuries happen with the wrist in the supinated position, meaning palm facing upwards or outwards. Delving deeper into the study it was summarized that *“in experimental studies the incidence rate of fracture was investigated by loading cadaveric arms (with and without wrist guard) in conditions representing a fall on the outstretched arm. Generally a wide spread of data was observed. Giacobetti et al. (1997), for instance, report an average force to fracture of an unprotected wrist of 2245 N (ranging from 1470–4116 N).”*¹² This force test on the wrist was very interesting as it gave me a baseline for testing how effective my own design would be at protecting a wrist. This study concluded by stating *“To prevent wrist fractures various designs of wrist guards are available. These guards mainly aim at transferring load from the hand to a larger area of the lower arm in the case of a fall.”*¹³ This information is relevant for understanding what designers have already done to try to prevent wrist injuries.

Psychology

¹¹ . Berger, Richard A., M.D. "The Anatomy and Basic Biomechanics of the Wrist Joint." *Journal of Hand Therapy* 9, no. 2 (June 1996): 84-93. Accessed October 15, 2016. doi:[https://doi.org/10.1016/S0894-1130\(96\)80066-4](https://doi.org/10.1016/S0894-1130(96)80066-4) .

¹² . Berger, Richard A., M.D. "The Anatomy and Basic Biomechanics of the Wrist Joint." *Journal of Hand Therapy* 9, no. 2 (June 1996): 84-93. Accessed October 15, 2016. doi:[https://doi.org/10.1016/S0894-1130\(96\)80066-4](https://doi.org/10.1016/S0894-1130(96)80066-4) .

¹³ . Berger, Richard A., M.D. "The Anatomy and Basic Biomechanics of the Wrist Joint." *Journal of Hand Therapy* 9, no. 2 (June 1996): 84-93. Accessed October 15, 2016. doi:[https://doi.org/10.1016/S0894-1130\(96\)80066-4](https://doi.org/10.1016/S0894-1130(96)80066-4) .

Psychology also plays a key part in understanding the events leading up to a snowboarder breaking or injuring their wrist. What happened in the moments before a wrist injury? Was the snowboarder trying to avoid an obstacle and lost control? Or was the snowboarder a beginner who panicked after riding too fast down the hill? Did the snowboarder think to catch themselves during a fall or was the fall so sudden they didn't have time to? Upon starting to research for these answers, I realised the types of questions I was asking are behavior conditioning type questions. Behavioral conditioning is a large and deeply complicated subject, for the general purposes of this project I can summarise it as follows. Behavioral conditioning in relation to snowboarders and wrist injuries is most prominently seen during the moments before or during a fall. As little children we learn to catch ourselves during a fall. We outstretch our hands or legs to minimise the impact of the fall. While this often works and results in no injury when we take into account the forces being applied during a snowboard fall, the prospect of catching yourself and it resulting in no injury are much slimmer. It's out of self preservation that many snowboarders break their wrists, they suddenly find themselves falling and revert to human instinct, which as discussed above is to catch themselves.

While this instinct can be overridden it takes practice and someone there to teach snowboarders how to fall correctly. *" Learning to fall correctly. This is very important from the outset, because beginners are at highest risk of injury. More and more snowboard schools are teaching this now which is good.....it basically involves keeping your arms out of the way when you fall. Easier said than done initially, but it can be invaluable."*¹⁴ This type of behavioral reconditioning is already a part of some learning programs, but without a way to easily quantify

¹⁴ "Wrist Injuries and their Prevention During Snowboarding - Expert Treatments Sports Injury Products & Physiotherapy Advice." Expert Treatments - PhysioRoom.com. Accessed November 5, 2016.
http://www.physioroom.com/experts/expertupdate/snowboarding_wrist_injury.php.

if beginners are following through with their training, we cannot determine if it's an effective solution. So how then is this research relevant to preventing wrist injuries? It's relevant, because it's important to understand the behaviors of snowboarders so that I can create a more informed design to fit their needs. In understanding that the majority of snowboarders are not trained to fall correctly, we can design for the worst case scenario. Beyond behavior conditioning it's important to also understand how snowboarders interact with the snow sport community at large.

Sociology

Snowboarding was born out of the rebellious 1960's counterculture. The country was going through immense political and social turmoil which birthed counterculture. With the rise of counterculture came the rise of snowboarding, the traditional sport of skiing became everything "the man" stood for. There were social rules and contracts that every skier abided too. They dressed a certain way talked a certain way even skied the same way. For the rebellious youth of the 1960's that wasn't okay. Snowboarding stood for everything skiing wasn't you dressed however you wanted, rode the mountain however you wanted. It was a sport with no rules and no limits. This stigma stuck with a lot of skiers until the 1990's when it became more socially acceptable to snowboard. Although the counterculture attitude has never left snowboarding, there is still negative stigmas associated to wearing ski brands and using protective equipment. Herein lies the importance of sociology as it relates to wrist injuries in snowboarding. It is among groups of young snowboarders that these stigmas reveal themselves.

In a survey done by myself, I interviewed a number of snowboarders both young and old and asked them about their thoughts on wrist protection. Over 80 percent of interviewee's

revealed they didn't wear wrist protection because they thought their friends would make fun of them. The survey also revealed they didn't wear wrist protection because they felt they were uncomfortable or didn't fit their gloves correctly. From a sociology standpoint the peer pressure associated with "fitting in" has overridden snowboarders need for injury protection. How might we reverse this negative social stigma through design? How can we change snowboarder's perceptions of that which isn't cool? Sociology has played an important role in understanding the motives behind why snowboarders both young and old don't wear wrist protection.

In summary of my research I've determined four different key area's that I believe to be beneficial in understanding the problem of encouraging beginner snowboarders to use wrist protection. Injury statistics have validated my problem as relevant and revealed types of snowboarders most susceptible to injury. While both biomechanics and trauma biomechanics have given me enough information to design an ergonomically fitting solution. While simultaneously revealing the technical data needed to design a product that can be tested using real physics. By studying the psychology of snowboarders, I've come to understand the thought process of a snowboarder during a fall. While sociology has revealed the social stigmas that are stopping current snowboarders from adopting wrist protection as a means of prevention. A successful design should distill this research into a tangible product that could possibly lead to preventing injuries and keeping more snowboarders on the mountains slopes and out of the ER waiting room.

Literature Review

The Rebellious Birth of Snowboarding

*“Snowboarding was born in the 1960’s out of youthful resistance to the popular sport skiing and the values of a sport it represented.”*¹⁵ Snowboarding was also heavily influenced by the rebellious nature of skateboarding and surfing culture. During its early years *“There was considerable resistance in the 1970’s to snowboarding’s presence at ski resorts.”*¹⁶ Regarded as the “Godfather of Snowboarding,” Jake *“Burton recalls attempting to convince many ski resorts into allowing him to ride his snowboard. Others document their own removal from various resorts because of their board.”*¹⁷ Snowboarding was fighting a literal uphill battle, with it’s rebellious influences and youthful attitude, ski resorts were used to a very orderly and disciplined sport.

Skiing had developed a strong set of rules of conduct that were shared among most skiers. In contrast snowboarding broke all the rules. *“Snowboarders clashed with skiers in style of dress and body presentation, equipment, and language.”*¹⁸ It was new and different during the 1980’s the youth flocked to it. Snowboarding gave them a way to differentiate from everyone else. While skiers wore tight, aerodynamic clothing in bright colors, snowboarders took influence from music and skateboard culture. They classically wore baggy clothes often times in

¹⁵ Heckler Magazine , Editors. *Declaration of independents : skateboarding, snowboarding & music : an intersection of cultures / by the editors of Heckler magazine.* San Francisco , CA: Chronicle Books, 2001.

¹⁶ Heckler Magazine , Editors. *Declaration of independents : skateboarding, snowboarding & music : an intersection of cultures / by the editors of Heckler magazine.* San Francisco , CA: Chronicle Books, 2001.

¹⁷ Heckler Magazine , Editors. *Declaration of independents : skateboarding, snowboarding & music : an intersection of cultures / by the editors of Heckler magazine.* San Francisco , CA: Chronicle Books, 2001.

¹⁸ Heckler Magazine , Editors. *Declaration of independents : skateboarding, snowboarding & music : an intersection of cultures / by the editors of Heckler magazine.* San Francisco , CA: Chronicle Books, 2001.

*“drab colors.”*¹⁹ Snowboarders had developed an *“I don’t care about my appearance attitude.”*²⁰

This attitude was in part because of the influences of popular 80’s punk rock and hip-hop. Most notable bands like Metallica and Public Enemy all attributed to the rebellious birth of snowboarding. Having found it’s roots in the underground rebellious scenes of skateboarding and surfing culture. Snowboarding was about being aggressive on the ski-slope, using the natural terrain to “freeride” the mountain. It’s this aggressive mentality and rebellious attitude that has grown a sport from a few thousand to fifteen million snowboarders today. It’s also the cause of many injuries, since it’s birth researchers and physicians have been studying the pattern of trauma injuries sustained by this fast growing extreme sport.

Snowboarding Injuries

Snowboarding shares many similarities with it’s inspirations. Just like with skateboarding and surfing there is always the possibility for injury. This is true regardless of age and skill-level, these are activities that are classified as “extreme sports.” Snowboarding comes with a higher than normal risk of injury due to the nature of sports youth. Researchers and physicians took notice of the increasing amount of injuries in snowboarders and came to a number of conclusions based on data analysis. *“Matsumoto and colleagues found that among injured snowboarders, 40% sustained upper extremity injuries, while only 19% of skiers did ($p < 0.0001$).”*²¹ This data could point to a pattern of increased risk for upper extremity injuries in snowboarders. Following

¹⁹ Heckler Magazine , Editors. *Declaration of independents : skateboarding, snowboarding & music : an intersection of cultures / by the editors of Heckler magazine*. San Francisco , CA: Chronicle Books, 2001.

²⁰ Heckler Magazine , Editors. *Declaration of independents : skateboarding, snowboarding & music : an intersection of cultures / by the editors of Heckler magazine*. San Francisco , CA: Chronicle Books, 2001.

²¹ Michel, Frank I , Kai Uwe Schmitt, Richard M. Greenwald, Kelly Russel, Frank I. Simpson, David Schulz, and Mike Langran. "White Paper: functionality and efficacy of wrist protectors in snowboarding—towards a harmonized international standard." *Sports Engineering* 16, no. 4 (March 14, 2013): 197-210. Accessed April 24, 2017. doi:10.1007/s12283-013-0113-3

this increase study, researchers concluded that *“The most common injury location among snowboarders was the wrist, 33.3% among first-day participants and 21.2% among all others.”*²² Another study found that *“An estimated 25% of snowboarding injuries occur to the wrist. Most are fractures of the forearm bone, just above the wrist joint. Others commonly involve a small wrist bone called the scaphoid.”*²³ Based on the results of multiple studies on wrist injuries in snowboarding, a pattern starts to become clear, Snowboarders are more likely than skiers to sustain an upper extremity injury and of those injured a greater percentage are wrist related injuries. Among these conclusions researchers also found a link between wrist injury and novice snowboarders.

Frequency of Wrist Injuries in Novice Snowboarders

Interestingly another pattern also emerged from these injury studies. They found that novice snowboarders were among the most at risk for injury. In the systematic review *“Snowboard Wrist Guards-Use, Efficacy, and Design”* by Suezie Kim, M.D., and Steve K. Lee, M.D, they try to gauge the efficiency of wrist protection in snowboarding by analyzing current research on wrist protection efficacy. Based on sixteen other research studies they concluded the limb that was most commonly injured among snowboarders was the wrist, and of those who injured their wrist *“33.3% were first-day participants.”* First day participants also made up *“21.2% of all injured snowboarders.”* Among the literature they reviewed they also found *“Wrist guard use was more prevalent in the advanced group (19%), compared with the intermediate*

²² Michel, Frank I , Kai Uwe Schmitt, Richard M. Greenwald, Kelly Russel, Frank I. Simpson, David Schulz, and Mike Langran. "White Paper: functionality and efficacy of wrist protectors in snowboarding—towards a harmonized international standard." *Sports Engineering* 16, no. 4 (March 14, 2013): 197-210. Accessed April 24, 2017. doi:10.1007/s12283-013-0113-3

²³ Suezie, Kim, M.D., and Steve K. Lee, M.D. "Snowboard Wrist Guards-Use, Efficacy, and Design." *Bulletin of the NYU Hospital for Joint Diseases*, 149-157. Accessed April 24, 2017. http://presentationgrafix.com/_dev/cake/files/archive/pdfs/223.pdf.

group (10%) and the beginner group (7%).” A number of other studies researching similar area’s came to reveal similar patterns of injury in novice riders. In the “*White Paper: functionality and efficacy of wrist protectors in snowboarding towards a harmonized international standard*” by Frank I. Michel, Kai-Uwe Schmitt, Richard M. Greenwalk, Kelly Russell, Frank I. Simpson, David Schulz, Mike Langran, they examine a way to create a standard for judging the efficacy of wrist protectors. The author’s start by reviewing current literature on wrist protection. They concluded that “*the wrist represents the most frequently injured body region and accounts for 19-28% of all injuries*” among snowboarders. They also reported that “*the most significant risk factors for a wrist fracture were age less than 16 years, being on holiday, and being a first time participant.*” The white paper revealed that “*novice snowboarders were at higher risk of a distal radius or a distal radius and ulna fracture than experienced riders.*” Although research has uncovered a connection between wrist injuries and novice riders, they were still missing vital information about these novice riders in order to fully understand the root of the pattern.

In the journal article “*Snowboarding Injuries in Australia Investigating Risk Factors in Wrist Fractures to Enhance Injury Prevention Strategies*” by Tracy J. Dickson, PhD and Anne F. Terwiel, they explore the efficacy of wrist protection and the predictors behind a wrist fracture. Their study showed the strongest factor in having a wrist fracture “*was being less than 16 years old, followed by not wearing a wrist guard and being in the region for holiday/vacation.*” Their study indicated that snowboarders “*under the age of 16 were over 3 times more likely to injure their wrist.*” They also indicated that “*all people who experienced a wrist fracture while wearing a wrist guard were wearing a short wrist guard.*” Another interesting result they found was

“43% of snowboarders were not wearing any form of protective equipment at the time of their injury.” This journal article starts to delve deeper into the influences behind wrist injuries in novice riders. The connection the author’s made between being younger than 16 years old and being on vacation are particularly interesting. The age factor may be due to the lower density of children’s bones as they are still maturing at that age. The second factor might mean there is a connection between “first-day participants” and those who are on vacation.

Furthermore in the article “Physics of Snowboarding” by M.E Franco Normani, he discusses the physics behind the sport of snowboarding. The author starts by illustrating the basic physics behind moving downhill. He explains *“A snowboarder typically gains speed by converting gravitational potential energy into kinetic energy of motion.”* Franco goes on to illustrate the difference between a “carve” and “skid” turn on a snowboard. He explains that *“Amateur (less experienced) snowboarders typically “skid” around their turns. This occurs when the snowboard is tilted on its edge and the exposed base of the board “plows” into the snow head on. Although the skidding can be controlled and the turn successfully executed, it ultimately results in a significant loss in speed, which can be undesirable. This occurs because the “plowing” action generates frictional resistance with the snow, by physically pushing it.”* While a “carved” turn *“there is no skidding, and the only snow resistance present is the very small sliding friction between snowboard and snow. As a result of this minimal level of friction between snowboard and snow, the speed reduction of the snowboarder is minimized, and he is able to navigate.”* The author’s creates a comparison in the habits of novice and experienced snowboarders on the mountain slope. In particular his comments on the amateur “skid turn” may be connected to the increase in injuries in novices. Skid turns are typically done in a less

controlled manner than a carved turn. This allows for a higher risk of injury and falls onto the wrist due to “skidding out,” a common term in teaching snowboarding.

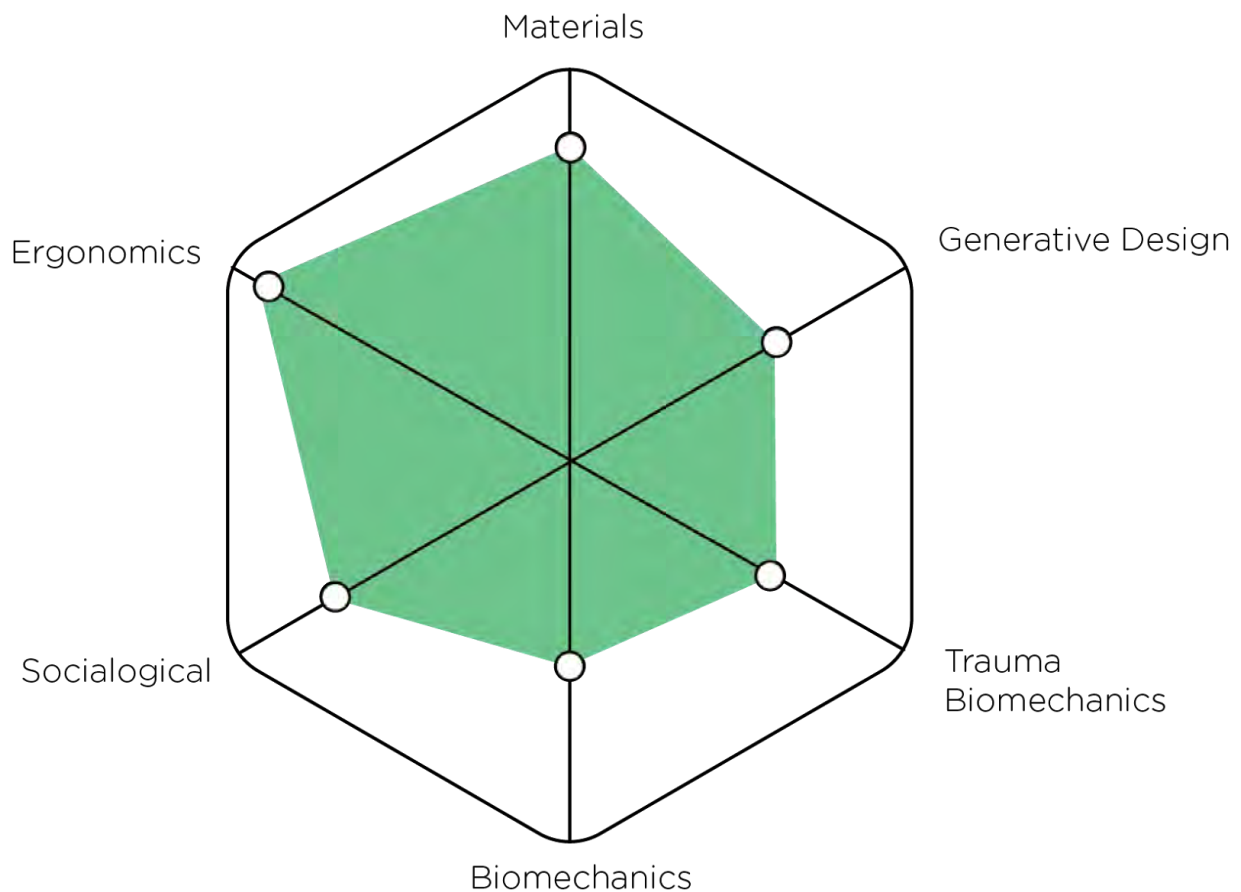
Benefits of Efficient Wrist Protection

In the paper “*Risk of Injury through Snowboarding*” by Machold, Wolfgang, M.D., Oscar Kwasny, M.D., Peter Galer, M.D., Alexander Kolonja, M.D., Brian, M.D, Ewald Bauer, M.S., and Stephen Lehr they try to compare injuries with the conditions under which they occurred on mountain slope. In their study they concluded that the “*use of wrist protection devices reduced injuries to the wrist*” by over 50%. Furthermore they also concluded that based on a literature search, “wrist guard use did significantly reduce the risk of wrist injury across many sports. The investigators did note that due to the various wrist guards that were used in all of the included studies, no particular wrist guard was deemed optimal to reduce the number of wrist injuries.” Other studies point to In the informational pamphlet “*Wrist Injuries and Their Prevention During Snowboarding*” by leading sports injury professionals. They discussed several key points when addressing prevention of wrist injuries in snowboarding. Researchers also found that wrist guards reduced the overall risk of wrist or forearm injury by 85%. Not only would efficient wrist protection reduce the risks new and experienced riders take but it might also translate to more novices that keep coming back to the sport. Often times in cases where someone is injured there is a fear of becoming re-injured doing the same thing again. This keeps novices snowboarders from coming back to the sport especially if they injured on their first day. Efficient wrist protection could result in fewer and less severe wrist injuries in the sport and could also translate into more riding days for healthy snowboarders and reduced health care costs for families and

individuals. There is also evidence that wrist fractures in teenagers can lead to problems in future growth and strength of the injured wrist. A wrist fracture that does not heal correctly “*can lead to chronic pain and inability to extend the wrist through its’ full range of motions.*”

Early Concepts

I felt it was important to break down the broad areas of research that were important to understanding the larger problems associated with my thesis problem. As illustrated below my design will combine several different areas of industrial design that are informed by my research.



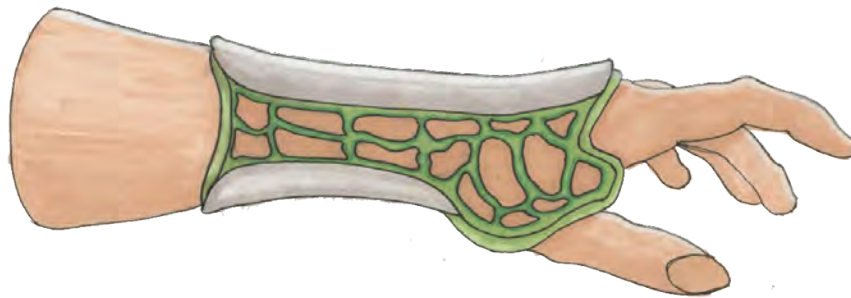
The first key area I'll be designing for is **ergonomics**. My solution is most likely going to be something worn by a rider so therefore the ergonomics of how the user interacts with my solution is a key part to the success of my thesis. Following ergonomics it's also important to address these problems from a **sociological** perspective. Snowboarding is a sport shared by families, couples, and, individuals sociology is large part of what attracts people to snowboarding in the first place. Therefore the sociological aspect of my design will hopefully address the negative stigmas associated with current wrist protection. Due to the nature of snowboarding, physics plays a key role in enabling people to snowboard. These same gravitational forces are what also disable people from snowboarding through injury, With this in mind **generative design** seems like a nature tool for addressing injury prevention, I believe by analysing how snowboarders fall and measuring the forces behind these falls generative design could curate structure that utilizes those forces to prevent injury instead of cause it. Lastly material selection is an equally important part of designing snowboarding accessories, as riders spend many hours in harsh potentially dangerous terrain pushing themselves to go faster and bigger than the ride before. I believe by combining these areas of research and design I can create a wrist guard that snowboarders not only want to wear, but also a design they feel confident in.

These are all important factors when addressing wrist guard use and how design might encourage its continued use. In my research/interviews, these were all common issues people had with wrist guards. Many of their issues were ergonomic concerns, like being "uncomfortable." Delving deeper into this specific concern, it was revealed that many wrist guards limited the mobility of the hand and wrist to much for most snowboarders. It often affected their ability to

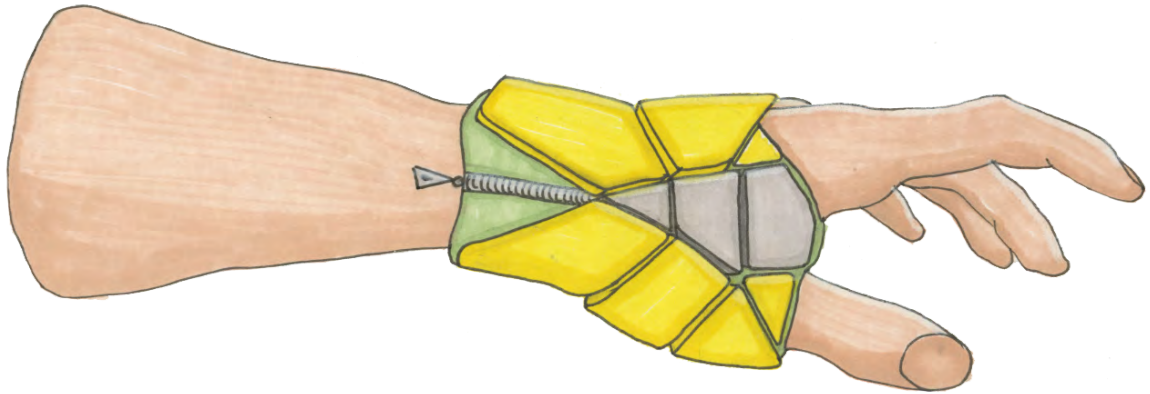
grab their board or buckle their bindings. Many current risk guards are modeled after medical wrist braces worn predominantly after an injury. These medical wrist braces are built to mostly immobilize the wrist so that an injury doesn't occur during healing. Due to this fact many wrist guards are also very robust and the other complaints about being too hot and not fitting in their gloves seem to make sense. Ergonomic complaints aside, the sociological issues associated with people's lack of faith in wrist protection was most troubling. With this information and feedback in mind I believe that my design has to address both the ergonomic and social issues related to why people aren't wearing wrist protection.

Using these research insights I started sketching and exploring ideas that would hopefully give me a basis from which to build some rough 3D mock-ups. I started with ideas that might addressed the key areas discussed above. My sketches pull inspiration from my readings on the biomechanics of our bone structure. Our bone structure is based on the naturally recurring property know as the "Maximum-minimum law." "Maximum-minimum law states that a maximum of strength is reached with a minimum of constructive material. These structures are called minimum structures."²⁴ I believe the exploration of minimum structures could lead to a systemic solution for addressing the social/ergonomic needs of the user.

²⁴ Kozaburo, Hayashi, and Ishikawa Hiromasa. *Computational Biomechanics*. , . Place of publication not identified: Springer Verlag, Japan, 2012.



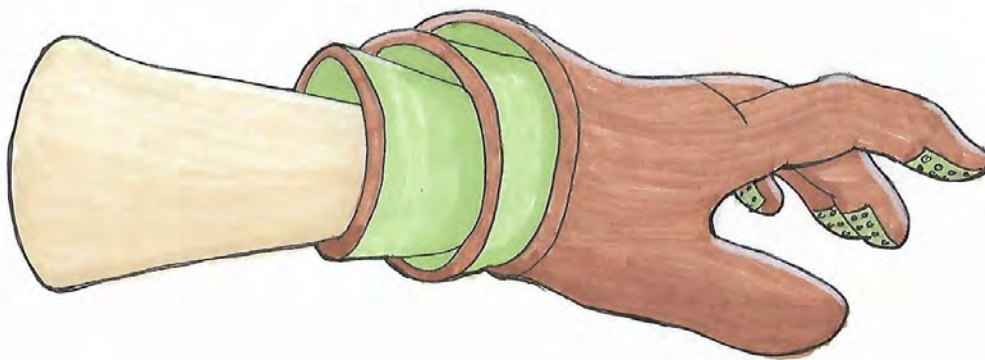
Seen in the sketch above, I explored ways reducing the weight and breathability of wrist protection by integrating biological patterns that mimic our bone structure. From this basis I sketched a number of other sketches that explore other possible solutions. Inspired by non-newtonian fluids and materials, I explored the idea of situational functionality. The sketches below visualize my early ideations of a situationally rigid wrist guard.

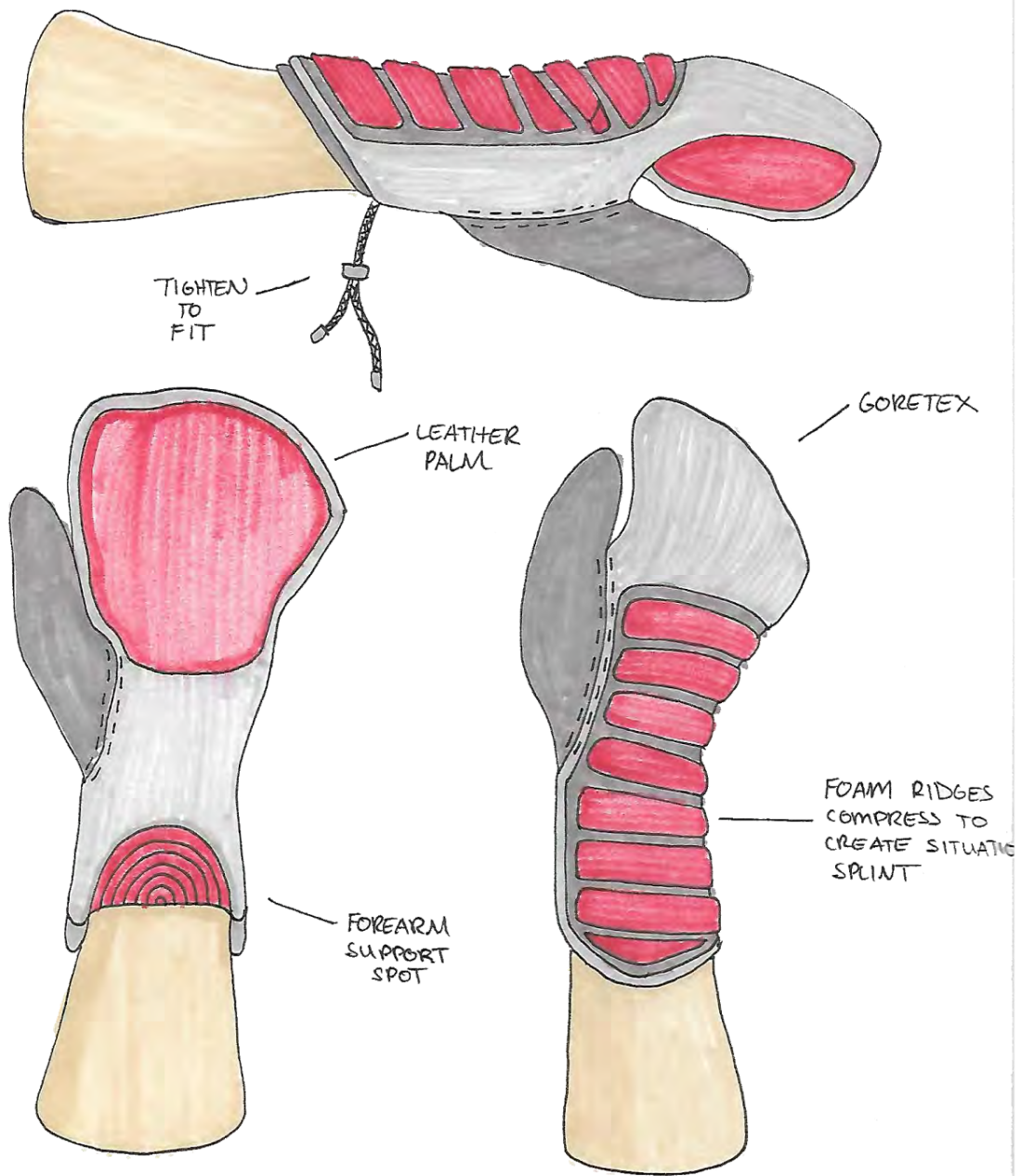


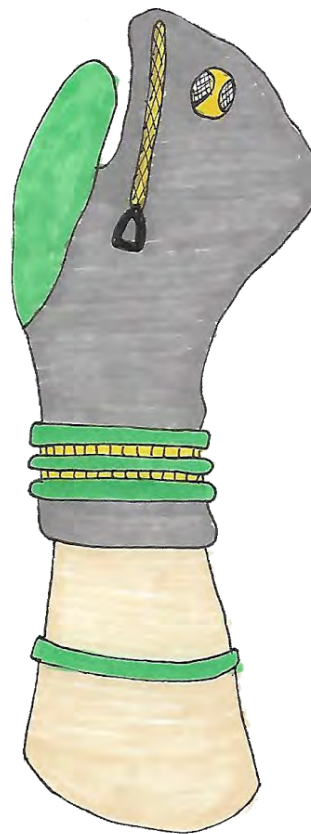
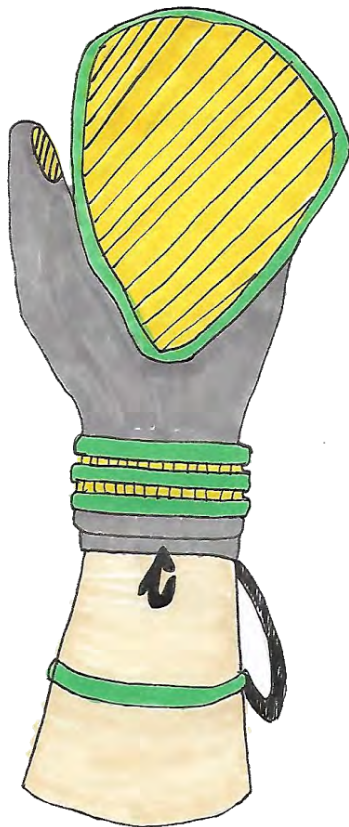
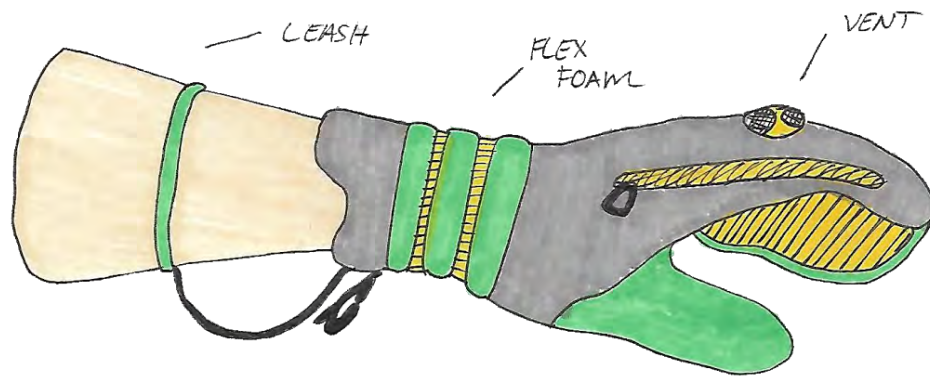
- GLOVE
- SHIELDED FOAM



FLEX-UP TO
CREATE WRIST
SUPPORT







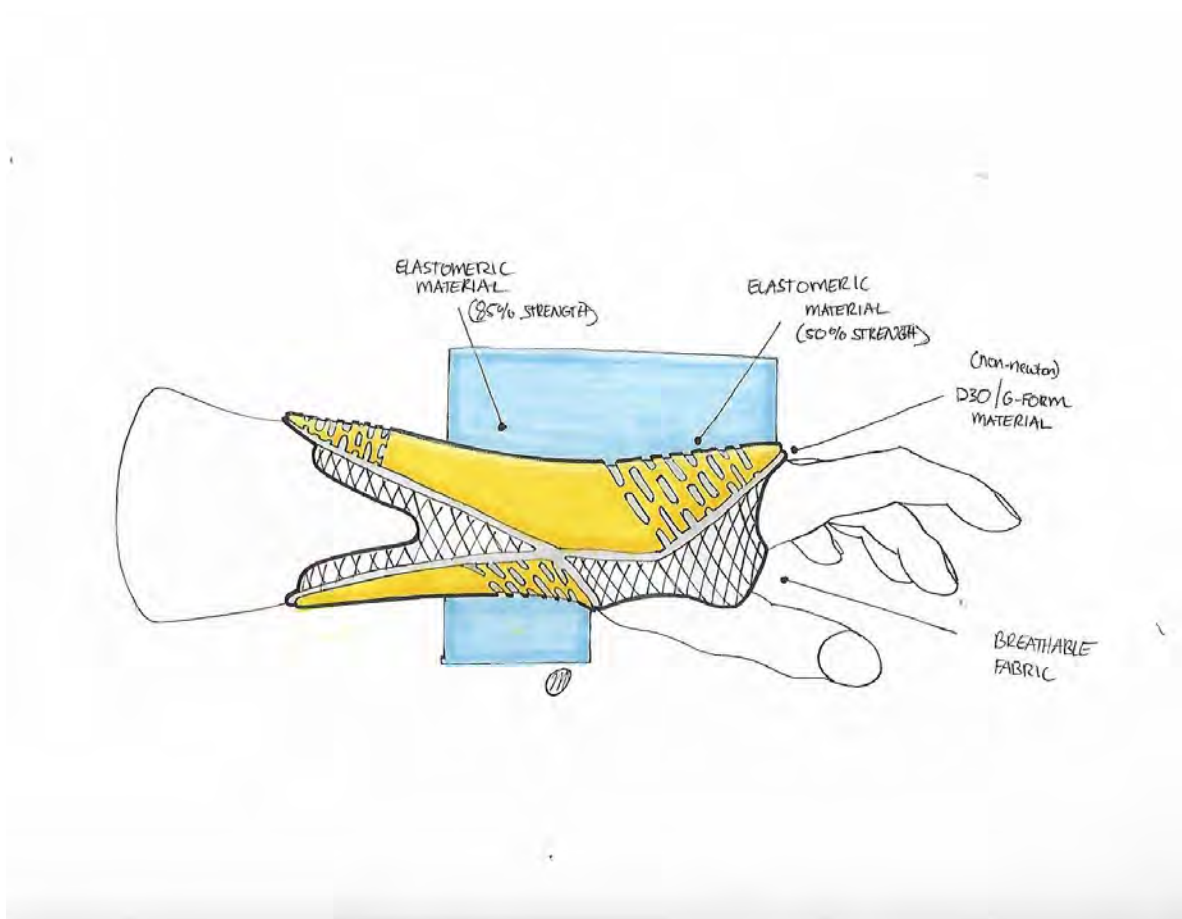
As I moved from rough sketches to starting to develop my rough 3D mock-ups, I decided to explore two different ways of possibly achieving “situational rigidity.” My early ideas are illustrated in the sketches above. First I explored using a series of foam patterned blocks to create a splint that transitioned between flexible and rigid states. This transition is informed by the biomechanics of the wrist, meaning the splint would only become rigid when the wrist flexed upward towards the forearm. I focused on this motion, because my research showed that this wrist motion was involved in the majority of wrist fractures in youth snowboarders. Below are my earliest prototypes testing situational rigidity using foam blocks.



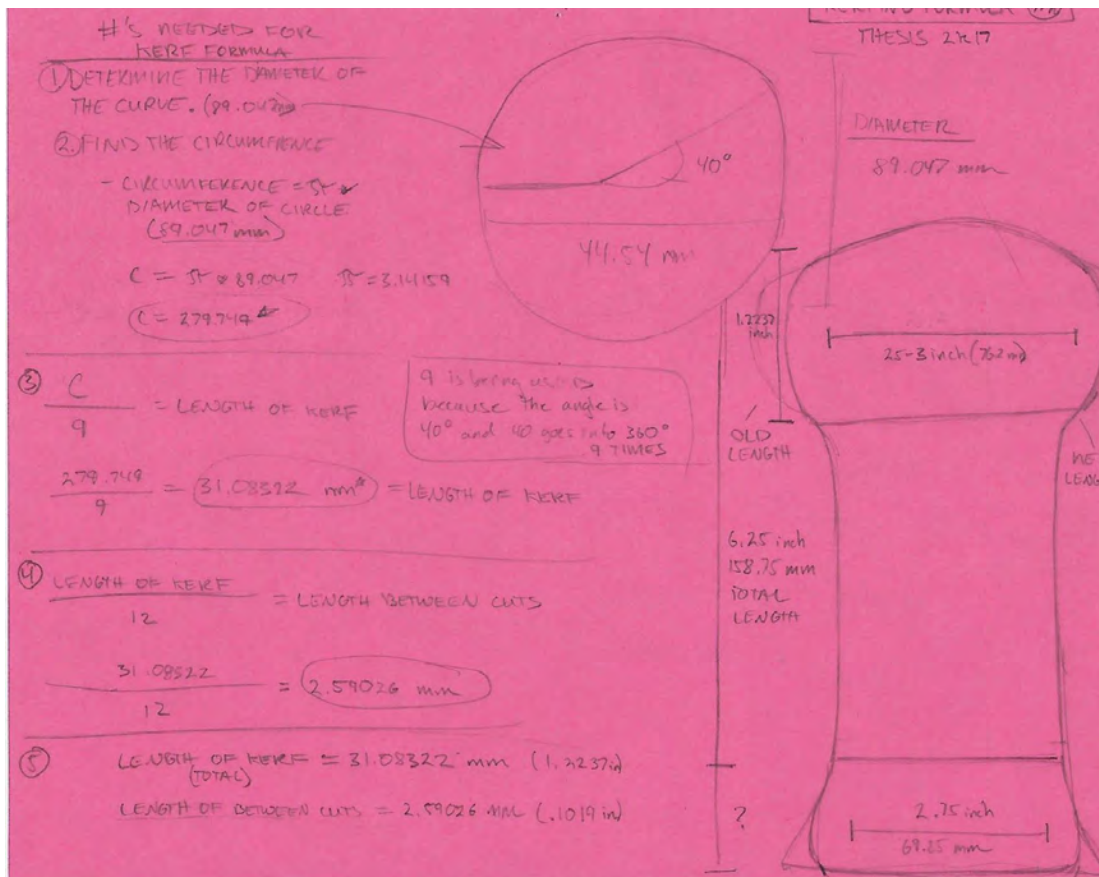
After concluding that using foam patterned structures was not a viable design for improved flexibility and protection, I moved to my second idea. This idea was inspired by woodworking technique known as “kerfing.” Kerfing is a term used to describe a subtractive method of making a solid piece of wood flexible. This was inspiring to me because current splints are rigid all the time and I’m looking to create a splint that is situationally flexible. I started prototyping kerfed splints by using wood, fabric, and velcro. I quickly learned that wood was not the most reliable material for prototyping so I pivoted towards a 3d printed resin version of the splint.

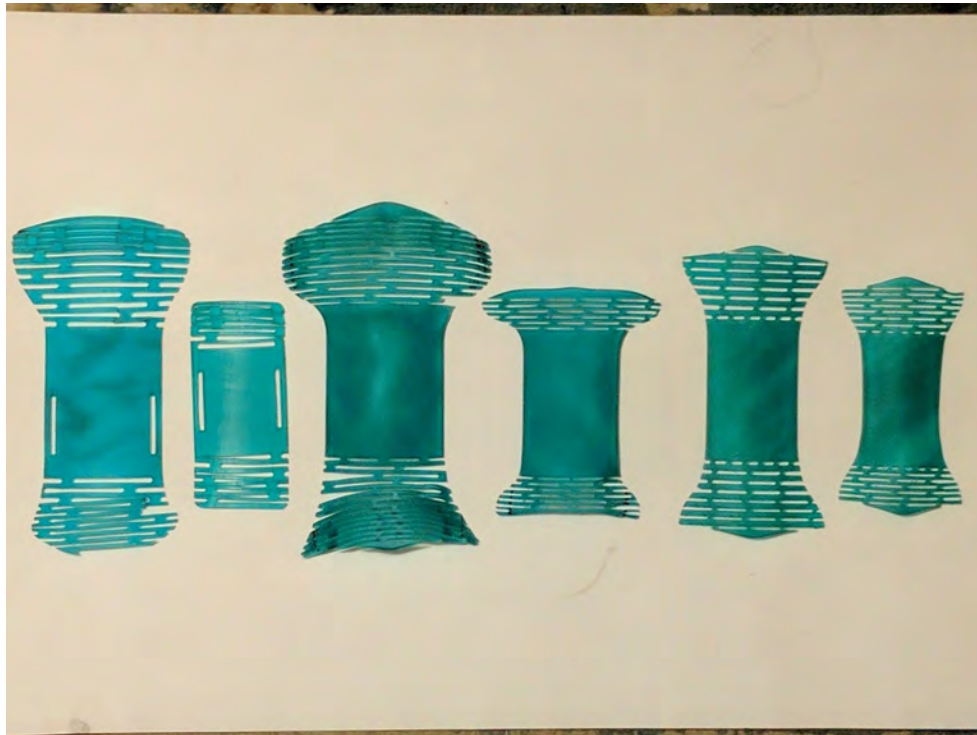


.Based on the insights gained by my research and early prototyping I feel a kerfed splint is possible solution to solving part of the issues user's currently have with wrist protection. A kerfed splint would allow flexibility in both extension and flexion movements of the wrist. Kerfing also functions to reduce the weight of the over splint. Although currently I'm skeptical of the strength of a kerfed splint, I believe with the right material a kerfed splint could work. As I moved towards a more refined prototype I sketched more ideas exploring kerfing.



I started prototyping testable versions so that I could gain feedback on the fit and usability. using Autodesk Fusion 360 I modeled plastic versions that I could print on RIT's SLA printers. The modeling process for the prototypes were fairly straight forward. I took a 3D scanned arm and designed splints based off of kerfing mathematics that fit the hand. The equations related to kerfing mathematics I found easily online. The basic equation can be viewed below.





Using the above equation I was able to fairly accurately determine the number of kerfs needed to bend a splint to a specified angle. Each splint explores the application of this equation to a different amount of rigidity. The five pairs of kerfed splints I designed and 3D printed in tough resin can be seen above. Each bends to a different angle allowing me to further explore the balance of flexibility and rigidity. Before being able to test these five prototypes I needed to first refine how they would attach to the user. Looking at how wrist protection is currently applied to snowboarder's wrists, gave me a baseline of current methods for attachment. These methods have their advantages and disadvantages, with that in mind, I'm wary of developing a mitten/glove because in my experience snowboarders are generally very attached to their gloves. Once they find that pair they really enjoy and break in, they wear them for years. With this in mind I believe it could difficult to get them to part with their gloves for a new pair. Instead I

believe by designing a universally fitting wrist guard that can work with their favorite gloves, I can increase the possibility that they wear wrist protection.

Mid Concepts

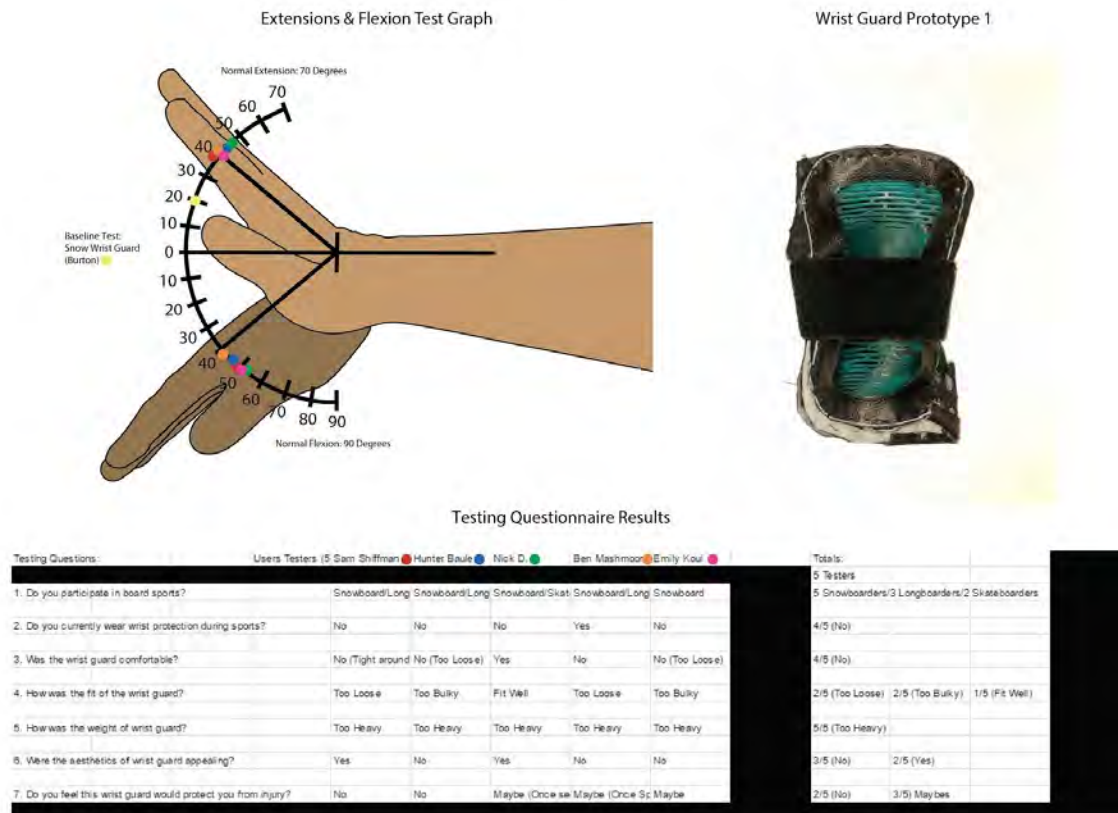
My refined hand-sewn prototypes explore form and attachment systems. Earlier ideas use a wrap around design with velcro, later ideas utilize spandex and velcro combinations. These prototypes were used throughout the testing phase of my thesis.



User Testing

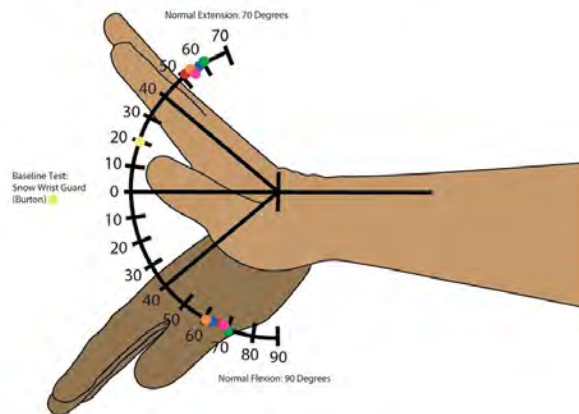
User testing my prototypes was the one of the most challenging parts of developing a solution for my thesis. Current wrist protection on the market is tested by dropping a cadaveric arms with the wrist guards attached to them on force measuring devices and then assessing the forces on impact. Sadly I don't have the funding for such a setup, so my testing is limited to what is available here at RIT. The bend tests will help me gauge if my splints are bending to the proper angles for flexibility. Finally the surveys will help me gather feedback on the ergonomics and aesthetics of my designs. User testing was done both online and in person. The following four prototypes were tested with five snowboarders of varying skill level and experience.

Prototype 1



Prototype 2

Extensions & Flexion Test Graph



Wrist Guard Prototype 2

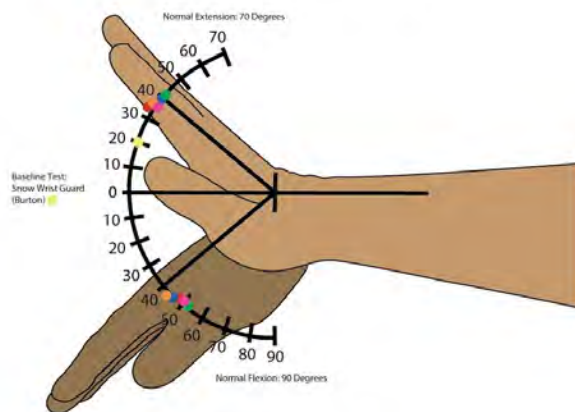


Testing Questionnaire Results

Testing Questions:	Users Tested: 5 Sam Shiffman	Hunter Baile	Nick D.	Ben Mashmore	Emily Kaur	Totals:
						5 Testers
1. Do you participate in board sports?	Snowboard/Long	Snowboard/Long	Snowboard/Skate	Snowboard/Long	Snowboard	5 Snowboarders/3 Longboarders/2 Skateboarders
2. Do you currently wear wrist protection during sports?	No	No	No	Yes	No	4/5 (No)
3. Was the wrist guard comfortable?	Yes	No	No	Yes	Yes	3/5 (Yes) 2/5 (No)
4. How was the fit of the wrist guard?	Fit Well	Fit Well	Fit Well	Fit Well	Too Loose	4/5 (Fit Well) 1/5 (Too Loose)
5. How was the weight of wrist guard?	Just Right	Just Right	Just Right	Just Right	Just Right	5/5 (Just Right)
6. Were the aesthetics of wrist guard appealing?	Yes	No	Yes	No	No	3/5 (No) 2/5 (Yes)
7. Do you feel this wrist guard would protect you from injury?	No	No	No	No	No	5/5 No

Prototype 3

Extensions & Flexion Test Graph



Wrist Guard Prototype 3



Testing Questionnaire Results

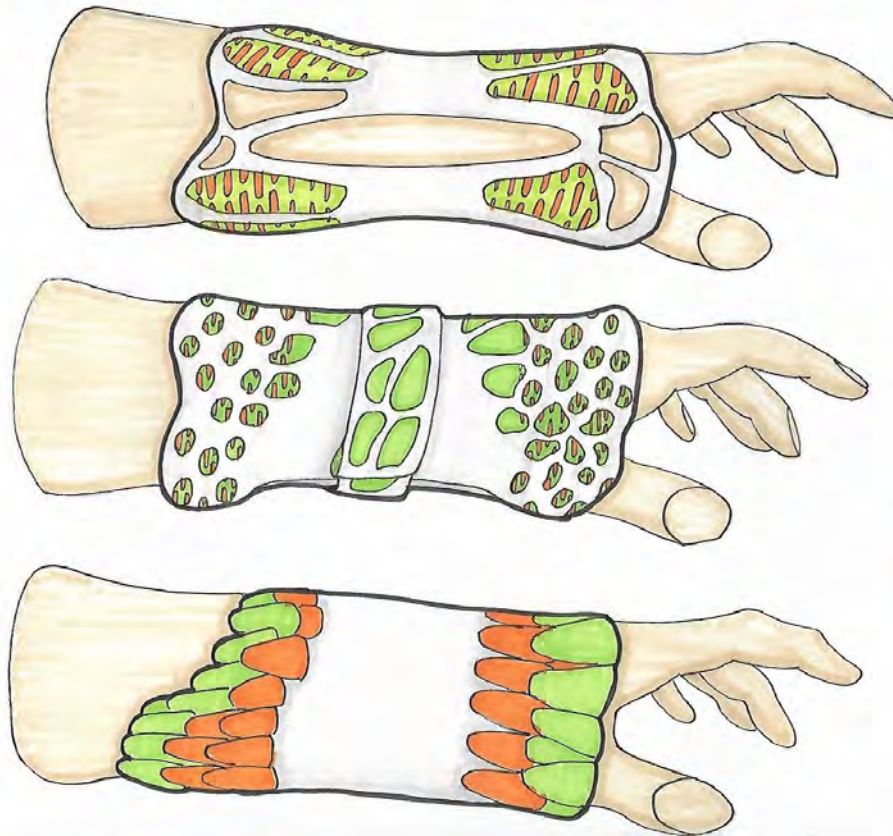
Testing Questions:	Users Tested: 15 (5 Sam Shiffner, 5 Hunter Baice, 5 Nick D., 5 Ben Mashmore, 5 Emily Kuo)					Totals:
1. Do you participate in board sports?	Snowboard/Long Snowboard/Long Snowboard/Skate Snowboard/Long Snowboard					5 Testers 5 Snowboarders/3 Longboarders/2 Skateboarders
2. Do you currently wear wrist protection during sports?	No	No	No	Yes	No	4/5 (No)
3. Was the wrist guard comfortable?	Yes	Yes	Yes	Yes	Yes	5/5 (Yes)
4. How was the fit of the wrist guard?	Fit Well	Fit Well	Fit Well	Fit Well	Fit Well	5/5 (Fit Well)
5. How was the weight of wrist guard?	Just Right	Just Right	Just Right	Just Right	Just Right	5/5 (Just Right)
6. Were the aesthetics of wrist guard appealing?	Yes	Yes	Yes	Yes	Yes	5/5 (Yes)
7. Do you feel this wrist guard would protect you from injury?	Yes	Yes	Yes	Yes	Maybe	4/5 Yes 1/5 (Maybe)

My user testing showed a gradual progression from an uncomfortable rough design to a refined prototype informed by user feedback. Users in general expressed the opinion that the kerfing pattern was very appealing. My advisors echoed this opinion and challenged me with finding a better way integrate it into the fabric part for my final prototype. My advisors also confirmed that I could take the final design a more conceptual route.

By making my fourth prototype a conceptual version, I gave myself the freedom to explore different materials and technologies. This new direction would also help in solving a key sociological issue my research identified. The issue of the “coolness” of wrist guards many young snowboarders felt social pressures, because wrist guards weren’t considered cool. By choosing a more conceptual route, it allows me to focus on making my design “cool to wear”. A big part of snowboarding is the culture and fashion of the sport. By designing a wrist guard that is treated as a fashion statement and not a protective piece of gear. Wrist guards will become something young snowboarders want to wear.

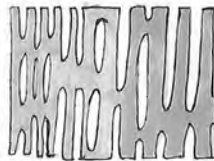
Having been focused on a market facing wrist design, I was limited to what the industry uses. Since I pivoted towards a conceptual version, I had more freedom to explore various organic patterns. Since my kerfing patterns were already starting to look organic, I really dove into that aesthetic. I also explored different materials in my sketches.

CONCEPTUAL DESIGN

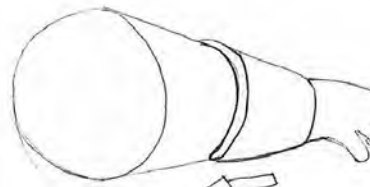


NYLON/6
CARBON
INTERIOR

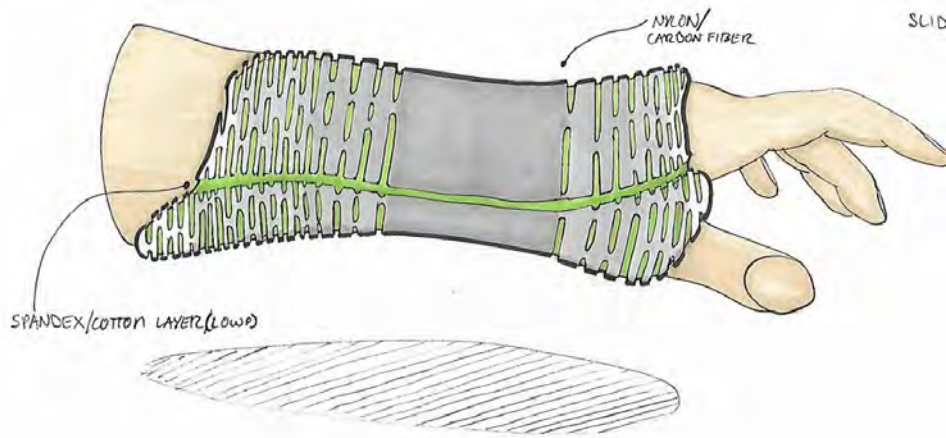
PATTERN 01



SMALL TO LARGE KEEFING



SLIDES OVER HAND



Final Materials

After meeting with Dr. Cormier Head of RIT's AMPrint Lab, he explained that they could print in multiple materials by tricking the 3d printer. He went on to explain he had already been creating test prints using carbon fibre and nylon mixtures. This information solidified the direction for my conceptual version as applying this technology to my splint design seemed like a promising direction for my splint material. Unfortunately due to scheduling and time conflicts between Dr. Cormier and myself, I was not able to print a wrist splint to test the mixture of the materials discussed above. It's a fairly complex process and had I known earlier in the semester, I would have put a heavier emphasis on prototyping with those materials. Although I wasn't able to test those final materials, I feel confident that it could yield promising results.

Once I had defined a final material for the wrist splint, I shifted my time towards defining and acquiring the final materials for the rest of the wrist guard. Having tested several materials during my earlier prototyping sessions. I knew the types of attributes I was looking for in my materials, For each piece of material, I defined a set of material attributes based on my research, prototyping, and user testing sessions. With the splint material I learned from my research that the splint had to function with situational rigidity. Naturally a blend of materials might serve that functionality. Nylon would allow flexibility in the areas of the splint where flexibility was needed, while carbon fibre was used to reinforce areas of nylon that needed to be rigid. I approached the rest of my materials in a similar fashion. From my prototyping and user testing stages I learned that my material choice for the sleeve of the wrist guard would require three material attributes. It would require "flexibility" to allow a range of users to wear it comfortably.

It would also have to be a lightweight material, users expressed the need for the wrist guard to fit within their gloves, The final attribute was breathability, user's didn't want to cause their hands to sweat during snowboarding. Based on these outlined material attributes I ordered fifteen different athletic fabric samples to test and play with.



I settled on an athletic spandex material from Rockywoods that I felt satisfied the material attributes outlined above. After defining the final material for the sleeve, there was two materials left to define. The first being the foam which functions for impact absorption. The material attributes I was looking for in my foam were similar to my splints. The foam ideally

would be situationally rigid to compliment the movements of the splint. Based on my research into phase change materials, these types of material properties could be achieved using a non-newtonian material like D3O. Non-newtonian materials are resistant to impact forces due to their molecular make-up. Upon reaching out to D3O to test their material with my splints I was told that they don't give out samples and don't work with students or universities. So although I am not able to test the material I believe based on its current uses that it would be an effective material. For the sake of my final prototype I've ordered a industry standard foam used commonly in current wrist guard designs as a place holder. Based on my user testing, users responded positively towards the black leather detailing I had designed and been testing, It also happened to fit the material attribute I was looking for. With the all the materials defined for my final prototype all that was left to do was make a pair of wrist guards.

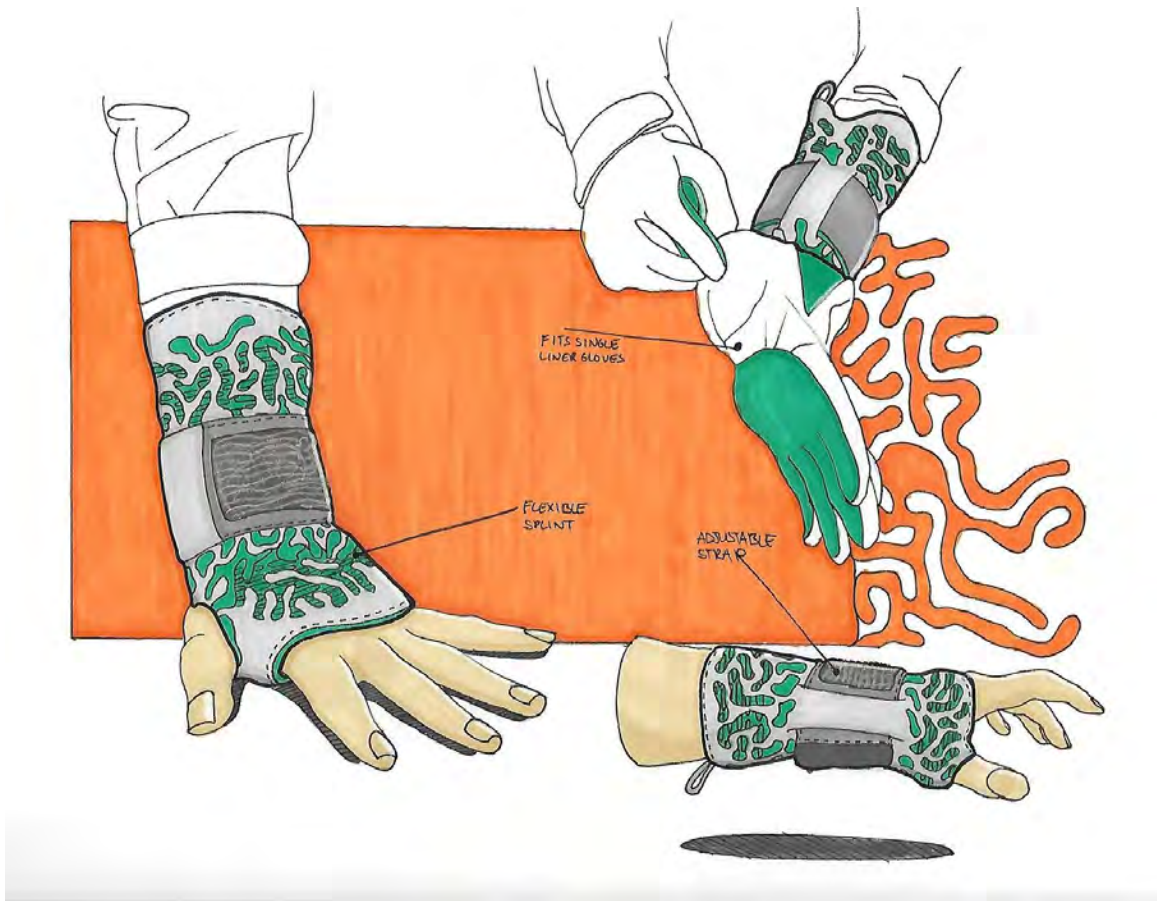
Final Concept

I approached the making of my final prototype with the intention of capturing the conceptualization of my design. This prototype wouldn't be fully functional due to the limitations discussed above, but it would capture both the look and feel of my final design. Below is a sketch of the final prototype I designed. This version diverged from the aesthetics of previous prototypes as discussed above my final prototype aimed to shift snowboarders perception's of wrist guards from a protection device to a fashion statement. With the aesthetic shift, I was given more freedom to explore patterns and color. I referenced biological patterns, fashion textile design and designed the cellular automaton pattern you see in my sketch below. In discussions with my thesis advisors they expressed the concern that I shouldn't hide the wrist splint that I put a lot of work into designing. I felt their concern was valid, my solution to this

concern was to treat the splint as a detail in my design. Inspired by Charles Eames who said *“The details are details. They make the product. The connections, the connections, the connections. It will in the end be these details that give the product its life.”*²⁵ By layering and cutting away certain sections of my top patterning and revealing the parts of splint that were aesthetically interesting, I created a revealing of arguable the most important aspect of the design. The final aspect of the design that diverges from previous prototypes is that integration of the velcro strap into the form of the wrist guard. This design change was driven by a thoughtful discussion with one of my advisors who expressed the concern that the velcro strap was keeping the design from feeling unified. After much thought I agreed with her and integrated the velcro strap by weaving into the top layer of wrist guard. In this way it physically merges with the guard unifying the form.

²⁵ "Charles Eames Quotes." BrainyQuote. Accessed April 24, 2017.
<https://www.brainyquote.com/quotes/quotes/c/charleseam169627.html>.

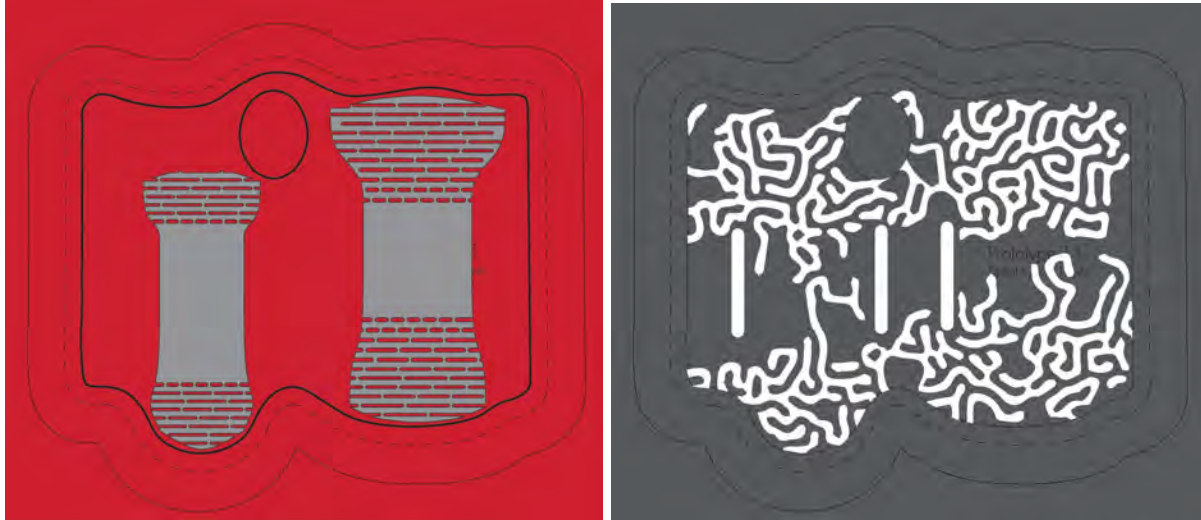
Keeping this in mind I approached the making of the prototype similarly to previous



prototypes. I started with a paper mock-up so as to get the general dimensions and fit of the wrist guard. I couldn't just use the dimensions from previous prototypes because I was using new materials that functioned differently. Following a paper mock-up, I moved to hand sewing a rough prototype from the final materials I'd chosen to refine the fit and details of the form.



Following the rough mock-up, I developed 2D production templates I could use to make the final pair of prototypes from. As per the guidelines from my seamstress, I needed to leave $\frac{5}{8}$ inch seams to allow her enough room to use the sewing machine. With that guideline in mind I created templates for both layers of fabrics, this would allow clarity during the production process.



The first challenge we ran into was how to deal with cutting the fabric pattern. As seen above the pattern is fairly complex and would require incredibly steady hand to cut manually. I solved this challenge by utilizing the laser cutter as I already had the proper files for cutting the graphics it seemed like the logical solution. This ended up saving my seamstress and I a lot of production time. I was able to bring her all the pre-cut fabrics and she was able to sew the final prototypes together in under two hours. Final touches included sewing/adhering the pattern directly to the splint and sleeve.



Manufacturability/Market Viability

I believe it's important to note that my current final prototype could be manufactured using traditional technologies and materials. There is no single part of my design that requires a technology that doesn't already exist. Bearing this in mind, I believe in a mass production environment my current prototype would need more refinement to become cost efficient for a business to pursue. Although if we look at the increasingly large market for customized protection equipment, my current prototype becomes more feasible. I see a business where customers could have their wrist 3d scanned and used to generate a pair of wrist guards custom formed and fitted to their wrist. This could be both a retail or online experience. Customers

would come in and scan their arms and order a pair that would arrive at their door three to four weeks later.

Final Concept Photoshoot





Conclusion

How can design encourage the use of wrist protection in beginner snowboarders? Based on my research and final concept I believe by approaching the design of wrist protection by focusing on the social, psychological, and ergonomic issues, use of wrist protection can be encouraged and celebrated in ways it never has been in the snowboard sport. Through my research it has become apparent that there is a justified need for more effective wrist guard protection in snowboarding. Design especially has the unique ability to allow designers the ability to empathize with users. In this way I was able to identify key problem areas where current wrist protection was working against protecting snowboarders. By applying a design

thinking methodology to wrist protection I was able address the key problem areas that kept beginners and experienced snowboarders from protecting their wrists. I also believe it's important to note the personal development this research and experience has given me. With this new experience came certain challenges. I've never taken a soft-goods or sewing related class in my time as a student. This was a completely new process of making for me, it pushed me to design outside of my comfort zone which in turn allowed me to grow my problem solving abilities. Although I believe my research to be innovative and pushing the boundaries of current wrist protection, I do not intend on pursuing this research any farther. Given the support of a soft goods department and a design team I might consider continuing this research but the project would need significant financial investment from investors or an established snowboard brand to push my research past where it current stands.

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