DESIGNING A KITEFOILING HARNESS FOR THE 2024 OLYMPIC GAMES

Master Thesis Integrated Product Design by

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MASTER THESIS

July 2021
Integrated Product Design
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ABSTRACT

The goal of this thesis was to propose a new design for a kitefoiling harness for the Dutch Olympic team, which does not cause major discomfort, stays in the same location on the body and properly supports the body of the athlete. In the discovery phase, three main problems with existing harnesses were found. First, as the harness is pulled up the body while kitefoiling, the legstraps put an uncomfortably large amount of pressure on the groin. Second, ideally the attachment point between the harness and the kite sits around the crotch, but as the harness is pulled up the attachment point moves as well. Furthermore, the attachment point moves around too much in general. Last, the shape of the harness does not always fit the athlete well, causing weird pressure points, which are perceived as uncomfortable. Two extreme postures were identified that harnesses need to perform well in: going upwind and doing a manoeuvre. Through force analysis it was found the highest forces that the harness has to endure are in the upwind posture. Major shear forces should be avoided. The athletes prefer to be supported most at the Gluteus Maximus and the lower back.

The design approach for this project was prototype focussed, with every design stage being tested and validated. First, general concept directions were designed and evaluated. This evaluation led to two major pain points in the design: too much pressure on the hips and too much pressure at the groin. Two subsequent design sprints were then completed to solve these two pain points. The outcomes were tested with members of the Dutch Olympic team. The final proposed design is radically different than existing kitefoiling harnesses on the market. The new design removes the spreaderbar and makes the attachment point much smaller. Additionally, it contains much bigger legstraps that keep the entire harness in place and are connected to a hard belt that is custom moulded to the shape of the back of the athlete. Apart from the hard belt, everything can be adjusted to ensure the best possible fit. During final testing it was found that, overall, the new design does not perform better than the current best harness on the market. The freedom of movement is greatly reduced and the leg straps were perceived as very uncomfortable, partly due to a much higher pressure from the kite in manoeuvres than anticipated. The newly designed leg straps did stay in place perfectly and kept the attachment point in the same place. Ultimately, the design should be tested with more participants. Even though the design is currently not better than the compared harness, some suggested adjustments could have a positive impact on the discomfort that the athlete perceived.

CONTENTS

CHAPTER 1
INTRODUCTION

1.1 PROBLEM DEFINITION

Kitefoiling as a discipline is closely related to kiteboarding, a sport in which a rider (surfer) moves over a body of water on a board and a kite connected to the rider. The main difference between these sports is the way the rider moves over the body of water: where in kiteboarding the board is in direct contact with the water (**Figure 1**), in kitefoiling the board is lifted above the water through a connected hydrofoil (**Figure 2**). In recent years competitive kitefoiling has quickly grown in popularity, including in The Netherlands, and is even set to be part of the 2024 Paris Olympic Games. Since kitefoiling is so new, most riders wear harnesses that were not specifically designed for this sport. This causes various problems. Mainly, the athletes of the Dutch Olympic team report insufficient support and that the harness rides up their body after a couple minutes, which causes discomfort in the intergluteal cleft and around the groin.

Problem Statement

Design a new harness for the athletes of the Dutch Olympic Team for the 2024 Paris Olympic Games. The new harness design should not cause major discomfort, stay in the same location on the body and properly support the body of the athlete.

Sailing Innovation Centre The Hague

1.2 CLIENT

The client for this project is the Sailing Innovation Centre located in The Hague. The Sailing Innovation Centre was founded by the Delft University of Technology, the VU University Amsterdam, the NOC NSF, the Royal Netherlands Watersport Association and the municipality of The Hague. The Sailing Innovation Center is supported by the European Union and Sport Innovator, which is a network of national sports innovation laboratories. The Sailing Innovation Centre helps to accelerate innovations in sailing. In this way the centre supports the sporting ambitions of the Netherlands in sailing, promotes interest in sailing and contributes to economic growth by supporting companies in realizing new and better products and services. In short: more medals, more people to experience the sailing sport, and more business (Sailing Innovation Centre, n.d.).

Figure 1: Top - Kiteboarding (from: indonesiakitesurfing.com)
Figure 2: Bottom - Kitefoiling (from: Salty Brothers Film - Youtube)

1.3 APPROACH

This Master thesis followed a multiple diamond approach. Each diamond includes a diverging and converging phase. The first diamond contained the discovery phase, which consists of desk research, interviews and questionnaires to create a broad understanding of the topic at hand. All the insights are converged into an overview, the design criteria. These are listed seperately at the end of every chapter. In the second, third and fourth diamond, the diverging stage involved brainstorming ideas that solved identified problems and the converging stage involved evaluating these ideas and selecting the most promising for further development into concepts. At every evaluation stage, the concepts were built into prototypes, so these could be tested with participants. This ensures that every part of the final design is tested and should decrease the chance of the final design not working significantly. This process is shown in **Figure 3**.

1.4 RESEARCH QUESTIONS

For this Master thesis the following research questions will be answered before the development phase begins.

1. What are the characteristics of harnesses used in other contexts?
2. What is the anatomy where the harness is located on the body?
3. Which forces play a dominant role in kitefoiling?
4. What discomforts are perceived by the athletes during kitefoiling caused by the harness?
5. How can the athlete be best supported during kitefoiling?

The formulated research questions will guide the research to better understand the context, as well as needs and desires of the athletes. The context will be discussed in-depth in the next chapter, with the other research questions being answered in subsequent chapters.

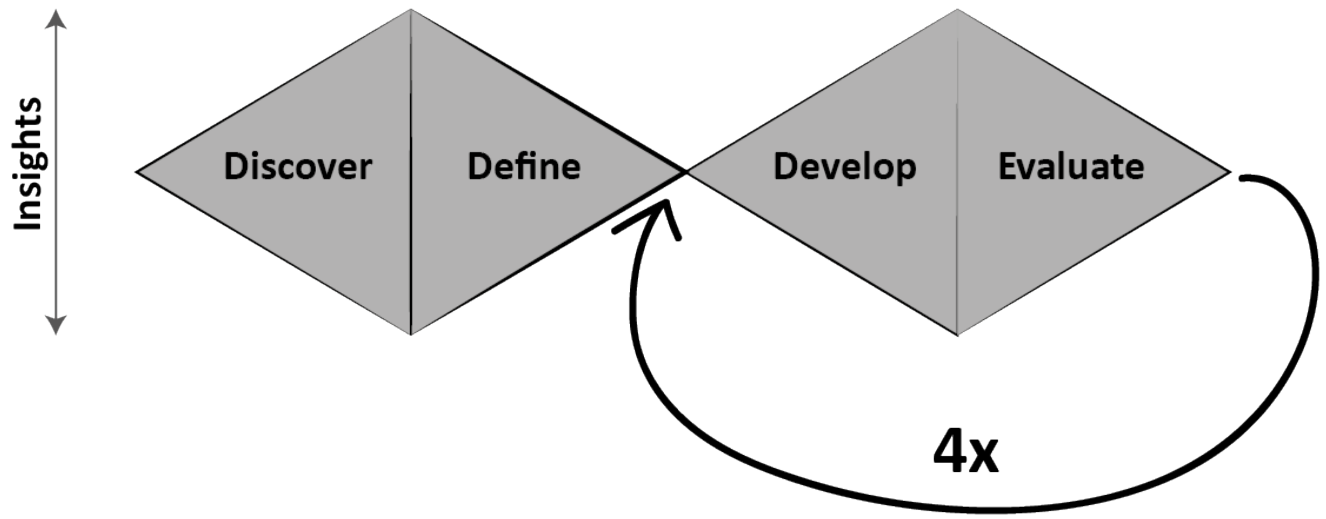


Figure 3: The approach of the project with the relevant chapters

CHAPTER 2 CONTEXT

2.1 HISTORY OF KITEBOARDING

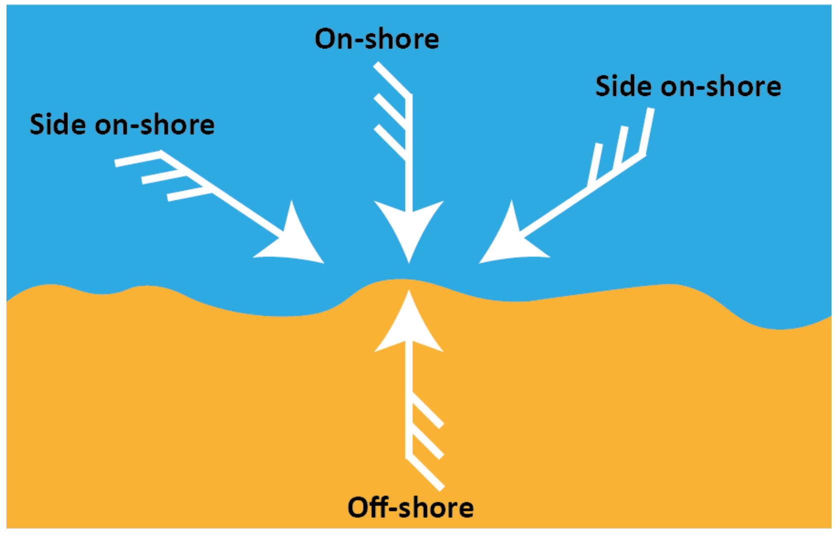
As mentioned before, kitefoiling is closely related to kiteboarding. Kiteboarding has seen an increase in popularity since the 1990's, but the first patent for a watersport where a rider stands on a floating board propelled by wind goes as far back as 1977 (Dunne et al., 2018). It is estimated that the number of kiteboarders worldwide increases by approximately 30% every year (Bryja, 2008). With the kite (5 – 20 m^2) and a board from 120 to 200 cm in length, the surfer can reach speeds of up to 35 knots (Bourgois et al., 2014). There are different competition forms in kiteboarding, like racing, freestyle, wave, slalom and speed (International Kiteboarding Association, n.d.). The only form of competition to be featured in the Olympic Games so far is the Formula Kite class, which involves the use of hydrofoils under the boards (and is often named kitefoiling).

In the following sections the specific elements of kitefoiling equipment in the Formula Kite class are explained in further detail.

2.2 COMPONENTS OF KITEFOILING

THere are various components, which are important to kitefoiling. Besides the harness, which will be discussed in great detail in **Chapter 3,** the wind, water, kite, bar, and lastly the board and hydrofoil are influential aspects of the sport. They will be introduced and explainedi n the following sections.

Figure 4: It is only recommended to go kitefoiling with side on-shore or on-shore wind. Off-shore wind is strongly discouraged on open waters



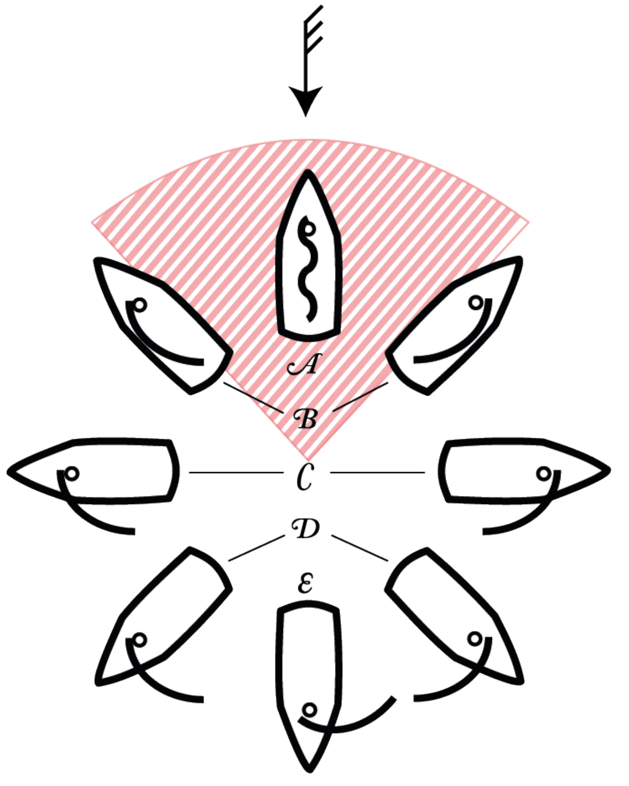
2.2.1 WIND

Wind is the main source of power in kitefoiling, with windspeeds ranging from 12 to 40 knots being allowed in competition. When kiteboarding on open water, it is recommended to only do this when the wind is at least partly blowing towards land (see **Figure 4**). Offshore wind should be avoided, and direct onshore wind should only be used if the surfer is capable of surfing upwind (MACkite, n.d.). Due to wind speed requirements, kiteboarding is often done at seas, however it is already possible to go kitefoiling with windspeeds of about 6 knots (Kitesurfist, n.d.). The sailing directions are indicated in relation to the wind, shown in **Figure 5**.

2.2.2 WATER

Formula Kite class competitions can be held on different types of waters, like seas and lakes. Kitefoiling gear should be able to withstand salt water and be abrasion resistant to the commonly found sand. No regulation could be found on water conditions, but competitions will obviously be held on clear days if with wind allows it. UV resistance of materials is therefore also important.

Figure 5: The different sailing directions.
A: Into the wind.
B: Upwind.
C: Across the wind.
D: Downwind.
E: With the wind.
It is impossible to reach the red zone
(From: Andrew C, CC BY-SA 3.0, via Wikimedia Commons)



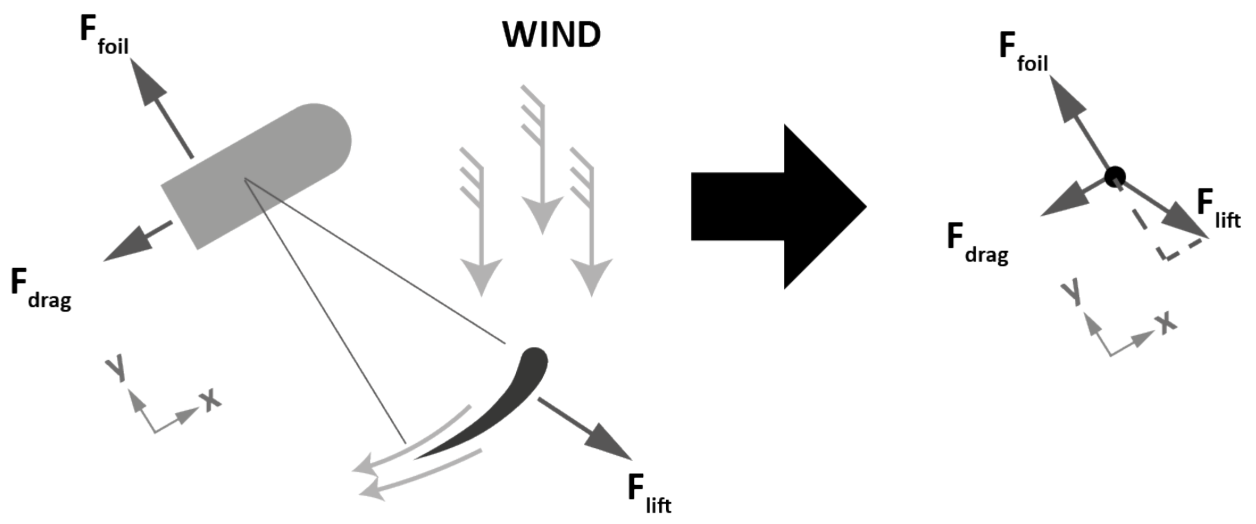


Figure 6: The wind is redirected around the kite and generates lift, on the right a simplified view

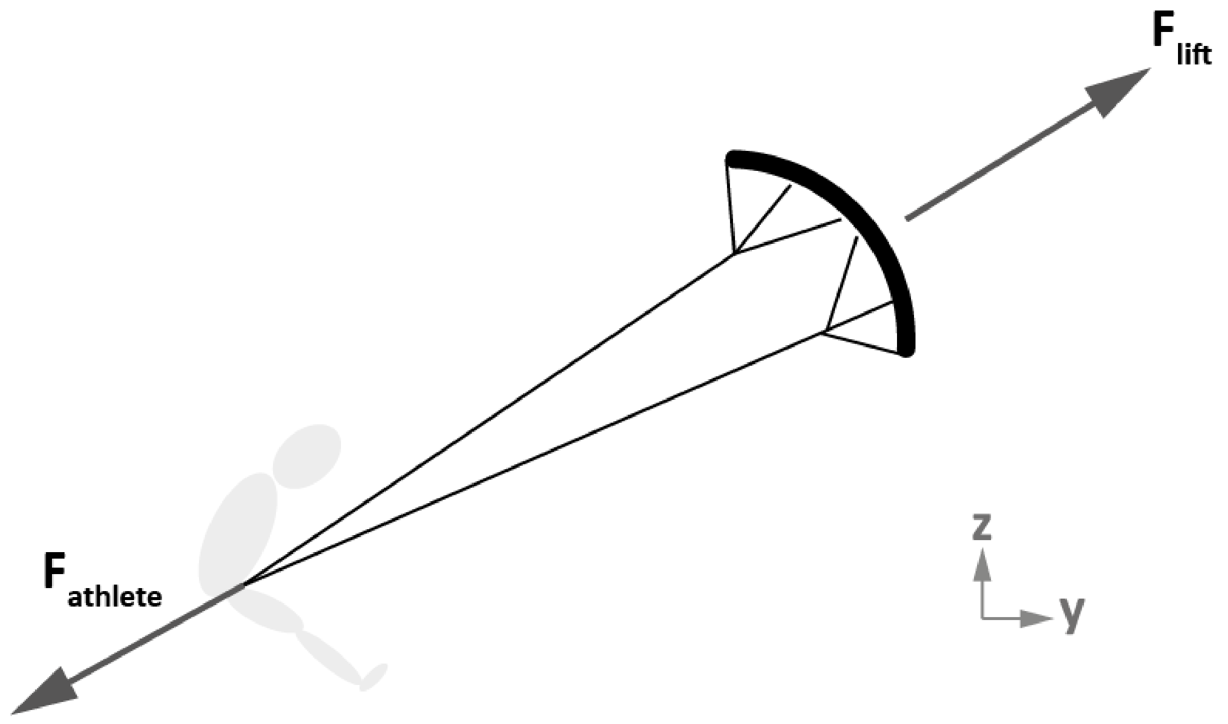


Figure 7: a side view of the kite

2.2.3 KITE

The kite uses the wind as a power source. The working principle of a kite is quite similar to that of a sail. As wind hits the leading edge of the kite, it is split and on the outside of the kite the wind is forced to speed up which generates low pressure. This pulls the kite towards the low-pressure region and is called lift (Wolfe, 2003). **Figure 6** shows a top view of this phenomenon and **Figure 7** a side view. This lift is what accelerates the athlete.

There exist different types of kites, but Formula Kite class regulations only allow the ram-air inflatable kite, which self inflates through air intakes in the front and has no inflated leading edge (**Figure 8**) (International Kiteboarding Association, 2021).

Competition guidelines for Formula Kite allow for only 1 kite to be registered per size per athlete. Table 1 shows an overview of these categories. Only equipment registered at the International Kiteboarding Association may be used at World and Continental Championships (International Kiteboarding Association, 2021).

Table 1: The size categories of the kites (International Kiteboarding Association, 2021)

Category	***Size***
Large	15 m^2 or bigger
Medium	11 - 15 m^2
Small	11 m^2 or smaller
X-Small	9 m^2 or smaller

Figure 8: An example of a ram-air kite, the Ozone R1 V4 (from: Kiteboarding.com)

2.2.4 BAR

The athlete can control the kite through a bar (see **Figure 9**). The central wires connect to the leading edge of the kite and the two outside wires connect to the back of the kite. If the athlete pulls the left side of the bar the kite moves to the left and vice-versa. The more the athlete pulls the bar towards their body, the more the kite moves down and generates more lift, as the curvature of the kite becomes tighter and the low-pressure region increases (explained in the previous paragraph). If a kite produces too much power, the athlete can push the bar away, relaxing the wires attached to the back of the kite, reducing the curvature and consequently reducing the lift. The central wires are also the wires that connect to the harness with what is called a chicken loop. Usually, the hook of the harness goes into the loop and is kept in place by what is called the chicken stick (see bottom of **Figure 9**). The chickenloop eject is a safety feature, which releases the wires of the kite from the harness in case the kite does not depower enough.

Figure 9: the bar in kiteboarding. The athlete is able to steer the kite by pulling on either end of the bar

Figure 10: An example of a kitefoil board with hydrofoil

2.2.5 BOARD AND FOIL

A board is allowed to compete in the Formula Kite class if there is a production run of at least 100 pieces until the end of the Olympic Cycle with production capacities of at least 50 pieces per month. The board can have a maximum length of 1250 mm and width of 500 mm, and has to have a minimum weight of 2 kg. The board usually contains three foot-straps (**Figure 10)**.

The hydrofoil is the main difference between kiteboarding and kitefoiling. The hydrofoil causes the board to rise above the water with generated lift following the same principle as the kite, but with water instead of air. The higher the speed, the more lift is generated (NASA GRC, n.d.). **Figure 11** shows this principle in a free body diagram.

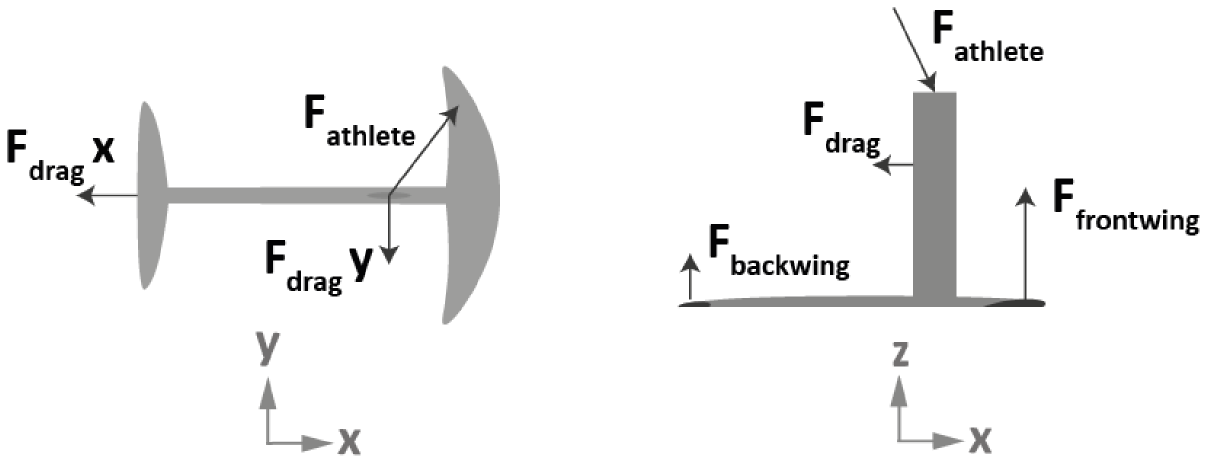


Figure 11: A simplified view of the forces that act on the hydrofoil

2.3 COMPETITIVE KITEFOILING

Formula Kite competition in the Netherlands started in 2015 with approximately 5 athletes competing. In recent years this has grown to around 50 or 60 competitors on a national level (Kitefoil Cup Holland, n.d.). According to the co-founder of the Kitefoil Cup Holland, the Dutch competition is arguably one of the most competitive in the world. The Formula Kite class is set to be part of the 2024 Paris Olympic Games and will follow the mixed team relay race format (International Kiteboarding Association, 2020). It is important to note that as of June 2021, World Sailing and the Olympic Committee decided to change the format to seperate Men's and Women's events (World Sailing, 2021). This thesis is based on the information that was available at the beginning of 2021 and does not reflect this recent change in regulations.

In the mixed team relay race format a team, consisting of a male and a female athlete, competes to cross the finish line first. It is up to strategy which athlete starts first. **Figure 12** shows one version of the circuit, though depending on weather conditions this can change (International Kiteboarding Association, n.d.)

A complete competition spans over multiple days shown in **Figure 13**. The winner and the runner-up of the Final Series are prequalified with 2 points and 1 point respectively. The first team to reach 3 points wins the regatta in the Medal Series, so the prequalified teams have an advantage. All the other teams that are not in the Medal Series compete in one final race (International Kiteboarding Association, n.d.).

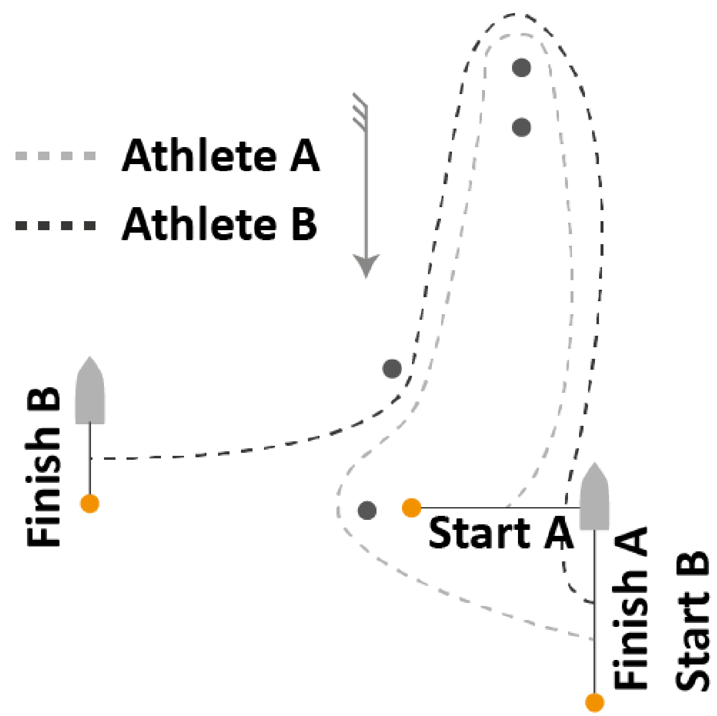


Figure 12: A version of the Formula Kite class circuit.

2.4 ATHLETES

This thesis focusses on the male Dutch athletes set to compete for the 2024 Olympic Games. At time of writing there are six athletes part of the Dutch team (teamNL in short). The athletes train weekly in Brouwersdam. Since the Olympics are still three years away, the Watersportverbond is searching for more team members, mainly between 15 and 22 years old (Watersportverbond, 2019).

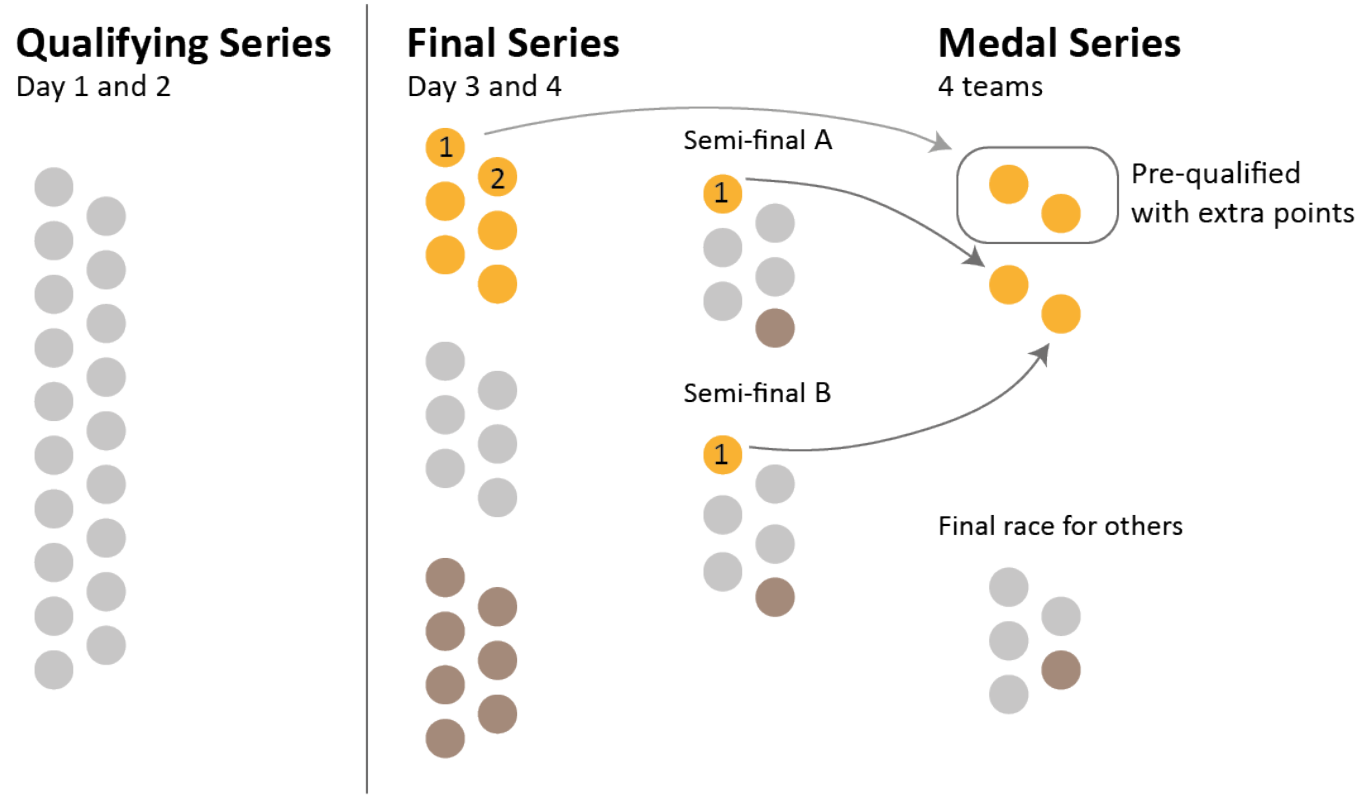


Figure 13: The format of a Formula Kite regatta

2.5 SAFETY AND INJURIES

The official rules for competition dictate the required use of a personal flotation device and participants are required to carry a knife to cut the lines. Usually these items are integrated in the harness (International Kiteboarding Association, 2021). The chickenloop is a safety mechanism that is included in every bar sold, which allows the surfer to further depower the kite if pushing the bar away is not enough. The kite is still connected with a single wire to ensure it does not fly away. If this still causes dangerous situations, the knife can be used to cut the last line.

Since kitefoiling is such a new sport no information could be found regarding injuries. Available data from kiteboarding as a closely related discpline has been used instead, to give an impression. According to Nickel et al. (2004), 6 to 7 injuries occur per 1000 hours of kiteboarding (6,3 – 9,7 for soccer (Parkkari et al., 2004)), with a 2,5 times higher chance of injuries happening in competition compared to training. Injuries to the foot/ankle are most common and account for 28% of the total injuries. In this study 3% of the injuries involved fractures. In a study done in The Netherlands at Rotterdam’s Helicopter Emergency Medical Service, Spanjersberg & Schipper (2007) found the main injuries were fractures caused by collision with an on-shore stationary object. Three main contributing factors account for this; surfing too close to the shore, loss of kite control and on-shore flow (where wind runs e.g. against a house and causes wind to go upwards) (Petersen et al., 2002). This confirms the importance of being able to decouple the kite and the harness.

2.6 CONCLUSION

Kitefoiling is a discipline closely related to kiteboarding, which is rapidly gaining popularity. Kitefoiling is done in both fresh and salt water, in many different weather conditions due to low wind requirements. This means that the harness should be abrasion resistant from sand, UV resistant and also be compatible with salt water. Currently, the Olympic format will be a team relay, in which a team is formed out of one male and one female athlete.

Kitefoiling is an inherently dangerous sport. Therefore, in competition, the athletes are required to wear a personal floatation device and carry a knife to be able to cut the lines to the kite as a last resort for safety. This knife is usually integrated in the harness.

CRITERIA

- The athlete should be able to wear a personal floatation device and the harness at the same time
- The harness should have a knife integrated
- The materials used should be UV resistant
- The materials used should be abrasion resistant
- The materials should be able to withstand salt water

CHAPTER 3
TYPES OF HARNESSES

The harness plays a central role in kitefoiling. As the kite is connected to the athlete through a harness, meaning it transfers the forces from the kite to the athlete. In this chapter, the different types of kitefoiling harnesses will be introduced with their characteristics. Since harnesses are also used in other sports or even professions, it is worthwhile to explore how these other harnesses work as they can be used for inspiration. The selection of other harnesses was found by searching for the keyword 'harness' in a search engine.

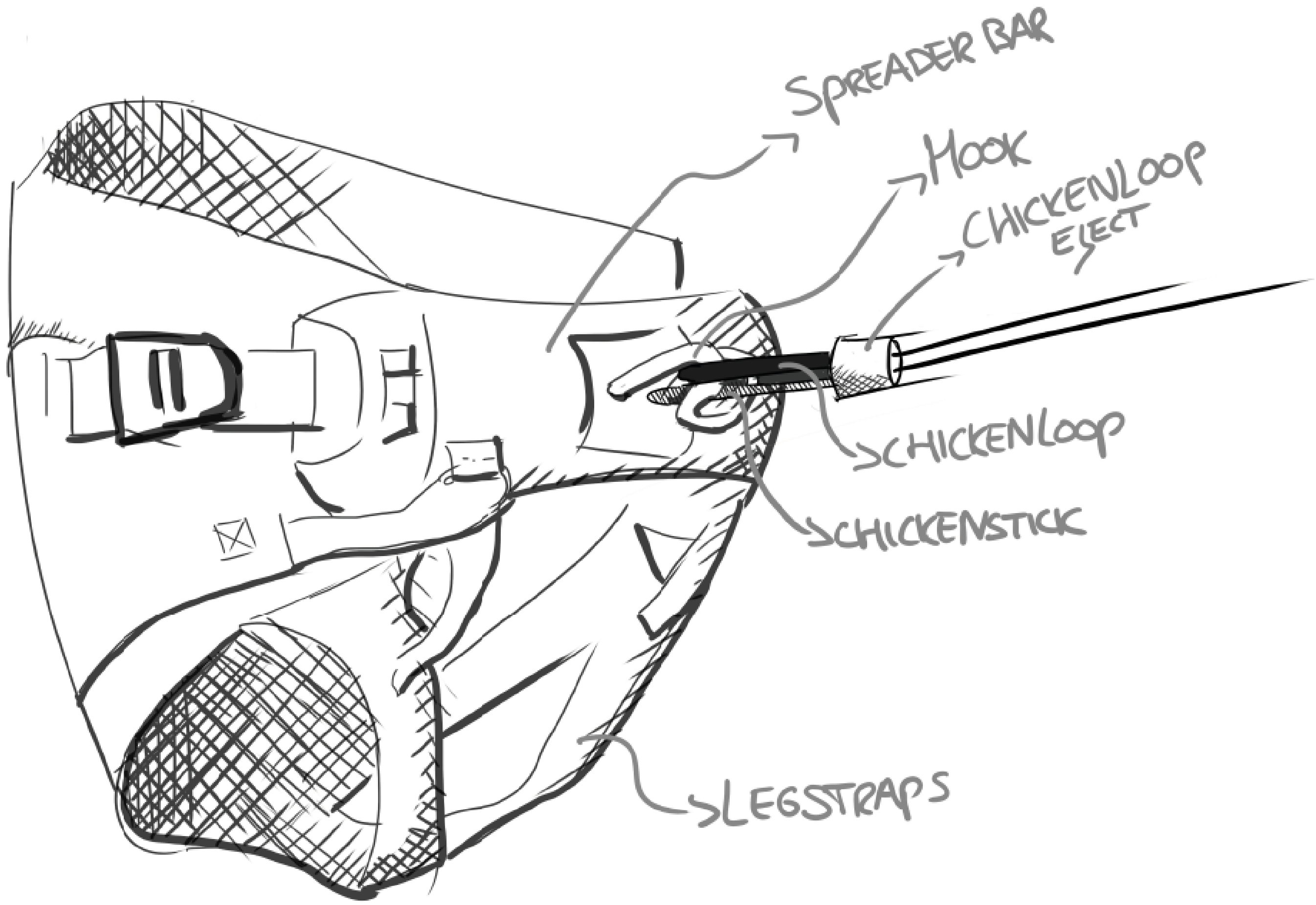


Figure 14: The different components from a harness

Figure 15: A hip harness sits higher than a seat harness and offers more freedom of movement

Figure 16: A seat harness has leg straps that keep the harness in place (From: https://www.thekiteboarder.com)

3.1 KITEFOILING HARNESS

There are two main harness types, a waist harness (**Figure 15**), and a seat harness (**Figure 16**). The waist harness offers more freedom of movement and is often used in freestyle. For competitive kitefoiling, the athletes often use a seat harness as it offers more support and stays in place better due to the leg straps. Similarly there are two main spreaderbar types, one with a hook and one with a rope (Ride Engine, n.d.). Typically, the rope offers more freedom of movement and is often used when a rider wants to do tricks.

When looking closer at where the waist harness sits on the body of the wearer, it is apparent that the harness has the possibility to ride up the body (**Figure 17**). The forces from the kite are causing shear forces on the body. Shear force plays an important role in the discomfort in seats and hospital beds, it is assumed this will also play a big role in the design of the harness (Goossens et al., 1994; Goossens & Snijders, 1995; Snijders et al., 2018). Therefore, the forces from the kite should be perpendicular to the body as much as possible. Furthermore, the forces are loaded on the back of the wearer, putting a lot of pressure on it. Similar behaviour was noted by the athletes for the seat harness.

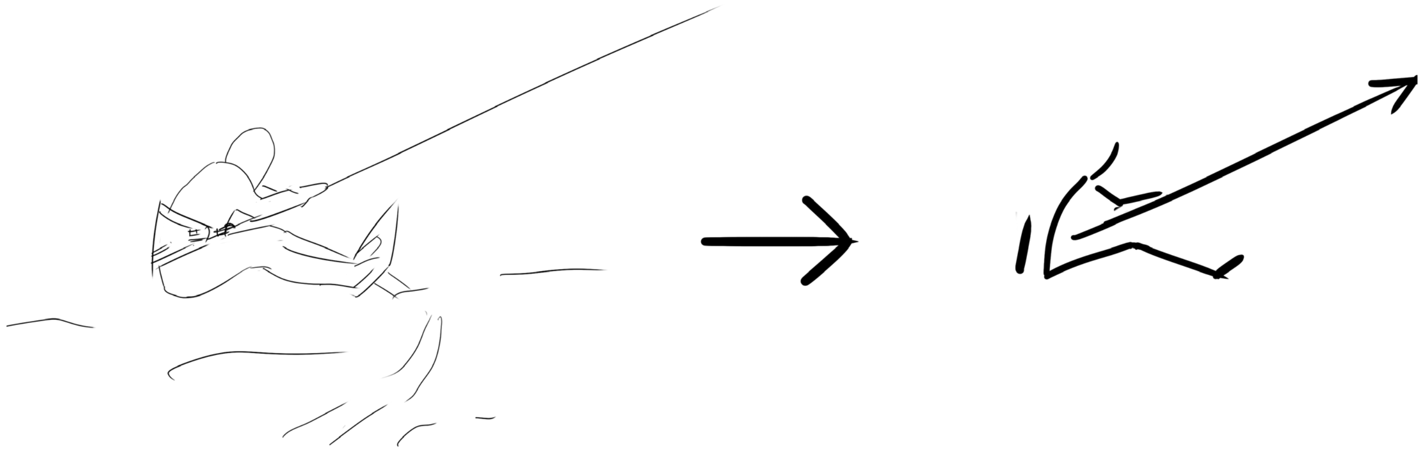


Figure 17: The direction the harness is loaded in in kitefoiling. The person in this image is wearing a waist harness

3.2 WINDSURFING HARNESSES

For windsurfing, similar harnesses are used, though these are structurally different as the forces involved are lower. The harness is designed to lessen the strain on the arms. An example of a windsurf harness can be seen in **Figure 18** and the way the harness is used in **Figure 20**. Since the harness is designed to withstand lower forces, the harness is more flexible. **Figure 19** illustrates the way the harness is loaded, with the force vector almost perpendicular to the seat area of the harness.

Figure 18: A windsurf harness from ION, note that there are less straps (spreaderbar is removed in the picture) (Source: ion-products.com)

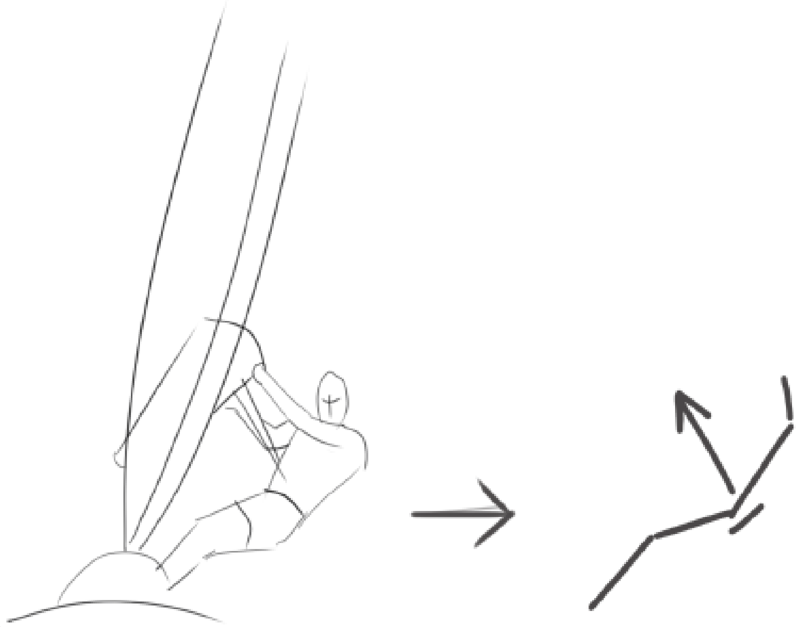


Figure 19: The direction in which the harness is loaded in windsurfing

Figure 20: A windsurfer using the harness to reduce strain in his arms (from: Bryanmcdonald at English Wikipedia, Public domain, via Wikimedia Commons)

3.3 SAILING HARNESSES

In the 470, 49er and the Nacra 17 sailing classes sailing harnesses (**Figure 22**) are used (Poiesz, 2018). In these sports the sailor hangs on the edge of the boat to counter the moment created by the sail (**Figure 21**). As can be seen in **Figure 23**, the harness is again loaded roughly perpendicular to the body, with little force moving the harness or spreaderbar up or down. Similar to the previously mentioned harnesses, these contain a spreaderbar. However, a sailing harness does not contain leg straps and wraps over the shoulder. There is additional padding around the waist to spread the forces. The straps over the shoulder and around the crotch are designed to keep the spreaderbar in place.

Figure 21: The 470 sailing class (source: northsails.com)

Figure 22: A sailing harness from Forward Sailings. Note the lack of leg straps (source: Porttackracing.com

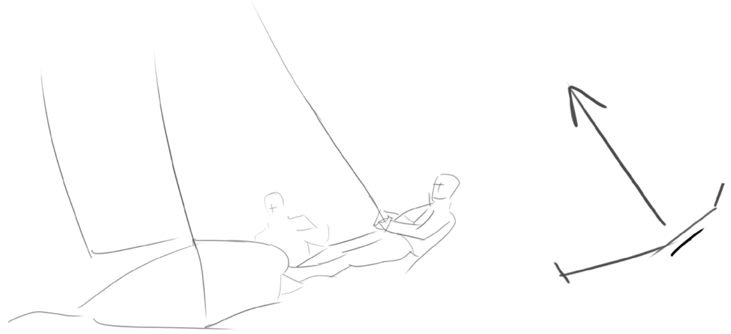


Figure 23: The direction in which the harness is loaded for the 470 sailing class

Figure 24: Rope access in forestry. Note that the user in this picture also wears an upper body harness

Figure 25: The Petzl Astro Sit-Fast (From: petzl.com)

3.4 CLIMBING HARNESSES

Another field in which harnesses are used are in industry and in the climbing sport. In climbing the wearer is only briefly loaded by the harness, while in the industry the wearer can be suspended for a prolonged period of time. Rope access harnesses are used in the industry to get to hard-to-reach places, and are functionally very similar to climbing harnesses. Examples of rope access professions are window washers, forestry or maintenance (**Figure 24**). For rope access harness there are two main variants, one with just the seat and one which extends over the shoulder. The focus is on the seat harness (**Figure 25**).

Rope access harnesses are designed so the wearer can be suspended for a prolonged period of time. These harnesses mainly consist of 2 parts, the leg straps and the waistbelt. These parts are connected with straps. The straps on the front are the main load carriers. The leg straps are wider in the back and are slimmer in the front to reduce pinching. Usually, the harness also has a big surface area in the back, but a smaller strap in the front. When the wearer is suspended, the leg straps keep the waistbelt in place and put pressure on the back of the legs and the lower back. **Figure 26** shows a simplified view of the loading characteristics of these harnesses. These harnesses are designed for two main events; if the harness is loaded horizontally, the waistbelt spreads the forces over the lower back. If loaded from the top, and if the harness is loaded vertically the leg straps spread the forces.

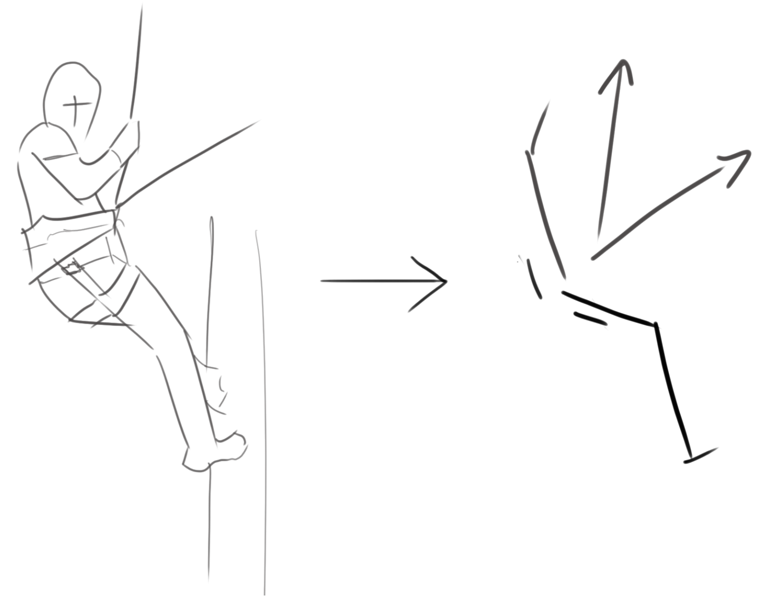


Figure 26: The direction in which the rope access harness is loaded in

3.5 CONCLUSION

For kitefoiling, the preferred harness is the seat harness as it has leg straps that keep it from riding up the body too much. Literature shows that shear forces play an important role in discomfort and most harnesses minimise these forces. This does not seem to be the case for the kitefoiling harness, where shear forces are so high it moves up the body. While most of these harnesses are designed to be loaded in one particular way, which is quite different compared to kitefoiling, the rope access harnesses are designed for two loading directions, which also appear to roughly correspond to the way the riders are loaded in kitefoiling. This distinction of two separate loading characteristics could offer inspiration for future designs. To be able to design an improved harness for kitefoiling, an analysis is needed on how the harness interacts with the relevant body parts. This will be discussed in the next chapter.

CRITERIA

- The athlete should be able to wear a personal floatation device and the harness at the same time
- The harness should have a knife integrated
- The materials used should be UV resistant
- The materials used should be abrasion resistant
- The materials should be able to withstand salt water
- Major forces should be loaded perpendicular to the body as much as possible

CHAPTER 4
PHYSIOLOGY: INTERACTION BETWEEN BODY & HARNESS

This chapter describes the physiology and anatomy of the relevant body parts. In this examination the postures that the athlete assumes, the anatomy of the pelvis, discomfort and the anthropometric data are included. This offers insights on the interaction between the harness and the human body.

4.1 DISCOMFORT

In the initial project brief, the athletes mentioned discomfort at the groin and the lower back. The following paragraphs dive deeper into the topic of discomfort to get a better understanding of what it is and what causes it.

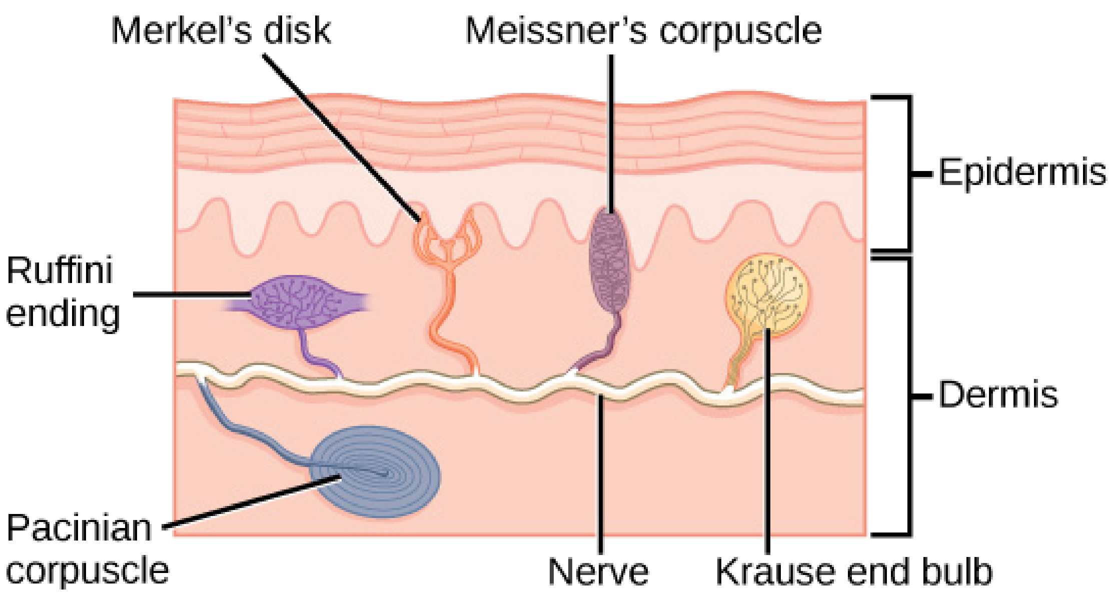


Figure 27: The location of the different mechanoreceptors (From: lumalearning.com)

The state of mind influences whether something is experienced as comfortable or uncomfortable. When somebody is tired after heavy physical exercise, a relaxed chair is more comfortable than when someone has already spent time sitting in a different chair (Vink, 2004). Discomfort is commonly described or associated with fatigue, restlessness, tiredness or unsupported, and comfort is more related to well-being, relaxation, cosy or calm (Zhang et al., 1996). Specifically related to products, Picard (1997) showed that emotions, feelings and mood play a role in how someone evaluates (discomfort in) a product. Vink (2004) states that a product is not capable of being comfortable, but it becomes (un) comfortable during use. Vink (2004) also states that an absence of discomfort stimulates optimal human performance. He describes three manifestations of comfort:

1. Discomfort, because of physical disturbances.
2. No discomfort, the user is not aware of discomfort or comfort
3. Comfort, a higher experienced comfort than expected

Different senses can cause physical discomfort, but this thesis will only look at the discomfort caused in the somatosensorial category. This category includes mixed senses from the skin like temperature, pain or pressure, felt through what are called mechanoreceptors (Johansen-Berg & Lloyd, 2000). Again, any of these senses are able to be experienced as uncomfortable when stimulated too much. Different mechanoreceptors in the skin respond to different intervals; Merkel disks, Ruffini endings, Pacinian and Meissner's corpuscle (**Figure 27**). The Merkel disks are found in the upper layers of the skin, respond mainly to deep static touch from objects and respond to pressures over prolonged periods of time. The Ruffini endings detect stretch in the skin and also respond over a prolonged period of time. Pacinian and Meissner's corpuscles sense (short) deep pressure in the skin and fine touch respectively (Lumen Learning, n.d.). The Merkel disks and the Ruffini endings are most relevant for this thesis.

A study done by De Looze et al. (2003) showed of all objective measures considered in the study, pressure distribution has the best correlation to sitting discomfort. However, a uniform pressure distribution is not necessarily desirable as found by both Kamijo et al. (1982) and Yun et al. (1992), as it is associated with local discomfort. McGill et al. (2006) suggests that great surface area can cause greater soft-tissue compression, and that this compression may lead to circulation blockage, as mentioned by De Looze et al. (2003). Prolonged exposure to shear forces can lead to discomfort, which was already briefly mentioned in the previous chapter.

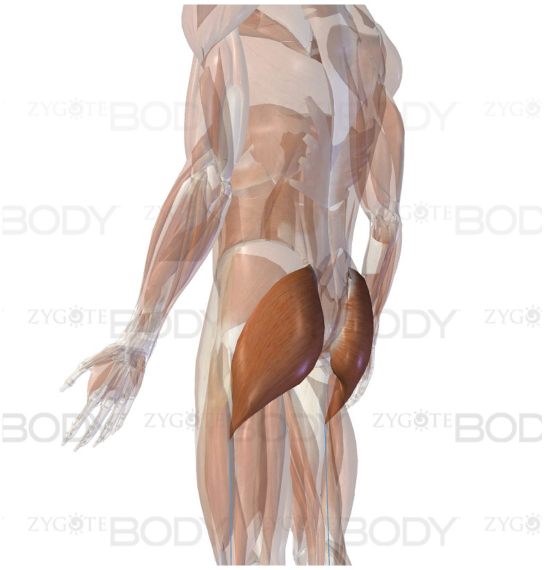


Figure 29: The location of the Gluteus Maximus illustrated (From: zygotebody.com)

4.2 PELVIS

The seat harnesses used by the athletes sit around the pelvis. The pelvis connects to the sacrum, the lowest bones of the spine (**Figure 28**). On either side the Iliac Crest can be found, often referred to as the hipbone. There is little tissue between the skin and the Iliac Crest. Right underneath the Iliac Crest are a set of muscles that help stabilise the pelvis and are also extensively used in sports like water skiing or horse riding (Jarmey, 2008). At the back of the hip the Gluteus Maximus can be found, which is one of the prominent muscles surrounding the pelvis (**Figure 29**). The Gluteus Maximus plays an important role in the ability of the human body to stand straight, as it pulls the leg in a straight line with the upper body (Standring, 2016).

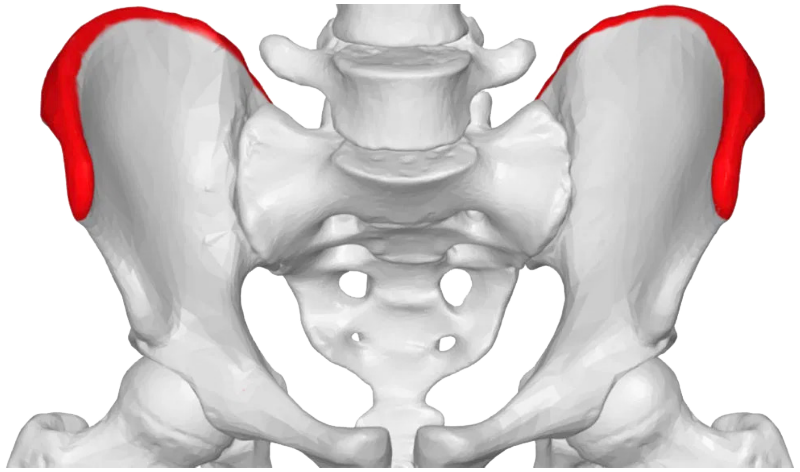


Figure 28: The pelvis and the Iliac Crest in red (From: Medicalnewstoday.com)

4.3 POSTURES

To understand the movements the body makes during kitefoiling, multiple videos were analysed that document recent Formula Kite class competition. In these videos, a course similar to the one described in **Chapter 2.3** was used. Three main postures could be identified that correspond to the sailing direction: Going upwind, going downwind and doing a manoeuvre. These postures are explained in the following paragraphs.

4.3.1 UPWIND

Going upwind is a large part of the competitive course and the posture of going upwind can be held up to 2 minutes (Xports Media, 2020). If the power of the kite allows it, the feet of the athlete are almost in the same horizontal plane as the Gluteus Maximus, which allows the athlete to align the force vector of the kite more to the one of the hydrofoil (**Figure 30**). Furthermore, the athlete leans the upper body towards the kite which allows greater power control, as the bar can be pushed away further.

In this position, the athletes are under flexion. A common complaint from the athletes which was indicated during personal communications was a lower back pain. Dreischarf et al. (2016) found that compression/shear forces increased from ~550N/200N in an upright position to ~5000N/2000N respectively under flexed postures in heavy or dynamic tasks, or sudden loading conditions on the discs between Lumbar disc 4 and 5, which could be a cause of this pain. However, this should be researched further to see if this is the actual cause of mentioned problems.

Figure 30: An athlete going upwind, which shows the posture of the athlete being folded double

4.3.2 MANOEUVRE

There are two manoeuvres in sailing; a jibe, in which you change direction with the wind and a tack, where you change direction by pointing the point of the boat (or board) in the wind (**Figure 31**). With both manoeuvres the kite is flown over the athlete so it switches sides. With these manoeuvres, there is relatively little line tension involved. **Figure 32** illustrates the procedure for a jibe.

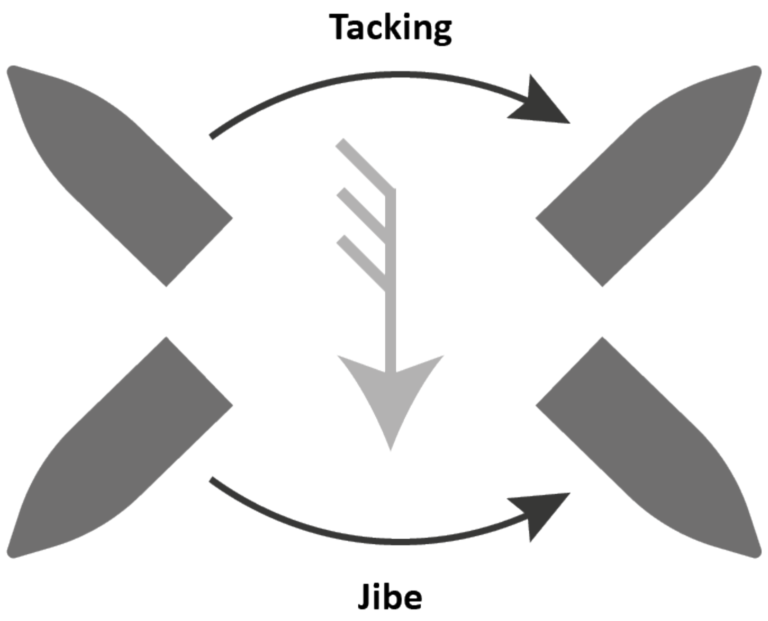


Figure 31: Turning into the wind is called tacking, turning with the wind is a jibe

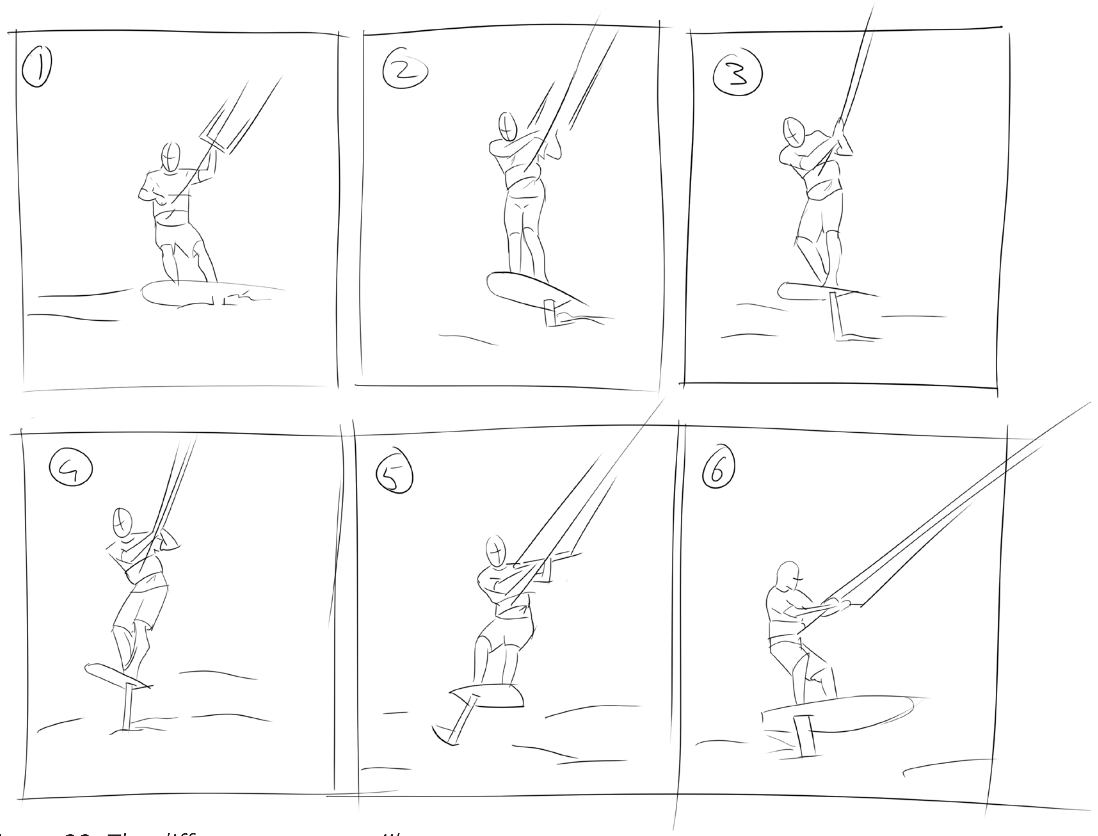
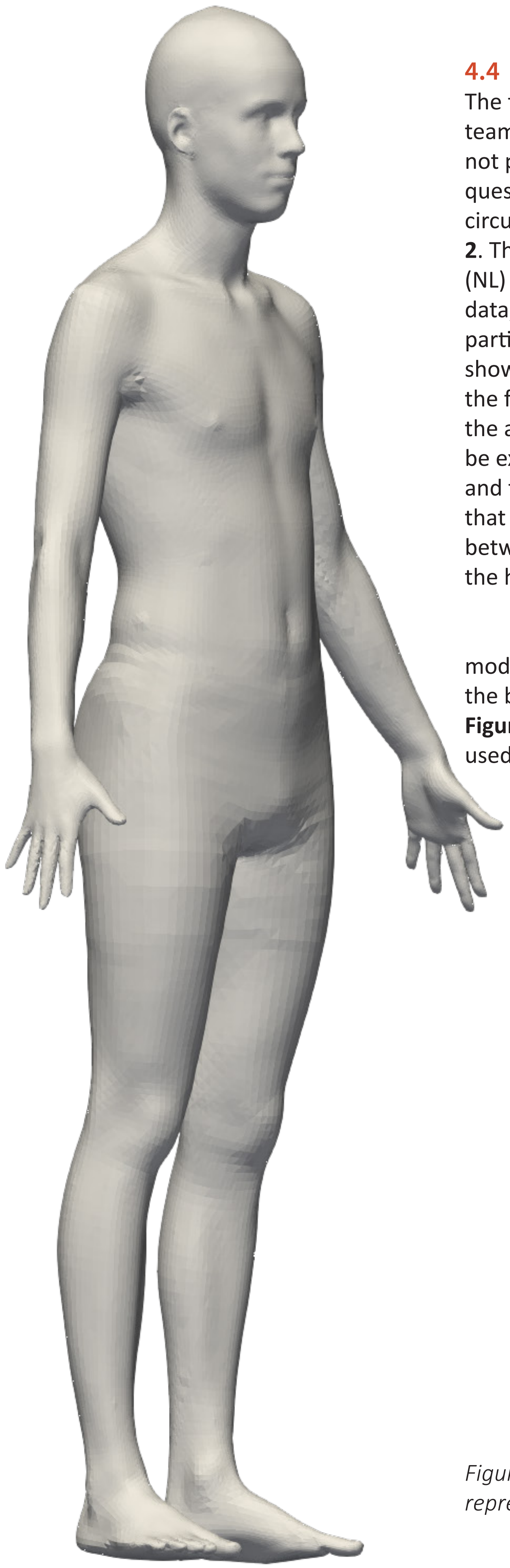


Figure 32: The different steps to a jibe.
1) The rider prepares for the manoeuvre and steers the kite upwards
2) The rider releases their feet from the foot bands
3) The rider shifts their weight to the port side of the board
4) The rider continues the motion
5) As the rider finishes the jibe, they start to generate more power
6) The rider continues to pick up speed

4.3.3 DOWNWIND

Similar to going upwind, downwind is a common posture during a race. In its loading characteristics it falls in between the upwind and the manoeuvre positions. In the downwind posture, the kite is flown diagonally in front of the athlete and the athlete is positioned straighter compared to the upwind position (**Figure 33**).

Figure 33: A rider going downwind (From: https://www.youtube.com/watch?v=YM7gnJwkiSc)



4.4 ANTHROPOMETRICS

The focus of this thesis are the male athletes of the Dutch Olympic team. Since this thesis was done during the Corona pandemic, it was not possible to measure athletes in person. Instead, each was sent a questionnaire asking them to measure their height, hip- and weist-circumference and their weight. The results are summarised in **Table 2**. This data was compared to a similar population from the CEASEAR (NL) database. The CEASEAR (NL) database contains anthropometric data, but also more general information, like how often the participant exercises. The database was filtered with the settings shown in **Table 3**. A comparison between the anthropometric data of the filtered population and the athletes can be found in **Table 4**. Only the age and hip circumference show a significant difference. This can be explained by the fact that one of the athletes is still quite young and that the CEASEAR database only includes adults. DINED shows that within the CEASEAR (NL) database there is a strong correlation between weight and hip circumference (r = 0.902), it is assumed that the hip circumference was measured wrong by the athletes.

Huysmans (2009) provides a set containing 3D corresponded models of every participant of the CEASEAR (NL) database. Using the beforementioned filters, the correct 3D models can be averaged. **Figure 34** shows the resulting 3D model of this process, which can be used in the development phase.

Figure 34: The 3D model that is representative of the athletes

Table 2: The self-measured anthropometric data of the different athletes (made anonymous)

Name	***Age (years)***	***Stature (mm)***	***Hip circumference (mm)***	***Waist circumference (mm)***	***Body mass (kg)***
Athlete 1	21	188	93	82	79
Athlete 2	15	177	78	76	61,7
Athlete 3	17	183	92	77	75
Athlete 4	18	194	96	79	72
Athlete 5	17	186	88	91	85
Athlete 6	17	187	-	-	82
Average	17,6	186	89	81	76

Table 3: The filters used for the CEASEAR (NL) database

Measurement	***Value(s)***
Gender	Male
Fitness level	6-10, or higher
Age	18 up until 21
Waist circumference	770 - 870 mm
Weight	72 - 79 kg

Table 4: A comparison between the mean values of the anthropometric data of the athletes and that of the filtered CEASEAR (NL) database

Dataset	***Age (years)***	***Stature (mm)***	***Hip circumference (mm)***	***Waist circumference (mm)***	***Body mass (kg)***
Average athletes	17,6	186	89	81	76
CEASEAR (NL)	19,5	186,2	100,7	83,5	75,9
Difference	9,7%	0,4%	11,3%	3,1%	0,2%

4.5 CONCLUSION

There is a difference between mental and physical discomfort. From a mental perspective the athlete will never be comfortable during competition due to the stressful nature of such events. However, the absence of physical discomfort can be perceived as comfort. As the harness could be worn over a prolonged period of time, the Merkel discs and the Ruffini endings are most likely the main cause of physical discomfort for the athletes. An equal distribution of forces over the skin is not necessarily desirable as this could lead to circulation blockage.

There are three main postures in kitefoiling, with the upwind and the manoeuvre postures being the two extremes. As long as the harness does not cause any major discomforts in those postures, the postures in between should not be uncomfortable either. As for the anthropometrics, the filtered CEASEAR (NL) database is representable of the athletes and can be used to derive further measurements, if necessary.

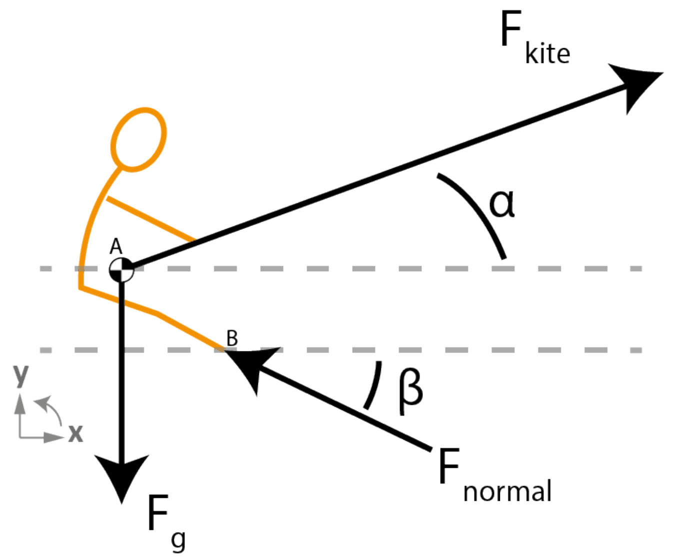
This chapter has explored the interaction between the harness and the body, however the interaction of the harness and the kite remains unclear. This will be discussed in the next chapter.

CRITERIA

- The athlete should be able to wear a personal floatation device and the harness at the same time
- The harness should have a knife integrated
- The materials used should be UV resistant
- The materials used should be abrasion resistant
- The materials should be able to withstand salt water
- Major forces should be loaded perpendicular to the body as much as possible
- The harness should not cause major discomfort in the upwind and the manoeuvre postures.
- The harness should not evenly distribute the forces over large areas of skin

CHAPTER 5
MECHANICS: INTERACTION BETWEEN KITE & HARNESS

To get a better sense of which forces are involved in kitefoiling, a mechanical analysis is done. Since the kite is the source of power, the forces will be analysed from the side and the upwind posture. First a theoretical model is made that will be tested following the method in the following paragraph. These results will then be compared to literature.



Equations of Equilibrium

$\Sigma F_x : F_{kite} * \cos \alpha - F_{normalx} = 0$

$\Sigma F_y : F_{kite} * \sin \alpha + F_{normaly} - F_g = 0$

$\Sigma M@B : AB * \cos \beta * F_g - AB * \cos \beta * F_{kite} * \sin \alpha - AB * \sin \beta * F_{kite} * \cos \alpha = 0$

Figure 35: The free body diagram of an athlete with the equations of equilibrium

Table 5: An overview of the parameters used in the theoretical model

Parameter	***Explanation***
Fkite (N)	The force exercised by the kite
Fnormal (N)	The normal force coming from the board (and the hydrofoil)
Fg (N)	The gravitational force acting on the athlete
Angle α (°)	The angle of the force vector Fkite in degrees
Angle β (°)	The angle of the force vector Fnormal in degrees

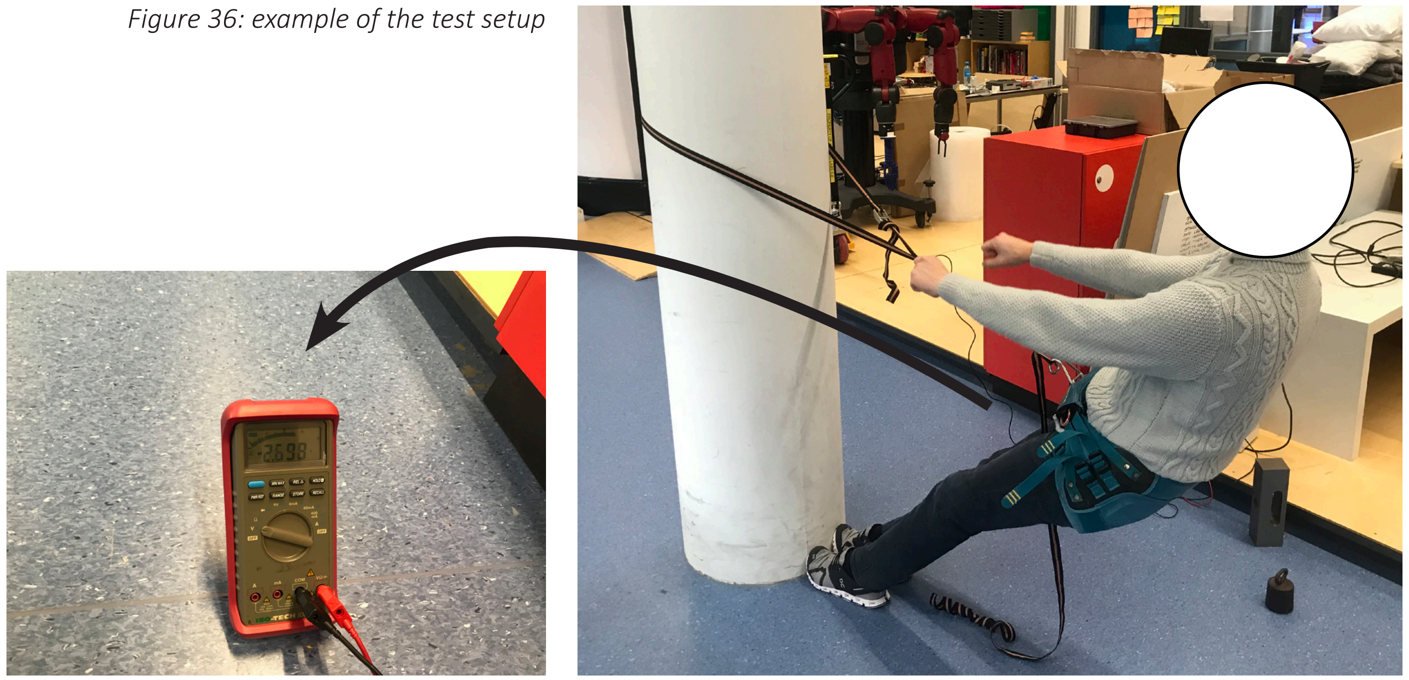
5.1 METHOD

The theoretical model constructed can be found in **Figure 35** and an overview of the parameters can be found in **Table 5**. Since the order of magnitude of F_{kite} and F_{normal} is unknown, but the gravitational force is known and there are 3 equations of equilibrium, F_{kite} can be solved using the following formula:

$$Fkite = \frac{AB * Fg}{\sin \alpha + \beta}$$

To verify the model the following method was used. A force sensor was put in between the harness and the kite. Due to constraints in the available sensors and testing locations, the test was done indoors. A band was put around a beam at an arbitrary height. The participant connected the harness to this band and started hanging on said band. The sensor was connected to an amplifier, which in turn was connected to a multimeter. The values of this sensor range from 0V to 10V. According to an Applied Labs employee (Martin Verwaal) these sensors are linear. An initial measurement with a known 2 kg and a 10 kg weight were done and the resultant values were noted. These values were used for calculating the resultant force. When the participant engaged the sensor, the value was noted. The length between the feet and the hook was also measured, just like the weight of the participant, while wearing the harness. Finally, a picture was made from the side to retrieve the angles of the band and the hook digitally. The force as measured by the sensor will then be compared to the force calculated to determine the accuracy. See **Figure 36** for a picture of the setup. The test was conducted with 2 participants.

Figure 36: example of the test setup



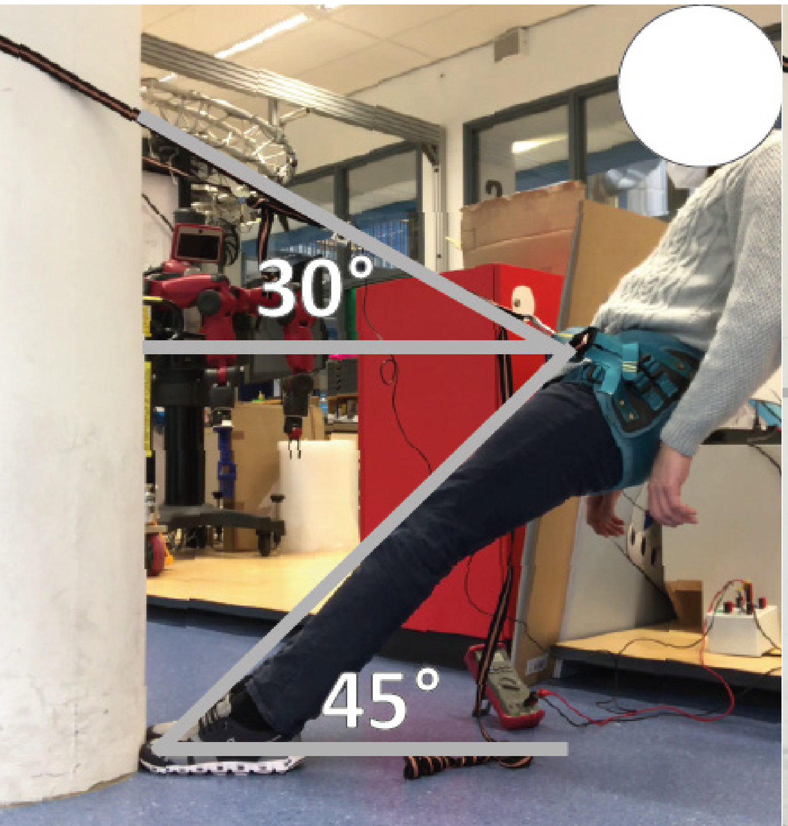
5.2 RESULTS

Table 6 shows the results as a comparison between the measured values and the calculated force.

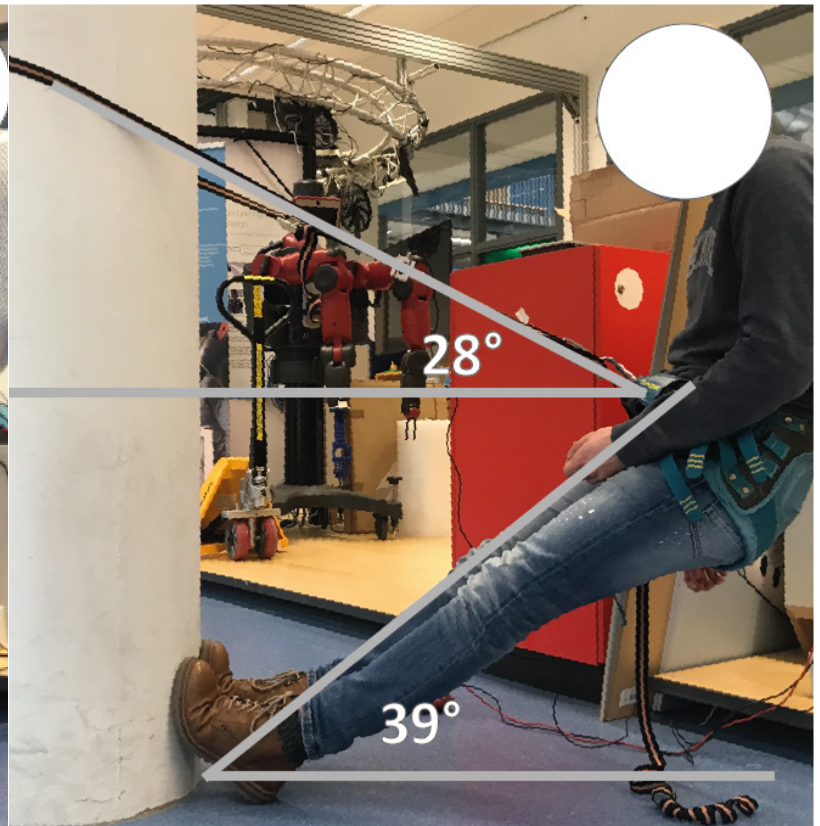
Table 6: the results from the test compared to the calculated results

#	*Voltage (V)*	*α (°)*	*β (°)*	*Weight (kg)*	*Measured Force (N)*	*Calculated Force (N)*	*Force difference (%)*
Test 1	2,47	30	45	86	573	634	11%
Test 2	2,8	28	39	82	649	699	8%

Test 1



Test 2

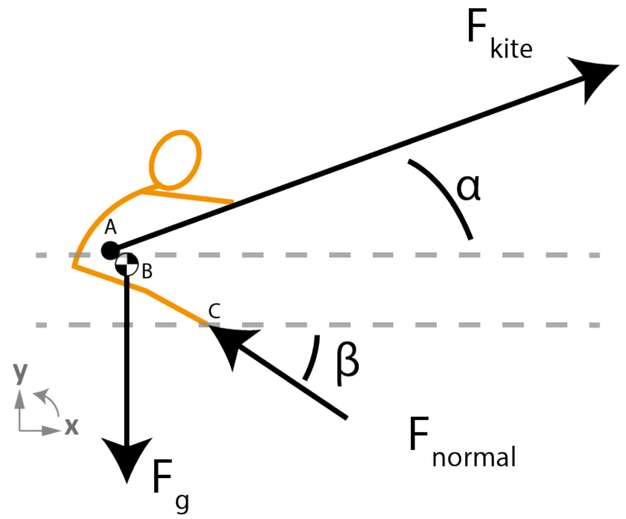


5.3 DISCUSSION

There is a considerable difference between the calculated and the measured forces. Since the measurements of the angles, the weight and the forces are very likely to be correct, the model must have some mistakes in it. The hypothesis is that the distance between the centre of gravity of the body and the rotation point is smaller than that of the hook. **Figure 37** shows an adjusted Free Body Diagram, in which the arm of the centre of gravity is smaller.

If this arm is made smaller by 7% the results come a lot closer to the measured values (**Table 7**). This makes the test more accurate (±4% roughly). This changes the formula for Fkite slightly:

$$Fkite = \frac{BC * \cos\beta * Fg}{AC * \sin(\alpha + \beta)}$$



Equations of Equilibrium

$\Sigma F_x : F_{kite} * \cos\alpha - F_{normalx} = 0$

$\Sigma F_y : F_{kite} * \sin\alpha + F_{normaly} - F_g = 0$

$\Sigma M@C : BC * \cos\beta * F_g - AC \cos\beta * F_{kite} \sin\alpha - AC \sin\beta * F_{kite} \cos\alpha = 0$

Figure 37: The adjusted Free Body Diagram

Table 7: The results of the adjusted model

#	*Voltage (V)*	*α (°)*	*β (°)*	*Weight (kg)*	*Distance to hook (m)*	*Distance to CoG (m)*	*Measured Newton (N)*	*Calculated Force (N)*	*Force difference (%)*
Test 1	2,47	30	45	86	1,07	1	573	593	4%
Test 2	2,8	28	39	82	1,01	0,94	649	632	-3%

5.3.1 SENSITIVITY

The impact of lowering angle α is quite tremendous, as can be seen for the measurements of test 1 and test 2. Even though the weight in test 2 was slightly less (4 kg), angle α was lower (2 degrees) which resulted in an increase of F_{kite} by 5%. This can be explained by the fact that as angle α approaches 0, the size of F_{kite} approaches infinity. This is similar for angle β.

5.3.2 MAXIMUM FORCE

To get a sense of the upper limit of Fkite, the 98th percentile of the DELSTU2016 database was used. The DELSTU2016 database contains anthropometric data of students, who are roughly the demographic of the athletes. For the angles, screenshots were made of competitions and approximated (**Figure 39**). In this analysis no attention was paid whether the rider was going upwind or downwind. Ultimately this leads to the variables used as shown in **Table 8**.

With this data the model is in equilibrium when Fkite (or line tension) is 1074 N. Literature measured (on land) that during wind gusts between 5 and 6 m/s line tension of kites of this type is between 1500 and 2000 N (Dadd et al., 2010; Van Der Vlugt, 2009). This difference can be explained because the model describes a state of equilibrium, while the literature involves dynamic forces. The literature does show the dynamic range of the line tension (**Figure 38**), while this model describes a more average line tension. This means the athlete is on average close their maximum power, but can briefly be overpowered to the extend shown in the literature. When the athlete realises they are overpowered they will depower the kite by pushing their handlebar away from them, rebalancing the force of the kite to the amount described in the model.

Table 8: Used variables

Fg (N)	*Angle α (°)*	*Angle β (°)*	*Distance AC (m)*	*Distance BC (m)*
1050	23	30	1,0	0,9

Figure 38: The measured total line tension (Van Der Vlugt, 2009). Van Der Vlugt tested on a beach and attached three load cells to the wires at the handlebar (left, right, center, see Figure 7). The kite was kept in position through a sandbag. The data from the three load sensors were combined into the graph below.

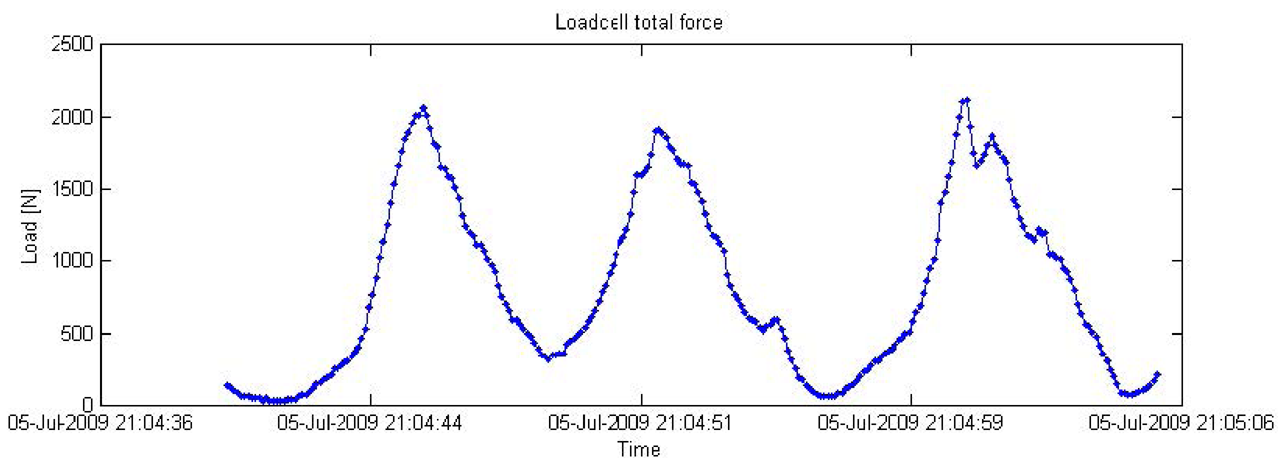


Figure 39: Screenshots from youtube videos used for angle aproximation

Figure 40: The results from VIBE

SIDE TRACK; VIDEO ANALYSIS

Two weeks of this Master thesis were devoted retreiving data on the postures of the athlete through video analysis. This analysis is done through machine learning and interpretates to postures of people in videos or images. The performance of two pieces of software were compared, VIBE (**Figure 40**) and VideoPose3D (**Figure 41**) (Kocabas et al., 2020; Pavllo et al., 2018). VideoPose3D showed a significantly better performance in accuracy and jittering. However, when the viewport of the reconstructed data is changed, it still shows a significant difference compared to the original video file (**Figure 42**). Furthermore, the author lacked the programming skills to retrieve the angles from the different sections.

VideoPose3D appears to be a good method to quantitively retrieve posture data from videos. There are two main requirements that have to be met that could not be met during the timespan of this thesis. First the video should ideally show as much of the body as clearly as possible (No black suits, filmed from a close distance, no overlap between body parts). Since the thesis was mostly done during winter and Corona, it was difficult to record new videos. Second, to retrieve the angle data knowledge of 3d vectors and their processing is required.

The difference in the accuracy of this method compared to the more traditional method of taking a screenshot and measuring by hand was in the end doubted by the author and evantually abandoned due to time constraints.

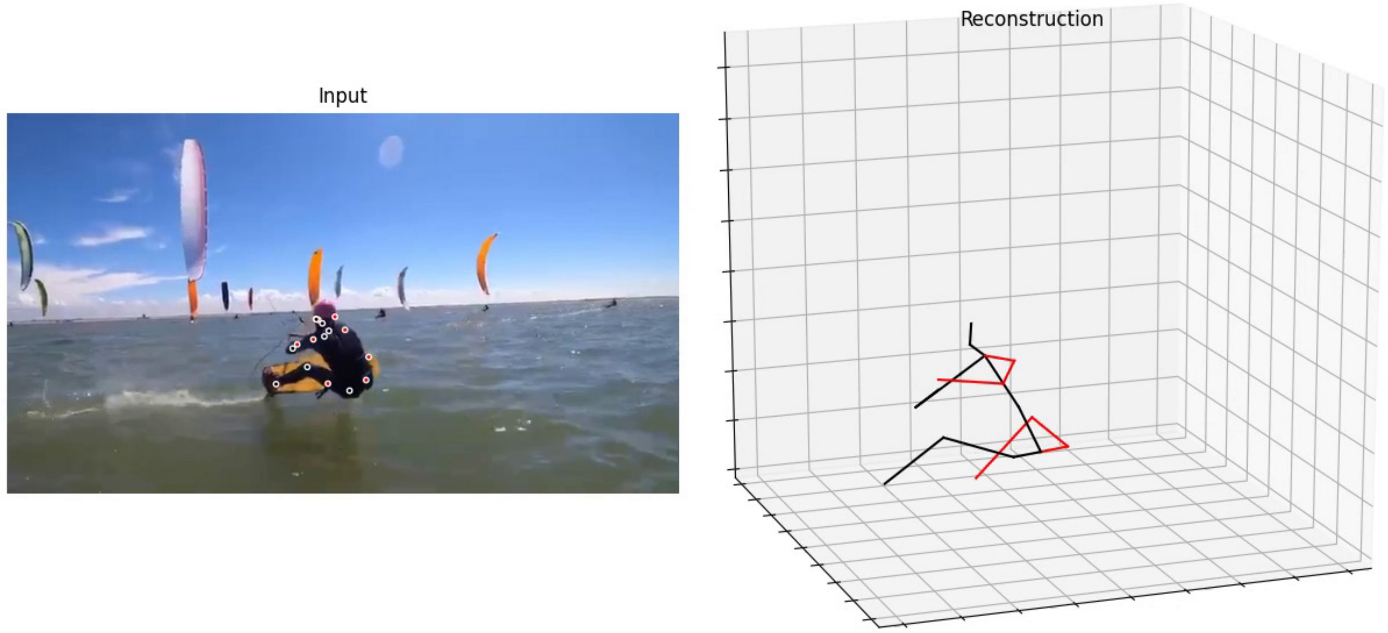


Figure 41: The results from VideoPose3D

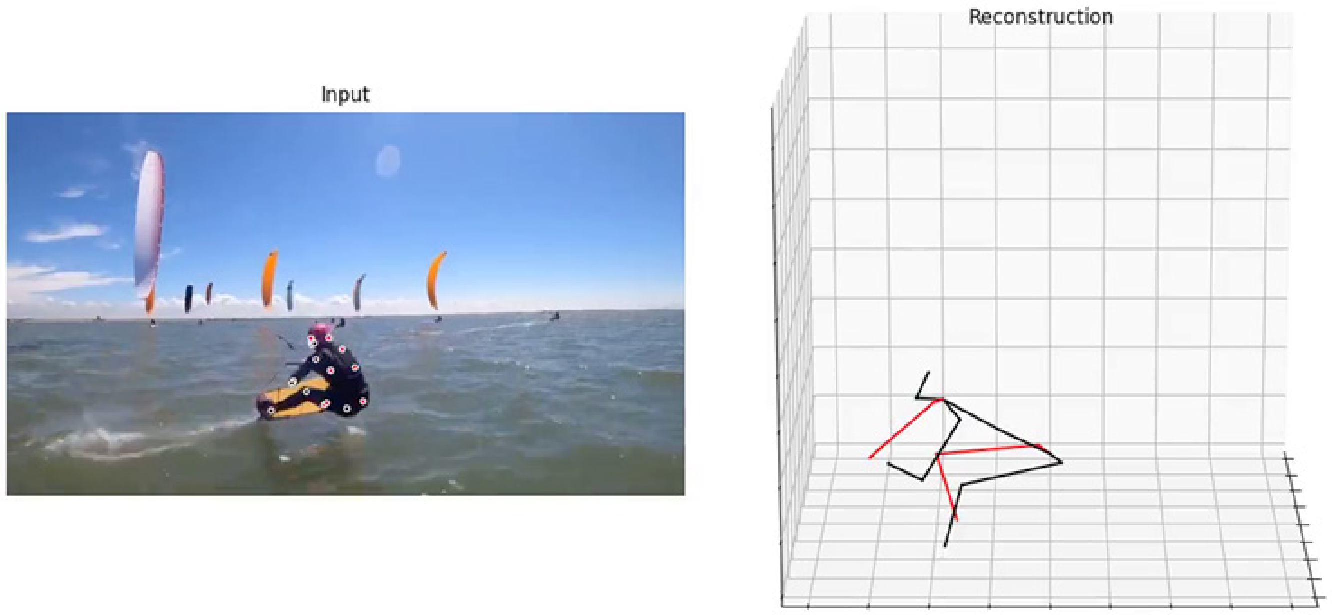


Figure 42: The results from VideoPose3D with an adjusted viewport

5.4 CONCLUSION

A mechanical model was created that calculates the pulling force on the harness. The model was verified through testing in a lab setting and deemed accurate enough with a difference between the measured force and the calculated force of about 4%. The resultant maximum statical force on the harness would be around 1 kN. Literature showed that dynamic forces could be as high as 2 kN. Given that the data in the literature was measured with a windspeed of approximately 10 to 12 knots, but the Formula Kite competition is officially done until 40 knots, it is safe to assume that these dynamic forces can be even higher. For now, the assumption will be made that the harness will have to be able to withstand a force of about 3 kN, given that the windspeed can be up to 3-4 times as high and the angles steeper, but that the athlete will depower the kite appropriately.

All the research done so far examines the harness and the context surrounding it. The next two chapters will zoom in on the properties of the harnesses used by the athletes themselves.

CRITERIA

- The athlete should be able to wear a personal floatation device and the harness at the same time
- The harness should have a knife integrated
- The materials used should be UV resistant
- The materials used should be abrasion resistant
- The materials should be able to withstand salt water
- Major forces should be loaded perpendicular to the body as much as possible
- The harness should not cause major discomfort in the upwind and the manoeuvre postures.
- The harness should not evenly distribute the forces over large areas of skin
- The harness should at least withstand a pulling force of 3 kN in the upwind position

CHAPTER 6
USER RESEARCH: PERCIEVED DISCOMFORT

So far most of the insights gathered concerned the context of the harness. This chapter aims to provide an overview on what properties the athletes dislike about their harnesses, what they would change and where the ideal harness would support them. The next chapter will evaluate the two most used harnesses on their positive aspects.

6.1 METHOD

This research used a quantitative research method, a questionnaire, as this research focusses more on the general complaints and feedback on the current harnesses from the athletes. The type of questions asked were open ended and the answers that could be provided could be typed into a text box in an online Google Form. The questionnaire can be found in **"Appendix B: Questionnaire current harnesses"** for further details. The questionnaire was sent out to 13 participants (10 male and 3 female) all of whom responded. These participants are either in teamNL (3 female and 7 male) or in the support crew (3 males). This research also involves the female athletes as this research is about general perceived discomfort and support. It was assumed gender would not be a major factor.

When is the harness the right size? (n = 13)

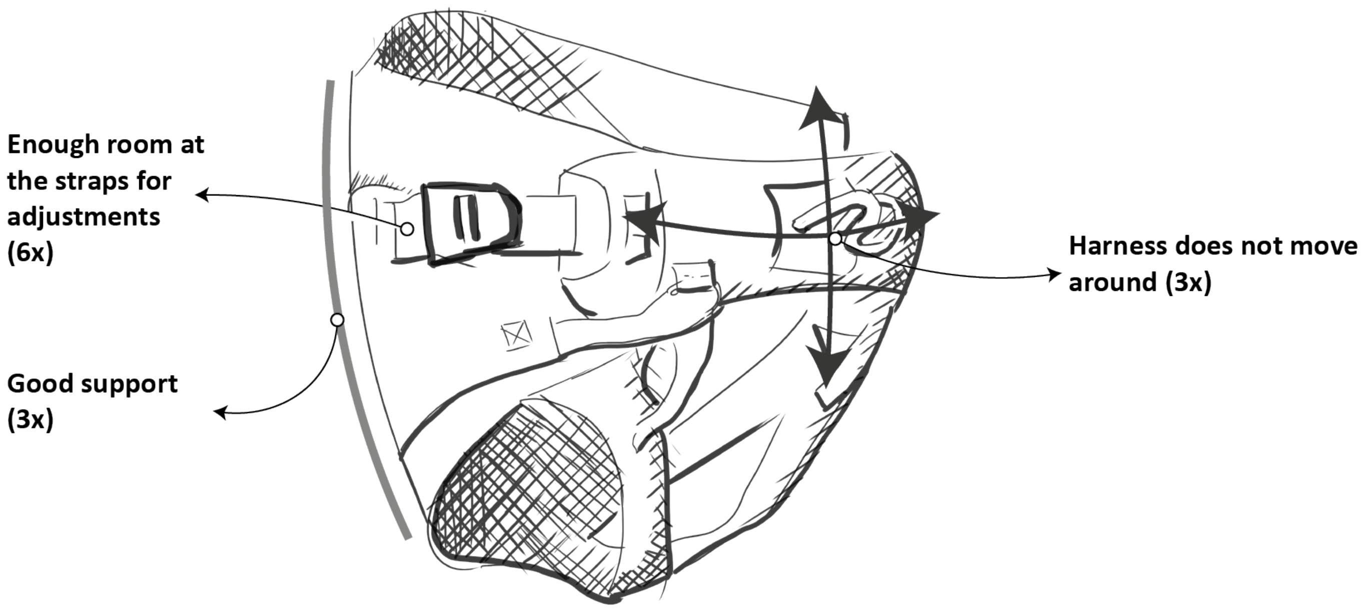


Figure 43: Visualisation of the results from the question "When is the harness the right size"?

6.2 RESULTS

6.2.1 CORRECT SIZE

Six of the respondents said that a harness fits well if it there is enough room to adjust the harness. Two important areas to check are the legs and the back. The harness should not be able to move around, according to two respondents. **Figure 43** visualises these results.

6.2.2 MOST IMPORTANT HARNESS PROPERTIES

It was mentioned six times as the most important aspect that the harness/hook should not move around or upwards (**Figure 44**). Good support and a lack of discomfort were both mentioned 4 times. Unrestrained freedom of movement was mentioned twice. One participant said that for him the most important thing about a harness is being able to stay in the racing positions for a long time.

What are the most important properties of a harness? (n = 13)

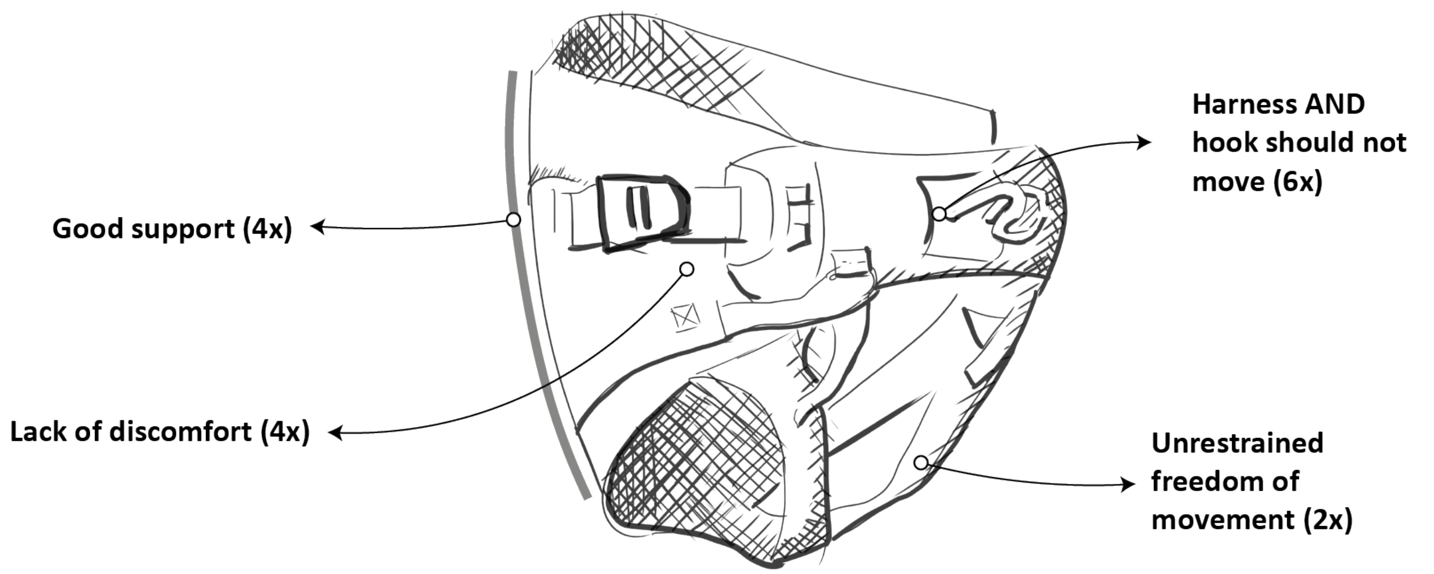


Figure 44: Visualisation of the results from the question "What are the ost important properties of a harness?

6.2.3 CURRENT HARNESS COMPLAINTS

An overview of what was the most bothersome aspect about their harnesses according to the participants can be seen in **Table 9**. The fact that the hook does not stay in place and that there is too much pressure on the groin are the most common complaints. Two other complaints that were mentioned more than once were the harness moving up the body and that the harness pinches at the hip.

The participants reported different strategies to resolve their perceived discomfort. Four participants mention that they loosen the straps, but 3 of these participants also mention that this action has negative results: Hook goes up, higher likelihood of straps tearing and less support. Two participants say they try to change the angle of the hook to alleviate their discomfort. Lastly, three participants mention that they take no action to resolve the discomfort, two of them because they do not have problems.

Table 9: An overview of the most bothersome aspects of the harness

ION Sonar ***n = 3 (male)***	***Dakine Vega*** ***n = 6 (male)***	***Brunotti ... (?)*** ***n = 1 (female)***	***Dakine Reflex*** ***n = 1 (female)***	***Prolimit Race*** ***n = 1 (male)***	***Prolimit Pure Girl Kite Seat*** ***n = 1 (female)***
					
Pressure on the lower back (1) Moves up the body (1) Pinches at the hip (1) Hook does not stay in place (1)	Pressure on hips (1) Wrong seat shape (1) Pressure on buttocks (1) Too much groin pressure (2) Hook tilting (1) Loss of stiffness (1)	Smallest size still too big (1) Bad support (sore spots) (1)	Nothing	Too many straps (1) Hook does not stay in place (1) Too much groin pressure (1)	Moves up the body (1) Spreader bar not tight enough (1) Leg straps uncomfortable (1)
Hook does not stay in place (4) Too much pressure on the groin (4) Moves up the body (2) Pinches at the hip (2)					

6.2.4 IMPROVEMENTS TO THE CURRENT HARNESSES

If the participants could change anything, 4 of them would improve the straps around the legs by making them less likely to move, softer and better at spreading the loads. Another four participants would make the harness stiffer and four participants would want the harness to be better fitted. Two would keep the hook centred and low. Of the women, two would improve the seat area so that the athlete can really put pressure on it and obtain a better fit. One would change the leg straps to be wider and softer. Another would improve the backside, so it supports the back better and spreads the loads.

6.2.5 PERCEIVED DISCOMFORT

For the male athletes, six participants indicated that the groin area as the location of discomfort. Three participants perceive discomfort at their lower back and two participants perceive discomfort at the lower abdomen, the Gluteus Maximus and the back of their legs. For the women, the groin area is mentioned twice and the lower back is mentioned once. **Figure 45** illustrates these results.

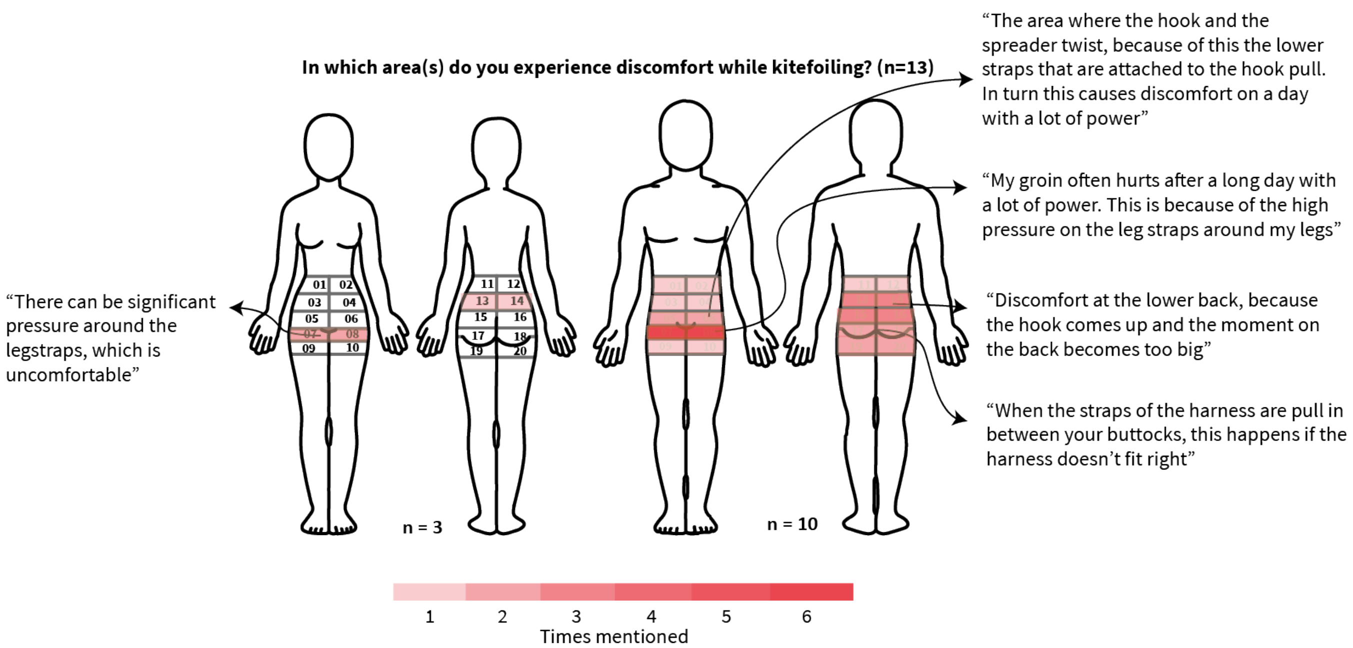


Figure 45: The areas where the athletes perceive their discomfort

6.2.6 DESIRED SUPPORT

All ten of the male participants desire support at the Gluteus Maximus. The lower back is mentioned by six participants. The back of the legs are mentioned four times. On the front, the groin and abdomen are also mentioned 4 times. Two of the female participants mentioned desired support at the upper part of the Gluteus Maximus and the lower back. These results are visualised in **Figure 46**.

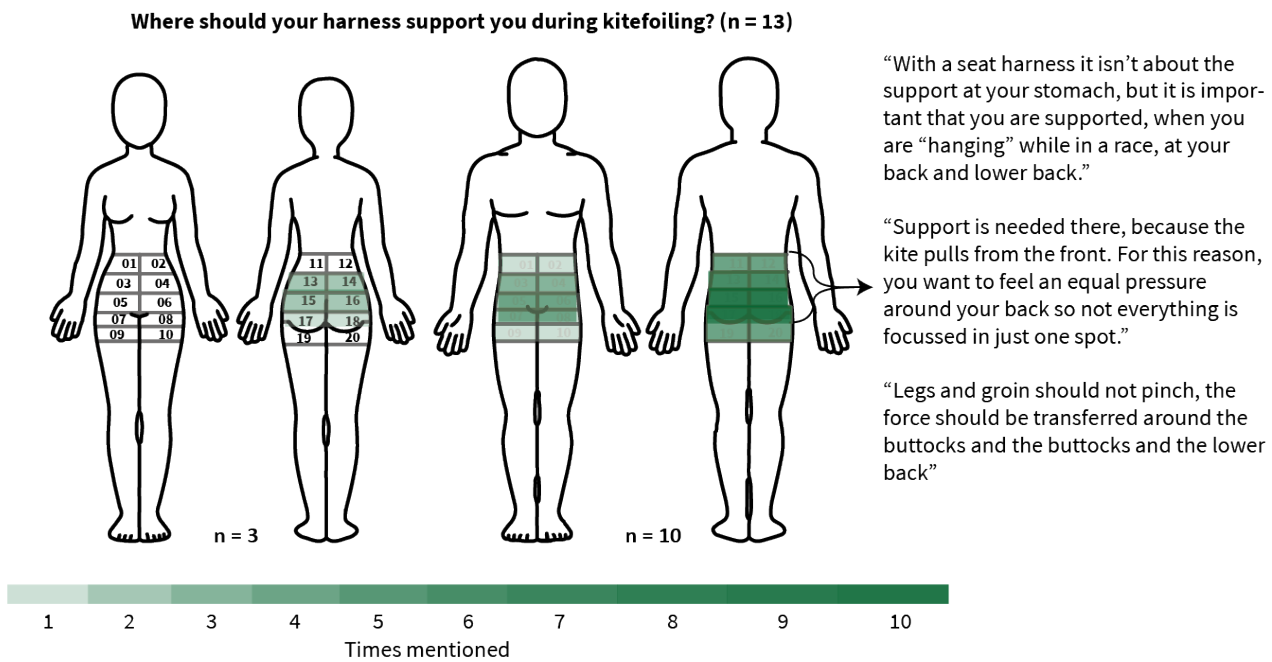


Figure 46: the areas where support is desired

DISCUSSION

There are different views on how to decide on whether a harness is right for you. Most of the participants mention that a harness is the right size when there is still enough room to adjust the straps, especially around the hips and legs. Once adjusted, the harness should not be able to move around, to keep the hook centred.

As expected, all participants have slightly different views on their current harnesses and the ideal one. Regardless, there are some patterns in the results. First, a major complaint about the current harnesses are the leg straps, that put a lot of pressure around groin to keep the harness in place. They cut into the legs of the participants, sometimes even causing bruising. The athletes can alleviate the pain of this by loosening the straps, but this causes different problems, like back problems or faster deterioration of the straps. From **Figure 45** it can be seen that the lower back area is also mentioned quite often. When asked what they would change, the participants did mention that they would make the back area of the harness stiffer to improve support and spread the forces. Another complaint that was mentioned was the hook of the harness. Apparently, it is difficult to keep it in a low position, without it turning. One way to address this is to tighten the straps, but this in turn causes discomfort around the hips. Furthermore, from **Figure 45** it can also be seen that the abdomen is often a source of discomfort. This is where the spreader bar tilts, but due to the nature of the graphic could also indicate the sides of the pelvis are the cause of the discomfort. There is also discomfort at the Gluteus Maximus, caused by insufficient stiffness by which the harness is pulled into the intergluteal cleft. Some participants noted that that stiffness of the harness decreases too fast, and that they therefore lose a lot of support.

An obvious improvement as indicated by the participants were the leg straps. These straps put too much pressure around the groin. Multiple ways to fix it have been proposed by the participants, making the straps thicker, softer or less likely to move around. Another aspect that the participants would like to have changed is stiffness and the amount of support from the back of the harness. In **Figure 46** an overview is seen where the participants think they need support the most. A better fit for the shape of the “seat” area was mentioned multiple times, which is in line with the results from **Figure 46**. Another problem that the participants want to fix is the hook. They report that the hook does not stay in place very well and that it tilts upward. This is most likely due to the relatively big size of the hook, which in turn creates a big arm for the force of the kite.

6.2.7 LIMITATIONS

This research was sent out in the beginning of the project to get a better overview of the problems. At the time there was no direct contact with the participants, so it was opted for a questionnaire format, but in hindsight semi-structured interviews would possibly have provided a deeper understanding. Additionaly, the local perceived discomfort maps did not offer enough granularity for the participants to provide information about the sides.

6.3 CONCLUSION

The leg straps are the biggest problem reported by the participants. Due to their small size, but big forces pulling upwards there is too much pressure around the groin. The participants report that the harnesses are not stiff enough or lose their stiffness. According to them, this results in less support around the lower back area. They also indicate that the harness does not fit them as well as they had hoped. Especially around the Gluteus Maximus the participants report lack of the ability to adjust the sizing. The hook does not stay in place well enough. The participants report attempts to keep it in place, but that it is pulled back up by the kite. Lastly, the participants want to be supported the most at the Gluteus Maximus, hips and the lower back.

CRITERIA

- The athlete should be able to wear a personal floatation device and the harness at the same time
- The harness should have a knife integrated
- The materials used should be UV resistant
- The materials used should be abrasion resistant
- The materials should be able to withstand salt water
- Major forces should be loaded perpendicular to the body as much as possible
- The harness should not cause major discomfort in the upwind and the manoeuvre postures.
- The harness should not evenly distribute the forces over large areas of skin
- The harness should at least withstand a pulling force of 3 kN in the upwind position
- The harness should not be a source of the level of discomfort that causes the athlete to change posture
- The attachment point between the harness and the kite should not be able to move around
- The harness should support at the Gluteus Maximus, the hips and at the Lumbar spine

CHAPTER 7
USER RESEARCH: MOST USED HARNESSES

The previous chapter offered an overview of the general problems that the athletes face with their harnesses. There are two harnesses which are used most often: the Dakine Vega and the ION Sonar. In this chapter these two harnesses will be researched more thoroughly through semi-structured interviews with the athletes currently using them.

Figure 47: The Dakine Vega

Figure 48: The ION Sonar

7.1 METHOD

Semi structured interviews through Zoom are conducted with four members of the core team and two members of the support team, all male. Two members of the core team and one member of the support team were supposed to be interviewed about the Dakine Vega and the rest were supposed to be interviewed about the ION Sonar. During the interviews a mix up happened and one member of the core team was interviewed about the ION Sonar instead of the Dakine Vega, which he both owned. The interviews were recorded and transcribed. The results were analysed through labelling. The questions that were asked (translated from Dutch) are listed below:

1. Which harness(es) did you use lately?
2. If you have your own sponsor, does this play a role in which harness you end up using?
3. Why did you switch to your current harness?
4. How did you find your current harness?
5. What do you like about your current harness?
6. Why do you like it?
7. How does this differ to other harnesses?
8. Is there anything else you would like to mention?

The transcriptions of these interviews (in Dutch) can be found in **"Appendix B: Interviews"**.

7.2 RESULTS

7.2.1 PREVIOUS HARNESSES

Three of the respondents switched from the Dakine Vega to the Ion Sonar. All the other respondents had different harnesses that they had used before.

7.2.2 SPONSORS

Five of the six respondents said that their sponsor does not play a significant role in their choice of their harness. Many mentioned that there was a distinction between their gear sponsor and their accessory sponsor.

7.2.3 REASON TO CHANGE

Three athletes said that they changed from the Dakine Vega to something else because of the lacklustre quality of the harness. Two of those athletes also mentioned the discomfort that the Vega caused. Another athlete mentioned that his sponsor offered a new harness design to him which he tried. The other two said that the previous harness (waist harness) was inadequate and that the previous harness was limiting his freedom of movement, respectively.

7.2.4 FINDING THE CURRENT HARNESS

Three athletes that switched to the Sonar said that their teammate was the reason they switched to that model. That teammate had a prototype version of it, which they tried at his place. They had initially switched to the Vega because the competition was using them as well. One athlete of chose the harnes by himself, independently.

7.2.5 POSITIVE ASPECTS DAKINE VEGA

What	*Times mentioned*	*Why is it good?*
Good force placement	2	The forces are not applied above the Lumbar spine
The harness is light weight	2	

Table 10: The positive points of the Dakine Vega that were mentioned more than once (n = 2)

Figure 49: The positive points of the Dakine Vega that were mentioned more than once, illustrated

7.2.6 POSITIVE ASPECTS ION SONAR

What	*Times mentioned*	*Why is it good?*
Better leg straps	4	They do not cut as much into the groin area
The hook stays put	3	The hook stays put through an extra strap and the spreaderbar can be tighter
The harness is comfortable	2	Different pressure points, but the ION Sonar generally sits lower at the pelvis
The closure of the spread-erbar is good	2	It contains a lever, which allows the spreaderbar to be even tighter

Table 11: The positive points of the ION Sonar that were mentioned more than once (n = 4)

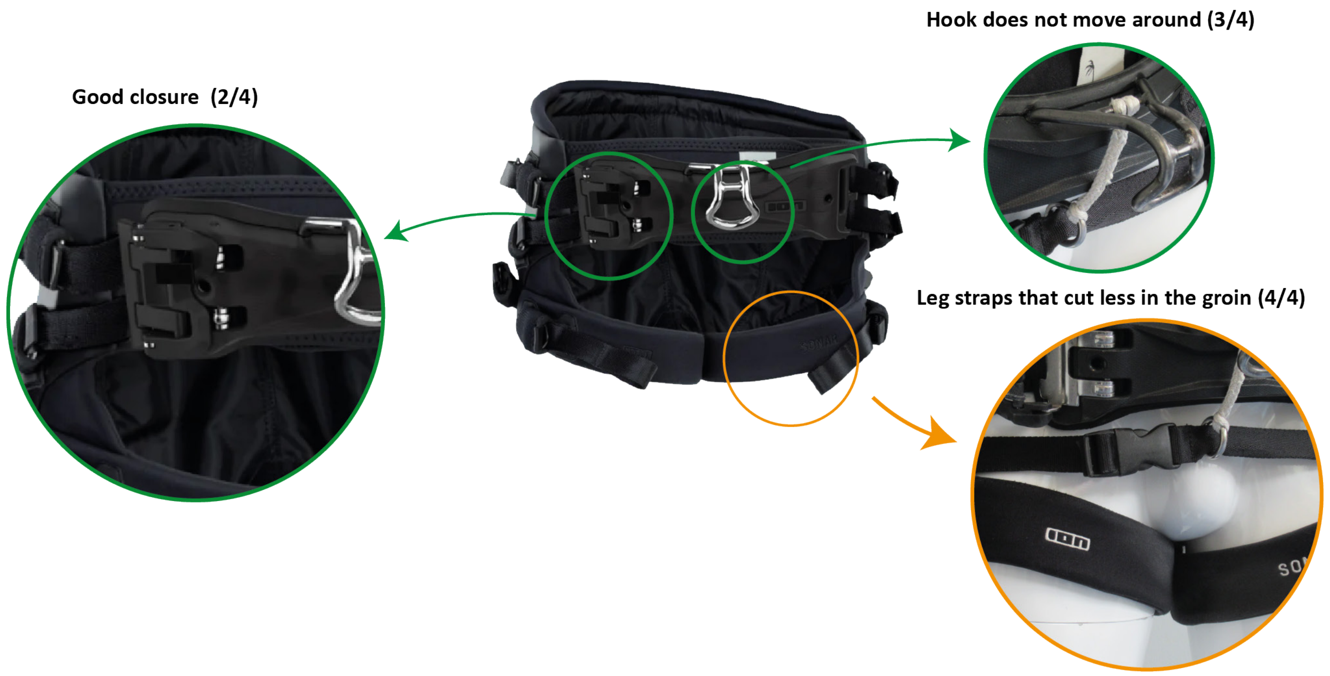


Table 12: The positive points of the ION Sonar that were mentioned more than once, illustrated

7.3 DISCUSSION

The main reason why the Vega was initially being used by various team members was because they saw the best athletes use it during competition, assuming it would be good. The Sonar was chosen because one of the athletes is sponsored by Ion and had a prototype that a lot of people tested and liked better than the Vega. Product sponsors do play a big role within the sport, but if the product of a competitor is superior all five participants that have a sponsor said that they would switch to the competitor.

A major reason for switching harnesses is the durability. The respondents mentioned the lack of confidence when wearing the harnesses, which arguably harmed their performance (less likely to push harder). One interviewee said the following: “You were genuinely scared sometimes that it would snap if you would tighten the speaderbar”. There is a market for harnesses of brands that do not sponsor an athlete. As long as the product is superior, the athletes will use it. Discomfort is another reason why a switch happened, with oncomfortable pressure points or the harness pulling in between the Gluteus Maximus. This happened mainly during manoeuvres. “The moving of the harness mainly happens during manoeuvres, but it also happens slowly during long straights.” Generally speaking, the positions that the athletes hold are quite static, however on rougher waters the athletes change their stance continuously. It was mentioned as a reason for switching that the harness was limiting the freedom of movement of the athlete. “You want to have as much freedom of movement as you can (..) and when you are doing a manoeuvre this harness was in the way.”

The mentioned positive points of the ION Sonar show that the harness was designed with kitefoiling in mind, as advertised on the website of ION (ION, n.d.). The two most common complaints that were found in **Chapter 6** were noted as improved compared to their previous harness they had used. The participants mentioned four times that the leg straps of the ION Sonar cut less into the groin compared to the Dakine Vega, but were still a source of discomfort. Furthermore, the ION Sonar contains an extra strap that can be attached to the hook to keep it from twisting and keeps it low, which three participants appreciated. Two of these participants mentioned that they want to keep the hook lower, mentioning this allows them to push the forces more efficiently from the kite into the hydrofoil. “(...) Because everything is in one line. This causes you to handle a lot of force, but if the harness comes up the force dynamics becomes weird, which means you cannot control as much power”. Two participants find the Dakine Vega to be more comfortable, as the seat area nicely fits around their body and through this the forces are spread correctly. Furthermore, two participants have mentioned that the closure of the spreaderbar is good, which allows them to tighten the spreaderbar even further, which keeps it from moving around. ION has done this through adding an extra lever.

As mentioned before, due to a mix-up in the interviews only two participants were ultimately interviewed about the Dakine Vega instead of three. One of these participants (an athlete) was clearly very critical about the harness, having difficulties finding good aspects, but the other participant liked it a lot (support crew). Ultimately only two aspects were mentioned more than once. First, the placement of the forces by the Dakine Vega were mentioned as good; "There is a band that is above the buttocks, below the lower back. That is where I want the forces to be, I do not want forces on my back, because if that is the case you are finished very quickly". Furthermore, both participants mention that the harness is light-weight, at 1050 g.

7.3.1 THE BEST HARNESS ON THE MARKET

From the interviews, 5 participants ultimately preferred the ION Sonar over the Dakine Vega, as they see it as the superior product. A new design will have to match or surpass the ION Sonar in performance, otherwise the athletes will not use it. Combining the insights from this chapter with the insights from last chapter there three problems with the ION Sonar.

1. The leg straps are noted as better, but are still a source of discomfort after longer kitefoiling sessions. This is mostly due to the nature of these leg straps. As the harness moves up the body, the leg straps are pulled tighter from in between the legs. This is a design flaw and is also prevalent in other harnesses, see **Table 12**.

2. As the harness moves up the body, the attachment point, in this case the hook, moves up as well. The ION Sonar does have an extra strap that keeps the spreaderbar from moving around, but this does not prevent the entire harness from moving up. It was mentioned that the attachment point could be even lower, effectively at the level of the crotch. In an attempt to keep the spreaderbar from moving up, the spreaderbar is pulled uncomfortably tight (done through the lever). This has the side effect that, when the harness moves up, it is impossible to move it down again. Ultimately, the existing method to keep the attachment point low is not effective enough.

3. The shape of the seat does not always fit the body of an athlete. This issue was mentioned with other harnesses, but these harnesses do share the seat design of the ION Sonar. If the harness would offer a higher degree of customisation in its shape, the athletes would also be able to tweak where they feel most of the forces. This is not possible in the current design of any of the harnesses.

7.4 CONCLUSION

Everyone, bar one participant, preferred the ION Sonar over the Dakine Vega. Any improvement ultimately has to lead to better performance compared to the ION Sonar. The build quality is a major driver for the participants to have moved away from the Dakine Vega, which made some participants feel like they had to hold back, so as to not break the harness. Usually, the postures assumed by riders are quite static, but during rougher waters they become dynamic and the harness needs to provide enough freedom of movement for this. The ION Sonar is seen as the best harness that the Dutch team has found so far, but still contains critical problems. First, the leg straps are better than the competition, but due to the nature of the design trying to improve this would be like curing the symptoms instead of the decease. Second, the attachment point between the harness and the kite still moves too much, mainly during manoeuvres. Ideally, this attachment point would also be lower, making it easier for the athletes to transfer the forces from the kite to the hydrofoil. Third, a customisable seat shape would offer the athletes a way to ensure that the harness fits properly and allow them to adjust where they feel the forces.

CRITERIA

- The athlete should be able to wear a personal floatation device and the harness at the same time
- The harness should have a knife integrated
- The materials used should be UV resistant
- The materials used should be abrasion resistant
- The materials should be able to withstand salt water
- Major forces should be loaded perpendicular to the body as much as possible
- The harness should not cause major discomfort in the upwind and the manoeuvre postures.
- The harness should not evenly distribute the forces over large areas of skin
- The harness should at least withstand a pulling force of 3 kN in the upwind position
- The harness should not be a source of the level of discomfort that causes the athlete to change posture
- The attachment point between the harness and the kite should not be able to move around
- The harness should support at the Gluteus Maximus, the hips and at the Lumbar spine
- The harness should feel dependable, so the athlete does not feel like they have to hold back
- The harness should not limit freedom of movement
- The harness should not move up the body during a manoeuvre
- The attachment point between the kite and the harness should be at the level of the crotch
- The shape of the harness should be adjustable by the athlete

CHAPTER 8
CRITERIA

All the information and insights from the previous chapters are diverged into a set of criteria. These criteria help evaluate concepts and ensure that the final design fits the needs of the users.

8.1 CRITERIA

The criteria found in each chapter are presented in the list below.

- The athlete should be able to wear a personal floatation device and the harness at the same time (Chapter 2)
- The harness should have a knife integrated (Chapter 2)
- The materials used should be UV resistant (Chapter 2)
- The materials used should be abrasion resistant (Chapter 2)
- The materials should be able to withstand salt water (Chapter 2)
- Major forces should be loaded perpendicular to the body as much as possible (Chapter 3)
- The harness should not cause major discomfort in the upwind and the manoeuvre postures. (Chapter 4)
- The harness should not evenly distribute the forces over large areas of skin (Chapter 4)
- The harness should at least withstand a pulling force of 3 kN in the upwind position (Chapter 5)
- The harness should not be a source of the level of discomfort that causes the athlete to change posture (Chapter 6)
- The attachment point between the harness and the kite should not be able to move around (Chapter 6)
- The harness should support at the Gluteus Maximus, the hips and at the Lumbar spine (Chapter 6)
- The harness should feel dependable, so the athlete does not feel like they have to hold back (Chapter 7)
- The harness should not limit freedom of movement (Chapter 7)
- The harness should not move up the body during a manoeuvre (Chapter 7)
- The attachment point between the kite and the harness should be at the level of the crotch (Chapter 7)
- The shape of the harness should be adjustable by the athlete (Chapter 7)

8.2 ORDERED CRITERIA

The criteria were ordered in importance by two athletes, to obtain a better understanding of what they find most important. This ordering can be found in the list below, in which the lower the number the more important it is. Please note that criteria concerning material properties were omitted from the list, as these can be evaluated more objectively.

0	The athlete should be able to wear a personal floatation device and the harness at the same time (Mandatory)
0	The harness should have a knife integrated (Mandatory)
1	The harness should not move up the body during a manoeuvre
1	The harness should not be a source of the level of discomfort that causes the athlete to change posture
1	The harness should not cause major discomfort in the upwind and the manoeuvre postures
2	The attachment point between the kite and the harness should be at the level of the crotch
2	The attachment point between the harness and the kite should not be able to move around
3	The harness should feel dependable, so the athlete does not feel like they have to hold back
4	The harness should support the athlete at the Gluteus Maximus, the hips and at the Lumbar spine
5	The harness should not limit freedom of movement
5	The shape of the harness should be adjustable by the athlete
6	Major forces should be loaded perpendicular to the body as much as possible
7	The harness should not evenly distribute the forces

8.3 FINAL LIST OF CRITERIA

The importance according to the found literature was compared with the indications the athletes gave to form the final ordered list of criteria. The concepts generated in the next chapters will be evaluated using Harris Profiles. A Harris Profile is based on ordered design criteria, and is often used when concepts need to be evaluated and eliminated (Van Boeijen, Daalhuizen, Zijlstra, & Van Der Schoor, 2013). Using this method, the Harris Profiles are visually evaluated based on the generated profile. The ordered list of criteria, based on the feedback of the athletes and the research can be found below.

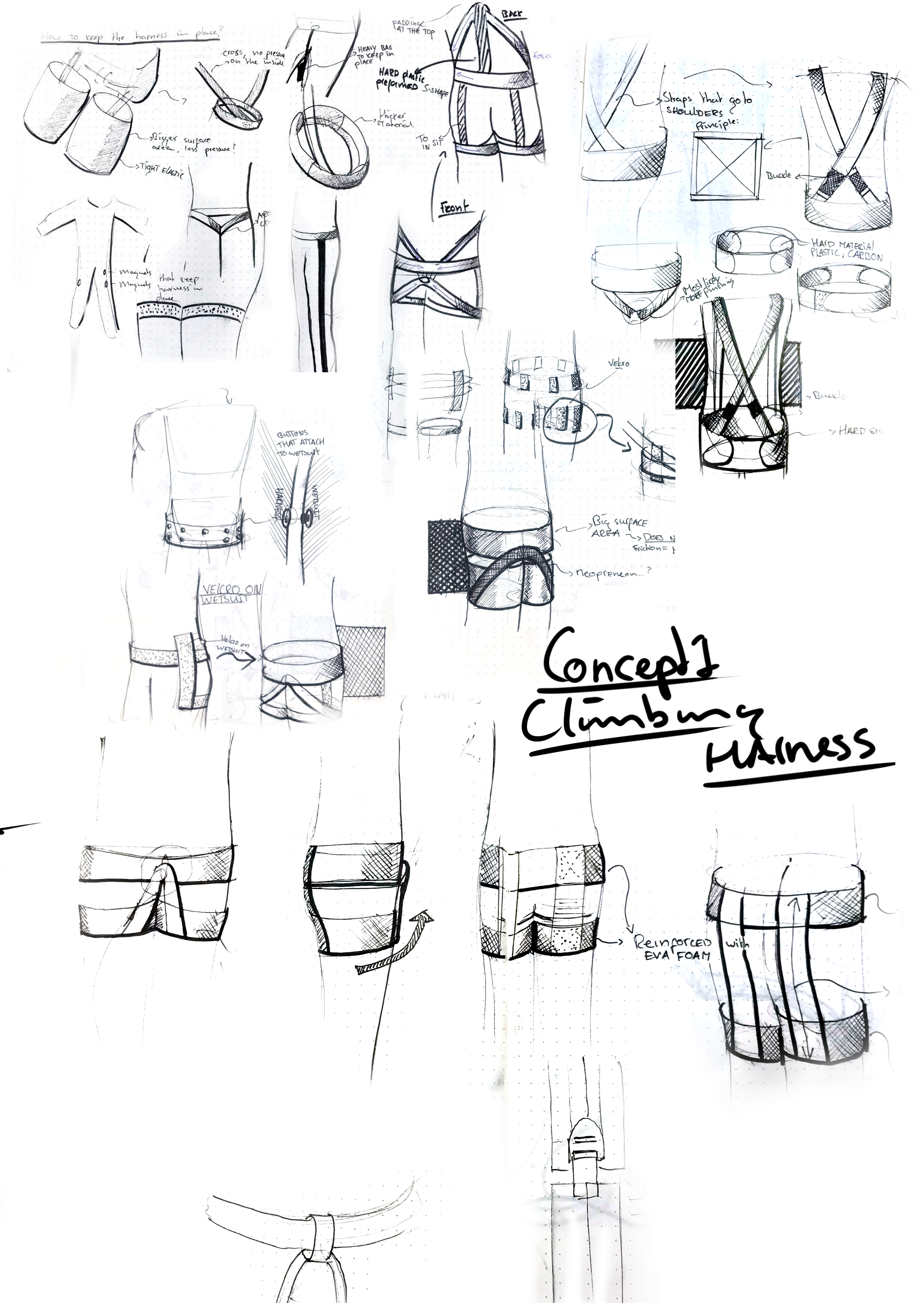
1. The athlete should be able to wear a personal floatation device and the harness at the same time
2. The harness should have a knife integrated
3. The harness should support the athlete at the Gluteus Maximus, the hips and at the Lumbar spine
4. The harness should not move up the body during a manoeuvre
5. The harness should not be a source of discomfort that causes the athlete to change posture
6. The harness should not cause major discomfort in the upwind and the manoeuvre postures
7. The attachment point between the kite and the harness should be at the level of the crotch
8. The attachment point between the harness and the kite should not be able to move around
9. Major forces should be loaded perpendicular to the body as much as possible
10. The harness should feel dependable, so the athlete does not feel like they have to hold back
11. The harness should at least withstand a pulling force of 3 kN in the upwind position
12. The harness should not limit freedom of movement
13. The shape of the harness should be adjustable by the athlete
14. The harness should not evenly distribute the forces
15. The materials used should be UV resistant
16. The materials used should be abrasion resistant
17. The materials should be compatible with salt water

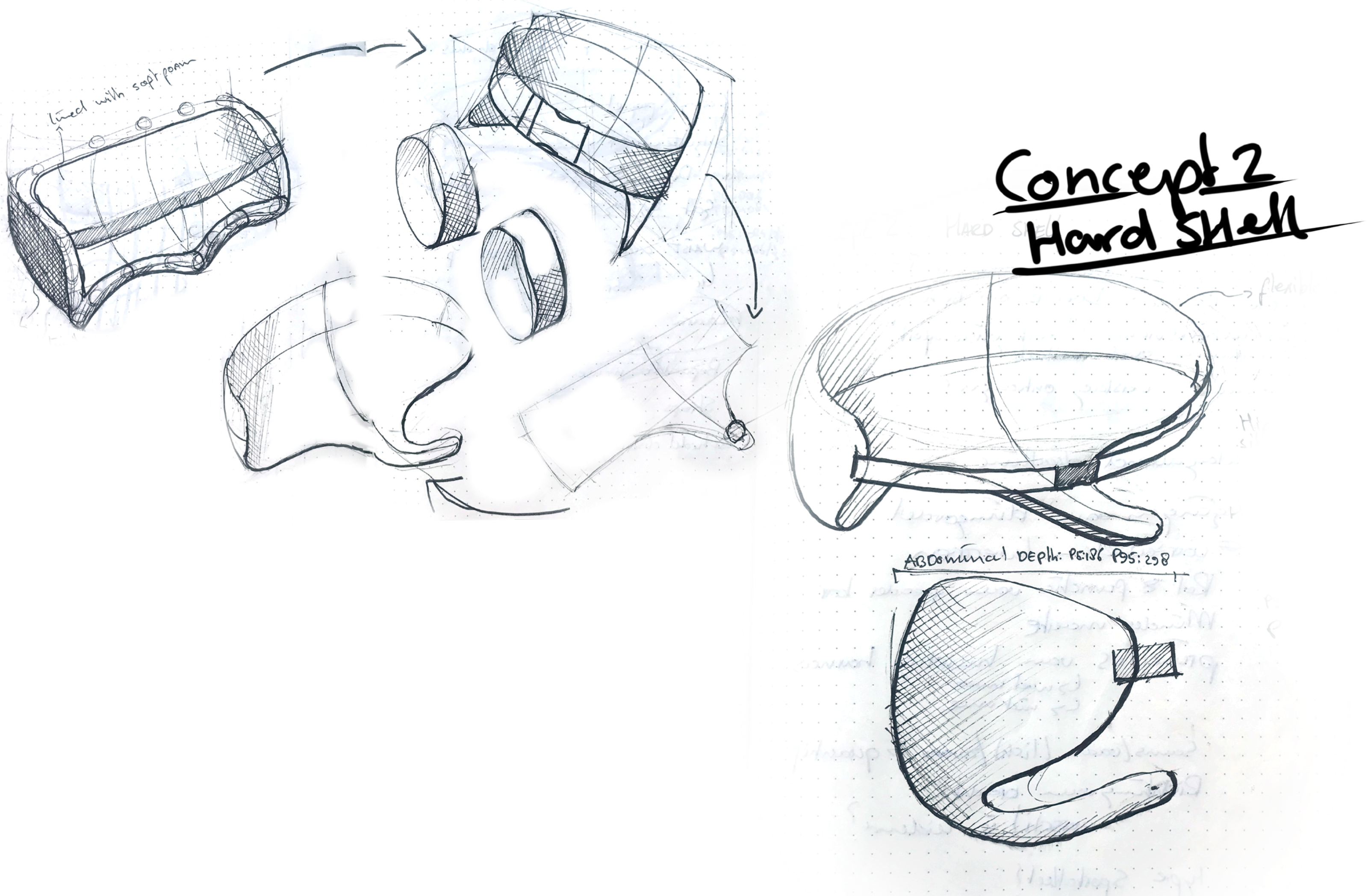
CHAPTER 9
CONCEPT DIRECTION

All the information that was gathered previously will be put into practice going into the first design sprint. Considering the existing problems of the ION Sonar and other harnesses, it was decided to create a new design for the harness. The goal of this sprint is to find the concept direction with the most promise. The concepts are evaluated on the before mentioned criteria, backed up with data from a usertest discussed later in this chapter. The best concept direction will form a skeleton on which improvements can be added.

9.1 IDEATION

Ideas were generated through the How-To method. During ideation two main idea directions could be identified, one where the harness is kept in place with leg straps and one where the leg straps are omitted and the harness wraps around the groin.





9.2 CONCEPTS

The ideation of the previous chapter led to the prototypes below. These prototypes were built as a minimal viable product so the working principle could be evaluated.

9.2.1 CLIMBING HARNESS

As mentioned in Chapter **3.4**, the design of a rope-access harness seems compatible with kitefoiling. **Figure 50** shows the final prototype that was used for testing. It contains an extra wide strap (1) that connects the leg straps to the waistbelt. At the crotch there is a loop with which the user can attach themselves to wires (2). This loop is connected to the waistbelt and the leg straps. The leg straps are pulled from the inside of the legs (3), which should put pressure on the outside where there is extra padding for increased surface area (4).

To ensure that as many people can test the prototype the measurements in **Table 13** were used. The CEASEAR database was used with mixed genders from an age of 18 – 30 years old, as the test participants would be mainly students at the faculty of Industrial Design Engineering at the Delft University of Technology. The lower end was the 5th percentile and the upper limit was the 95th percentile.

Some challenges were encountered during the building of the prototype. First, the size ranges proved to be difficult to realise. The back straps in particular had such a big range that they came above the waistbelt (5). Secondly, the straps and closures that were ordered were 3 cm wide and had to be sewn together to increase surface area for the back straps (1). Third, the sewing machine could not sew through the foam and the straps at the same time, so pockets had to be made that the foam could slide into and stay in place.

Table 13: Measurements of the prototype

Part	*Size range*
Waistbelt circumference (cm)	90 - 115
Back straps length (cm)	30 - 50
Leg straps (cm)	49 - 68

Figure 50: The prototype used for testing

9.2.2 HARD SHELL HARNESS

The fundamental problem of the kitefoiling harnesses that are currently in use, is that they put pressure on the inside of the legs as the harness is pulled upward. This concept attempts to alleviate this by taking inspiration from the 49er harness discussed in Chapter **3.3**, forgoing the leg straps but have the harness reach underneath the crotch (**Figure 51**). To ensure that the back of the shell does not tilt away from the back when the users are bending forward, the waistbelt is connected to the "tongue" (1).

Since this prototype contains a hard shell, the design is less adjustable than the Climbing Harness prototype. The main measurement is the hip circumference. Since the hard shell does not completely envelop the user, it was assumed that 2/3 of the hip circumference would be a sufficient width for the shell. This came down to a range of 59 cm to 72 cm. The distance from the top of the harness to the tip of the tongue was copied from the Dakine Vega (since the athletes liked the size of it), which was 45 cm.

As the prototype was built from one sheet of Vicureen and it contained double curvatures. The shape was first prototyped with cardboard and then laser cut. To release internal stresses, the plastic sheet was heated. Shaping the sheet correctly was quite challenging, a next step would be to strategically remove more material and thermoform the sheets. The initial yarns that were supposed to keep the straps in place proofed to be not strong enough and were replaced with rivets. During testing the tongue unfortunately broke, but a strap on the bottom ensured testing could continue.

Figure 51: The prototype used for testing

9.3 TESTING METHOD

The test was done in a lab setup. For this test, the participants were in two positions: first in the upwind position and then in the manoeuvre position. The upwind position were held for 2 minutes and the manoeuvre position for 30 seconds. **Figure 52** shows an example of the test setup. The participant put on the Climbing Harness and sat in the manoeuvre position and filled in the questionnaire. Then the participant changed to the upwind position. The participant was then be asked to fill in a questionnaire containing Likert-scale questions about the local perceived discomfort map. Afterwards, the participant changed to the Hard Shell and did the test again. When both harnesses had been tested, the participant was asked to rank the harnesses and is interviewed about the provided answers. This test was done with 8 participants, 3 males and 5 females. These participants were a mix of kiteboarders and students of Industrial Design Engineering without experience in kiteboarding. Ideally the test would have been done with the athletes, but due to Corona measures this was not possible at the time. The questionnaire and questions can be found in **"Appendix C: Design sprint 1 questionnaire".**

Figure 52: One of the participants testing the hard-shell prototype in the upwind position

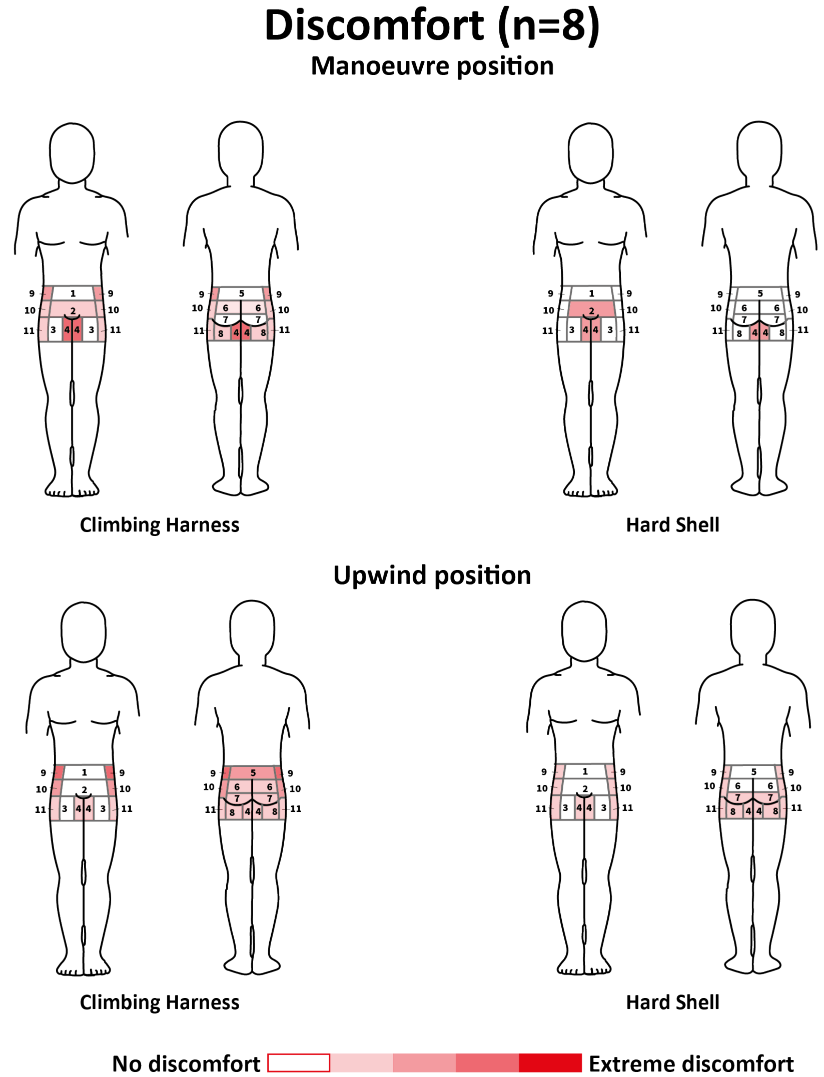


Figure 53: The results of the discomfort visualised

9.4 RESULTS

9.4.1 DISCOMFORT

In the manoeuvres, for the Climbing Harness the leg straps still cut into the groin, even though the attachment to the leg straps were placed differently. This is especially the case in the manoeuvre position. Furthermore, all participants noted a high discomfort at the Iliac Crest. The rated perceived discomforts were generally lower, but more concentrated in area 2 and 4 for the Hard shell. These results are visualised in **Figure 53**. There is quite a difference in the normal distribution between the areas (**Figure 54**), which could be explained due to a gender difference.

For the upwind posture, the participants noted an almost extreme perceived discomfort at the Iliac Crest for the Climbing Harness. The other regions were indicated on the scale as quite uncomfortable or below. While wearing the Hard shell, the perceived discomfort in the upwind position drastically decreased for area 2 and 4, but overall slightly increased. The distribution of the responses were quite high for the Hard Shell, and really high for area 10 for the Climbing Harness (**Figure 55**).

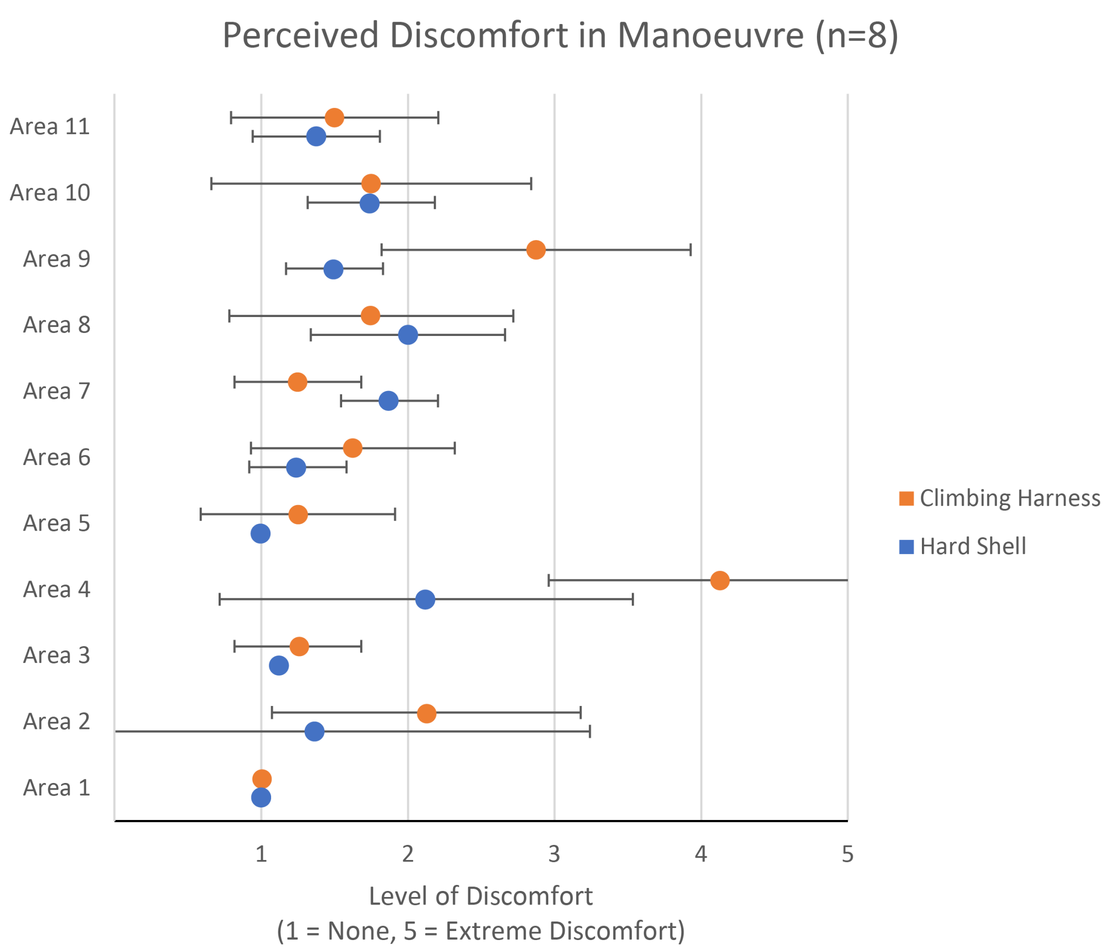


Figure 54: The normal distribution of the perceived discomfort in manoeuvres

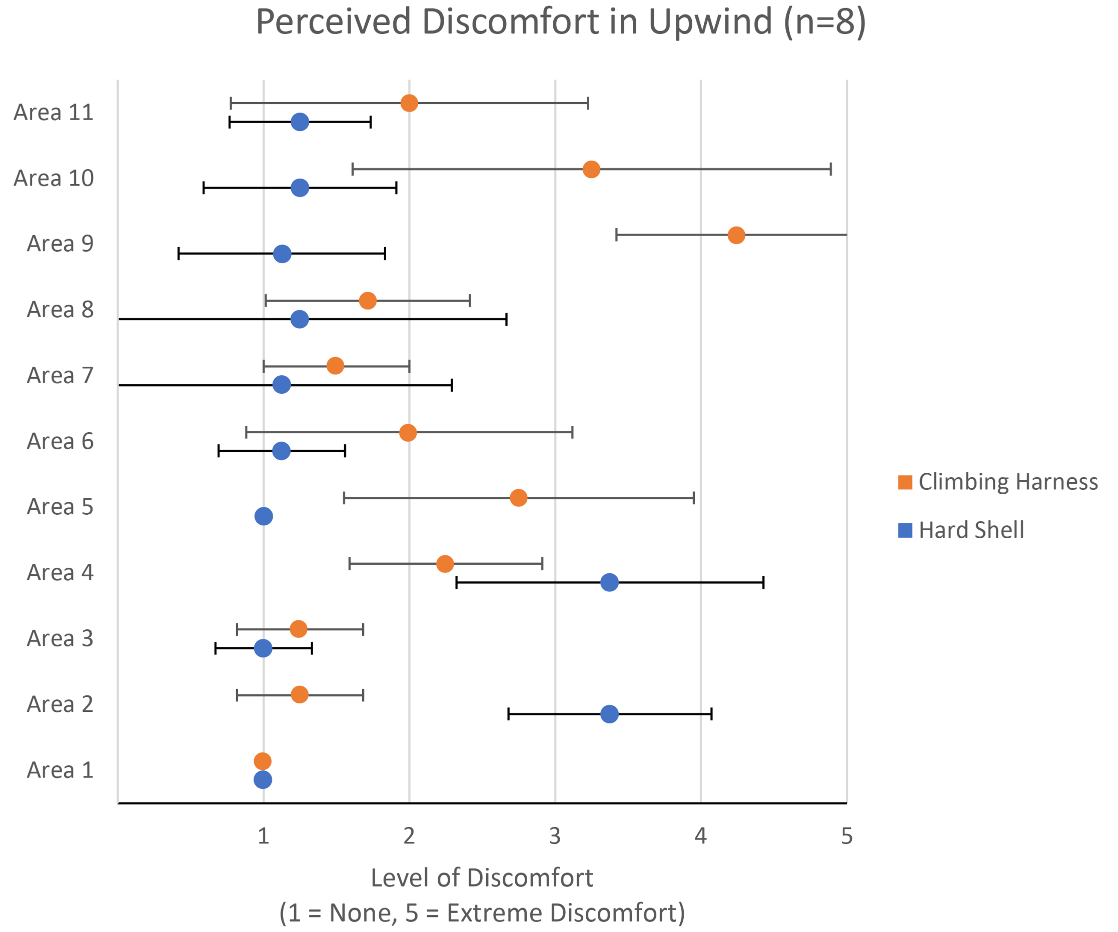


Figure 55: The normal distribution of the perceived discomfort in upwind

9.4.2 SUPPORT

In the manoeuvres for the Climbing Harness, the participants did feel supported in regions 5, 6 and 7 exactly where the athletes indicated where they would like to be supported. For the Hard shell, the participants did perceive less support compared to the Climbing Harness, and this lack of support was mainly in area 2 and 4. These results are visualised in **Figure 56**. The distribution of the responses is also quite high, especially in areas 5 and up (**Figure 57**).

In the upwind position the results are a bit different. The Climbing Harness supports exactly where the athletes indicated they wanted to feel support. The perceived support for the Hard shell was especially noted in areas 7 and 8, with no support felt in area 5. During testing it could be seen that the harness was pulled from under the participant, so the lower back was not supported. Also in the upwind position the distribution of responses are high from area 5 and up (**Figure 58**).

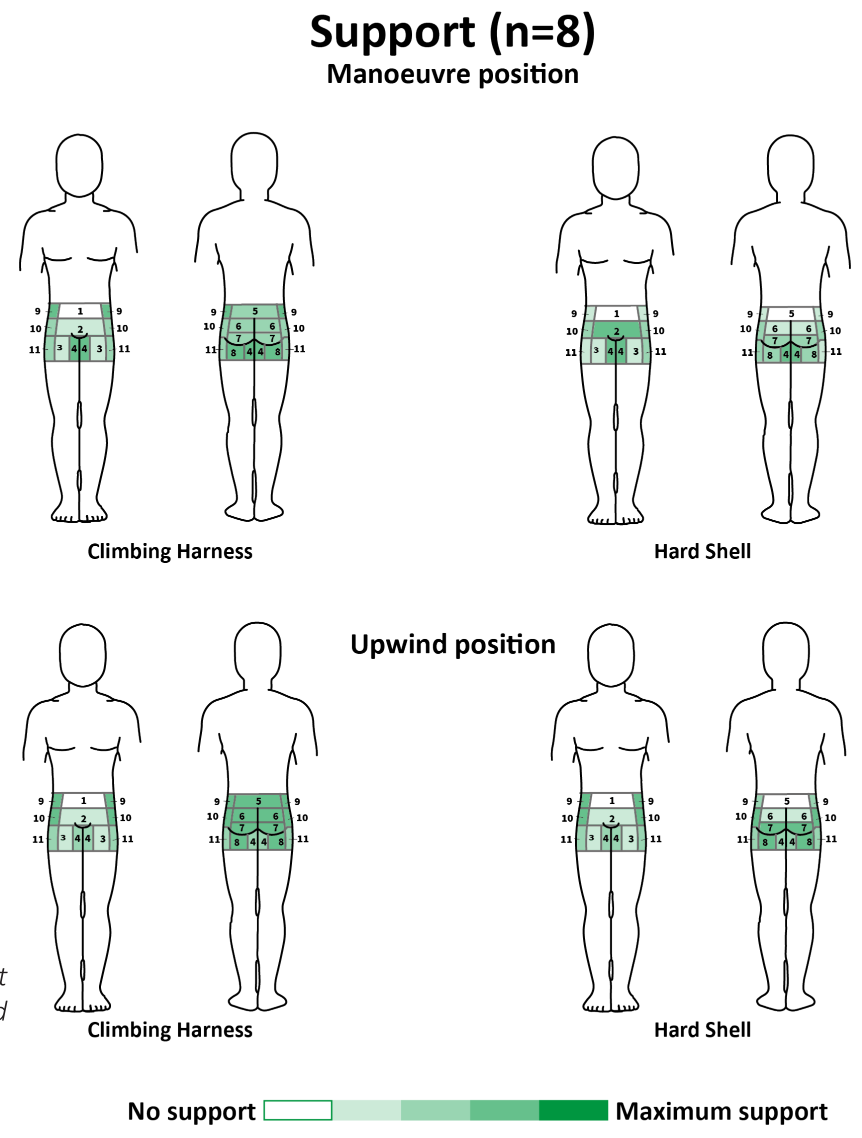


Figure 56: The results of the support visualised

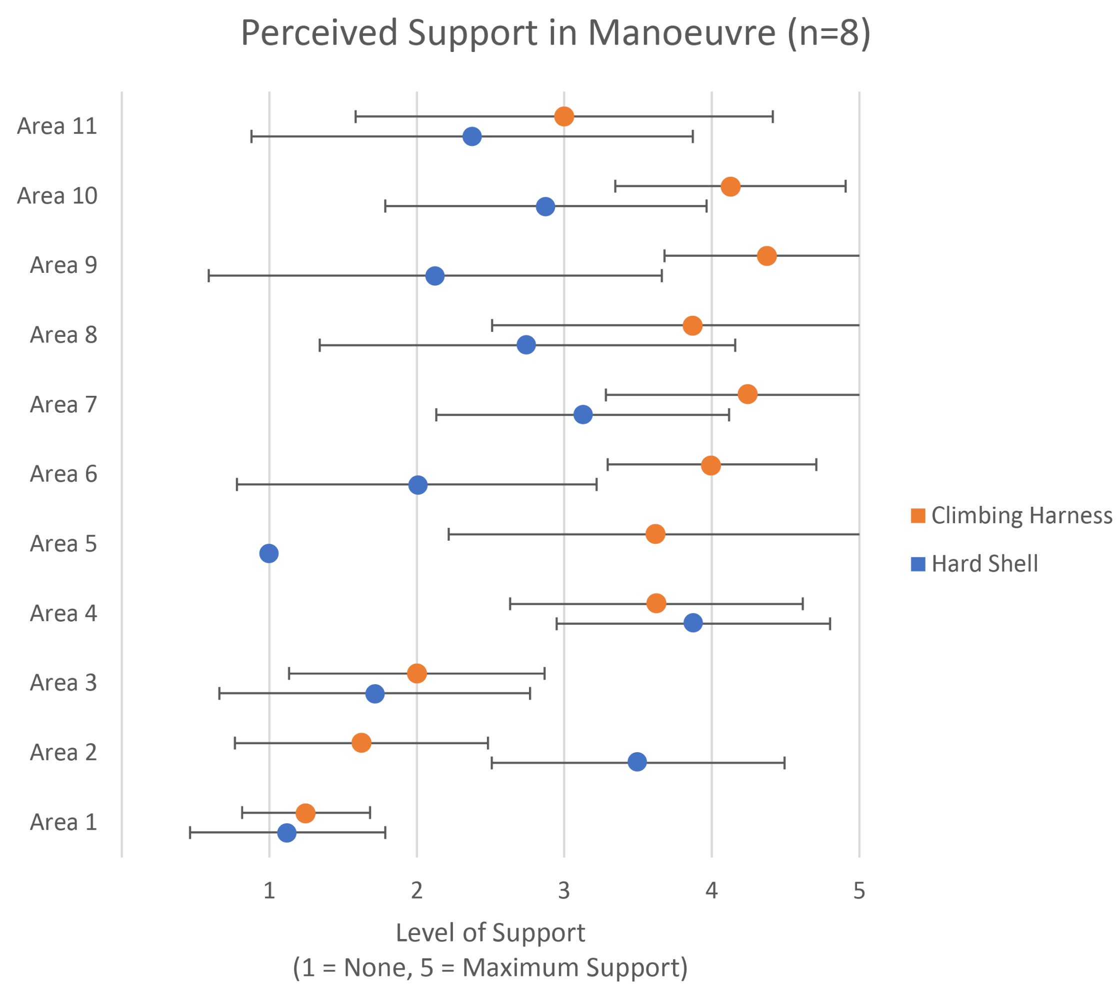


Figure 57: The normal distribution of the perceived support in manoeuvres

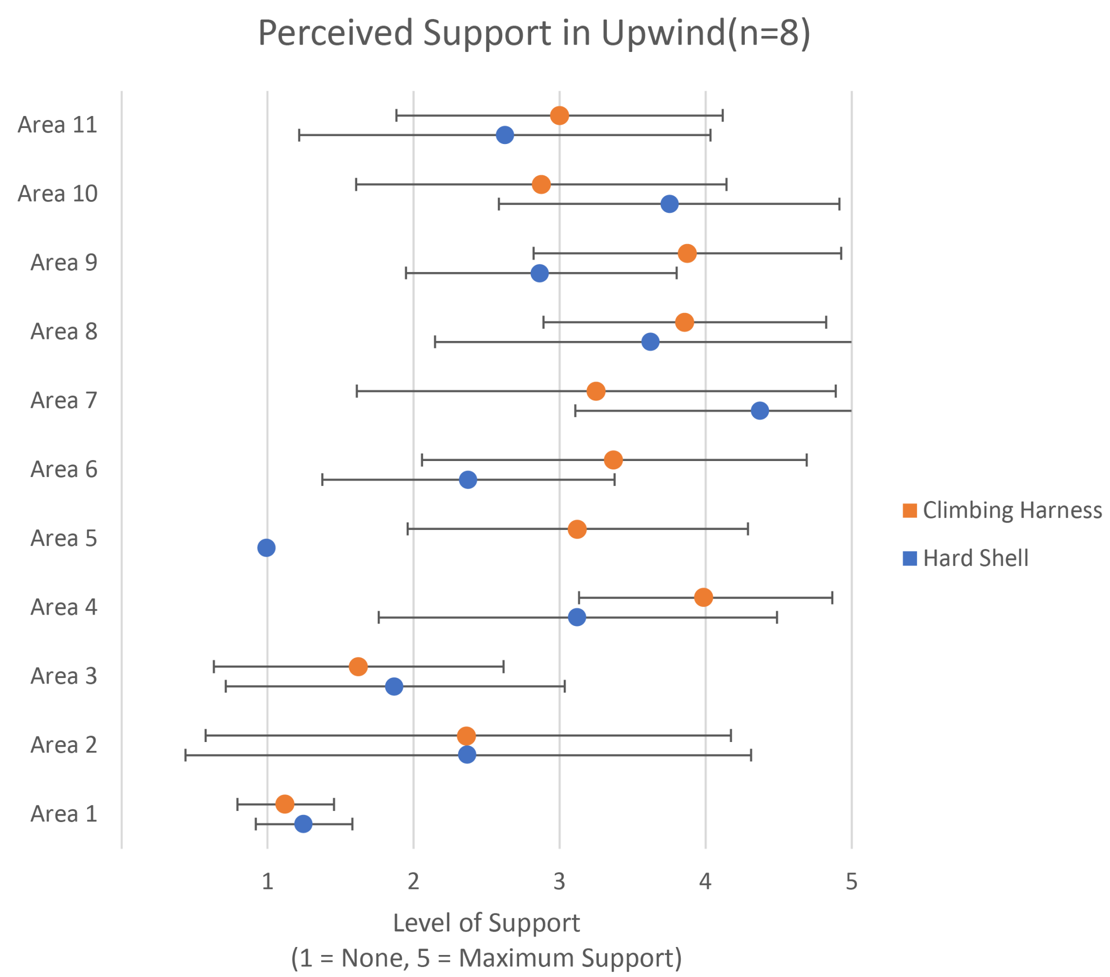


Figure 58: The normal distribution of the perceived support in upwind

9.4.3 PREFERRED CONCEPT

When the participants were asked which harness they preferred, only 1 participant preferred the Hard Shell. All participants that had experience in kiteboarding preferred the Climbing Harness. Even though the Hard Shell was perceived to have less discomfort, the support that the Climbing Harness provided was more important to them. Some participants even mentioned that since the Hard Shell was so comfortable, they did not feel supported. Since the Hard Shell featured, of course, a hard shell, this sometimes bulged out, moving completely away from the body. The Climbing Harness fit better according to some participants, which was another reason why they preferred that.

9.5 CRITERIA EVALUATION

The concepts are evaluated against the criteria mentioned in **Chapter 8** using Harris Profiles. In the end the Climbing Harness scores better for criteria 1, fully supporting the user where the athletes indicated they wanted to be supported. In its current form the Hard Shell scores relatively bad, not supporting the athlete at all at the lower back and barely around the Sacrum. For both directions the attachment point did move around quite a bit, since the loop, which the wires were connected to, was too big and stretched in the direction of the force. The Climbing Harness did very much cut into the groin of the participants during a manoeuvre, but the duration was too short for the participants to notice any blood flow reduction to the legs. In the upwind position this was not the case at all. The Hard Shell scores much better for this criteria as there is no pressure on the legs. For both concepts the attachment point did stay around the crotch quite well, but as mentioned before was able to move around a bit too much to get the best score.

Since the Climbing Harness scores better on the most important criteria it is considered the superior direction. However, some clear improvements still have to be made and will be discussed in the next chapter.

LIMITATIONS

As mentioned in the results section, the normal distribution of the responses was quite high. This is partly due to the subjective nature of the research, but could also be explained by the difference between the two genders. This was not researched further, but could be an interesting subject to be examined closer in the future. Furthermore, not all participants in this test had experience in kitesurfing or kitefoiling, which could have impacted their perceptions of discomfort and support.

Table 14: Harris Profile of the two concepts. Not all criteria are evaluated since the materials have not been chosen yet.

	Climbing Harness				Hard Shell			
Criteria	--	-	+	++	--	-	+	++
The harness should support the athlete at the Gluteus Maximus, the hips and at the Lumbar spine			■	■		■		
The harness should not move up the body during a manoeuvre			■				■	
The harness should not be a source of discomfort that causes the athlete to change posture		■					■	
The harness should not cause major discomfort in the upwind and the manoeuvre postures	■	■					■	
The attachment point between the kite and the harness should be at the level of the crotch			■		■	■		
The attachment point between the harness and the kite should not be able to move around		■			■	■		
Major forces should be loaded perpendicular to the body as much as possible			■			■		
The harness should feel dependable, so the athlete does not feel like they have to hold back			■	■			■	
The harness should at least withstand a pulling force of 3 kN in the upwind position								
The harness should not limit freedom of movement			■	■	■	■		
The shape of the harness should be adjustable by the athlete			■	■	■	■		
The harness should not evenly distribute the forces			■	■		■		
The materials used should be UV resistant								
The materials used should be abrasion resistant								
The materials should be compatible with salt water								

9.6 CONCLUSION

There appears to be a correlation between the pressure felt on the body and the feeling of support. In the end the Climbing Harness scored best out of the two concepts and will be used for the next design sprints. The testing showed areas of discomfort at the Iliac Crest, the groin and the lower back.

The pressure should be lessened on the Iliac Crest. As more force is put on the attachment point the harness puts pressure on the bone. Since the loop around the hipbone was not reinforced, the band collapsed inward. This pressure can be reduced by a way to distribute the forces more, or by keeping the harness in a D-shape from the top. The Hard Shell contained a solid material that first needed to deform before the foam distributed the force over a bigger surface area, which proved to be quite effective. The next chapter will explore how to best reduce this pressure. Especially in the manoeuvre position the Climbing Harness is still perceived as very uncomfortable. The bands still cut into the groin of the wearer. The pressure should also be distributed better on the lower back, as the participants reported discomfort in area 5 for the Climbing Harness. This is where the waistbelt was located.

CHAPTER 10
HIP PRESSURE

In the previous chapter a concept direction was chosen, which had two main pain points: The pressure on the Iliac Crest and the pinching at the groin. This design sprint will focus on addressing the first pain point, the pressure on the Iliac Crest.

10.1 IDEA GENERATION

Ideas were generated following the How-To method, in which a series of solutions are generated for a stated problem. In this case the How-To was phrased as follows: How to reduce pressure on the Iliac Crest? An overview of the generated ideas can be found in **Figure 59**.

The ideas were evaluated using the plus-minus method, which lead to three ideas: Extra Padding, spreaderbar, stiff outer layer. Most harnesses offer a combination of these solutions, but it is not clear which solution performs best. Therefore, they are developed into separate concepts.

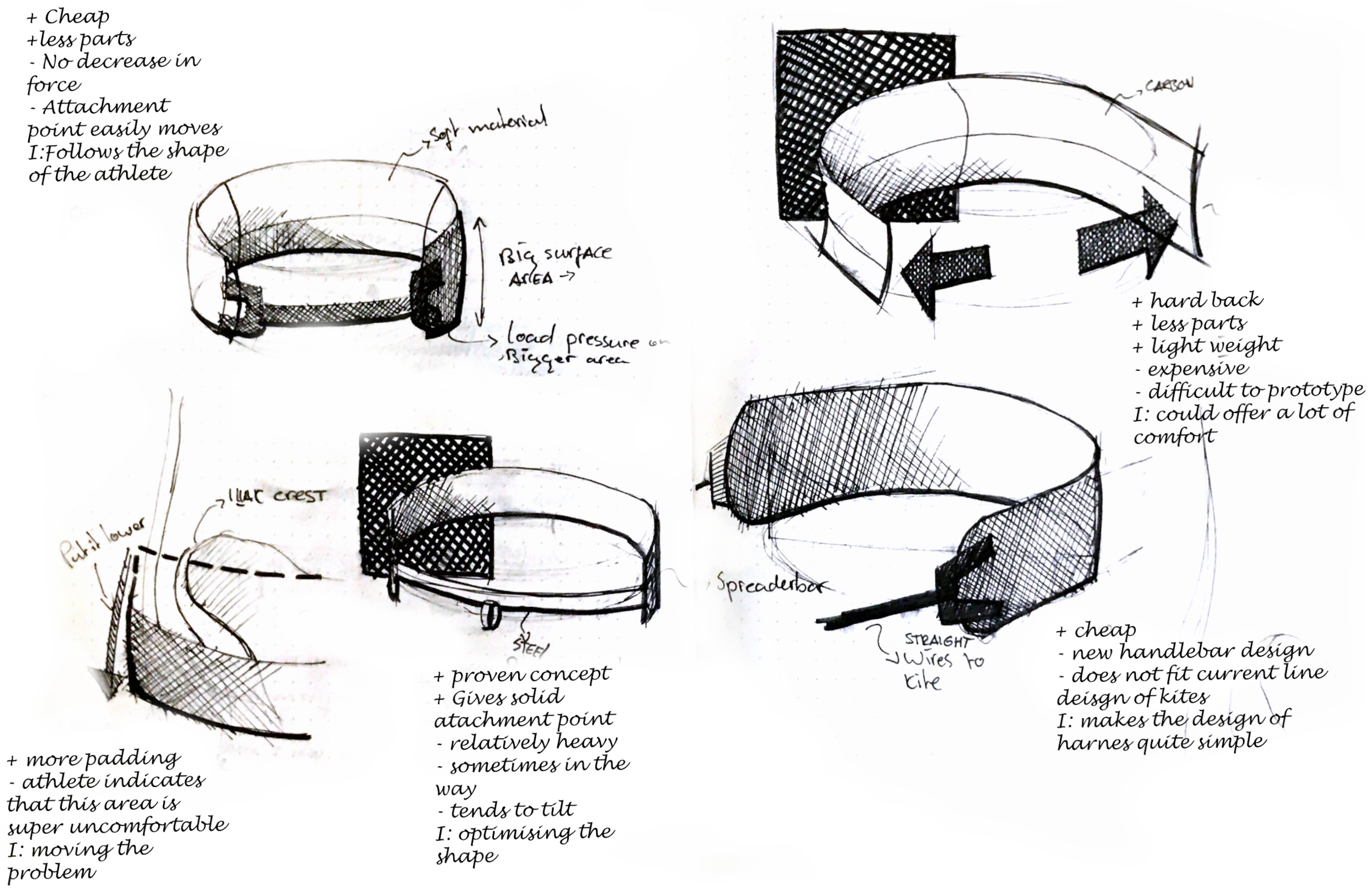
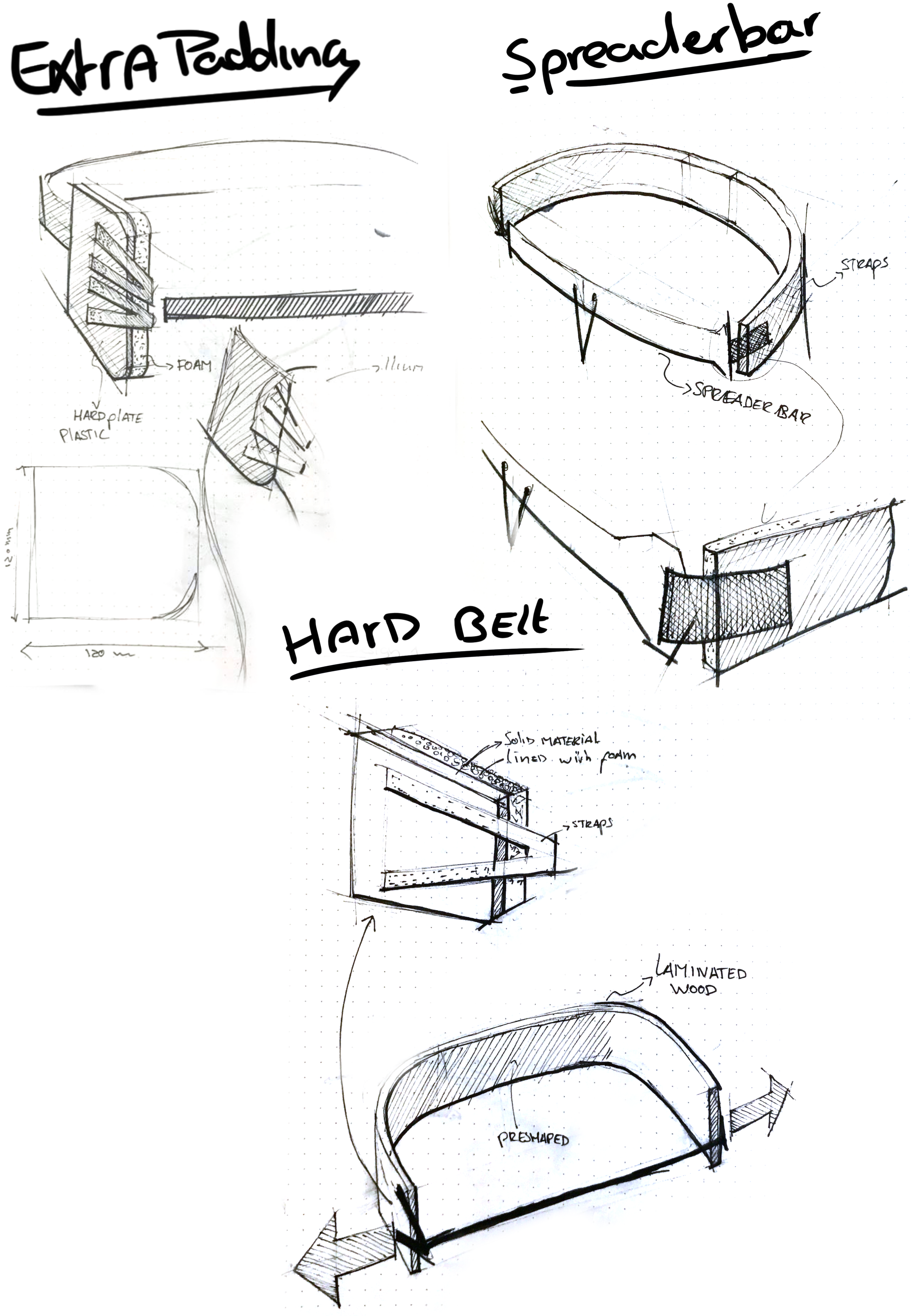


Figure 59: The generated ideas



10.2 CONCEPTS

To be able to accurately test the effect of the different concepts they will be built using a modular system. This system consists of Velcro on the inside of the hipband of concept 1 of the previous sprint. Five mm EVA foam will be used for all versions. The concepts are explained in-depth in the following paragraphs.

10.2.1 CONCEPT 1: FORCE DISTRIBUTION

In this concept the pressure on the Iliac Crest is lessened by increasing the surface area. Instead of a width of 6 cm, this concepts spreads the forces over a surface of 12 x 13 cm. On each side there are two individual loops that are connected through another loop (**Figure 60**). These two individual loops are connected at the back of a 2 mm PS plate through rivets. The PS plate can still deform but ensures that the pressures are distributed better.

Figure 60: Concept 1

10.2.2 CONCEPT 2: SPREADERBAR

The spreaderbar concept uses the spreaderbar from the Dakine Vega, but most of the hook is cut off (**Figure 61**). It is connected with the waistbelt using 1 strap on each side, spreading the load over the strap width of 6 cm. The straps can be tightened or loosened.

Figure 61: Concept 2

10.2.3 CONCEPT 3: HARD BELT

The Hard Belt concept reduces the pressure on the Iliac Crest by barely deforming, but fitting snugly around the athlete. Since the concept barely deforms, it is important that it follows the contour of the body.

The corresponding models of the filtered CEASEAR database (Chapter **4.4)** were downloaded and averaged. The contour at the height of the Iliac Crest was exported and used to form the belt, **Figure 62** illustrates this process. The shape was realised through laminating 1 mm triplex wood in a mould. **Figure 63** shows the final result.

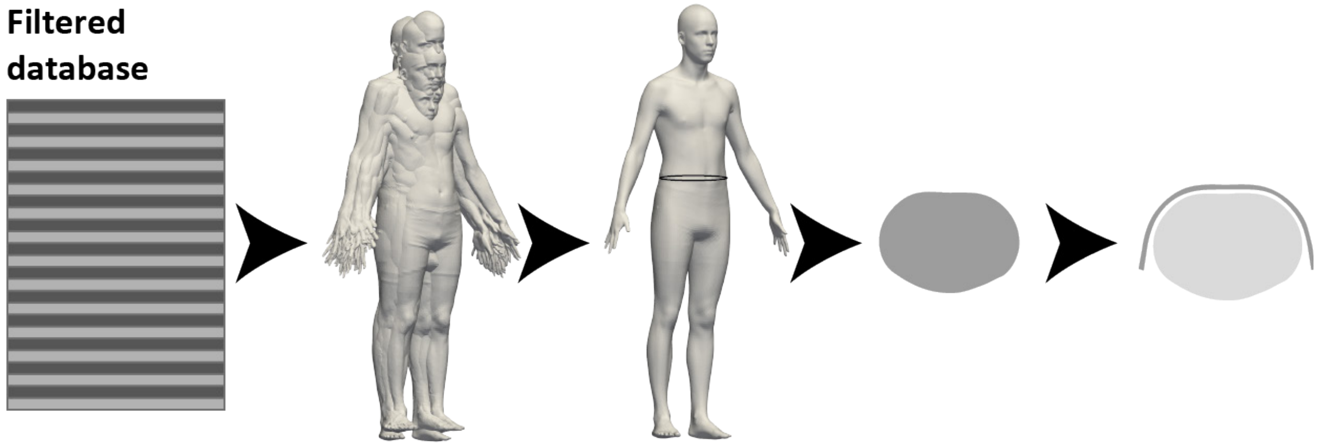


Figure 62: The process to get the shape of the hard shell

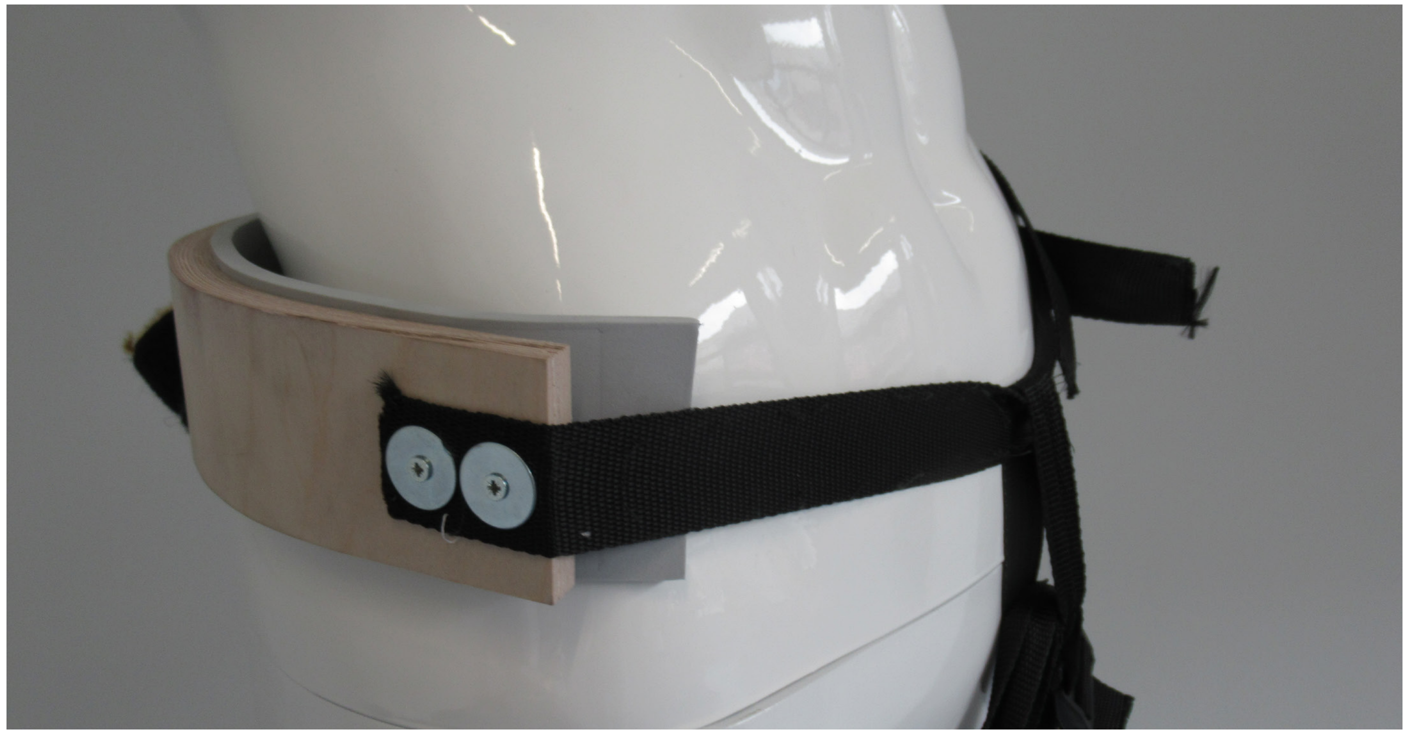


Figure 63: Concept 3

10.2.4 TESTING METHOD

The concepts were mounted on the Climbing Harness built in the first design sprint. The concepts were evaluated with 3 male athletes. The athlete wore the design in the upwind position for 2 minutes, then the athlete was asked to fill in a local perceived discomfort map, while still in the position (See **"Appendix D: Design Sprint 2 & 3"**. To be able to evaluate the effectiveness of the concepts, a control measurement was done with the harness without improvements. After the concepts had been tested the participants were asked the following questions:

- Which concept do you ultimately prefer for the upwind position and why?
- How do you expect these concepts to hold up while on the water?
- What are your main concerns with these concepts in the upwind position?

Figure 64 shows the test setup, which includes the test setup for the next design sprint.

Figure 64: The test setup

10.3 RESULTS

The results from the questionnaire are visualised in **Figure 65** and **Figure 66** and standard deviations are displayed in **Figure 67 and Figure 68**. Again, there is quite a significant standard deviation in certain areas, for both the perceived discomfort and the perceived support. Especially for the perceived support the answers deviate substantially. A table containing all the answers can be found in **"Appendix D: Design Sprint 2 & 3"**.

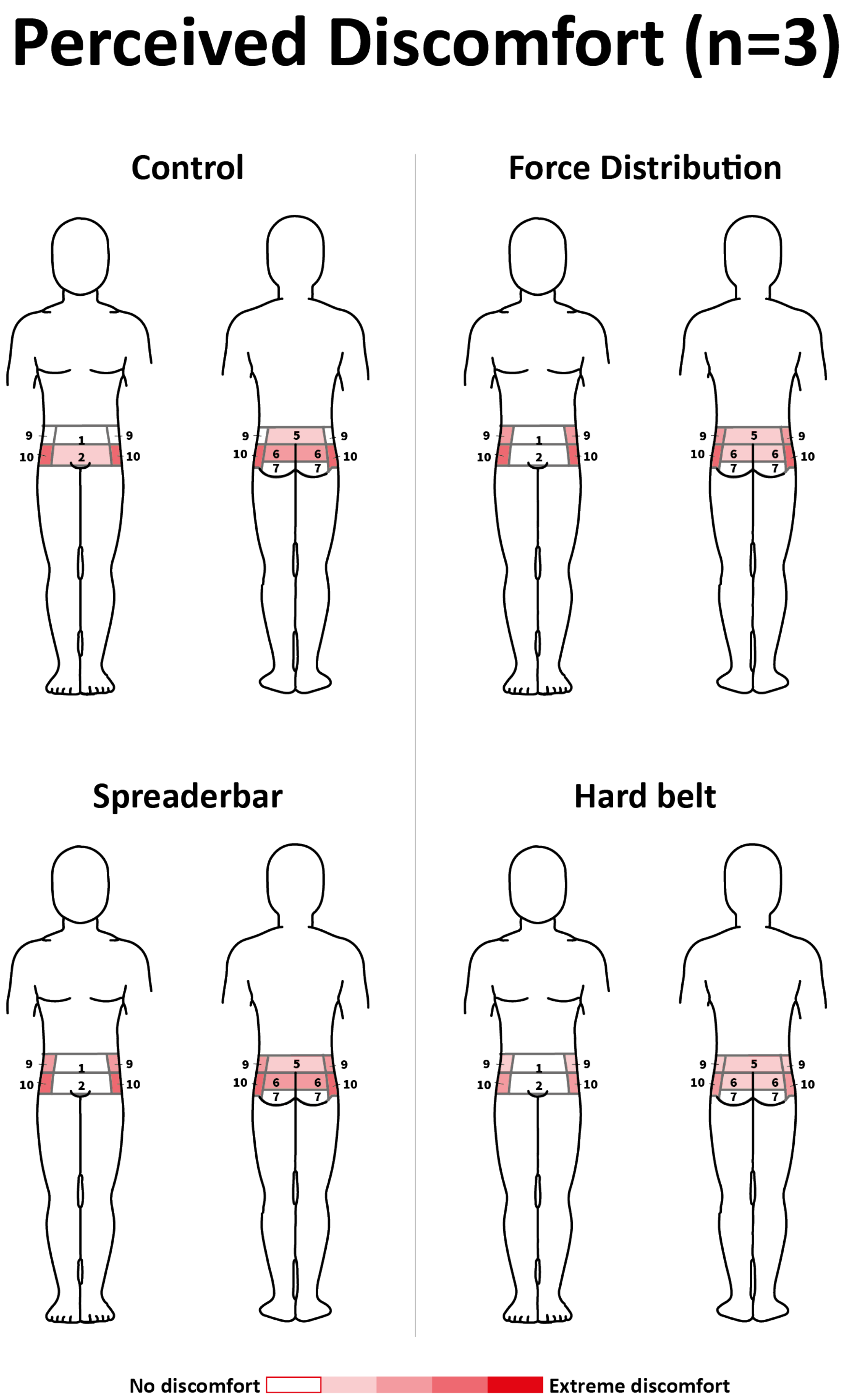


Figure 65: The perceived discomfort visualised of the concepts

The control is perceived as very uncomfortable at the sides of the pelvis. Also, around the upper half of the Gluteus Maximus the control concept is seen as quite uncomfortable. The force distribution has similar results, where the sides of the pelvis are also very uncomfortable, but the Gluteus maximus is barely uncomfortable. The spreaderbar is barely an improvement on the control. The Hard Belt is perceived as better, with the worst score being 'quite uncomfortable'. As for the perceived support, there is little difference between the concepts.

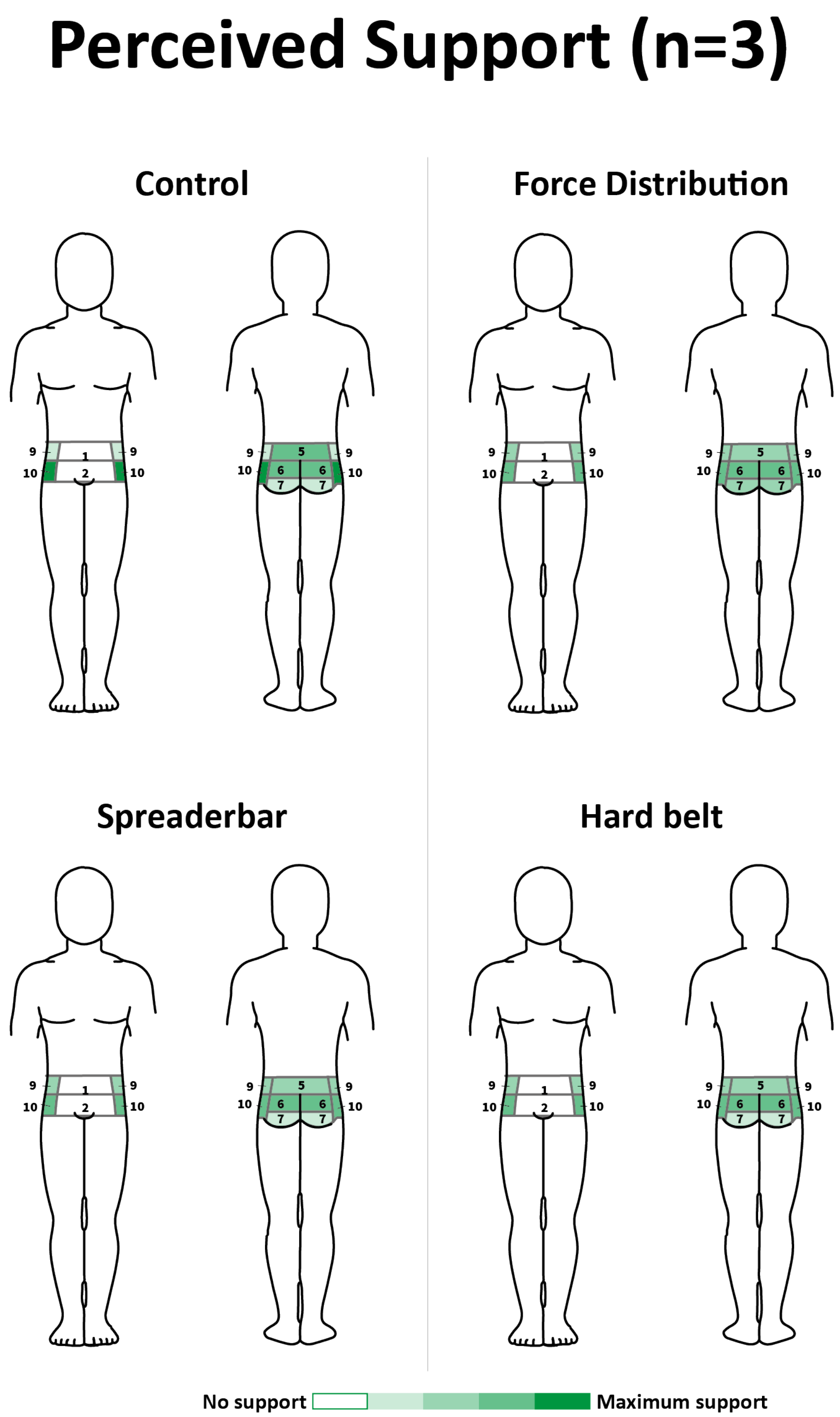


Figure 66: The perceived upport visualised of the concepts

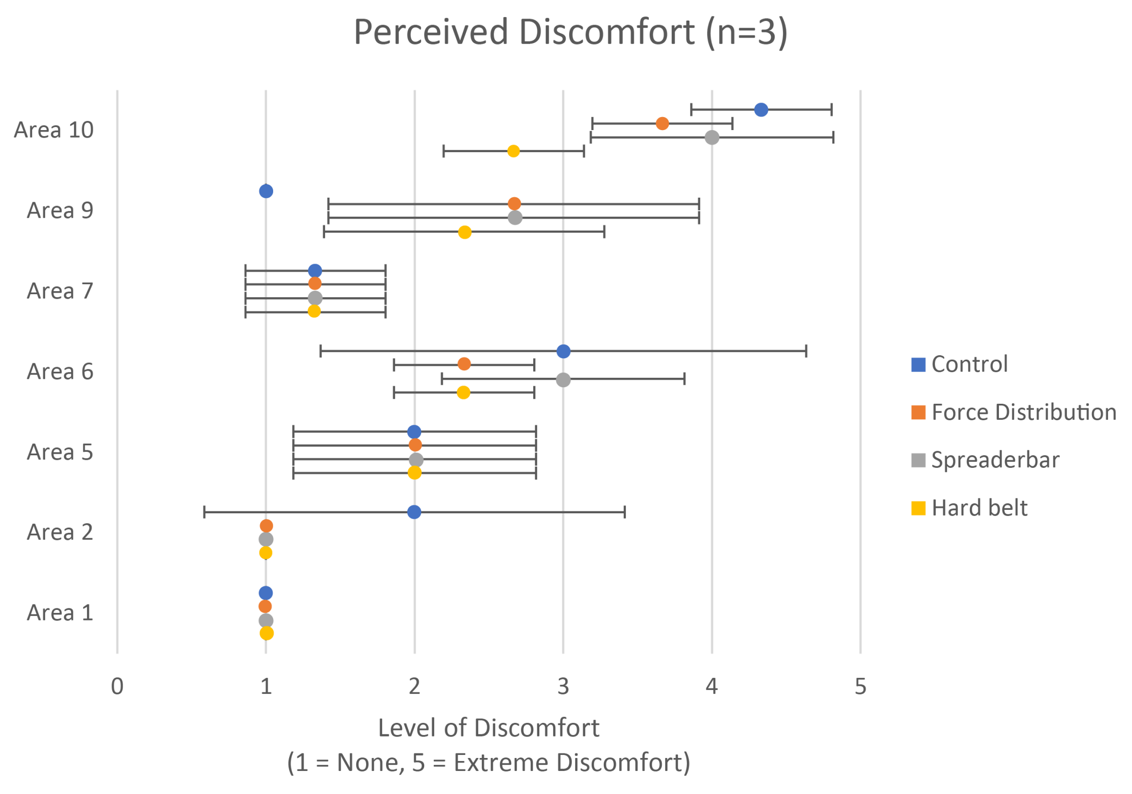


Figure 67: The standard deviation for the perceived discomfort

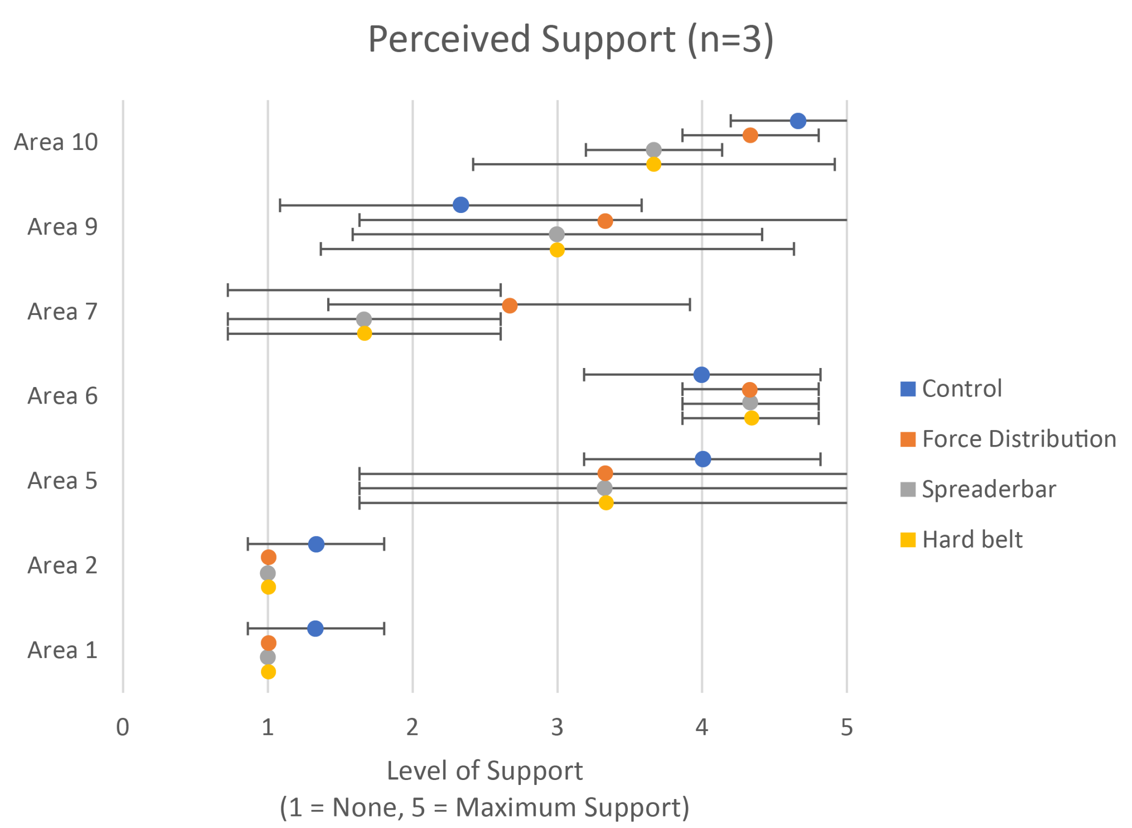


Figure 68: The standard deviation for the perceived support

10.3.1 INTERVIEW

When asked which concept the participants preferred, all three participants preferred the Hard Belt. One participant indicated that if the fit would have been slightly better, the concept would have been perfect for him. Another indicated that the support was the best in the Hard Belt, but was a little uncomfortable. The last participant said that he liked the feeling of direct feedback the concept gave him.

The participants did indicate some concerns about the Hard Belt. One participant said that the measurements were slightly too big and therefore the pressure was still quite high. Another said that the way the concept fit would be a very important factor and if it would not fit properly, the Hard Belt would start hurting a lot. The last participant had two main concerns with the Hard Belt. First, he was not sure if the concept in its current state would be stiff enough, as he mentioned that the forces while kitefoiling could be quite a bit higher than in this test (same conclusion in **Chapter 5**). Secondly, he was concerned if the Hard Belt would sit tightly enough around the pelvis, lso ensuring it stays in place when the athletes twist their hips for a manoeuvre.

10.4 CRITERIA EVALUATION

From the Harris Profile shown in **Table 15**, the Hard Belt is the best option. All three concepts score good for support and not moving up the body. The Hard Belt has the least amount of discomfort, comfortably beating the other concepts. The location of the attachment point is not as good for the spreaderbar, since it cannot be pulled down enough. All three concepts score poor for the amount that the attachment point is able to move, since in the current iteration it consists of straps and will have to be improved upon. The only other outlier in the Harris Profile is the adjustability of the Hard Belt, as it is a solid piece, the form will have to be shaped to the athlete personally.

Table 15: The Harris Profile for the three concepts. Criteria concerning materials are again not filled in since this is not yet considered.

	Force Distribution				Spreaderbar				Hard Belt			
Criteria	--	-	+	++	--	-	+	++	--	-	+	++
The harness should support the athlete at the Gluteus Maximus, the hips and at the Lumbar spine			■	■			■				■	
The harness should not move up the body during a manoeuvre			■				■				■	■
The harness should not be a source of discomfort that causes the athlete to change posture			■				■				■	
The harness should not cause major discomfort in the upwind and the manoeuvre postures		■			■	■					■	■
The attachment point between the kite and the harness should be at the level of the crotch			■			■					■	
The attachment point between the harness and the kite should not be able to move around	■	■			■	■			■	■		
Major forces should be loaded perpendicular to the body as much as possible		■					■				■	
The harness should feel dependable, so the athlete does not feel like they have to hold back			■				■				■	■
The harness should at least withstand a pulling force of 3 kN in the upwind position												
The harness should not limit freedom of movement			■	■			■	■			■	■
The shape of the harness should be adjustable by the athlete			■	■			■	■	■	■		
The harness should not evenly distribute the forces			■	■			■	■			■	■
The materials used should be UV resistant												
The materials used should be abrasion resistant												
The materials should be compatible with salt water												

LIMITATIONS

The quantity of participants in this study is extremely limited. Due to this low participant count, the range of perceived support and discomfort is sometimes really significant. Due to the lack of time and restrictions, it was not possible to recruit more participants. Therefore, it was chosen for this analysis to only work with the calculated averages.

10.5 CONCLUSION

The Hard Belt appears to be slightly more efficient in reducing the pressure at the Iliac Crest. Especially at the area just below it, the participants note a difference between the Hard Belt and the other two concepts. The participants also noted that there seems to be a correlation between the discomfort and the amount of support they experience. This is in line with what the participants noted in the previous test.

All three participants liked the Hard Belt the most. Their enthusiasm for the concept could already be noted when they saw it for the first time. There could be some bias there, however the numbers do show less discomfort. There are some concerns that come with the stiffness of the Hard Belt. The main concern is that it would have to fit very well for there to be no discomfort.

This test shows that a kitefoiling harness does not need to have a spreaderbar to alleviate the discomfort at the Iliac Crest, even though all existing harnesses examined have one. The Force Distribution and the Hard Belt even proved to be slightly better. There is quite a significant standard deviation in some results due to the low participant count. Ideally the test should have been conducted with more participants, but in doing so, the results would have most likely skewed more towards discomfort, since the Hard Belt would not fit properly.

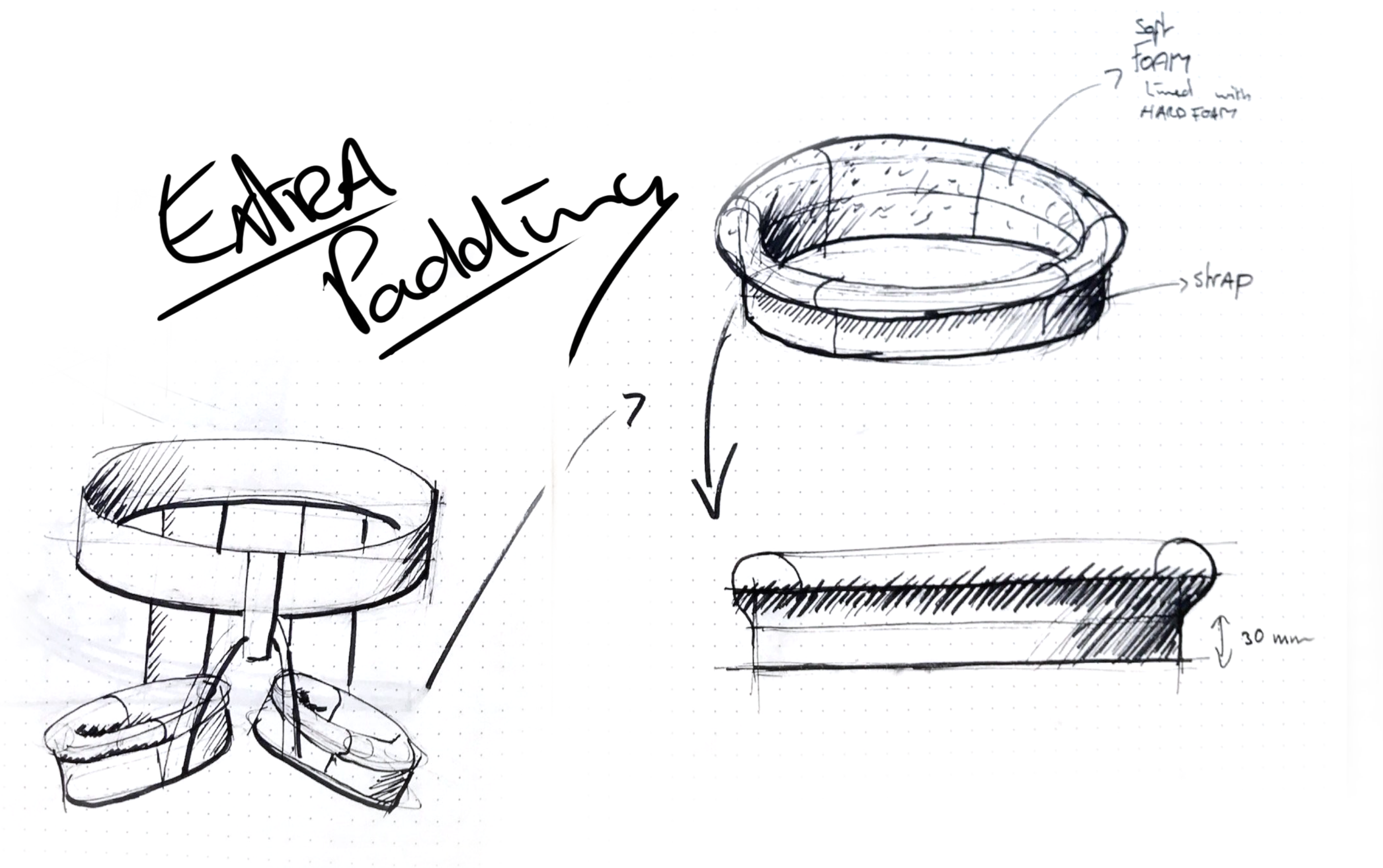
Out of the three concepts proposed, the Hard Belt scores best. It is evaluated with the least amount of discomfort and also scores best in the Harris Profiles. The experienced discomfort is still higher than it ideally should be. The concept could be made stiffer or be combined with the force distribution or both.

CHAPTER 11
GROIN PINCHING

The previous design sprint solved the problem of too much pressure on the hips. The goal of this design sprint is to alleviate the discomfort at the groin, as shown in **Chapter 9.** This design sprint will follow a similar methodology as the previous one, with first doing brainstorming, developing the ideas into concepts and testing these concepts with the athletes. Lastly, the concepts will be evaluated through a Harris Profile.

11.1 IDEATION

Ideas were generated through the How-To method with the phrase; How to relieve pressure at the groin. These ideas were then clustered **Figure 69**. Two of these clusters (Moving the problem & Decrease pressure) seemed to have promise and were further developed. One concept consists of more foam to increase the surface area at the groin. The other concept moves the leg straps to the middle of the leg to entirely remove the pressure at the groin.



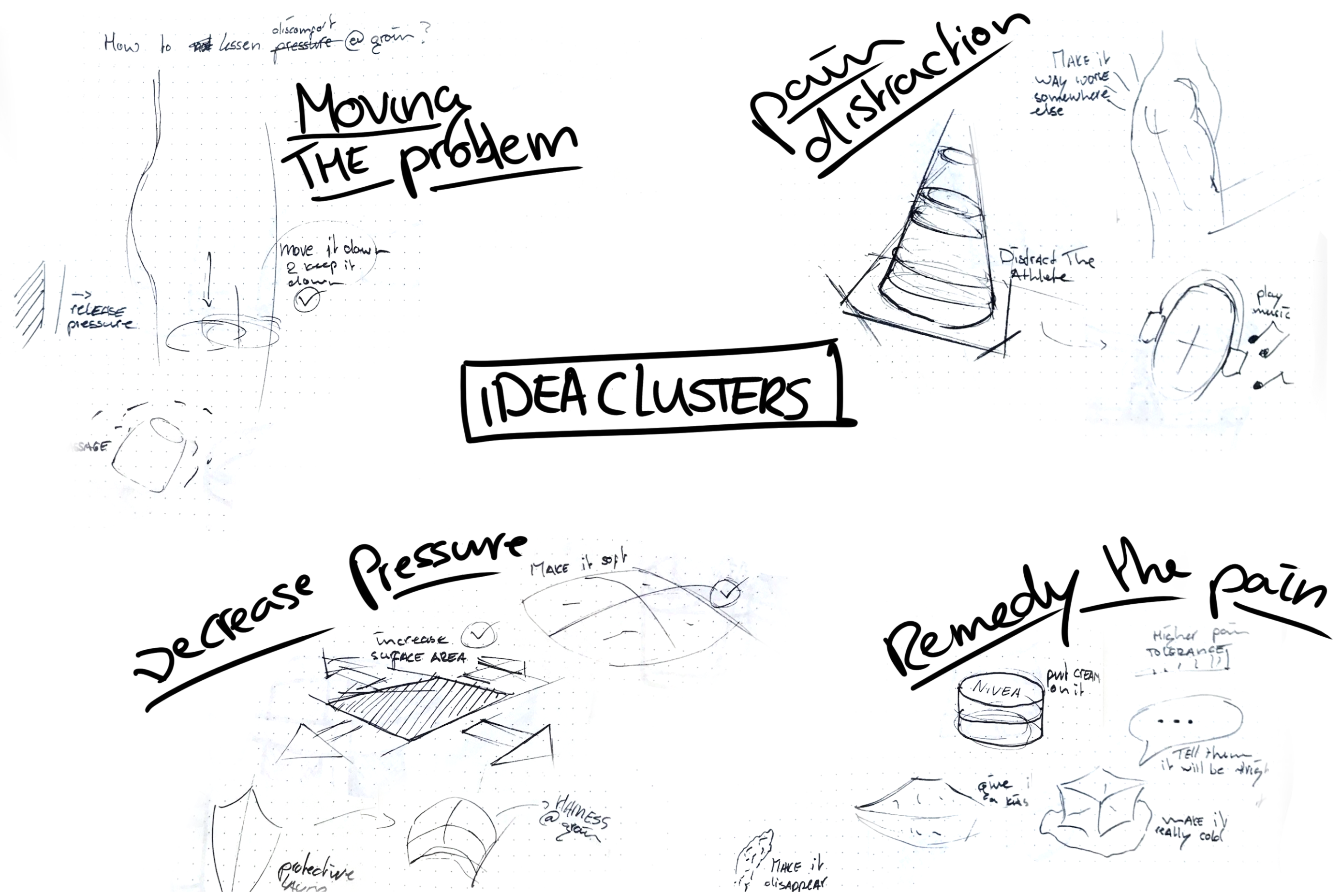
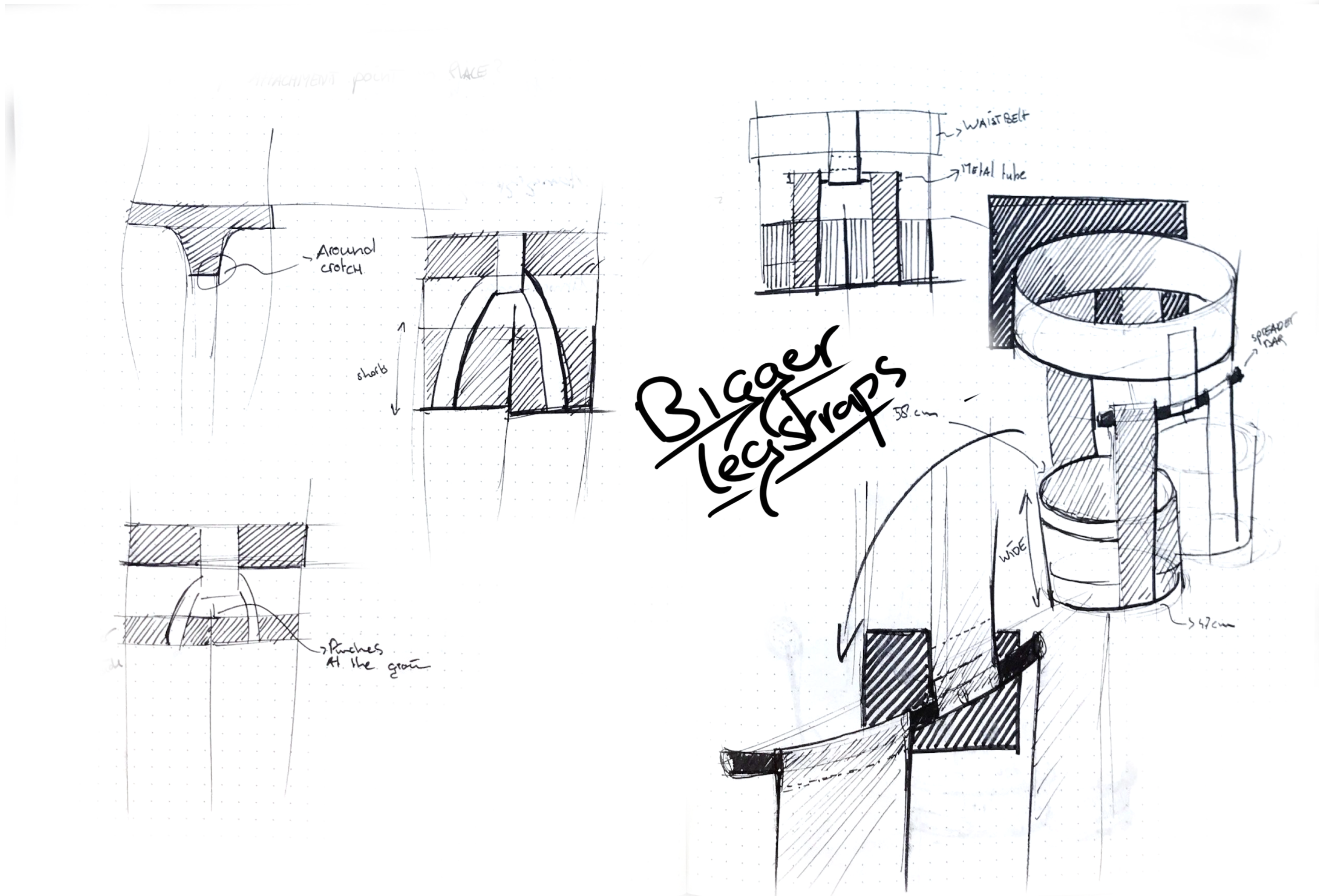


Figure 69: The generated ideas and clusters



11.2 CONCEPTS

Just like the previous chapter, the prototypes for these concepts could be added and removed from the harness. This ensured that for testing the circumstances were similar and the initial design as seen in **Chapter 9** could be used for a control measurement.

11.2.1 EXTRA PADDING

The first concept can be seen in **Figure 70**. The prototype consists of two different foams to decrease the pressure, while making it more uniform. As the leg straps were pulled towards the groin, more foam is placed above the strap. This should ensure that the strap does not slide off the foam and stays put.

Figure 70: Concept with extra padding. Note that in this picture only one side has the extra padding as the other pad did not fit on the mannequin as well.

11.2.2 BIGGER LEG STRAPS

The second concept moves the leg straps away from the groin and lower on the leg (**Figure 71**). To ensure that the blood flow is not inhibited the size of the legstraps are increased and lined with foam. The connection to the attachment point is a horizontal metal rod that ensures that all straps stay clear of the groin area.

Figure 71: Concept with bigger leg straps

11.3 TESTING METHOD

Testing was done on the same day as the previous chapter and with the same participants. The participant wore the design in the manoeuvre position for 30 seconds, then the athlete was asked to fill in a local perceived discomfort map while still in the position (See **"Design Sprint 2 & 3"**. To be able to evaluate the effectiveness of the concepts, a control measurement was done with the harness without improvements. After the concepts had been tested the participants were asked questions about the concepts. These questions were as follows:

- Which concept do you ultimately prefer for the manoeuvre positions and why?
- How do you expect these concepts to hold up while on the water?
- What are your main concerns with these concepts in the manoeuvre position?

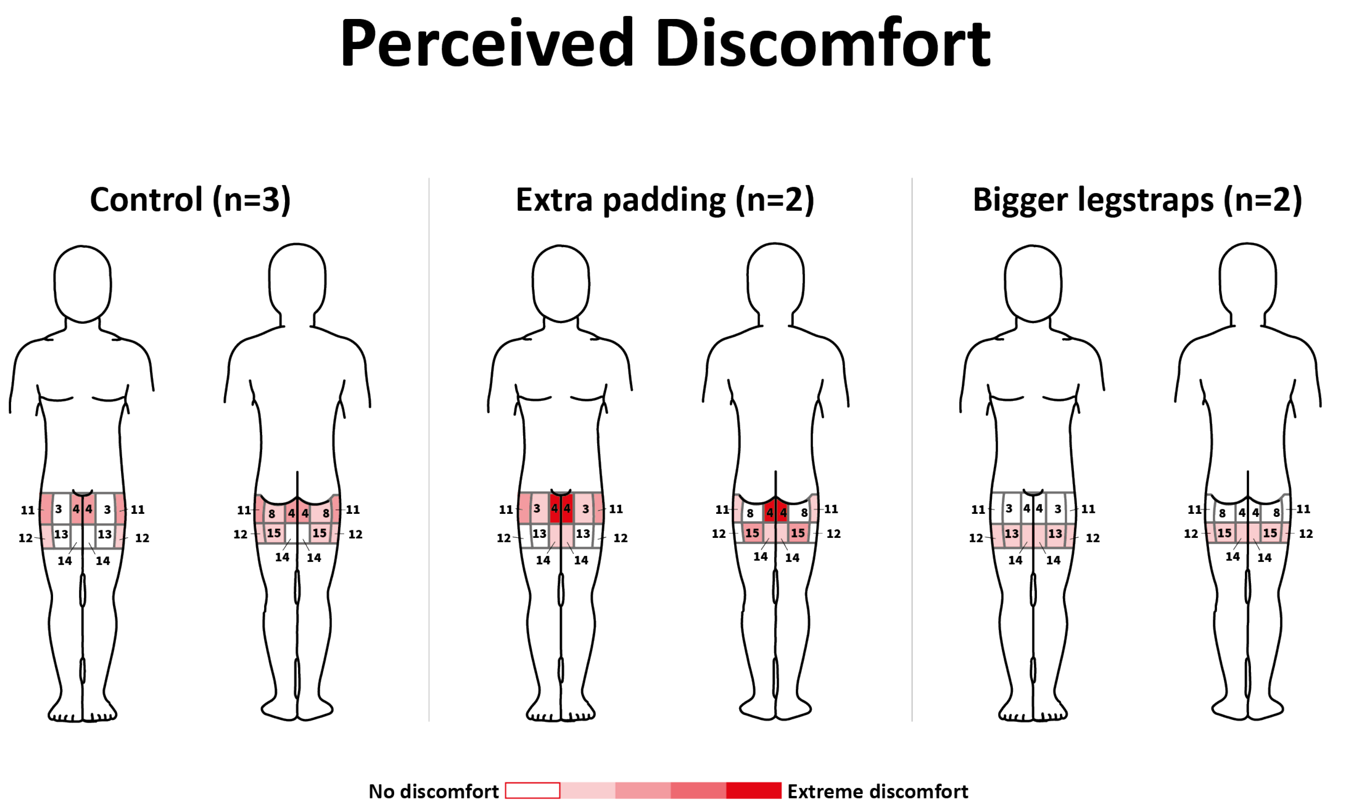


Figure 72: The perceived discomfort per concept visualised

11.4 RESULTS

11.4.1 QUESTIONNAIRE

The extra padding prototype is regarded as extremely uncomfortable, being even worse than the control prototype. On the outside of the legs the discomfort of the extra padding equals that of the control. The bigger legstraps were perceived as much less uncomfortable, with the worst perceived rating being barely uncomfortable. These results are visualised in **Figure 72** and **Figure 73**.

As for support, the participants perceive the extra padding and the control prototype as quite similar. The most amount of support is at the insides of the legs as well as at the back, for the control prototype described as moderately and for the extra padding the insides of the legs are described as provding 'a lot of support'. The bigger legstraps are barely supporting around the groin, but a lot of support is felt on the middle of the thigh.

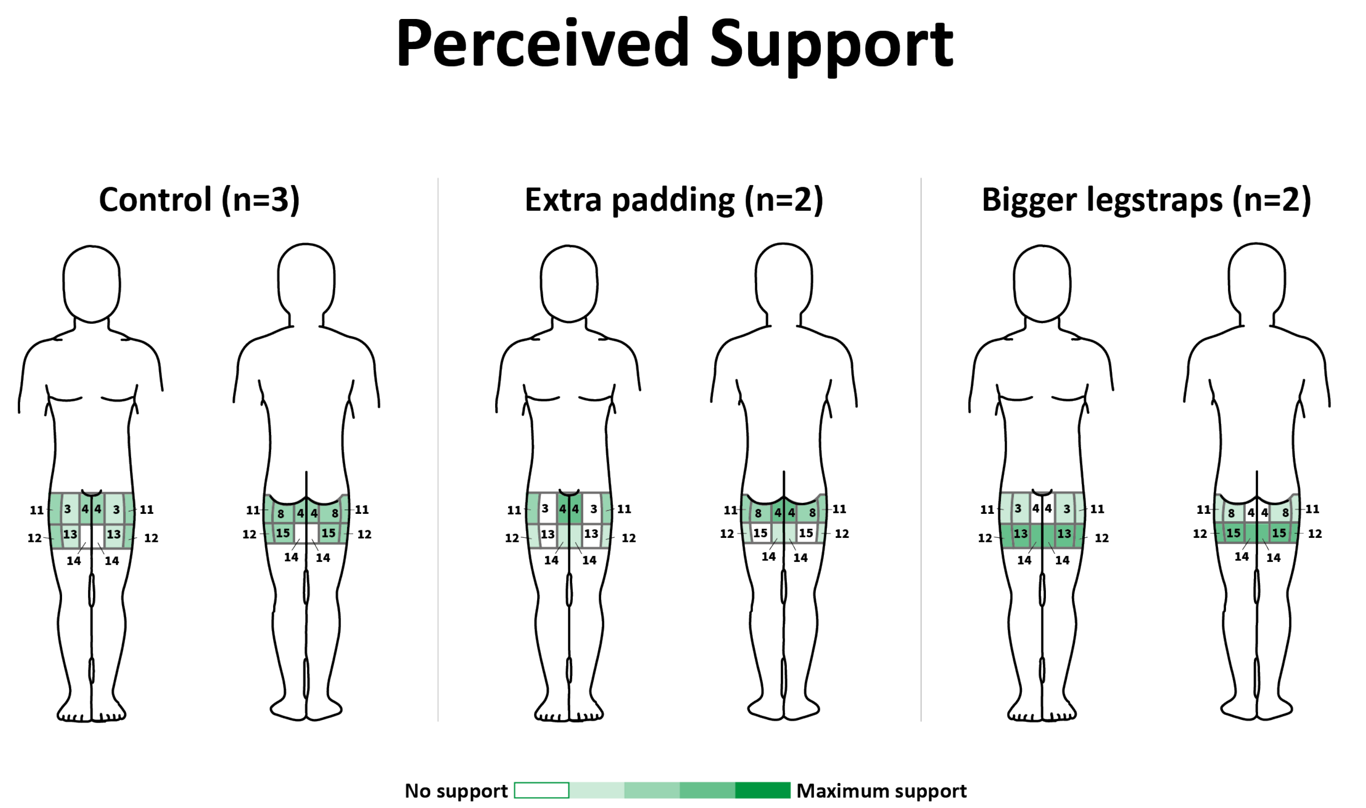


Figure 73: The perceived support per concept visualised

The standard deviation of the tests can be found in **Figure 74** and **Figure 75**. This standard deviation is quite high in certain areas (area 15 for the control prototype). This is not unexpected, since only two participants filled in the questionnaire in the end. Considering the quantity of participants, the overall standard deviation seems not too bad.

11.4.2 INTERVIEW

When asked which concept the participants preferred, two mentioned that they preferred the bigger legstraps. Both preferred this concept over the other, because that one caused major discomfort at the scrotum. Due to the amount of added padding and it being pulled up, the scrotum got stuck in between the extra padding. The other participant actually preferred the control variant, partly because of the previously mentioned reason of the extra padding, partly because of circulation issues with the legs because there was so much pressure on it and partly because he was not used to feeling pressure at that location of the legs.

To the question of what their main concern was with each of the concepts, they all noted that for the extra padding it would be very hard to adjust the scrotum while wearing a suit so it would not be crushed in between the padding. Furthermore, they noted that they still felt a lot of pressure at the groin. For the bigger legstraps, two participants noted the pinching of the legs as a concern. Another mentioned concerns about that it would really have to stay in place for it to work, but did add that it was the most comfortable option for him.

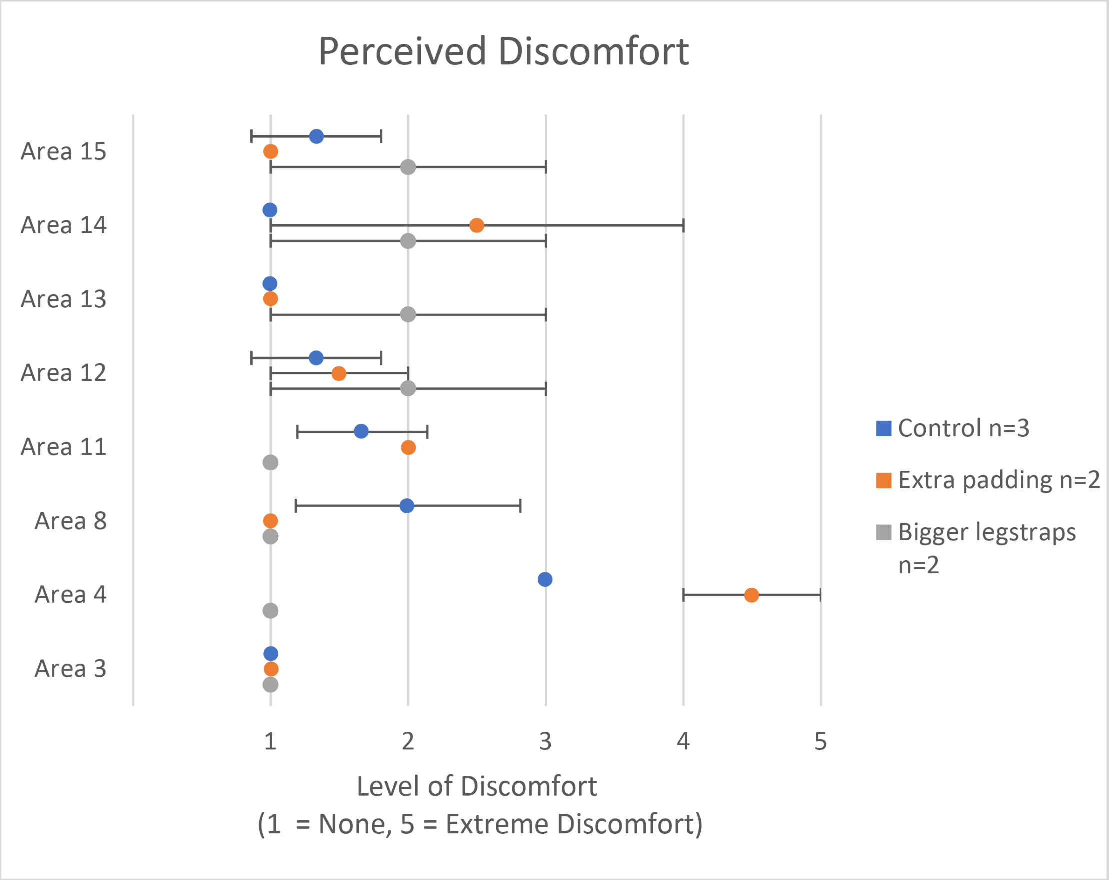


Figure 74: The standard deviation of the perceived discomfort

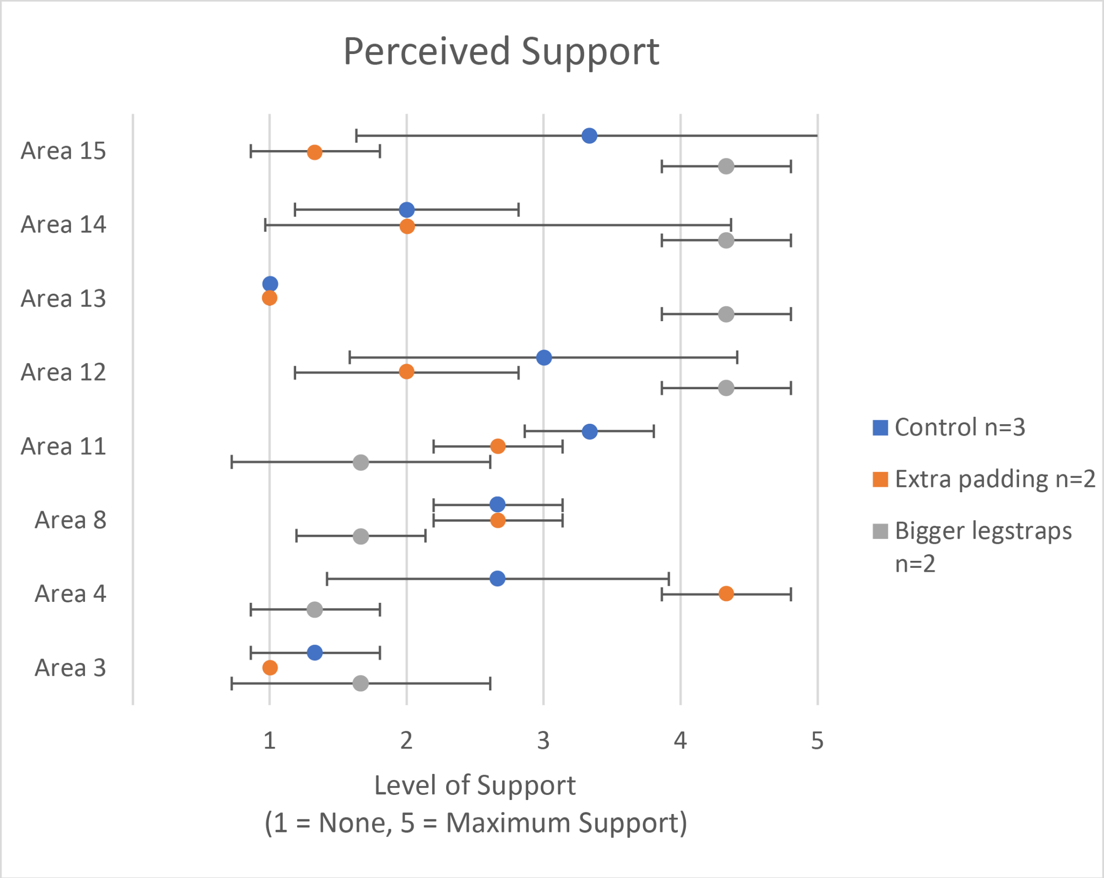


Figure 75: The standard deviation of the perceived discomfort

11.5 CRITERIA EVALUATION

Using the results from the previous paragraphs, the Harris Profile can be filled in. For the extra padding, the harness moved up a bit due to the straps being able to move into the groin. Furthermore, the concept fails in removing discomfort (actually adds more) and therefore scores poorly with the criteria concerning discomfort. In these criteria the bigger legstraps do a much better job, but still with concerns for blood circulation. Both concepts have to improve on the attachment point, as this can still move around too much. Neither concept feels dependable, as the first concept causes too much discomfort and the second concept creates an unusual feeling for the athletes. The first concept limits the freedom of movement by pinching the scrotum. For both concepts the shape could be changed still (interpreted in this case as size), but the bigger legstraps can be moved around a bit more.

LIMITATIONS

The quantity of participants in this study is extremely limited. Due to this low participant count, the range of perceived support and discomfort is sometimes very significant. Due to the lack of time and restrictions, it was not possible to recruit more participants. Therefore, it was chosen for this analysis to only work with the calculated averages.

	Extra padding				Bigger legstraps			
Criteria	--	-	+	++	--	-	+	++
The harness should support the athlete at the Gluteus Maximus, the hips and at the Lumbar spine								
The harness should not move up the body during a manoeuvre		■					■	
The harness should not be a source of discomfort that causes the athlete to change posture	■	■					■	■
The harness should not cause major discomfort in the upwind and the manoeuvre postures			■				■	
The attachment point between the kite and the harness should be at the level of the crotch	■	■			■	■		
The attachment point between the harness and the kite should not be able to move around								
Major forces should be loaded perpendicular to the body as much as possible		■				■		
The harness should feel dependable, so the athlete does not feel like they have to hold back								
The harness should at least withstand a pulling force of 3 kN in the upwind position		■					■	
The harness should not limit freedom of movement			■				■	■
The shape of the harness should be adjustable by the athlete								
The harness should not evenly distribute the forces								
The materials used should be UV resistant								
The materials used should be abrasion resistant								
The materials should be compatible with salt water								

Table 16: The Harris Profile for the two concepts. Not all criteria are filled in, since not all are relevant for the leg straps.

11.6 CONCLUSION

A direct comparison between the concepts and the control is quite difficult since their placement on the athlete's body differs. However, during testing all the participants were complaining about the discomfort that the extra padding caused at their scrotum. If the control and extra padding are compared, the control scores much better, especially around the groin. This shows that just adding more padding is not an option. Since the bigger legstraps are not located at the groin, very little discomfort was experienced there. However, all participants noted how strange it felt, as they had not experienced pressure in that location on their legs yet. The bigger legstraps are judged by two of the participants as the best concept, but with concerns about pinching and it staying in place.

When evaluated with the criteria, the bigger legstraps win by being perceived as less uncomfortable. The attachment point is where the bigger legstraps score the lowest in the criteria and will have to be improved. The feeling that the athletes experienced while wearing it, causes the concept to not score great with the criteria of the harness needing to feel dependable.

The path forward is taking the bigger legstraps into the next conceptualisation phase. Now that the crucial flaws from the initial design as proposed in **Chapter 9** (pressure on the hips and discomfort at the groin) have been solved, the next step is to bring all parts together into a coherent concept. This will be described in detail in the next chapter.

CHAPTER 12
FINAL DESIGN

Since all major parts of the harness have been tested and chosen, the next step is to combine them into a final concept. This will involve a more detailed design that includes material choice and a working prototype. The manufacturability of the design is evaluated and a process is proposed. This prototype is then tested with the athletes on the water and compared to the ION Sonar, which is described in the next chapter.

12.1 IDEATION

The outcomes of the previous chapters were combined and merged into a final concept. This process can be seen in **Figure 77**. The main idea directions ranged between creating a small attachment point that is connected through a set of bands, going back to a spreaderbar that is held down by straps, to a combination of these.

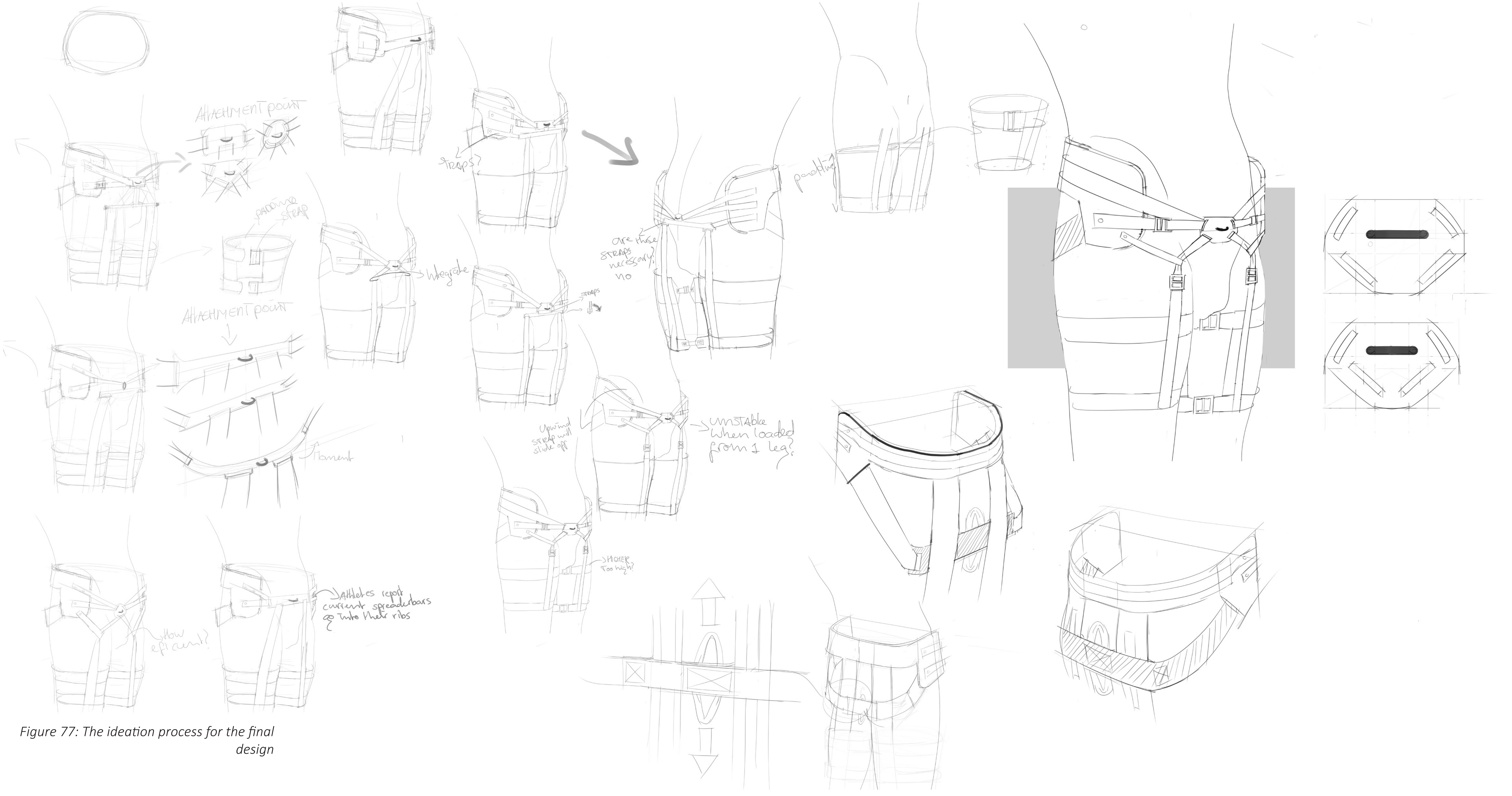


Figure 77: The ideation process for the final design

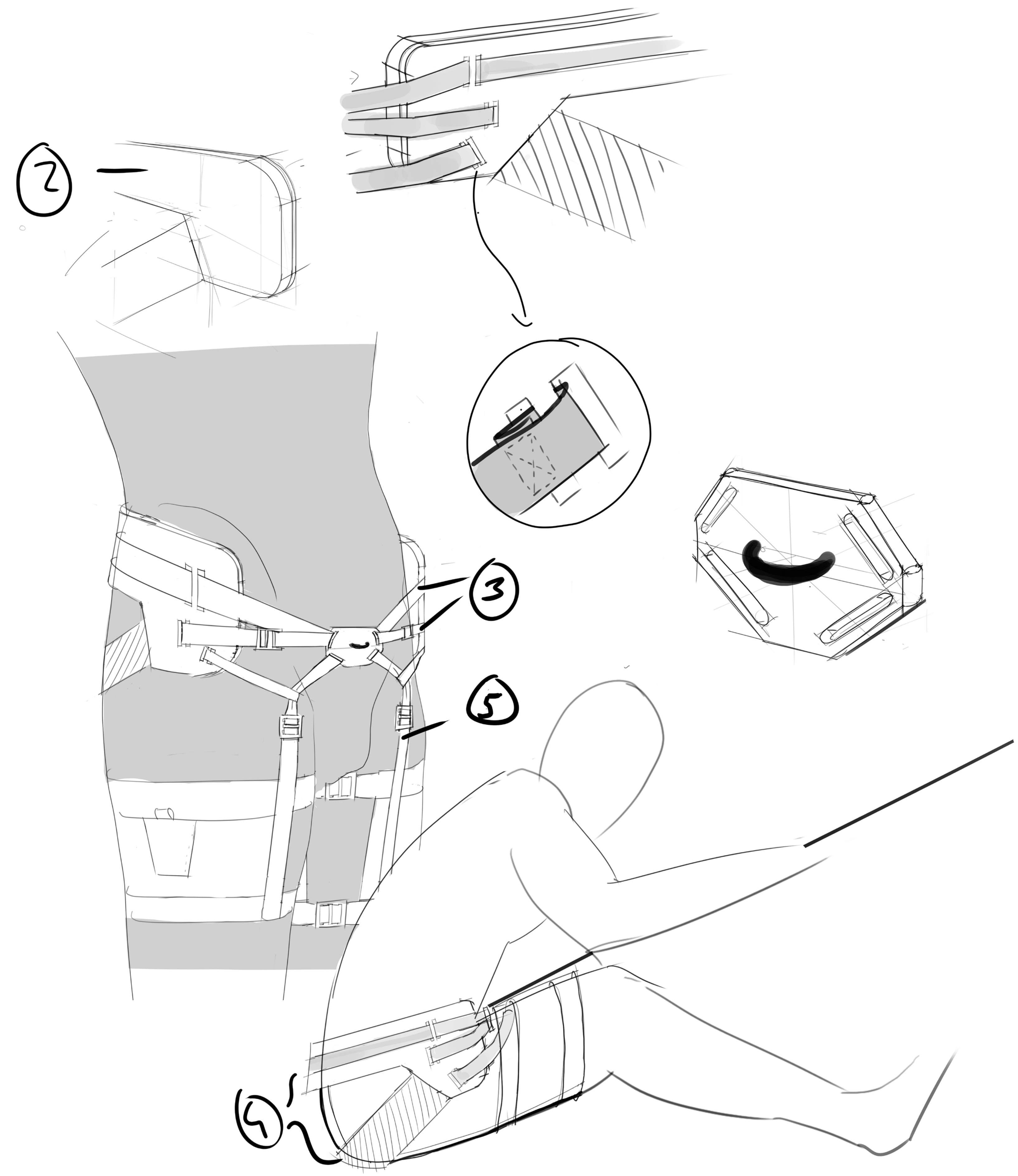


Figure 78: The final concept

12.2 CONCEPT

The final concept (**Figure 78**) consists of a hard belt that is moulded to the shape of the back of the athlete (1). Inside this belt is a 10 mm layer EVA foam for padding (2). The attachment point for the kite is connected to the hard belt through two straps (3), one that goes around the belt and one that ends at the location of the hips. These straps ensure that the forces from the kite in the upwind position are redirected to the Gluteus Maximus and the lower back (4). During manoeuvres, the attachment point is kept in place through straps that connect to the leg straps (5). These leg straps are also connected with wide straps that run along the back of the legs up to the hard belt (6). Since the wide straps connect the hard belt and the leg straps, the hard belt stays in the same location and the athlete is able to push the forces of the kite into the hydrofoil.

12.2.1 PROTOTYPE

The prototype reflects the design as accurately as possible, with one difference: the material of the hard belt. In the design this is made out of carbon fibre, but in the prototype this is made out of laminated wood. Due to the wrong grain direction the belt was too flexible and had to become significantly thicker than initially planned. The process to built the hard belt of the prototype can be found in **"Appendix E: Building the prototype".**

12.3 COMPONENTS

12.3.1 HARD BELT

The hard belt consists of laminated carbon fibre. Since the harness' intended user group is the athletes, the hard belt is personalised to the contour of the athletes' back. This customisation allows the harness to have a perfect fit and should reduce the amount of discomfort the athlete feels. The manufacturing of this part is discussed in **"12.4 Manufacturing"**.

12.3.2 STRAPS

Straps are made out of nylon webbing, this was selected for its coarse structure and excellent fresh and salt water resistance. The UV resistance of this material is fair (GRANTA Design Limited, 2020). It is assumed the UV resistance will not be problematic as the ION Sonar also uses Nylon straps without issues. An alternative would be PS straps, which offer superior UV resistance, but the texture is likely too smooth to be used with the buckles. Two different widths will be used, 25 mm and 50 mm, both standard sizes (Extremtextil, n.d.). The 50 mm straps are used along the back of the harness, to increase surface area.

12.3.3 BUCKLES

During testing in **Chapter 9**, it was noticed how the plastic buckles (**Figure 79**) let the straps slip. For the straps that connect to the attachment point it was opted to go for a two-part buckle, which are made out of anodised aluminium, and therefore more corrosion resistant compared to regular aluminium (GRANTA Design Limited, 2020). For the wider straps, acetal buckles will be used, since with straps it is less critical that they slip a little.

12.3.4 ATTACHMENT POINT

The attachment point is made of a 1 mm stainless steel plate and a 3 mm stainless steel loop. Stainless steel has excellent corrosion resistance and a high yield strength, which makes it the ideal material for this part, as the harness has to be able to resist a pulling force of at least 3 kN (GRANTA Design Limited, 2020).

12.3.5 PADDING

For padding it was opted to go for high density EVA foam. This type of foam is often used in sport articles like climbing gear and harnesses, but also in running shoes. Furthermore, EVA has excellent resistance to salt and fresh water. Since the UV resistance is poor, the foam will have to be covered from sunlight to protect it from degradation.

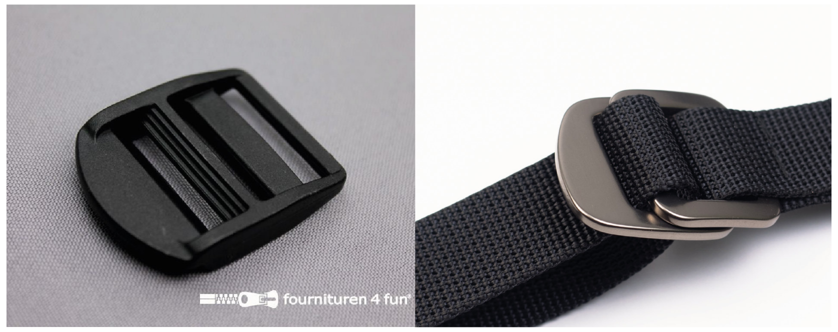


Figure 79: On the left the plastic buckle, on the right the two part buckle

12.3.6 FABRIC

Since the fabric at the leg straps will not be bearing any major load, done by the straps, the goal of the fabric is to ensure that the horizontal legstraps stay apart and to wrap the padding. It was opted to go for the same fabric as used in the ION Sonar, which is a blend of 5% neoprene, 55% polyester and 40% nylon (ION, n.d.). This fabric should ensure good abrasion resistance and water compatibility. However, it should be researched further if this would indeed be the best blend of synthetic material.

12.3.7 MATERIAL COSTS ESTIMATION

Now that the materials are known a cost estimation can be made for them. This overview can be found in **Table 17**. The total costs of the materials are €57,17, but this estimate excludes the fabric costs, since these could not be found. Since these prices are based on information from consumer websites, the material costs will most likely drop, if materials are bought in bulk.

Table 17: The estimate material costs for the final design

Part	Material	Amount	Unit price	Costs	Source
Hard belt	Carbon fibre	0.15 m2	€36,30/ m2	€5,45	https://www.easycomposites.co.uk/ xc110-210g-22-twill-3k-prepreg-carbon-fibre
Hard belt mould	PLA	131 g	€0,02/g	€2,62	https://www.3dfilamentshop.nl/pla-filament/fill3d-pla-white-wit-23-kg
Straps 25 mm	Nylon	8 meter	€1,50/m	€12	https://www.extremtextil.de/en/ webbing-polyamid-25mm-strong.html
Straps 50 mm	Nylon	3 meter	€1,90/m	€5,70	https://www.extremtextil.de/en/ webbing-polyamid-50mm-strong.html
Buckle 25 mm	Anodized Aluminium	8	€2,70/ piece	€21,60	https://www.extremtextil.de/en/ buckle-for-webbing-25mm-2-parts-aluminium-anodised.html
Buckle 50 mm	Acetal	4	€1,20/ piece	€4,80	https://www.extremtextil.de/en/ ladderloc-50mm.html
Attachment Point	Stainless Steel	30 g	€2,80/kg	€0.08	GRANTA Design Limited, 2020
Padding	EVA foam 10 mm	0,3 m2	€15,00/ m2	€5	https://www.foamatelier.nl/nl/ foam/eva-foam/eva-foam-10-mm/ poly-props-cf-65-10mm-1-x-2m-per-stuk/a-46773-20000695
Fabric	5% Neoprene, 55% polyester, 40% nylon	0,14 m2	N/A	N/A	
Total				€57,17	

12.4 MANUFACTURING

The harness will most likely be produced by a brand that is skilled in making harnesses. These existing harnesses are much complex in their sewing patterns than the design of this harness, therefore it is assumed that the patterns that will have to be sewn will not present a problem. The buckles can be bought from a supplier and the attachment point involves relatively easy metal working, comparable with the process of creating the spreaderbar. By far the most complex part of the product is the hard belt made out of carbon fibre. This will involve working with composites, and moulds that have to ensure a proper fit with the user. Caselli (2004) describes three types of foot orthoses with different amounts of personalisation, which are also relevant for this thesis:

- Prefabricated, mass produced products which can be bought off the shelf
- Customised, a modified prefabricated component to which features can be added
- Custom-moulded, a product manufactured from the cast or mould of a body part

Since the product is aimed for athletes at the highest level of kitefoiling, a custom-moulded part that perfectly fits their body ensures that the harness will fit properly. To make the product commercially available, custom-moulding is out of the question and prefabrication will be the level of personalisation of choice.

12.4.1 PROPOSED PROCESS FOR THE CUSTOM-MOULDED HARD BELT

The next paragraphs explore a process to create the custom-moulded hard belt part. Different techniques for this process are analysed and a final process is recommended.

There are two types of 3D scanning, contact and non-contact. Rakitina et al. (2008) (latest paper reference to this literature was in 2019) lists the main techniques for non-contact 3D scanning:

- Time of Flight, which uses an emitting light source that bounces off an object and is sensed. The time needed for this round trip is measured and since the speed of light is known the distance can be calculated. This is done many times per second to construct a 3D model.
- Triangulation, where a laser stripe is projected on a surface. Dependent on the location of the stripe in the field of view of the camera, the locations can be calculated, as the angle of the camera is known and the distance between the source of the laser and the camera is known.
- Structured light, a technology similar to triangulation. Instead of a laser, white light is projected following either a 1D or 2D pattern. An offset camera detects the pattern and in the case of the 2D pattern using Multistripe Laser Triangulation and the deformation of the pattern the geometry can be calculated.
- Stereoscopic/Photogrammetry, uses images taken slightly apart from each other. Using the differences in the images the distance can be calculated

"Appendix F: 3D Scanning products" shows a select overview of 3D scanning products. Some of these methods are so precise they are used for CAD and therefore too expensive. Since the goal is to retrieve the shape of the lower back, precision below a millimetre is assumed to be unnecessary. Using an iPad with LiDAR, the Structure Sensor Mark II or a software solution like 3DF Zephyr seem to be viable options, based on precision and costs. Ultimately, the Structure Sensor Mark II seems to be the best choice, offering excellent precision (~1 mm) for its price and its ease of use (Occipital, Inc., n.d.).

Bere et al. (2020) propose a method of creating customised products using fused deposition modelling (FDM), which is also applicable for this thesis. In the study, the mould is 3D printed with PLA and a gel coat is applied to the part. In the study, a bicycle seat was created using pre-impregnated carbon fibre-reinforced polymer (prepreg) sheets, vacuum bag technology and a curing oven. The mean difference between the CAD model and the produced part was -0,3 mm. Compared to CNC milling aluminium and epoxy, this 3D printed mould at a cost of €150 was estimated to be 10x and 8,6x cheaper respectively. Furthermore, the authors were able to successfully produce a part seven times, with the mould still being in good condition. The dimensions of this mould were 270x145mm with 100% infill ratio. The process to create the part as described in the paper is listed below:

1. Create the mould in a CAD software
2. Print the mould with 100% infill with PLA
3. Treat the surface of the mould with epoxy gel coating
4. Treated mould polymerized at 20°C for 24 hours
5. Treat the surface of the mould with polyester gel coating
6. Mould heat treated at 85°C for 24 hours
7. Mechanically process mould with sand paper up to 1000 grid and polish
8. Apply mould sealer layer and mould release layer
9. Apply prepreg sheets to the mould
10. Insert mould into the vacuum bag and seal the bag
11. Apply vacuum to the bag for 30 mins and check the seals of the bag
12. Cure the part and mould in an oven at 80°C in a vacuum for 5 hours
13. Remove the part from the mould and finish the part with glass paper

This process would be essentially the same for the hard belt part. The advantage of this method is the flexibility it offers for part complexity. The proposed process is shown in **Figure 80.**

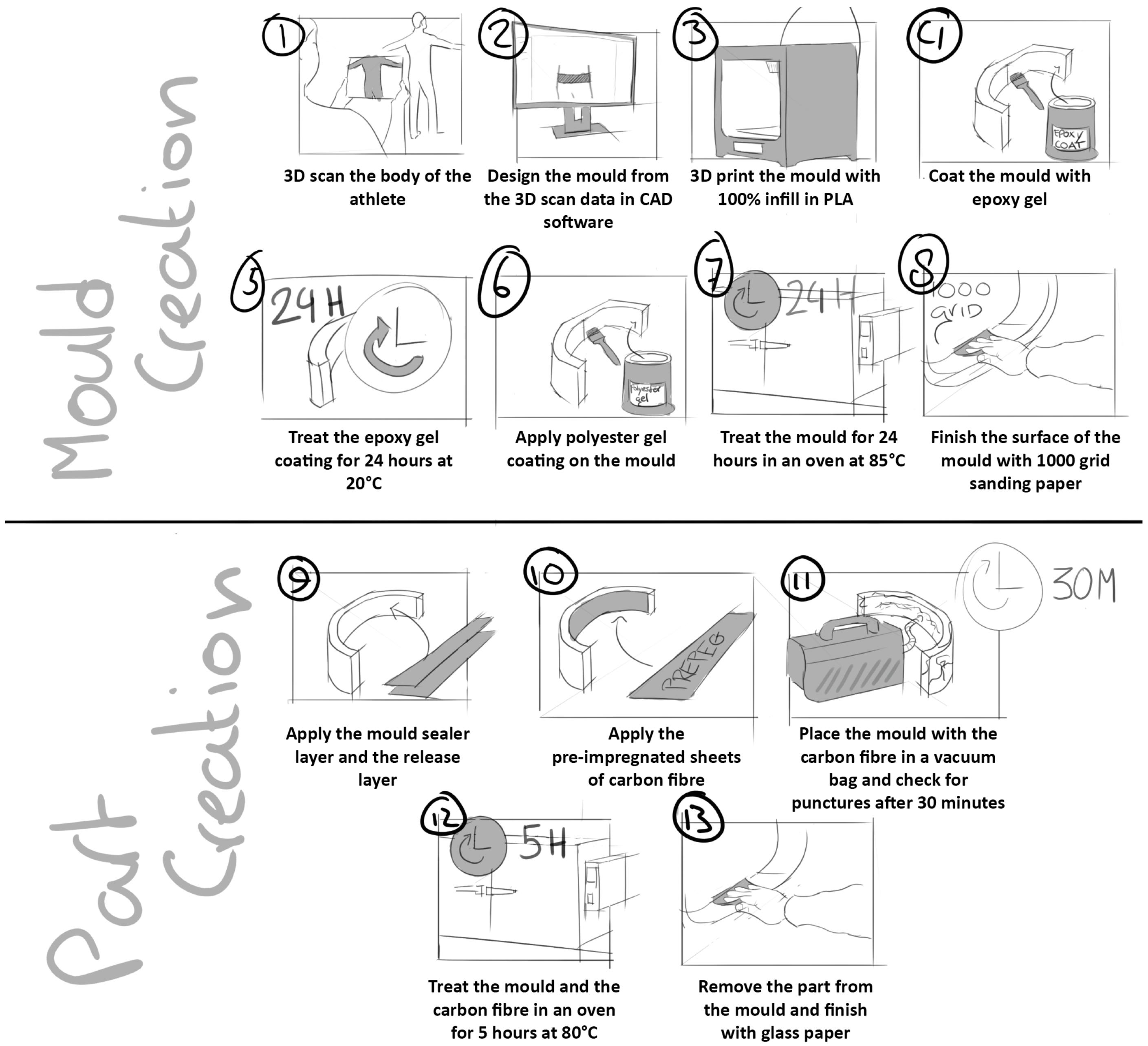


Figure 80: Proposal for the manufacturing process of the hard belt

12.4.2 MANUFACTURING COSTS

It is assumed that the manufacturing complexity of all the parts, excluding the hard belt, is similar to existing harnesses and will not be discussed, since no good sources could be found to calculate such costs. The hard belt part will be by far the most expensive part to make of the entire product, since it is so labour intensive and needs for specialised equipment. A time estimation can be found per step of the process in **Table 18**. This cost estimation assumes a working week of 38 hours at an hourly rate of €10,34, which is the minimum salary in The Netherlands as of the July 1, 2021 (Rijksoverheid, N.D).

Table 18: The labour cost estimation of the hard belt part

#	*Step*	*Estimated time (minutes)*	*Costs*
1	Scanning the body	30	€ 5,17
2	Designing the mould	120	€ 20,68
3	Setting up the 3D print	20	€ 3,45
4	Coating with epoxy gel	30	€ 5,17
5	Coating polyester gel	30	€ 5,17
6	Finish surface	45	€ 7,76
7	Apply the mould sealer	15	€ 2,59
7	Apply the mould release * 5	75	€ 12,93
8	Apply carbon fibre sheets	30	€ 5,17
9	Vacuum bag	15	€ 2,59
10	Oven treatment	15	€ 2,59
11	Part removal and finishing	60	€ 10,34
12	Total	485	€ 83,58

CHAPTER 13
EVALUATION OF FINAL DESIGN

Now that there is a final design and prototype, it can be evaluated and compared to the current best harness, the ION Sonar. This evaluation is done by the athletes on the water in Brouwersdam, the Netherlands. The results of the test will be used to evaluate the harness with the criteria, similar to the previous chapters.

13.1 METHOD

13.1.1 RESEARCH QUESTIONS

The identified research questions are as follows:

- How does the new design perform compared to the ION Sonar according to the design criteria?
- How can the design be improved?

13.1.2 STUDY SETUP

One male athlete of the Dutch Olympic team was recruited. The participant tested two different harnesses, the new prototype and the ION Sonar. Two buoys were placed in the water (**Figure 81**), one downwind (buoy 1) and one in the wind (buoy 2), so that the participant had to do manoeuvres to reach the buoy in the wind. The travel time between these buoys was approximately 2 minutes. The participant was accompanied by a boat that traveled behind the participant.

The questionnaires are printed out and wrapped in plastic to ensure they do not get damaged when the participants fill them out on the water using a non-permanent marker. When the participant has completed the questionnaires, these questionnaires are photographed and the answers on the plasticised questionnaire erased for the next evaluation. The questions can be found in **"Appendix G: Final Test Questionnaire"**.

13.1.3 PROCEDURE

The participant first started with the prototype. First, the participant evaluated the manoeuvre performance through the discomfort/support questionnaire, by kitefoiling to the buoy 2 and back to buoy 1, while doing eight manoeuvres in total. After, the prototype was evaluated for its upwind performance, by kitefoiling to buoy 2 and filling in the same questionnaire. Finally, the prototype is evaluated for its performance in downwind by letting the participant kitefoil to buoy 1 and filling in the questionnaire.
After the participant finished the first part of the procedure, they were asked to fill in a questionnaire containing Likert-scale questions regarding discomfort, support and the handling of the harness. Once the evaluation of the harness was completed, the participant went back to the shore. The prototpye was switched for the ION Sonar and the procedures was repeated.

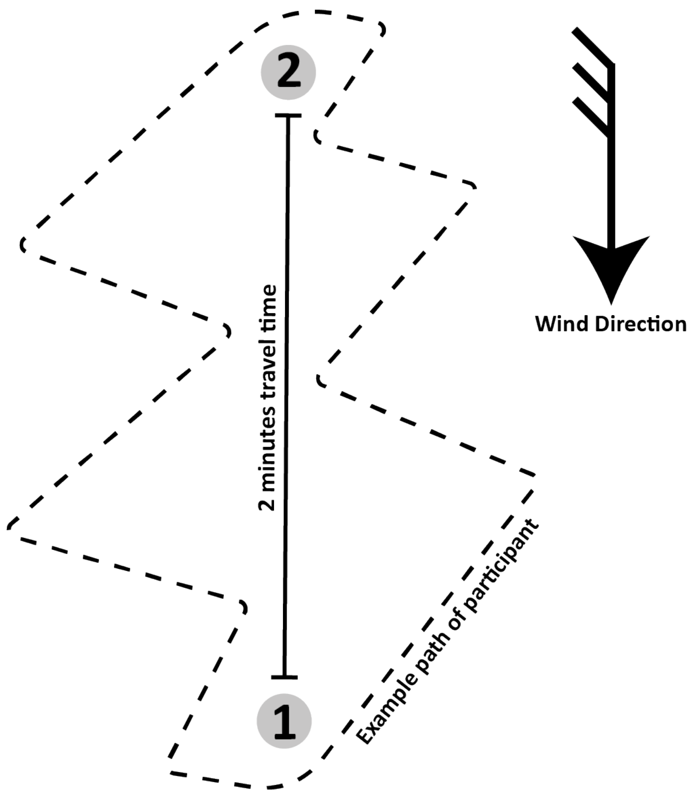


Figure 81: Study setup

13.2 RESULTS

13.2.1 MANOEUVRE

The results of the questionnaire are illustrated in **Figure 82**. The participant found the leg straps of the ION Sonar very uncomfortable at the groin and the sides of the pelvis quite uncomfortable. There was no discomfort reported for the Gluteus Maximus and the lower back. The participant felt moderate support at the groin, barely any support at the lower back, Gluteus Maximus, at the hamstrings and the hips. The participant perceived moderate support at the sides of the pelvis.

For the prototype, the entire upper leg was found to be very uncomfortable. The discomfort at the Gluteus Maximus was described as quite uncomfortable and the sides of the pelvis as barely uncomfortable. There was no discomfort at the lower back. The participant felt maximum support around the leg and moderate support at the sides of the pelvis. At the Gluteus Maximus and the lower back the participant perceived barely any support.

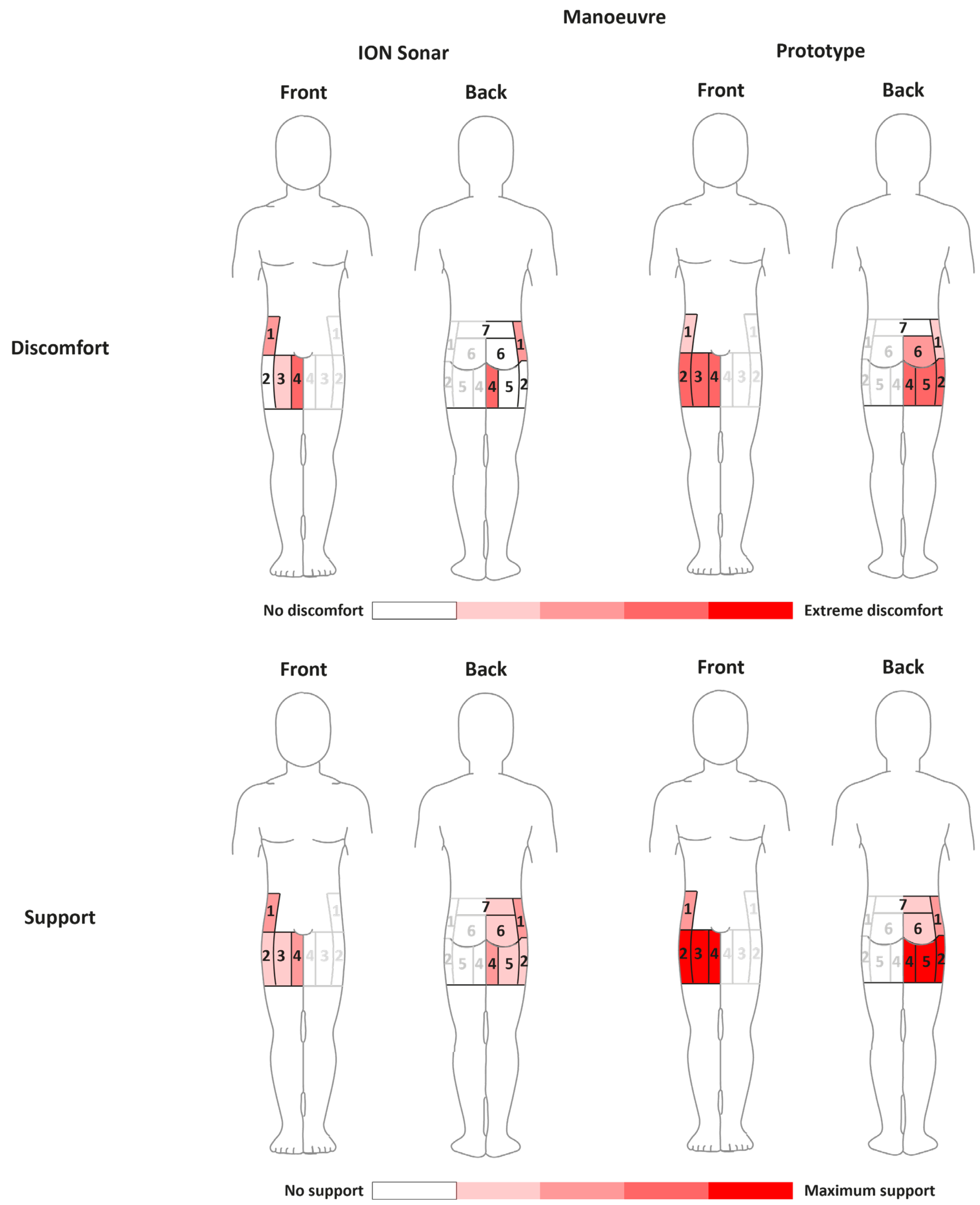


Figure 82: The Support and Discomfort of the ION Sonar and the Prototype in the manoeuvre position

13.2.2 DOWNWIND

In the downwind position, the groin was perceived as very uncomfortable for the ION Sonar, with barely any discomfort on other parts of the body (**Figure 83)**. A lot of support was perceived at the groin and barely any support in all the other spots.

As for the prototype, again, the participant noted extreme discomfort surrounding the legs. The sides of the pelvis were perceived as barely uncomfortable, and in the lower back and the Gluteus Maximus no discomfort was perceived. Maximum support was perceived at the legs and moderate support at the sides of the pelvis. No support was felt at the Gluteus Maximus and the lower back.

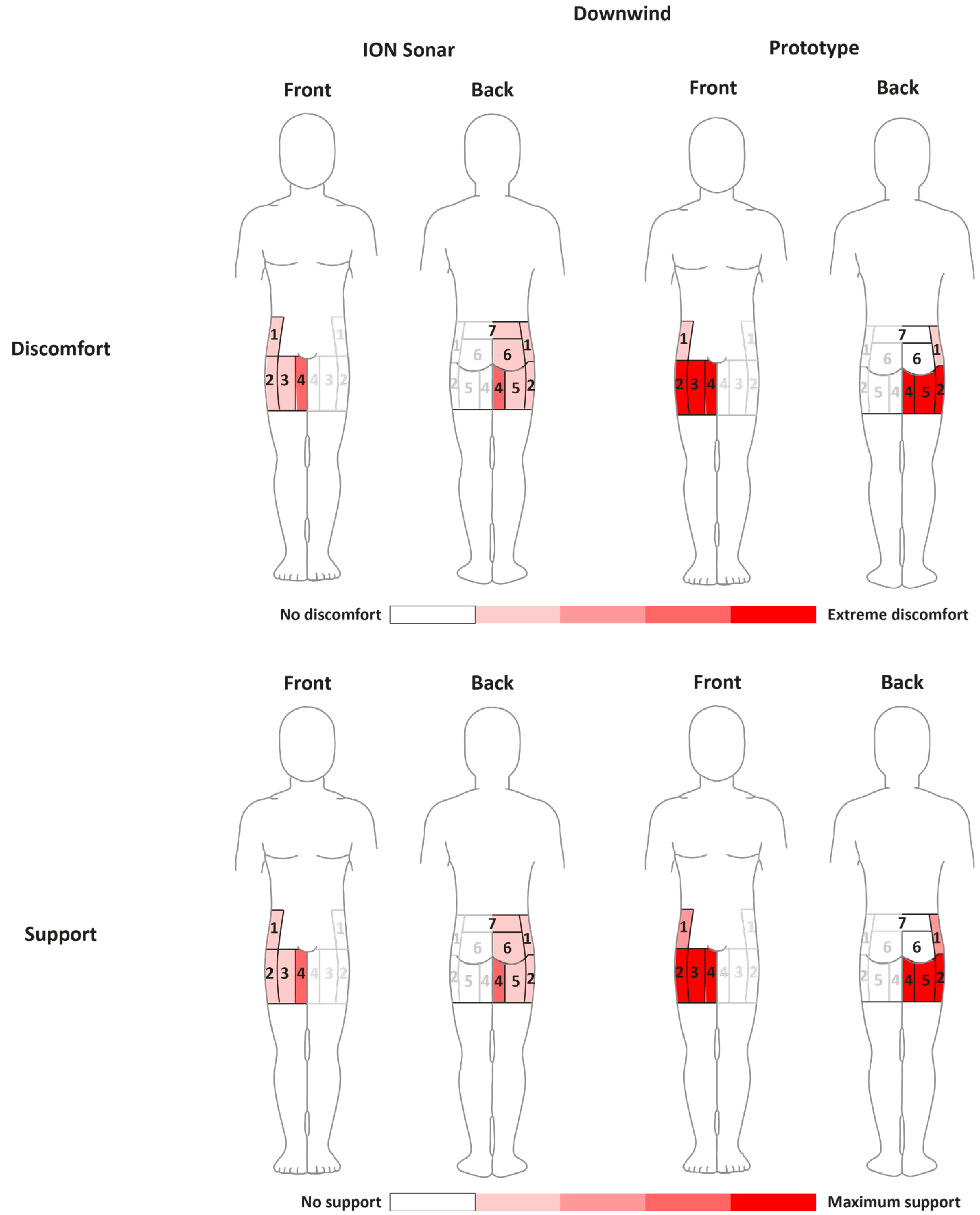


Figure 83: The discomfort and support of the ION Sonar and the prototype for the downwind position

13.2.3 UPWIND

In the upwind position, the participant perceived the pressure at the sides of the hips from the ION Sonar as very uncomfortable (**Figure 84**). The pressure in the lower back was noted as quite uncomfortable. Elsewhere, the participant perceived barely any discomfort. The sides of the hips were perceived as 'a lot of support', while at the lower back moderate support was perceived. Everywhere else, the participant noted barely any support.

The prototype caused extreme discomfort at the Gluteus Maximus and was perceived as very uncomfortable around the legs. The lower back and the sides of the pelvis were perceived as barely uncomfortable. The participant mentioned however, that the harness had moved above the 7th region and was causing discomfort there. The participant perceived maximum support around the legs and at the Gluteus Maximus, with a lot of support at the lower back and barely any support at the sides of the pelvis.

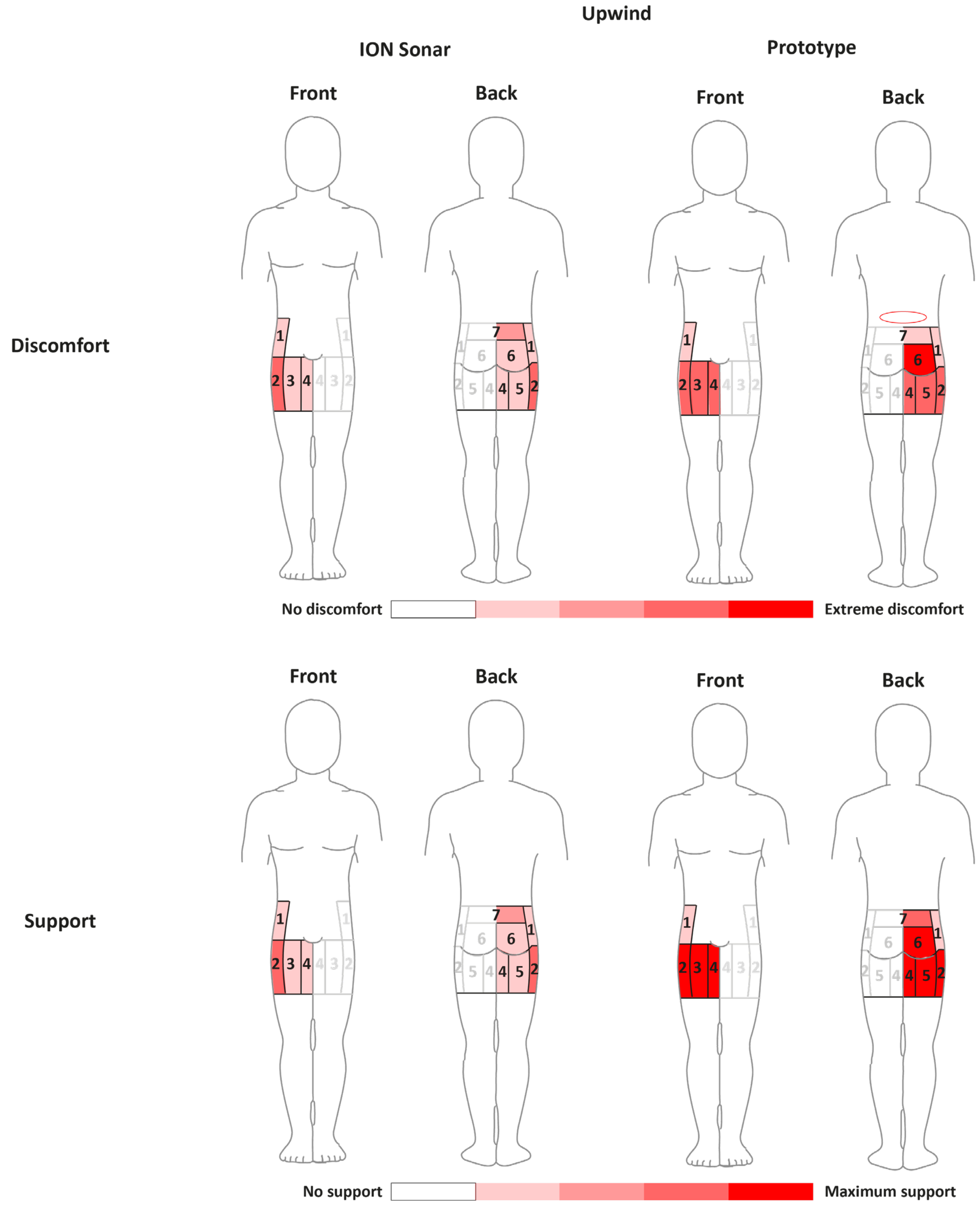


Figure 84: The discomfort and support for the ION Sonar and the prototype in the upwind position

13.3 CRITERIA EVALUATION

Using the data from both questionnaires, the Harris Profile can be populated (**Table 19**). With both harnesses the wearer is able to wear a personal floatation device and both harnesses contain a knife to cut the lines. The participant noted that the ION Sonar supported him better than the prototype, since for the prototype most of the support came from the leg straps, which is not where he wanted to be supported. The participant evaluated that both harnesses still moved during manoeuvres, but that the prototype did stay in place better due to the leg straps. The prototype causes more discomfort in the upwind and the manoeuvre positions. The upwind position was more uncomfortable, because the hard belt was located too high and because the participant could not fold himself forward. The manoeuvre position was evaluated as uncomfortable, because of the amount of pressure on the legs. For the ION Sonar, in the upwind position some discomfort was perceived at his hips and in the manoeuvre position at his groin and the sides of the pelvis. The attachment point for both harnesses moved around a bit and did not stay at the crotch. For the prototype, since there was so much pressure on the legs, the major forces were not loaded perpendicular to the local body geometry. This was the case for the ION Sonar. Both harnesses were able to withstand the forces in the upwind position. The ION Sonar did not limit the freedom of movement. The prototype greatly limited the freedom of movement, as the participant struggled to put his feet in the footstraps due to the pressure on the legs and could not properly fold over. The ION Sonar has less opportunities to be tweaked properly, while the prototype offers this in many more places. Lastly, neither harness distributed the forces equally.

Table 19: The final Harris Profile

	ION Sonar				Prototype			
Criteria	--	-	+	++	--	-	+	++
The athlete should be able to wear a personal floatation device and the harness at the same time			■	■			■	■
The harness should have a knife integrated			■	■			■	■
The harness should support the athlete at the Gluteus Maximus, the hips and at the Lumbar spine			■			■		
The harness should not move up the body during a manoeuvre	■	■				■		
The harness should not be a source of discomfort that causes the athlete to change posture		■			■	■		
The harness should not cause major discomfort in the upwind and the manoeuvre postures		■			■	■		
The attachment point between the kite and the harness should be at the level of the crotch		■				■		
The attachment point between the harness and the kite should not be able to move around		■					■	
Major forces should be loaded perpendicular as much as possible			■		■	■		
The harness should feel dependable, so the athlete does not feel like they have to hold back								
The harness should at least withstand a pulling force of 3 kN in the upwind position			■	■			■	■
The harness should not limit freedom of movement			■	■	■	■		
The shape of the harness should be adjustable by the athlete		■					■	
The harness should not evenly distribute the forces		■				■		
The materials used should be UV resistant			■	■			■	
The materials used should be abrasion resistant			■	■			■	■
The materials should be compatible with salt water			■	■			■	■

13.4 DISCUSSION

Regardless of position, the leg straps of the prototype are perceived as at least very uncomfortable. The participant mentioned during testing, that he felt most of the pressure from the kite on his legs. It was clearly visible from the boat that the participant struggled with manoeuvres, repeatedly falling in the water, explaining later that the pressure on the legs was so much that he struggled to put his feet in the footstraps on the board. During manoeuvres with the ION Sonar, the well-known issue of pressure in the groin was prevalent. The main advantage of the ION Sonar was that the freedom of movement was not limited, something that inhibited the participant to do proper manoeuvres with the prototype. It can be concluded that the pressure coming from the kite during manoeuvres is much higher than anticipated.

In the upwind position, the main source of discomfort can also be traced back to the leg straps. Since the leg straps were tight around the legs, they were able to stay in place. However, the straps that run over the Gluteus Maximus restricted the upwind posture. The hard belt had moved up, but was not able to move back down. This could be due to the fact that the extra surface area was incredibly stiff, and the pelvis might have been wider than the hard belt at that location. Therefore, the straps that run over the Gluteus Maximus were already under tension by barely folding forwards. This put a lot of pressure on the Gluteus Maximus. It could be seen from the boat that the strap running horizontal over the Gluteus Maximus was too high and not supporting the participant. It is unknown whether this strap had moved up or was not positioned correctly from the get-go as the participant put the harness on without assistance. Furthermore, since the hard belt had moved, the pressure of the kite was put too high on the back, causing discomfort above the Lumbar spine. Since the entire harness had moved up a little bit, the attachment point in the upwind position also moved up. In the downwind, the leg straps again caused most discomfort. The participant mentioned that when he started to push harder, the leg straps started to pinch, because they were so tight around his legs. There was also not enough pressure on the Gluteus Maximus according to him. The participant noted that he felt the pressure from the hard belt more and that it felt quite good.

When evaluating the performance of both harnesses, the ION Sonar scores better on most parts. However, there are three criteria that the prototype scores better in, which are that the harness should stay in place; the attachment point should not be able to move around; and the shape can be customised. This means that the leg straps of the prototype were keeping the harness in place better than the leg straps of the ION Sonar, however, in the current iteration, at the cost of freedom of movement. The attachment point held in place by 4 different straps is also effective, staying centred better than the ION Sonar.

13.4.1 LIMITATIONS

The organisation of testing on the water faced some difficulties. Most notably, it had to be postponed several times due to poor wind conditions. Ultimately, a day had to be chosen that was suboptimal in participant count, with only two athletes being able to participate instead of the intended four. During the day itself, it turned out that the boat still had to be retrieved from another location, which caused a delay in the starting time for the testing. Unfortunately, the buoys were not present in the boat as was communicated, so the testing had to be done without buoys. It was unknown that once in the boat, it would be difficult to get out again, which meant that the athlete could not be supported during the fitting of the harness, ensuring that everything would be positioned correctly. The harness tore at the fabric in the leg straps during testing (**Figure 85**), cutting down the final participant count to just one. Since the organisation around the testing went poorly and ultimately only one participant could test the prototype, it is recommended to repair the current prototype, strengthen and elongate the legstraps, and redo the test with more participants.

Figure 85: The torn leg straps

13.5 CONCLUSION

The pressure that the kite generates during manoeuvres is higher than expected, causing significant discomfort at the legstraps and causing a negative effect on the freedom of movement of the athlete. This was so severe that the participant struggled to successfully complete manoeuvres. In the upwind position, the straps that run over the Gluteus Maximus were unable to pull the hard belt down, causing the participant to be unable to fully get into the upwind posture. The participant was positive about the hard belt, which did not cause much discomfort even though it did not fit properly. The leg straps were more effective than the ION Sonar in keeping the harness and the attachment point in the same location.

CHAPTER 14 RECOMMENDATIONS AND ROADMAP

This chapter will lay out the recommended next steps for the development of the harness, based on the initial results of the previous chapter. This will include recommendations to develop it for the athletes, but also includes some recommended steps to adjust it for mass production. These recommendations will be displayed in a roadmap.

14.1 RECOMMENDATIONS

14.1.1 DESIGN VERIFICATION

The first recommendation would be to redo the test of the previous chapter with more participants. Some initial observations can be made, but since the data is so limited it is difficult to derive any concrete conclusions. Furthermore, it is important that the participants are supported when they put on the prototype to ensure that the prototype is located properly on the body.

14.1.2 LEG STRAPS

The initial results of the test showed that the leg straps restrict the movement of the athletes, due to the greater pressure from the kite than anticipated. Currently the leg straps sit relatively low on the legs of the athlete. The hypothesis is that putting the leg straps higher and decreasing the moment that the straps create on the legs will solve this problem. Another approach for this would be to press the vertical straps from the leg straps against the body at the groin, also reducing the moment. Furthermore, the possibility of integrating these leg straps into the suit is an interesting direction to explore. Research projects are on their way to develop a new suit for kitefoiling, a collaboration could benefit the development of the harness.

14.1.3 HARD BELT

The participant that tested the prototype on the water was positive about having a hard belt at the lower back. It would be recommended to research the effects of this adjustment on an existing harness, to see if that decreases the discomfort that the athletes feel and increases their performance. This thesis did not analyse the needed stiffness to ensure minimal deformation of the hard belt. It will have to be researched in the future however, to determine the amount of carbon fibre necessary for the hard belt. Since no company with production capabilities was involved in the project, the production method of the hard belt will have to be examined closer and adjusted accordingly. The need for padding in this part of the harness will have to be researched, which could have an impact on the need of customised moulds, although this part could potentially be customised through the use of EVA foam as well. During testing the participant was unable to fully get into the upwind posture, since the strap that connects hard belt and the leg straps in the back prevented this. The hypothesis here is that the extra surface area on the sides of the pelvis is partly responsible for this. It could be made smaller and should slightly curve away from the body, to accommodate the change of width of the hips/pelvis when positioned in the upwind posture. Layering the grain direction of the carbon fibres along the length of the hard belt could ensure that the wider area can still deform.

14.1.4 MATERIALS

Since the focus of the project was not as much on the embodiment of the design, more material research is necessary. Some initial areas to examine are the amount of padding necessary and whether EVA is indeed the best choice for the hard belt. It is recommended for the leg straps to examine whether these might benefit from a harder material instead of fabric on the outside. Furthermore, the straps are currently made out of nylon, which is vulnerable for UV radiation. The effects of this radiation on the strength of the material should be tested. The fabric used in the leg straps should also be examined in more detail.

14.1.5 MASS PRODUCTION

To make this design viable for manufacturers, it will have to be adjusted, so the masses can use it as well. Since the hard belt in its current form is custom fitted, changes to it will have to be made that allow it to elongate slightly while keeping its stiffness.

14.2 ROADMAP FOR DEVELOPMENT

With the recommendations in mind, a roadmap is proposed on how the final design can be developed further for use in the 2024 Paris Olympic Games. The roadmap lays out the next three years for two versions, a professional harness used for the athletes and one for mass production (**Figure 86**).

14.2.1 2021

The first recommend step is the redo the test with more participants. The results of this test will obviously affect the next steps to be taken, however, it is for now assumed that the conclusions will not be radically different. The next step would be to test the effect of moving the leg straps further up the leg to reduce the moment that they create on the legs. Testing of the effect of custom-made hard belts with multiple athletes, in which each athlete has a hard belt that perfectly fits their back should be conducted as well. Once it is confirmed that this has a positive effect on the discomfort and the performance, the production method proposed in this thesis should be tested further and evaluated whether it is indeed the best way to create such moulds. At the same time, the desired stiffness of the hard belt should be determined.

14.2.2 2022

The leg straps will have to be developed further, with the main focus on material choice. An interesting direction might be to look into how prosthetics stay in place without causing major discomfort. When the leg straps have been developed further, so that they do not cause as much discomfort and limit the freedom of movement, incorporating these leg straps into the wetsuit of the athlete can be explored. The general sizing for the professional harness will have to be determined and material choices need to be finalised. The feasibility of creating customised hard belts for remote athletes using photogrammetry can be explored too, increasing the viability by extending the product to international athletes. High fidelity working prototypes should be send out to athletes to evaluate. Once it is confirmed that the design works and is effective, it can be altered for mass production for a “recreational” harness. The necessary sizes for the masses should be determined, the hard belt should be altered, so the shape can be elongated, and a viable/feasible material should be chosen for the hard belt.

14.2.3 2023

By this time more athletes should have their hands on the harness and small iterations can be done to improve it based on the feedback of these athletes. By the middle of the year the professional design should be “finalised”, so the athletes can start training full time with it. Production processes should be initiated for both the professional harness and the recreational harness.

14.2.4 2024

Win Olympic medals with the new harness.

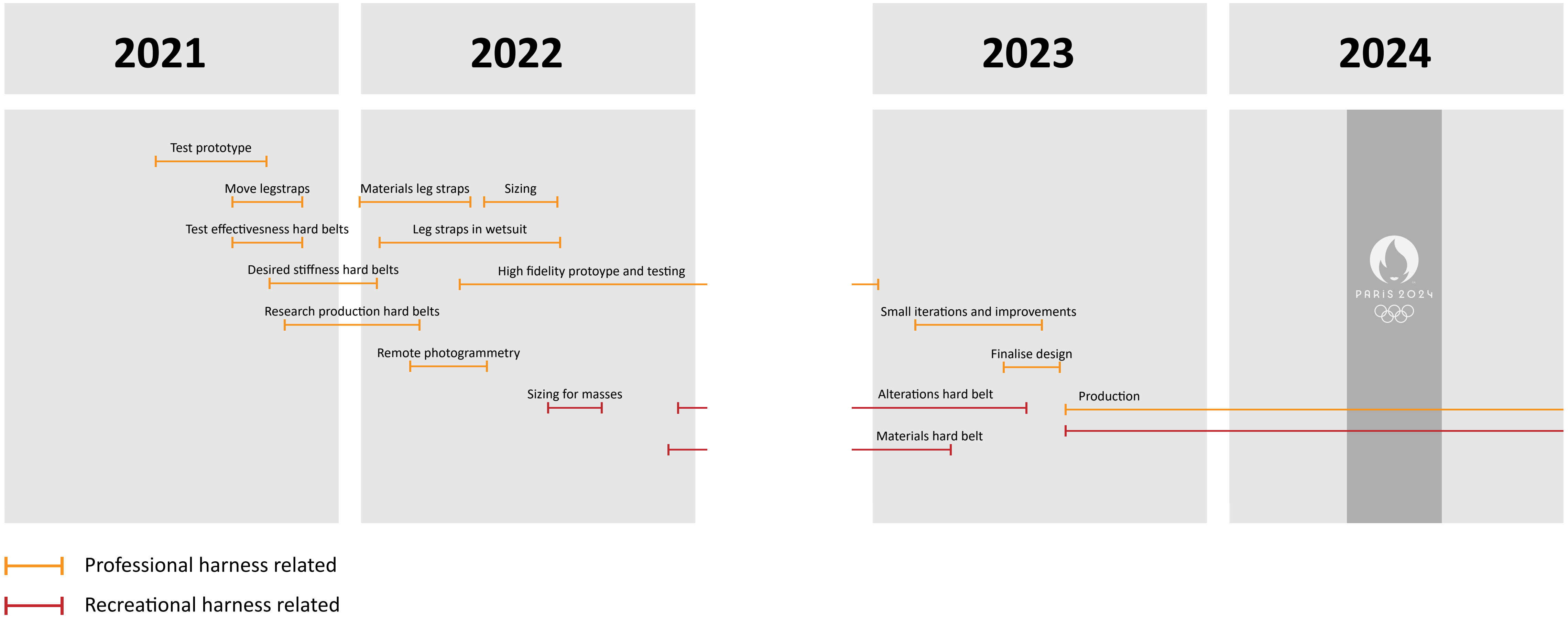


Figure 86: The roadmap

CHAPTER 15 CONCLUSION

The goal of this thesis was to propose a new design for a kitefoiling harness for the Dutch Olympic team, which does not cause major discomfort, stays in the same location on the body and properly supports the body of the athlete. Desk research, questionnaires and interviews with the athletes of the Dutch Olympic team gave an understanding of what was wrong with the current harnesses and led to a list of criteria, which was used to evaluate concepts throughout the design phase. Ultimately, the new harness needed to perform well in the upwind posture and the manoeuvre posture, which are the two extreme postures that exist in competitive kitefoiling.

The design approach for this project was prototype focussed, so every design stage could be tested and validated. Several design sprints were completed to arrive at the final design. First, general concept directions were designed and evaluated. This evaluation led to two major pain points in the design: too much pressure on the hips and too much pressure at the groin. Two subsequent design sprints were executed in an attempt to solve these two pain points and tested with members of the Dutch Olympic team.

The final proposed design is radically different than existing kitefoiling harnesses on the market. The new design removes the spreaderbar and makes the attachment point for the kite much smaller, contains much bigger legstraps that keep the entire harness in the same location and contains a hard belt that is custom moulded to the back of the athlete. Apart from the hard belt, everything can be adjusted to ensure the best possible fit.

During testing it was found that, overall, the new design does not perform better than the current best harness on the market. The freedom of movement is greatly inhibited and the leg straps were perceived as very uncomfortable, partly due to a much higher pressure from the kite in manoeuvres than anticipated. However, the newly designed leg straps did stay perfectly in place and kept the attachment point in the same place.

Recommendations were made for further development of the design. First, the design should be tested with more participants. Even though the design is currently not better than the compared harness, some suggested adjustments could have a positive impact on the discomfort that the athlete perceived.

Concluding, even though throughout the design process the individual parts were tested and the best concepts were chosen, the final design was not better than the current best harness on the market. This is partly due to a higher than anticipated force from the kite in the downwind and in the manoeuvres. The design does show promise, if some alterations are implented and tested.

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Appendix A: Project Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: van Dongen

initials: J. J. given name: Jeroen

student number: *********

street & no.: *********

zipcode & city: *********

country: The Netherlands

phone: *********

email: *********

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ◯ DfI ◯ SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: ◯ Honours Programme Master

specialisation / annotation: ◯ Medisign

◯ Tech. in Sustainable Design

◯ Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: A. J. Jansen dept. / section: S.D.E

** mentor: T. Huysmans dept. / section: A.E.D

2nd mentor: Inge de Zeeuw

organisation: Sailing Innovation Centre

city: The Hague country: The Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

TU Delft

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair A. J. Jansen date - - signature

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ______ EC

Of which, taking the conditional requirements into account, can be part of the exam programme ______ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name date - - signature

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name date - - signature

Personal Project Brief - IDE Master Graduation

TU Delft

An ergonomic Formula Kite harness for the 2024 Olympic Games project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 30 - 11 - 2020 11 - 06 - 2021 end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Formula Kite is a relatively new discipline, based on kiteboarding (image 1). Formula Kite is set to be an official part of the Olympic Games of 2024 in Paris. Currently, athletes use the harness designed for kiteboarding (image 2), however, this causes discomfort and pinching around the groin. Therefore, to ensure the best possible performance of their athletes, the Sailing Innovation Centre (SIC) requests a new harness that properly supports the athletes in the 2 main hip positions and distributes the loads of the kite. The SIC, collaborates with partners who would be interested in producing the harness. Another stakeholder is the TU Delft, a research partner, who would benefit from the acquired knowledge and possibly a patent.

The main opportunities in this project are the in-house researchers and knowledge that are available in the SIC. Previous research was already done by other students, mainly analysing the loads on the body. Obviously the target group (athletes) is well represented at the SIC, making quick user-testing an opportunity (if the Corona crisis allows it). The current kiteboarding harnesses will be used as a starting point for a design. Another opportunity is that there is experience in processing soft materials available at the SDE labs. The SIC is in talks with manufacturers, who could share their expertise and help build the prototypes.

As the SIC is a foundation, there is limited resources available. The Corona crisis will undoubtedly have an impact. For instance, only limited testing can most likely be done with the athletes, as they are kept in a bubble to reduce risks. Furthermore, as winter is coming, the amount of outdoor trainings is reducing. Due to the pandemic, the SIC is unable to offer a workplace, so most communication will have to be done remotely.

space available for images / figures on next page

Personal Project Brief - IDE Master Graduation

introduction (continued): space for images

image / figure 1: A Formula Kite competition (Sailing Innovation Centre, n.d.)

image / figure 2: Example of a Kiteboarding harness made by Mystic (From: Power Kite Shop)

Personal Project Brief - IDE Master Graduation

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The athletes experience discomfort during kiteboarding with the current harness. Mainly, the athletes report insufficient support in various positions on their body. More support is needed, but the harness should still allow for unrestrained movement during the dynamic sport of Formula Kite.

The angles between the surfer and the kite are different to regular kiteboarding. This results in the current seat harnesses being pulled up the body (figure 2). As a result the athlete experiences unpleasant pressure in the intergluteal cleft. Furthermore, as the angle between the upper body and legs becomes smaller, the groin is pinched more and more. The harness needs to be kept in place, with no reported discomfort for the athlete.

The current harnesses lack durability. The surfing environment in general can be quite hostile (e.g. sand/salt water), but the closures in particular appear to fail faster compared to regular kiteboarding, and is reportedly the main reason to buy a new harness. A balance needs to be found between durability and ultimately speed.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Design a Formula Kite harness which supports the athlete optimally and allows for enough freedom of movement to perform during the activity. The harness should not cause discomfort for the athlete. The closures of the harness should last longer than they do on current harnesses

The improved harness properly supports the athlete during kiteboarding. The athlete experiences no discomfort during surfing, and the surfers no longer experience any back problems. The closures last longer, so the surfers don't need to buy a new harness as often and there is no compromise on speed.

Personal Project Brief - IDE Master Graduation

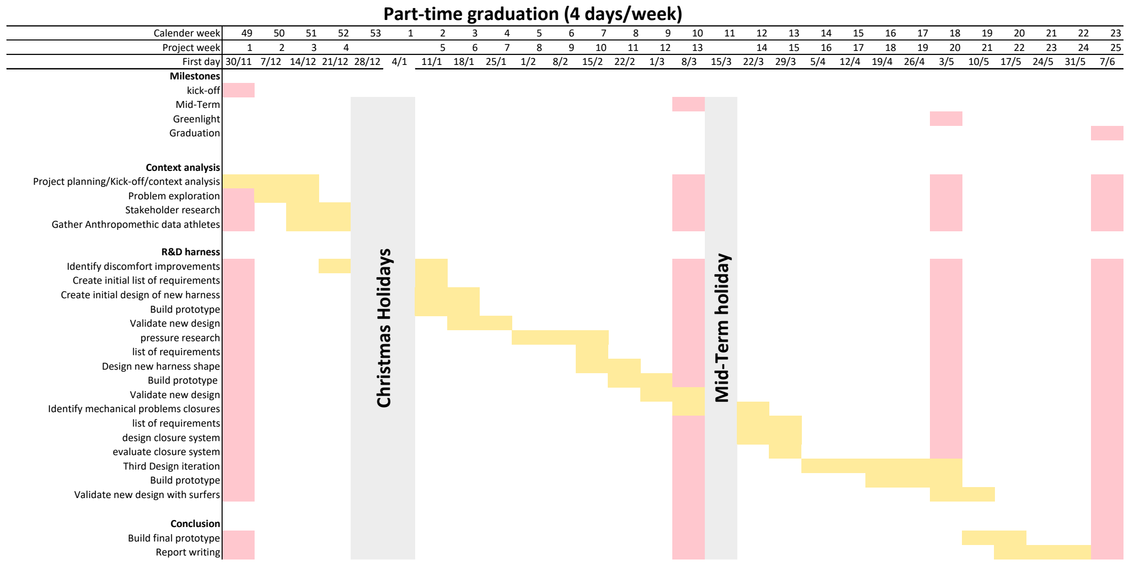
TU Delft

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 30 - 11 - 2020

11 - 6 - 2021 end date



Note: This will be a part-time 4 day/ week graduation, to be student assistant for the technical bachelor courses on the side.

The first 4 weeks are used for general research into context, gathering the correct anthropometric data for kiteboarders which will be used in the next phases.

The next R&D phase four different prototypes will be made, each time adding to or improving the previous design. The initial prototype targets the easy improvements identified through quantitative data. The next few weeks I will research the pressures that the new harness creates on the human body, accompanied with a new prototype that incorporates improvements. Afterwards, an improved system of the closures will be added for more durability. I reserved 5 weeks for unexpected delays, but also to be able to iterate more on the design of the harness. This version will then be tested in the field by the target group.

In the very end there is room for a final prototype and to conclude with a set of recommendations.

Personal Project Brief - IDE Master Graduation

TU Delft

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

This project allows me to see if working in a competitive sporting environment is something I enjoy and would be something I want to work in later in my life. I have an affinity with these kind of sports, as I have done competitive windsurfing for several years.

Most of the projects I have done at Industrial Design are purely academic and nothing is really done with the end-result. This project struck me as a project where the final results will definitely be used for further development. This really motivates me to ensure the data is reliable and prototype evaluations are done properly. I have always wanted to further my skills in prototyping and this project for the SIC is a perfect opportunity to do so. This project would be a chance for me to experiment with a prototype based design process.

Since I have access to the very best kiteboarders in The Netherlands, this seems to be an excellent opportunity to learn how to apply user feedback into the design process.

During my Master I have noticed a lack of focus on ergonomics during projects, which is an important part of good product design in my opinion. I would like to become better at using anthropometric data to design more ergonomic products.

Furthermore, I am interested in how digital design processes can help the development of products. In my elective space I have participated in a programming course and I enjoy working with electronics. I intend to combine these skills to digitally evaluate the prototypes made.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Appendix B: Questionnaire current harnesses

Questionnaire over huidige trapezes

In deze questionnaire wil ik kijken wat er fout gaat in je huidige trapeze als je aan het kitefoilen bent. Dit zal de basis gaan vormen van mijn project. De resultaten zullen een beeld geven van wat er verbeterd kan worden en wat de gebreken zijn. Dit kan ik vervolgens gebruiken om een eerste prototype te maken en te testen.

*Required

1. Wat is je naam?

2. Wat is je geslacht? *

Mark only one oval.

- Man *Skip to question 12*
- Vrouw *Skip to question 18*
- Other: ____________

3. Wat is je leeftijd?

4. Hoeveel verschillende trapezes gebruik je op dit moment voor het kitefoilen? *

Mark only one oval.

- 1
- 2
- 3
- 4
- Meer dan 4

5. Welke trapeze(s) gebruik je (merk en naam)? *

6. Wat zijn de verschillen tussen deze trapezes?

7. Hoe weet je of een trapeze goed past? *

8. Wat is voor jou het belangrijkste aan je trapeze? *

9. Wat stel je het meeste af aan je trapeze? *

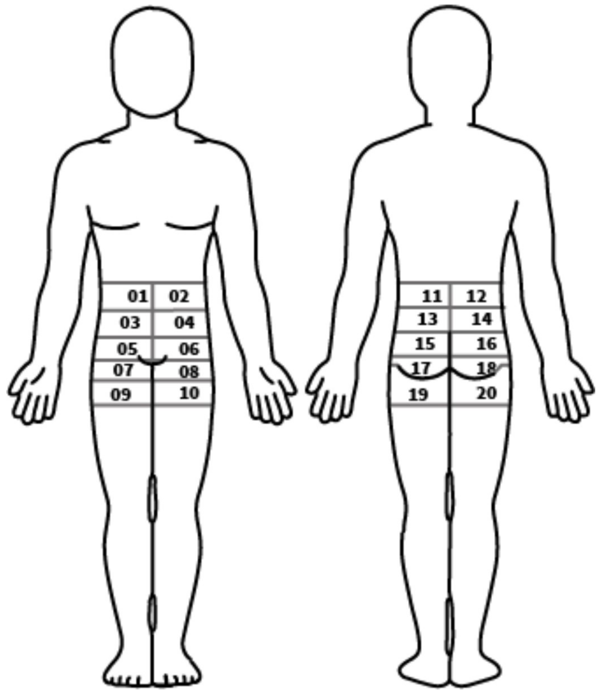
10. Aan welke dingen stoor jij je nu aan je huidige trapeze? *

11. Bij welke handeling zit de trapeze het meest in de weg?

Comfort Heren

In dit gedeelte van de questionnaire kan je aangeven waar je discomfort voelt. Maak gebruik van de plaatjes om te bepalen waar je precies je dit voelt. Je mag ook een combinatie van gebieden gebruiken.

12. In welke gebieden ondervind je discomfort tijdens het kitefoilen? *

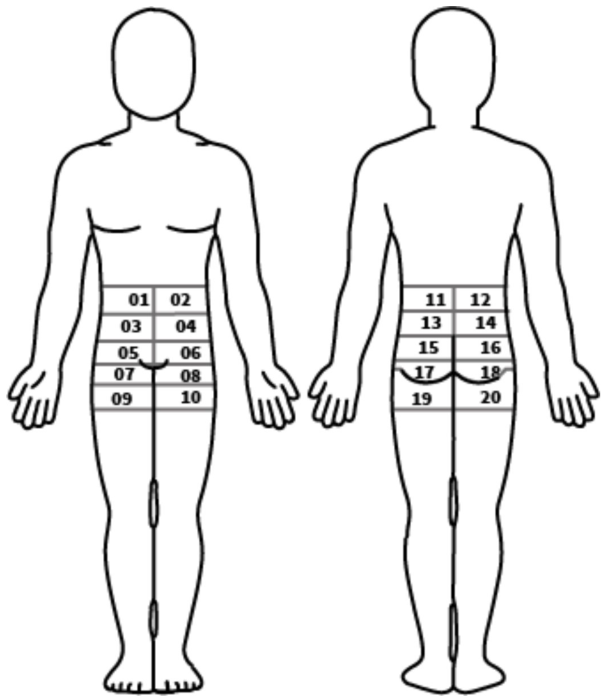


13. Kan je uitleg geven bij je vorige antwoord? (Wat voel je waar precies? Hoe komt dit?) *

14. Wat doe je om het discomfort te verlichten? *

15. Als je een toverstaf had om je trapeze veranderen, wat zou je aanpassen? *

16. Waar moet je trapeze je ondersteunen tijdens het kitefoilen? *



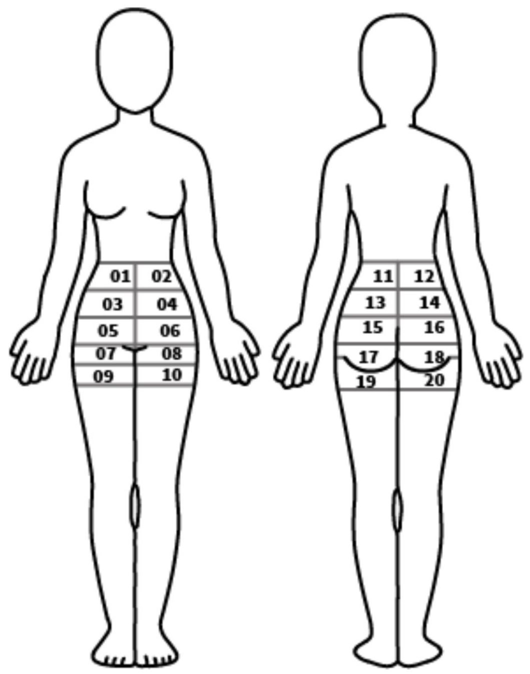
17. Kan je uitleg geven bij je vorige antwoord? *

Skip to question 24

Comfort Dames

In dit gedeelte van de questionnaire kan je aangeven waar je discomfort voelt. Maak gebruik van de plaatjes om te bepalen waar je precies je dit voelt. Je mag ook een combinatie van gebieden gebruiken.

18. In welke gebieden ondervind je discomfort tijdens het kitefoilen? *

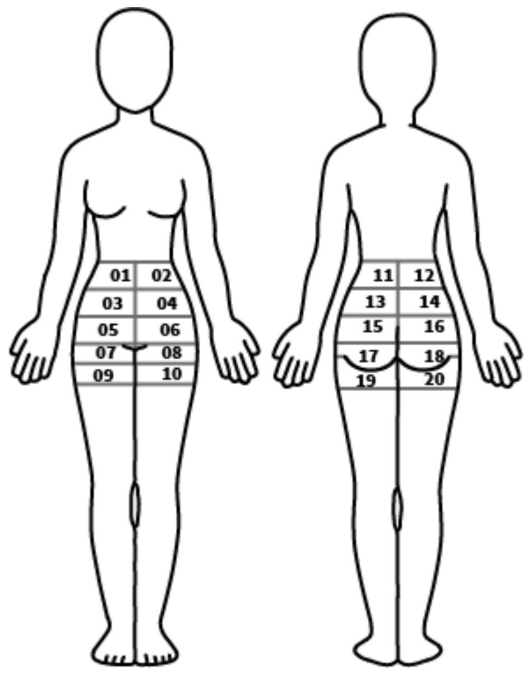


19. Kan je uitleg geven bij je vorige antwoord? (Wat voel je waar? Hoe komt dit?) *

20. Wat doe je om het discomfort te verlichten? *

21. Als je een toverstaf had om je trapeze veranderen, wat zou je aanpassen? *

22. Waar moet je trapeze je ondersteunen tijdens het kitefoilen? *



23. Kan je uitleg geven bij je vorige antwoord? (Wat voel je waar precies? Hoe komt dit?) *

Skip to question 24

Antropometrische Data

Hieronder staan vragen die gaan over je eigen lichaam. Deze data wil ik gebruiken om digitale mannequins te maken om het ontwerpen te versnellen en als dient als input voor mechanische modellen.

24. Wat is je lengte?

25. Wat is je heupomtrek? (Meten om breedste punt van je heup)

26. Wat is je tailleomtrek?

27. Wat is je gewicht?

Contactgegevens

Bedankt voor het invullen van de questionnaire! Als je bereid bent om je antwoorden op een later moment toe te lichten, zou je dan hieronder je telefoonnummer kunnen invullen?

28. Telefoonnummer:

APPENDIX B: INTERVIEWS

INTERVIEW 1

Participant 1 is a youth athlete in the team. The interview was done on 22/01/2021 through Zoom

De voornaamste treden waarom ik deze (dakine vega) gebruikte, en dat het kapot ging. Hij ging letterlijk kapot. Dat wil ik nog wel even laten zien. De trapezes zijn allemaal... Deze heeft geen haak meer, zoals deze (Ion Sonar). Dit zijn al die touwtjes, en dit is aardig versleten (bijna doorgesleten band). Maar dit maakt niet heel veel uit, maar hij was hier (aan de zijkant) waar hij vast zit, afgescheurd. Hij is nu gerepareerd. Sam heeft dezelfde trapeze kapot gemaakt, ook op dezelfde dag. En dit is door een paardenzadelmaker gerepareerd, en is doorgestikt. (...onhoorbaar...) Mag wel stevig zijn dus. Want deze hier zijn er helemaal doorheen gestikt en deze zijn er kinderachtig opgestikt maar dat overleeft het niet.

Weet je hoe dat faalt?

De witte stiksel zit er niet doorheen (het hele trapeze). Die zitten waarschijnlijk alleen op het zwarte plaatje, en dat zwarte plaatje zit eromheen gestikt. Het zwarte stiksel is door het zwarte plaatje en helemaal door de trapeze heengegaan, en dat is nog niet stuk gegaan. De paardenzadelmaker weet het beter.

Maar je bent nu van de Dakine naar de Ion gegaan toch?

Ja want de Dakine was kapot, dus ik had een nieuwe nodig en als ik die nog een keer ga kopen gaat die weer kapot. Toen bij deze (Ion sonar), maar die heeft heel veel handigheidjes. Dit is een officiële race trapeze. Deze heeft heel veel andere dingetjes. Het eerste is de haak om de bar met lijnen vast te maken. Normaal gebruik je een chicken loop en dat is veel meer afstand, dan heb je de chickenloop en de quickrelease daarboven. En met het nieuwe systeem begint de quickrelease gelijk hier omdat het maar één ringetje is. Dat is veel korter en dat is heel essentieel zeg maar. Als het hard waait wil je alles zo dicht mogelijk bij je hebben, want dan kun je het makkelijker van je af gooien. Als je de bar meer van je afduwt heb je minder power, kun je meer wind houden.

Welke trapeze had je voor de Dakine?

Een hele oude Mystic, echt een crack ding. Maar die is ook overleden trouwens. Op dezelfde manier als de Dakine, maar die had ook nog dat het bandje bij mijn benen afscheurde. Dus dat was wel heftig. Ik had wel mijn best gedaan wat dat betreft.

Maar hier zit een zelfgemaakt haakje op (Ion Sonar), ik vond deze toevallig in een schuur van iemand. Dit is een haak waar niets op zit en heb ik een touwtje om gebonden. Ik denk dat Evan ook zo een setup heeft. Iedereen heeft opzich dit ding (quickrelease), maar iedereen heeft hem anders vast. De meeste hebben hem op een haak met een boutje aan vastgemaakt en is net even wat langer. Maar ik moet zeggen dat dit wel heel nice is. De quickrelease is wel het draad aan het slijten (bijna doorgesleten).

Heb je een eigen sponsor die harnassen maakt?

Nee heb ik niet. Maar die kites kosten 2000€ per stuk en dan heb je er drie van en een harnas kost 120€ en daar kijkt niemand van op. Het is vaak dat je een wetsuit sponsor hebt. Want wetsuits zijn wel best wel duur. Iedereen van ons heeft wel een wetsuit sponsor, en wetsuit sponsor maken ook trapezes, maar die maken heuptrapezes voor het freeriden in plaats van zittrapezes. En dan kan je een andere trapeze dragen omdat je met heuptrapezes niet mee kan racen. Voor racetrapezes heeft iedereen een vrijstelling. Het ligt aan hoe diep je in je sponsor contract zit, maar je sponsor heeft vaak connecties met andere die je kunnen helpen. De Dakine heb ik ook gekregen via via. Ik heb van hun geen geld gekregen. Maar het zijn geen concurrenten ook al zitten ze in dezelfde niche en daardoor kunnen ze je wel gewoon helpen daarbij. En de Sonar heb ik gekregen van een kitesurf school waar ik heb gewerkt, en die wouden mij wel sponsoren. Dus die hebben me deze gegeven. Maar dat zijn van die kleine dingetjes.

Waarom ben je overgestapt naar je Ion Sonar?

Niet alleen omdat de Dakine kapot was, ik zou hem graag blijven willen gebruiken, maar deze heeft iets handigs. Want die haak moet heel erg laag blijven, dat is een beetje de essentie van alles. En deze heeft die twee banden waar de spreaderbar mee vast zit, dat is hetzelfde als bij de Dakine, maar de Sonar heeft nog een derde band die hierachter zit. En die loopt achterlangs de spreaderbar, en als je die strak trekt, trekt die band de spreaderbar naar beneden. En dat is heel erg slim, en is standaard op deze trapeze, en dat heeft nog geen enkel ander merk. Maar iedereen is daar wel hyped over die weet dat dit bestaat. Want als je foiled staat je kite in een lijn met je trapeze, maar soms stuur je de kite wel eens omhoog voor een transitie. Dan moet de haak zo laag mogelijk blijven, maar dat gebeurt niet. Dat omhoog kruipen gebeurt met name gedurende manoeuvres, maar als je in je rak zit kruipt hij een klein beetje omhoog. Je vaart op je heupbotten, dan kan het zijn dat hij daarboven gaat zitten waar je in je heup geen botten hebt. En dat is echt heel vervelend, echt heel kut.

Nog een dingetje wat ik wel fijn vond. De bandjes van de Dakine deden geen pijn maar gingen heel erg knellen en de

Sonar heeft dat niet. Met name bij je lies, de binnenkant van je bovenbeen, waar je been begint en je kont eindigt. Ik ben er nog niet achter waarom dat is. De Sonar is heel erg comfortabel gemaakt, hier zitten kussentjes in enzo en de Vega is gewoon een lapje stof. En het lapje stof is eigenlijk beter. Het schuim loopt vol met water, heel leuk dat het comfortabel is maar door het water in het foam ben je 10 kg zwaarder. Dat lapje stof moet wel goed geshaped lapje stof zijn, maar dat is wel echt veel chiller. Als het schuim geen water zal opnemen zou het perfect zijn.

Hoe ben je aan de Ion Sonar gekomen?
Joris vaart Ion, en moet ook prototypes testen. Hij had een prototype mee en vroeg wat wij ervan vonden. Hebben we het geprobeerd en was wel chil. Eigenlijk via hem eraan gekomen. En de Dakine ben ik gekomen door aan andere internationale racers gevraagd waar zij mee voeren. En iedereen is daar ook weer van af trouwens.
Het is een soort hype, of iig mensen die het gebruiken en er niet over klagen. Dan denken mensen nice, ik wil ook niet klagen en na een half jaar komt iedereen er weer achter dat het toch niet goed was. Niet heel veel mensen breken trapezes zoals ik en Sam dat hebben gedaan. Misschien zelfs de enige die ooit een trapeze hebben gebroken dus dat is redelijk zeldzaam. Dat kwam doordat we normaal met 10-20 knopen varen, hooguit 30 knopen. Een dag was het 40 knopen, mensen vonden het te gevaarlijk maar wij vonden het leuk en toen ging alles kapot. Sam en ik zijn wat zwaarder en sterker daarmee dus wij varen altijd een kitetje groter. Daardoor komt er elke dag net even wat meer op. Anderen hebben daar niet echt problemen mee, Jako misschien. Jako is wat ouder, die heeft 10 trapezes gebroken. Die is 110 kilo spier en dingen kapot maken. Dat is niet alleen trapezes. Dat is gewoon geweld. Hij is afgetrained, buikspier blokjes. Sterke jongen iig. Die maakt ook alles kapot. De dakine voor hem is het langste heel gebleven. Maar de meeste mensen vinden de Ion goed, mede door het bandje wat hem naar beneden houdt.
Maar de trapeze blijft dus tijdens de rakken redelijk op zijn plek maar tijdens de manoeuvres gaat hij vooral omhoog. Klopt, vooral tijdens de manoeuvres gaat hij omhoog. En als de trapeze hoog zit krijg je hem ook niet meer naar beneden.
Wat fijn is dus aan de Ion is dat hij past goed bij je benen. Hij past redelijk om je lichaam maar neemt wel weer veel water op. Comfort is beter, maar gewicht is nadeel. Maar het grootste voordeel is dat de trapeze laag blijft.
Ja dus dat de trapeze op zijn plek blijft zitten en dat je benen niet worden afgekneld. Dat zijn wel de essentiële dingen. Verder zijn ze beide heel laag uitgesneden. Heel veel trapezes hebben nog een heuvel zitten aan de achterkant voor de rug. Dit zijn eigenlijk broekjes, die niet ver boven je bilnaad komen. Dat is heel fijn. Wij leunen constant naar voren. Veel zijn gemaakt voor freeriden. Dan sta je bijna volledig rechtop. Wij zijn helemaal voor overgevouwen. Dan is er een heuvel die in de wegzit, geen nut heeft.

Wat voor impact heeft je houding?
Als je in die houding zit kan je heel veel houden qua power en qua wind. Omdat alles in 1 lijn staat. Daardoor kan je veel kracht houden. Maar als je een beetje omhoog komt, lopen de krachten heel raar en kan je minder power houden. De houding vol houden kost wel weer veel kracht omdat er al die kracht op je bovenbenen terecht komen. Je voelt je bovenbenen verzuren, omdat we ook heel statisch staan. Als we 1 kant op varen wat soms wel 2 minuten kan duren, dan voel je dat wel, dan is het heel belangrijk dat je bloedsomloop nog een beetje gaat. Dat was het probleem met de Dakine en 2 keer gehad met de Ion is dat je benen gewoon afknellen. Je staat zolang in 1 houding, en die bandjes zitten heel strak. Als je bandjes lost hebt dan gaat je hele trapeze weer omhoog. Dan zit de trapeze niet meer op je bilbot, maar daarboven en dan ga je veel onderrugspieren gebruiken. En dat gaat echt heel veel zeer doen op een gegeven moment. Maar dat is echt gewoon spier. Alsof je de hele tijd aan het deadliften bent.

Wat zijn de verschillende aspecten?
Ion is dik gevoerd en slecht, de Dakine is dun en goed. De bandjes van de Dakine zijn heel dun, maar van de Ion dikker en andere positie waardoor ze minder afknellen. De ion heeft specifiek een touwtje aan de onderkant die de haak omlaag houdt. Verder zelfde schnitt. De eerste trapeze was heel hoog, verder was die vergelijkbaar. De Dakine ging kapot omdat die niet goed gestikt was en de Ion heeft dat niet. De Ion gaat een gleufje in waar die waarschijnlijk wel goed vast zit. Verder hebben ze beide een touwtje aan de achterkant, voor vast houden maar die mag er van mij van af. Wij gebruiken hem voor vasthouden zodat je het strand niet op word getrokken bij het oplaten. Nog een dingetje. Bij de Dakine zitten de weerzijde vast met een kliksysteem en simpel touwtje. Bij de Ion hebben ze er een band van gemaakt, ala rug ondersteuning. Niet per se een voorkeur. Maar de band zou wel kunnen zijn dat dit de Ion lekker maakt. Alsof je de rugondersteuning van een deadlift draagt. Een Weightliftbelt. Je kan hem niet heel strak kan aantrekken. Maar bloeddoorstroom moet niet in geding raken.

Verschillende maten geprobeerd van de Ion?
Ja allemaal net te groot. Dit is een S, wat verassend was. Eerst een L maar dat was veel te groot. De Dakine is een L. Ook een M geprobeerd. Ik kwam erachter via Joris, gaat allemaal via dealers. Iedereen heeft andere maatjes, maar dragen allemaal nu een s. Kleine kontjes. Maten zijn wel belangrijk. Als het te groot is gaat de trapeze helemaal om

je heup, terwijl het beter is als de trapeze stop bij je bolste punt van je heup. Anders moet je hem helemaal strak trekken, daar heb je vaak geen ruimte voor met je haak en je krijgt een heel onhandig gevoel. Dan krijg je ook een heel gat bij je rug. Ik heb geen uitgesproken mening over het kussentje bij je onderrug.

Onder welke hoek zit de kite?
Doel van de kite is dat de lijnen net over je board gaan.

INTERVIEW 2

Participant 2 is a youth athlete in the team. The interview was done on 22/01/2021 through Zoom
Welke trapezes heb je gehad?
Ik ben begonnen met zittrapezes. Dat is het enige wat ik had, maar niet voor het racen.

Hoe ben je eraan gekomen?
Bij het begin had ik geen trapeze. Rondsharteren. Kijken wat een goede trapeze was. Toen hebben we gekeken naar het race circuit, en toen viel het ons op hoeveel mensen met deze (Dakine Vega) raceden. Toen kwamen tot het besluit dat dat dan de beste was. We wisten nog niet zo goed wat een goede trapeze was, maar het zat wel aanzienlijk beter dan de vorige. Want toen zat ik nog met een heuptrapeze. Dat werkte niet helemaal.

Heb jij ook een sponsor?
Ik heb niet een kledingsponsor. Ik zat eerst bij een merk, Ozone, waar manera ook bij zat. Toen ben ik overgestapt naar een concurrent, FlySurfer, maar die maken geen trapezes. Maar als het goed is zit ik nog bij Manera, maar het maakt niet zoveel uit waar ik zit. Misschien als je diep in een merk zit, die trapezes maakt dat je met een reden moet komen, maar ik denk dat het niet zoveel uitmaakt.

Kan je in je eigen woorden uitleggen waarom je de overstapt hebt gemaakt van de heuptrapeze naar de Dakine Vega?
Sowieso trapezes schuiven een beetje. Als die al om de middel zit, zit na een tijdje rond mijn ribben. Je kan je wel voorstellen, rond je bekken, scheelt het al zo een lengte (~40cm) met je armen extra hebt. Dus als je een heuptrapeze hebt, heb je zo een lengte arm die je niet hebt. De bar van je wegduwen heet throw, hoe verder je hem van je af kan duwen des te beter je vlagen kan opvangen. Dus niet alleen met je benen opvangen, maar ook nog eens met je armen. Dat was 1 reden, soort gas en koppeling. En, we zitten in een best wel vage houding. En, in principe zit best gecentreerd bij je bekken, als je dat bij je heupen hebt wordt je helemaal uit elkaar getrokken in een gekke houding geforceerd. Als je heuptrapezes hebt. Niemand racet met heuptrapezes.

Hoe was je bij je huidige terecht gekomen?
We hadden besloten dat we allemaal met hetzelfde zouden gaan varen. Ze waren best lastig te verkijgen, dus met zijn allen houden we een mooie stack.

Had je een soort eisenpakket voor je trapezes vanuit je team?
Viel wel mee, sowieso moest het beter zijn dan we eerst hadden. En dat was niet zo heel moeilijk. Alles was eigenlijk beter dan wat we eerst hadden. Omdat mensen er zoveel mensen mee voeren moest het wel goed zijn. Gekeken naar de competitie, de beste vrouw was toen ook daar, en die ondervraagd over de Dakine Vega. Die voer daar dus mee, en dat hielp ons besluit.

Hoeveel heb je gevaren met je huidige trapeze?
Best veel, in ieder geval een jaartje. We zijn van helemaal niets naar de middenmoot gegaan.

Wanneer zijn jullie begonnen?
We zijn sowieso vorig jaar augustus (2019?) begonnen, toen gingen we nog met vliegers en foils die niet heel hard gaan. Nog niet eens met houdingen en manoeuvres. Toen hebben hebben we trainingsweken gehad, die ons kennis ging overbrengen. Een Duitse Coach, hij voer vaak mee. Hij was gewoon heel goed. De Fransozen zijn heel goed, een stuk of 3 domineren. Jannis Maus was het die ons hielp. Het staat nog in de kinderschoenen. Je start iets op wat nog niet bestaat. Heel veel gaan trainen ook heel anders.

Zou je aan de hand van de trapeze laten zien wat je goed vind?
Er waren nog niet zoveel dingen die goed waren eigenlijk. Wat ik goed vond is dat hij licht is en dat je een bandje hebt als je hem omdoet, niet gelijk de haak vast hoeft te maken. Dan hoef je niet de hele tijd te sjorren aan de banden van de haak. Je hoeft dan alleen de rechterkant aan te passen. Aan de lichtheid is het fijn dat je niet een

lomp ding om je heen hebt. Je hebt nog bewegingsvrijheid. Je kan makkelijk van positie switchen. Makkelijk je benen bewegen. De heuptrapeze was nog vrijer, maar dat is eigenlijk niet te vergelijken. Dat waren eigenlijk de pluspunten? Ik heb nog niet de Sonar gevaren, volgens mij heeft de sonar een breder bandje om alvast de trapeze vast te maken.

Heb je plannen om naar de Sonar te switchen?
Ik zou eigenlijk gaan surfen met de Sonar, omdat mijn kiteschool die had gesponserd, maar Sven heeft die (Broertjes van elkaar). Ik wilde eigenlijk gaan varen, maar toen brak ik mijn enkel. Ik was helemaal van plan om te surfen met de Sonar, omdat die een iets heeft waardoor de haak wat gecentreerder blijft.

Hoe was je bij de Sonar gekomen?
Joris is gesponserd door Ion, die zit in de top van de sponsors. Die kreeg een prototype opgestuurd van Ion. Maar je kan wel alles van hem aannemen, maar hij vaart ervoor, dus het kan zijn dat hij zegt dat het goed is, terwijl het niet goed is. Dus toen had Sam er mee gevaren, en die zei dat het een stuk beter is, want de haak kantelt niet en beweegt een stuk minder. Dat was de voornaamste reden.

Wat vind je er kut aan de Vega?
Om te beginnen de beenbandjes, op zich wel goed, best zacht. Maar ze snijden in je liezen, want ze zitten daar omheen. Na een tijdje gaat dat irriteren daar, en dan moet je echt een pauze nemen. Ik heb daar last van. Ze zijn klein en compact zodat je er wel goed mee kan lopen, maar ik zou misschien een soort rondje ervan maken. In ieder geval meer afronding bij de naden. Dat gaat nu in je liezen snijden. Dus als je dat een bolletje van maakt zal dat misschien minder snijden. Maar dat zal de bewegingsvrijheid beperken. Daarmee, zou ik graag wat mee gedaan hebben. Mijn tweede punt is, hij kruipt in mijn naad. Denk niet dat je dat kan weghalen, het zit daar eigenlijk. Je steunt ook daarop. Omdat wanneer je de haak hebt vastgemaakt, blijft hij niet zitten. Eerst wordt hij omhoog getrokken. Of verder van je weg, beetje op de hoogte van je lul. Dan zit hij wat hoger. Als je de kite omhoog duwt dan gaat de kite trekken aan je haak, wat ervoor zorgt dat de haak ook gaat kantelen. Dus het is logisch dat hij hoger gaat zitten, onder andere in je naad. Dus tijdens Jibe of een voorstart, als je nog niet zo hard gaat. We zitten ook vrij gespreid dus dan gaat hij ook weer wat meer omhoog. Ik heb niet de Sonar gevaren, maar misschien is het bij die minder. Dat kantelen van de haak is het meest vervelende. In principe wil je één steady punt hebben waar je aan wordt getrokken. Ik heb nog een safety, die alle kanten opgaat. Als de trapeze het dan vervolgens ook doet, gaat het alle kanten op. Als je de krachten gecentreerd houdt, dan denk ik dat je de krachten vanuit de vlieger ook makkelijker in de foil trapt. In plaats van dat je energie verspilt in het bewegen van de spreader bar. De feedback is dan wat directer. Bij de Vega zit het wat te los. Dan heb je hem helemaal strak getrokken voor het foilen en daarna kan je de gespen nog veel strakker trekken. Zo af en toe zet ik het harnas nog wat strakker tijdens het varen. Een ander punt is op zich is dit een wat lagere trapeze, qua rug. Dan zit het punt waar je de kracht voelt wat vaag, als het laag is vind ik het nog beter. Maar nu heb ik nog veel dat er een opening zit op de achterkant van de rug. Dus de kracht van de trapeze niet meer in het geheel in de trapeze, maar alleen in de bandjes. Dan heb je een soort ring om je heup.

Waarom vind je dat lagere rug gedeelte fijner?
Dat hoge dat wordt nog een groter gat. Nu heb je het niet zo heel veel. Ik denk dat het hoge niet zoveel nut heeft. Voor mijn gevoel kan je het net goed ervan af halen. Dan denk ik ook dat je meer in je rug voelt, terwijl je hem meer rond je bekken wilt hebben. Dat eigenlijk, dan gaat hij ergens anders trekken terwijl je dat niet wilt.
Hij is niet stevig genoeg. Sven heeft 3 of 4 banden gesloopt. Ik heb er ook een paar gesloopt. Waar ze kapot gaan is zeg maar bij de aanhechtingspunten. Zoals je kan zien is het hier door een paardenzadelmaker gerepareerd. Het zijn de allerbovenste, de alleronderste en de onderste van boven. Het beenbandje is ook niet heel sterk meer, die is ook niet heel sterk. En aan de andere kant is ook het beenbandje en de bovenste en onderste. De bandjes waar de trapeze mee vastzit, trek je na een tijdje stuk. Dat viel wel echt tegen. Kantelen van de haak natuurlijk is ook een nadeel. Misschien hebben mensen er nog niet over nagedacht, maar voor het racen zelf moet je een mesje en een fluitje hebben. Dus daar moet ook een vakje voor komen. In de vega zit het mes bij de haak, maar misschien is het een idee om dan ook gelijk een rotfluitje erin te doen. Daar moet wel een vakje voor zijn, anders is je trapeze niet goed voor die events. Formula Kite doen ook alle races. Mes is sowieso verplicht, fluitje ben ik niet heel zeker. Dat waren al mijn minpunten, behalve dan de haak die niet goed is.

Heb je verder nog iets wat je kwijt wil?
Dat je als je het aan hebt dat het inderdaad voelt, aan de zijkant waar de bandjes zitten echt een soort dik touw om je heb. Dat je daar best wil de drukpunten hebt zitten. Dat die daar nu zitten. Dat het voelt alsof de trapeze als een geheel is in plaats van losse druk punten. Het voelt nu alsof je een bandje hebt om je heen, de beenlussen en een haak die los beweegt. Hoe het eigenlijk hoort te zijn is dat je het voelt als een geheel. Dat is het doel.

Verwacht je dan dat het lekker zit?
Ja denk het wel. Mijn grootste zorg is die haak eigenlijk. Er zullen altijd minpunten zijn bij iedere trapeze, maar dat hij vooral beter is dan wat we nu hebben.

INTERVIEW 3

Participant 3 is a youth athlete in the team. The interview was done on 22/01/2021 through Zoom
Welke trapezes heb je de afgelopen tijd gebruikt?
Ik heb twee trapezes gebruikt afgelopen tijd. Ik word ook door Ion gesponsord. Ik heb eigenlijk alleeen met Ion heuptrapezes gevaren, en zit trapezes. Ik had eerst een harnas dat echt voor beginners was. Rotox (verbetering: Radar) van Ion. Die was veel te veel kracht om je rug heen. Toen kreeg ik deze te zien, en die wilde ik eigenlijk direct testen. Meerdere mensen van team zeggen ook dat een van de beste trapezes is momenteel, die te verkrijgen is.

Want ion had met jou contact opgenomen, of hoe is dat gegaan?
Ik word gesponsord door Ion, ik heb wel een goede band met mijn sponsor. Met het racen neemt Ion contact met me op, met een nieuw product dat te testen is. Deze trapeze was zo een stap van wat het hiervoor was. Dat was een heel goedkoop of gefine tuned model. Dit is er echt speciaal voor ontworpen. Dat merk je bij de benen, bij de bil dat die een stuk beter blijft zitten. Volgens mij gaan Sven en Ivar er ook mee varen. Sam heeft er ook één. Ik ben er echt heel tevreden over. Ze hebben ook nog de Dakine, alleen die wordt niet meer gemaakt. Die is bijna niet meer te verkrijgen.

Daar heb jij niet mee gesurft, die Dakine?
Nee, daar zijn ze ook heel blij mee. Alleen gaat alles scheuren. Deze is ook uitgescheurd natuurlijk. Bij de andere heb ik dat niet gehad gelukkig.

Voordat je naar de Sonar ging had je de Rotox, waarom heb je die overstap gemaakt?
Ik zal naam even opzoeken. Puur omdat ik die trapeze had toen, toen kwam ik er net in. Was een mooie start trapeze. En toen zei de sponsor, dit wordt de nieuwe foil trapeze. Dus dat zal wel een stuk beter zijn. En dan ga je het testen, dan merk je gelijk dat hij een stuk beter om de kont blijft zitten. Dit was nog een M, omdat dat de enige prototype maat was de overbleef. Eigenlijk een maatje kleiner zou nog fijner zijn. Hoe groter hij is, des te meer hij omhoog gaat kruipen. Als hij precies aansluit, is dat een stuk fijner. Dat scheelt in omhoog kruipen.

Je hebt nu de productie variant?
Die heb ik ook, maar die is precies het zelfde.

Wat vind je goed aan die trapeze?
Vooral de banden bij de benen. Die zijn heel dik, niet heel ielig dun. Mooi stevig. Er zit een standaard mes ingebouwd, dat is altijd top. Bij races moet je die wel hebben, en bij veel trapezes zit die er niet bij geleverd. Maar bij deze zit die er gewoon in. Dat is gewoon eigenlijk, dat je niet zonder mes gaat racen. Ik heb het nog nooit hoeven te snijden. Maar als je met 15 man in de klits zit, kan je beter je leven redden dan dat je aan 15 kites hangt. Je hebt de haak, als die omhoog gaat, gaat hij schuin. Maar bij deze trapeze hebben ze een touwtje gemaakt, die is strak te trekken. En dan gaat hij niet omhoog. Dan blijft hij recht compact staan. Er is ook een dikke rand aan de bovenrand, geen scherpe delen ofzo. Eigenlijk voor mij allemaal toppunten. Niet alleen omdat ik gesponsord word, maar voor wat er nu is, is dit het beste vind ik.

Als ik met een nieuwe trapeze komt, heb je aspecten waarvan je hebt dat moet erin zitten?
Ik denk toch wel de achterkant. Ik weet niet van wat voor stof dit is. Maar dat zorgt wel goed voor profiel. Hij blijft mooi als een kuip om je rug heen zitten. Alleen wat ik had is dat de rand te dik was, en dan voel je hem zitten. Het is dus belangrijk dat je de goede maat hebt, anders gaat hij wel snijden in je rug. Als je de verkeerde maat hebt, dan zit hij niet goed. Dan merk je dat dit plastic deel te groot is. Dan zit dat te dicht bij elkaar. Dan merk je dat hij in je rib gaat snijden. Die banden zijn wel goed, en die ook is ook belangrijk. Het moet echt goed bij je kont aansluiten, en niet bij je ballen omhoog komen.

Waarom is dat aansluiten belangrijk?
Anders gaat het daar, onder je anus, precies in het midden lopen snijden en dat wil je echt niet hebben. Het zit dan niet fijn. Ik ben best wel groot, maar ik gebruik alsnog een S. Evan die gebruikt zelfs XS, maar daar kom ik niet in.

Die banden zijn dus heel fijn, de achterkant vind je fijn, de haak blijft op zijn plek. Maar waarom komt de haak omhoog?

Je kan hem wel strak doen om de banden, maar daar zit altijd wel speling in. Eigenlijk heb je die onderband, en die trekt de haak weer omlaag. Want die zit vlak bij de band van je been. Ik kan hem wel even aan doen als voorbeeld. Normaal kan de haak helemaal omhoog, en dan hier hebben we een klik elastiek die je dicht maakt. Dan kan je die band helemaal aanspannen (oefent veel kracht uit om strak te trekken). Dan zit hij strak op de lijn naar de onderkant van je kont. En nu gaat de haak een stuk minder omhoog. En de sluiting van de spreaderbar vind ik van Ion heel fijn. Die kan je zo los klikken. Die sluiting kan je ook gewoon zelf ontwerpen. Het is misschien slim om, alle merken hebben bepaalde punten die wel weer echt heel goed zijn. Dat moet je zien te combineren tot echt één hele goede.

Zijn er verder nog goede punten?
Ja niet echt. Ja deze manier van spanbanden vind ik echt heel fijn. Deze sluiting is mooi van metaal in plaats van plastic. Dit gaat echt heel makkelijk los en vast, en het slipt niet los ofzo.

Heb je bij de Sonar dat je banden weer strakker moet trekken?
Nee eigenlijk niet, ja heel af en toe misschien. Je gaat soms ook dagen varen, het heeft er ook mee te maken dat je vaak stil ligt en dan heb je geen kracht op de banden tuurlijk, dan gaat er weer speling komen en kan het losser gaan. Daarom heeft deze elastiekjes, dat als het wat losser gaat, dan blijft het zitten zoals het zit. Niet dat hij bij deze sluiting dat hij een beetje losgaat dat hij eruit kan komen.
Het is niet de Rotox maar de Radar trouwens!
Heb je verder nog punten, dit vind ik niet fijn?
Eigenlijk niet, want er is op dit moment niets beters. Dit is voor mij al het beste wat er is. Ik ben er echt heel tevreden over. Wat vind ik er slecht aan? Ik had het eerst dat die harde achterkant te groot was. Dat was eigenlijk met een te grote maat. Verder had ik daar geen last van. Dat kussentje aan de achterkant is ook wel fijn, maar die ben ik door een harde crash verloren. Ik mis hem niet echt, niet echt een groot verschil. Het kan wel een beetje verschil maken, als je achteruit hangt en de trapeze zit schuin kan het wel een beetje opvullen. Het beste is wel met, maar als je zonder hebt en je doet de trapeze strakker dat je het verschil niet merkt.

Als je dubbelgevouwen zit blijft hij wel goed zitten bij de rug?
Ja dan blijft het wel echt goed zitten hoor.
Ik heb voor de rest niet echt slechte punten, ik moet weer even surfen. Het moet weer lekker seizoen worden dan kunnen we weer lekker knallen.

Wanneer beginnen jullie weer in Nederland?
We gaan in april wel weer echt in Nederland vol, maar we hebben natuurlijk tussendoor reisjes op de planning staan, dat hangt ook weer van corona en bij mij van mijn school af. Dat moet ook gebeuren.

Sven had zijn Sonar aangepast met alleen een touwtje, in plaats van een haak, was je daar van op de hoogte?
Dat maakt eigenlijk niet zo veel verschil. Hij zit nog dichter bij je, nog compacter. Ja kijk, als alle kleine puntjes belangrijk zijn, kan dat verschil maken. Maar ik vind niet dat dat met vaar eigenschappen, dat die drie centimeter uit maakt. Uiteindelijk zit je bar op hetzelfde punt, alleen 5 cm opschoven. Je zit gewoon een stuk compacter.
Einde interview

INTERVIEW 4

Participant 4 supports the team and is an organiser of the Holland Kitesurf Cup. The interview was done on 25/01/2021 through Zoom
Zit je zelf in het coreteam?
Nee ik zit er zelf niet in, ik was heel lang fanatiek, 5 jaar. Maar dat is vorig jaar minder geworden. En die jongens die hebben zoveel tijd en trainen zoveel dat ik dat niet meer kan bijhouden. Ik heb mijn top gehad en ik organiseer de wedstrijden. Dat vind ik helemaal prima. Dat hele fantieke is er een beetje af. Ik foilde nu 5 jaar. Het was nieuw, maar nu beginnen steeds meer mensen het te doen. Het racen is wel vrij jong. Dat is ook heel hard gegroeid in de afgelopen jaren. De fransozen waren er heel vroeg bij, maar in Nederland hebben we een inhaalslag gemaakt. We hebben nu al wedstrijden van 50/60 man, dat is bijna groter dan alle wedstrijden die in de wereld gedaan worden. Dat is wel mooi, Nederland is echt perfect voor het foilen, met vlak water en altijd wind. Het verbaast ons ook wel, we zijn 5 jaar geleden simpel begonnen met een mannetje of 4 en dat ging steeds harder.

Had je voor de Vega een trapeze gebruikt?
Ik was begonnen met een heuptrapeze, maar dat is met foilen en het racen helemaal rot, omdat je allemaal klappen op je rug krijgt. Toen heb ik om te proberen een heel goedkope, echt de goedkoopste die ik kon vinden een zittrapeze gekocht. En dat was eigenlijk gelijk heel goed, bleek achteraf. En toen ging die na 3 jaar kapot en toen had ik een best wel chique Mystic nog iets, die heb ik 1 dag gehad, met allemaal pads en allemaal straps. Maar ik kwam er snel achter dat simpeler beter voor mij was. Toen had ik hier eens naar geken, en die zag er lekker basic uit zonder allemaal dingen die je niet nodig hebt.

Was de Prolimit die je als eerste had vergelijkbaar met de Vega?
Ja het is best vergelijkbaar, het grootst verschil zit in de hoeveelheid luxe pads en dingen er in zitten en in de rug hoe hoog hij is. De verzachtende pads zat mij alleen maar in de weg. Je wilt zoveel mogelijk bewegingsvrijheid hebben, en die luxe dingen zijn groot en zwaar. En als je dan aan het manoeuvreren bent zit het mij in ieder geval in de weg.

Heb jij toevallig ook sponsors?
Qua foils en kites wel, qua harnassen enzo niet. Het hangt ervan af of de sponsor een goed product heeft, anders niet. Dan kies ik wel mijn eigen, als je een verkeerd harnas hebt kun je net zo goed stoppen.
Was je bij toen de Vega werd gekozen door het team?
Mijn keuze stond een beetje los wat de rest deed. Ik wist toevallig dat het hele team er ook naar keek. Ik had het eigenlijk heel simpel gedaan, ik heb naar de beste foiler van de wereld gekeken en toen zag ik (dat was Daniela Moroz), en die had deze. Met in mijn achterhoofd wat ik niet wilde, leek dit wel wat dus had ik het besteld. Toen achteraf bleek dat de jongens er ook 5 hadden besteld. Er zijn wel een paar dingen die wel beter kunnen denk ik. Het grootste probleem bij hun dat er dingen kapot gingen. Bij mij is de sluiting van de spreaderbar het probleem. Vaak klikt hij helemaal naar buiten als ik in manoeuvres zit. Dat mag wel beter. Maar tijdens het foilen gebruik je het verder niet. Dat is alleen voor aan en uit doen. Op lange duur gaat het wel echt stuk.

Kan je in je eigen woorden uitleggen waarom je de overstap hebt gemaakt?
Ik was op zoek naar wat ik had gehad en tevreden over was. Mijn conclusie was dat het vrij basic harnassen zijn, als je op de websites kijkt zie je honderden modellen. Maar toen ik een chique had voelde ik me er echt in opgesloten, dus heb ik die na een uur terug gebracht. En deze sloot goed aan hoorde ik, bewegingsvrijheid niet inperkte en de wereldkampioene er mee vaart. Zodoende was ik er bij gekomen, lekker afkijken.

Wat vind je zo goed aan dit harnas?
Het is gewoon, er zit heel licht een versterking in. Er zit een band net boven je billen onder je onderrug. Dat is ook wat ik wil, want ik wil geen kracht op mijn rug hebben, want dan ben je snel klaar. Het lijkt eigenlijk op een zwembroek, dus hij zit lekker. Hij sluit overal goed aan, je kan hem overal goed verstellen en strak trekken, dus ook de beenbanden kan je goed strak trekken. Dat is goed want daar komt veel kracht op te staan. Wat ik ook goed vond, is dat de spreaderbar heel smal is, want met mijn vorige harnas was die echt 4x zo dik. Als je dan voorover buigt zit dat ding in je ribben end at wil je niet. Je hebt ook nog smaller speaderbarren, maar dan gaat hij kantelen en dat wil ik niet. Dus hij zit nu wel lekker stevig vast, dus het drukpunt blijft op dezelfde plek. En dat is belangrijk dat dat op 1 plek blijft.

Wat is zo fijn aan die brede rand op de bovenkant en achterkant van het harnas?
Het broekje is echt heel dun, wel stevige stof. Verder geen versteviging. En de versteviging is dan waar je op zit, en die komt dan echt net boven je billen te zitten. Er komt namelijk veel kracht op en als dat op je onderrug komt te staan loop je binnen een dag krom. Ik weet niet precies waarom, maar dit is voor mij wel echt de beste plek. Ook als je crasht krijg je geen rare zwiepers. Het is echt net onder je onderrug. Hij sluit ook goed aan. Dat is ook het mooie van deze, dat die broeken ver doorlopen. Deze stopt gewoon, en dat is goed. Anders gaat het schuren en draaien en dat heeft deze niet. Voor wat ik doe is dat hoge niet nodig. Je ziet ook aan de onderkant van de pijpen, en dan komt best veel druk onder je billen te zitten. Dat verspreidt het voldoende, de krachten. Deze snijdt nergens. Die beenbanden zit wel voldoende bescherming. Het is wel vrij basic en minimaal maar het zit niet vervelend.
De spreaderbar blijft voor mij ook goed zitten. Hij verschuift niet en als je hem goed strakt trekt blijft hij mooi zitten. Misschien dat de pro's meer last daarvan hebben, maar ik heb daar niet zoveel last van. Deze is echt prima, de haak kan nog wat korter, kan echt de helft. Dan heb je de bar nog dichter op je lichaam.

En waarom is dat fijn?
Dan hoef je arm niet zo ver uit te steken. Je druk punt zit wat dichter op je lichaam, dan zit alles wat centraler. Het voelt wat direct aan. Volgens mij als je hem wat dichter bij je hebt, heb je wat meer bereik. Je bereik word net wat groter.

In vergelijking met je allereerste verschilt dat nog?
De andere was wel aan het snijden op sommige plekken, maar deze biedt wel voldoende bescherming. Niet gaat snijden. Dat zat vooral bij mijn onderkant en bij mijn benen. Die straps was gewoon bloot, en dat zit natuurlijk niet heel lekker. Met onderkant bedoel ik met name de zijkanten, dat was een stuk stugger. Maar dat was wel een tijd

geleden hoor. Er hoeft niet heel veel padding te zijn voor mij, vooral rondom de rug, bij de billen vind ik wel handig en bij de benen. Bij de Mystic, waren de beenlussen echt best flink, bij de achterkant stak hij een stuk verder uit. Die had rond de rug en billen veel padding. Als je stil zat, zat hij wel echt lekker, maar als je ging bewegen kon je nergens heen. En rond de spreaderbar zat ook heel veel padding omheen. Dat drukte vooral in je ribben, vooral aan de bovenkant.

Wat zou je het liefst zien veranderen?
De sluiting werkt niet optimaal, de connectie van het harnas naar de speaderbar zou wel makkelijk kunnen. Ik had een vorige die zat aan de zijkant met een pinnetje en dat ging niet kapot. Maar dit is wel heel fragiel. En de haak mag korter, en verder heb ik niet zoveel verbeteringen.

Is er verder nog iets wat je kwijt wil?
De kleur haha. Het allerbelangrijkst vind ik bewegingsvrijheid en dat hij verder nergens snijdt. En dat heb je bij deze niet echt zo.
Had je nog vershcillende maten geprobeerd?
Volgens mij heb je een maattabel, en kan je je heup meten en dat heb ik gedaan. De rest kan je verstellen, maar de heup moet wel goed zitten.

INTERVIEW 5

Participant 5 supports the team. The interview was done on 26/01/2021 through Zoom
Zit je in het core team van TeamNl?
Beetje half half.

Somige jongens hebben sponsors, heb jij ook zoiets?
Alleen voor de kite en de foil. Nee ben niet gebonden aan een bepaald merk.

Waarom ben je van de Mystic naar de Vega overgestapt?
Die Mystic zat te hoog, en de bandjes sneden in de benen. De haak zat veel te hoog, de rug zat vrij hoog en dan zit de haak ook vrij hoog. Als je met de Sonar vergelijkt is de Sonar veel lager.

En waarom van de Vega naar de Sonar?
De Vega begon steeds mijn bilspleet in te kruipen. Dat was het irritatiepuntje van. Dat was eigenlijk het enige. Verder sleet hij snel. Vooral de buitenkant en de stiksels, hij zag er niet meer uit na een tijdje. Ik heb hem niet zover gekregen dat de banden van de spreaderbar aan het slijten waren. Dat slijten kwam met name door het zand, je zit op het strand. Je houdt hem blijkbaar vrij lang nog aan.

Hoe was je bij de Vega gekomen?
Via een maatje, die had hem dus toen had ik hem ook maar besteld. En veel internationale rijders hadden die.

Vanuit de Vega naar de ion?
Dat was omdat Ion met een echte race trapeze kwam. Via Joris die had een prototype. Voorlopig gaat het ook goed met de Ion. Alleen de onderste rand, die duwt in mijn bilspier. Misschien zit hij te hoog. Ik weet niet of ik een te kleine heb of het in alle modellen zit. De bandjes zitten al redelijk op het kleinst. Dit is de XS. Bij de andere moesten de bandjes helemaal strak zetten. Misschien dat de andere pasvormen beter is, maar daar heb ik nog niet mee gevaren.

Nu vaar je met de Sonar, wat zijn de verschillen tussen de Vega en de Sonar?
Het is al een paar maanden geleden. Maar vooral de drukpunten dan. De Sonar zit nog net wat lager. Die zit nog meer aan je billen te duwen. Voor mijn gevoel kan ik meer kracht kwijt. Dat komt gok ik omdat die lager zit, het zwaartepunt waar de kracht aan vast zit komt wat lager te zitten.

Welke aspecten zijn echt heel goed?
De spreaderbar zelf is netjes gemaakt, Voorlopig is hij nog heel dat is ook positief. Alleen de pasvorm rond mijn billen is nog niet 100%. Bandjes van de benen heb ik wel een stuk tussen moeten zetten, waarschijnlijk omdat het neopreen te krap was, omdat het een XSje is.

Wat maakt de spreaderbar zo netjes?
Mooi compact en kort. Ik heb een eigen quickrelease die vastzit aan een touw. Alles moet zo kort mogelijk. Hij zit wel vast in het midden van het touw, en de reden is puur zodat er geen haak meer zit. Die kan alleen maar tegen je boord aan komen.
Verder duwt het harnas het hardst op het dikste punt van de bilspier en dat is oncomfortabel. De Vega had dat niet, meer die ging weer wel in je bilspleet zitten, wat ook ging irriteren. Het snijden rond de lies was minder.

Ion sonar is wat dikker, hoe vind je dat?
Het is me niet direct opgevallen, met varen is er niet minder bewegingsvrijheid met het lopen wel. Je kan dan minder goed bukken/hurken. Tijdens het lopen kan je de benen niet de volledige slag geven. Maar dat is niet belangrijk, op het water moet het goed zitten. De rest maakt het niet uit. Op de kant kan je hem uit doen.
De beenbandjes zaten bij de anderen te strak, heb je dat ook?
Bij het begin wel. Het verzuurt wel, maar dat is vanwege uitputting niet omdat de bloed wordt afgekneld ofzo.

Wat bevalt je verder nog goed aan de Sonar?
De snelsluiting is fijn, dat hij snel open en dicht gaat. Bij de Vega heb ik een Mystic spreader opgezet. De Mystic had meer dikke flappen eromheen waardoor die beter op zijn plek bleef zitten. Dat is bij de Sonar, die zit er een beetje tussen in. Ik weet niet of de Ion anders moet, omdat hij vast zit met een touwtje kantelt hij ook niet echt naar boven. Met het touwtje, heb je niet dat het moment waardoor hij omhoog wilt buigen.

Hoe was je uitiendelijk bij de XS terecht gekomen?
Ik had dat bij Joris thuis gepast, die had verschillende maten opgestuurd gekregen. Maar mischien toch op het water moeten proberen. Hij paste wel het beste van alle maten die Joris had liggen. Op de kant leek de bandjes niet strak te zitten, maar op het water bleek het van wel. De beenlussen dan. Blijkbaar als je in een hurk gaat zitten worden je benen blijkbaar dikker. Dan begon hij te knellen, en daarom heb ik hem dus verlengt. Het interne bandje was wel lang genoeg, maar het neopreen was te kort, waardoor die wel te kort bleef.

INTERVIEW 6

Participant 6 is a youth athlete in the team. The interview was done on 27/01/2021 through Zoom
Welke trapezes heb je gebruikt in de afgelopen tijd?
Ik heb de afgelopen tijd alleen de Sonar gebruikt. Ik ben begin dit jaar 3 weken op training geweest toen heb ik alleen de Sonar gebruikt.

Is Manera puur je wetsuit sposnor?
Je hebt een verschil tussen je gear sponsor en je accessory sponsor. Alles wat niet je vlieger, je lijn of je boord zijn is wat zij doen (Manera). Ik heb nog steeds niet de nieuwe trapeze binnen van Manera die specifiek gemaakt was voor het foilen. Ik ga erachteraan of die binnenkort komt.
Ik zou toch wel een andere willen. Er zijn wel een paar dingen waarvan ik heb dat die wel beter kunnen. Ik denk vooral wat meer structuur bij je rug, een wat hardere shell. Dat zal in alle omstandigheden wel hebben, met zachte en wat hardere wind merk je dat wel. En ik vind de straps bij de benen nog niet optimaal naar mijn idee. Snijden nog iets te veel, ze houden dus dat punt waar je kite met je lichaam vast zit, zit nog te hoog. De spreaderbar.

Hoe zie je de harde shell voor je? Je zit namelijk vrij voor voorover gebogen.
Wat ik vooral wat meer bedoel, dat het support tijdens de houding die je hebt tijdens het racen, de shell wat moeilijker is om goed stijf te krijgen. Ik denk vooral dat dat middelhoog vooral hard moet zijn. Omdat je minder knelling hebt en je hebt een directere overgang. De krachten die uit de vlieger komen directer voelt, er zit dan wat minder vertraging in. Ik denk dat een dubbele curve niet heel belangrijk is, omdat hij een stuk lager zit, waar geen hol gedeelte van je rug zit. Ik denk ook niet dat op die plek waar dat wel zit, wat hoger in de rug, ik denk niet dat daar versteviging nodig is.

Wat vind jij ervan dat de Vega en de Sonar van die lage broekjes zijn?
Het zit niet mega fijn, in alle opzichten zit een heuptrapeze beter. Maar voor het racen is het hoe dan ook van belang, of het een broek is of wat dan ook, dat het laag moet zitten. Bij je bovenbenen, bij je bil moet zitten, waar daar zit de kracht op.

De Sonar heeft al best wat schuim bij de beenlussen, maar alsnog snijdt het?
Er zit inderdaad wel wat foam in, maar ik denk niet dat dat het probleem is. Ik denk toch dat het meer de plaatsing is. Of als je hem nog wat breder maakt, dat was bij de Vega wat breder maar die was aan de bovenkant smal wat weer moeilijk was. Ik denk dat die qua foam goed is, qua positie wat meer naar onder kan, en misschien iets breder de straps.

Worden de beenlussen je lies ingetrokken?
Bij de Sonar is dat al een stuk minder, het duurt langer of hardere wind hebben. Je wilt dat punt zo laag mogelijk houden, dus er moet een manier komen die het laag houdt. Dus ik denk niet dat het per se nodig is dat die straps hoog zitten, het gebeurt wel, maar het hoeft niet. Of die straps moeten lager blijven zitten, of je moet een ander punt hebben waar je dat hele harnas mee omlaag houdt.
Waarom was je specifiek overgestapt naar de Sonar?
Specifiek naar de Sonar, was eigenlijk mijn teammaatje Joris, die had een sample die we getest hadden. Toen vond ik het eigenlijk wel een goede vooruitgang. Ik heb contact gezocht met die mensen, en toen heb ik er 1 gekregen dus dat was een snelle oplossing als tussenstap voor hopelijk de Manera die gaat komen. Als de Manera niet goed is ga ik er niet mee varen, maar ik heb er zo veel vertrouwen in, dat het wel een goede zou zijn.

Speelt het feit dat ze een sponsor zijn een rol daarin?
Ik denk bij trapezes het minste een rol zal spelen. Omdat het een heel fundamenteel gedeelte is van je gear/kit, dus nee. Tuurlijk geef je ze altijd een kans, maar het is niet 1 op 1.

Waarom was überhaupt een switch nodig?
Goede vraag, we waren gewoon niet echt tevreden over de Vega. Allereerst zat hij niet best, daar los van was de kwaliteit gewoon echt niet goed. Hij was al een paar keer kapot gegaan bij mij, en een maatje. Dus ik dacht ik ga niet een nieuwe nemen. Er moest sowieso een switch komen en toen kwam de Sonar.

Welke maat heb je momenteel van de Sonar en hoe was je daar terecht bij gekomen?
Een M, ik had die M de prototype van getest. Ik heb wel het idee dat ze wat veranderd hebben in de maat. Want deze M zit toch een beetje wijder voor mijn gevoel. Ik heb wel een S geprobeerd, en die zat best wel strak. Toen heb ik toch maar de M gehouden. Er zit ook wel een groot verschil tussen. Dat is nog wel iets om naar te kijken.

Wat was er vervelend aan dat het strak zat?
Die S was gewoon, die zat heel erg strak. Je kreeg hem wel dicht, maar dat je hem gewoon voelt dat hij niet zit hoe hij hoort te zitten. Alsof je een te kleine broek aan hebt. Dan zit het strak, maar omdat het te klein is, dan zijn de punten van de spreaderbar die je aan moet trekken, die horen op je heupbot te zitten, op die hoogte en dan zitten die een stuk naar achter. Dan merk je dat het broekje te klein is. Dan gaat hij niet ver genoeg om je heup heen.
Ik was nog met het Poolse team gaan varen samen met een maatje van me, en dat was begin van dit jaar.

Zijn er aspecten waarvan je zegt dat de Sonar wel goed doet?
Ja die strap was al een hele vooruitgang. Bij de benen, dat die nog steeds wat snijden, maar het is al een grote verbetering. Verder is het kliksysteem van de spreaderbar best goed. Dat je een extra hefboom hebt die het nog net wat strakker trekt. Die kan ook strakker dan de Vega, bij de Vega was je oprecht soms bang dat hij ging knappen als je hem te strak trok. Qualitatief is de Sonar 10x zo goed. De pasvorm is heel anders, en ik denk dat zie verder niet heel goed met elkaar te vergelijken zijn, maar de kwaliteit is veel beter.

Zijn er verder dingen die goed zijn?
Verder vind ik hem niet heel erg bijzonder eigenlijk. Goed oke, goede kwaliteit verder niets. Ik vind hem niet speciaal dat ik zeg dit is top.
Ik heb hem ook veel in de golven gevaren in Tariffa, en wat je dan merkt is dat de statische houding vooral upwind dat je helemaal stijf staat en dat een stijve constructie wel fijn is, maar in de golven wil je dat hij wel meebeweegt en omdat je dan veel meer beweging maakt met je benen, om het boord over de golven te krijgen, maak je veel meer bewegingen met je benen en je heupen en daarin knelde hij al helemaal veel. Dat is wel iets om te verbeteren.

En waar knelde dat dat?
Gewoon weer bij je liezen. Als je heel veel beweegt dat die banden juist erg omhoog schuiven. Ik denk dat je het wel kan zeggen dat je bewegingen wel erg worden beperkt. Ik weet niet of dat dat het gevolg is van een stijf harnas wat dan wel weer goed zou zijn. Maar naar mijn wil je gewoon een broekje/harnas wat heel stijf is in dat gebied, maar de rest niet belemmerd.

In welk gebied specifiek?
Van hoog in je benen tot lage rug. Je benen wil je wel bewegen dat hij daar niet beperkt.

Zijn competities zelf niet vaker op vlakker water?
Tijdens wedstrijden is het meest op het vlakke water, maar ik denk niet dat dit is niet overal zo. Het is niet in de regels vastgelegd dat we met grote golven niet varen. Met grote golven varen we wel, ik denk dat ook een belangrijk punt is om naar te kijken.

Met wat voor winden varen jullie tijdens de competities?
In de officiële class rules staat in vanaf 6 knopen tot 40 knopen. Van de KIA heb je ook nog competities maar daar word met 45 knopen ook nog steeds gevaren. 40 knopen is wel een mooi limiet (8 beaufort).
De straps zijn dus best wel redelijk en de haak vind je goed.
Dat zijn wel echt de uitspringers naar mijn idee. Ik denk wat ze ook nog wel goed doen als ik dit vergelijk met de Vega, zijn de knelpunten boven je heup, de hele bovenste rand van de trapeze is ook goed comfortabel. Als dit niet comfortabel is snijdt dit.

Ervaar je ook dat de haak wat beter op zijn plek blijft?
Dat is inderdaad een hele goede. Er is een extra band die de haak omlaag houdt en dat is wel echt fijn, vergeleken met de Vega. Ik heb nog wel dezelfde haak erop zitten. Sven heeft dat gedaan, die haak komt er dan bij in “trim” die je hebt. Die haak van Sven is barebones, zonder enige padding, ik heb die nog niet geprobeerd. Die heeft ook nog wel weinig verbindingspunten. Ik denk dat je uiteindelijk wel de zelfde spreaderbar wilt, maar dan zonder de haak.

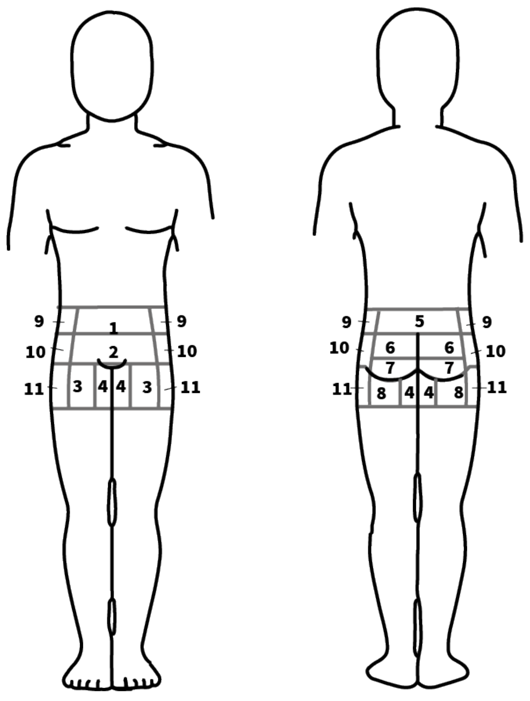
Stel je doet een veer tussen de kite en het harnas, om windvlagen op te vangen. Is dat irritant?
Ik denk dat je juist die windvlagen, ik denk dat de kunst van een race winnen is dat elke vlaag je juist harder gaat. Dan wil je daar geen, je doel is niet om zo comfortabel mogelijk te varen dan zou het wel fijn zijn. Maar uiteindelijk wil je zoveel mogelijk energie omzetten.

Zit er een sweetspot in de power die je wilt?
Er zit zeker een sweetspoit in, je wilt niet te veel en niet te weinig. Je wilt op het randje van zoveel mogelijk zitten, maar tegenwoordig met de nieuwe kites. Die zijn per maat die je kleiner gaat efficienter, zijn betere kites. Die zijn gewoon beter. Als je nu kan kiezen tussen heel erg gepowerd met een 18 meter kite, of goed gepowered met een 15 meter kite, pakken ze meestal die kleinere kite omdat je makkelijker harder mee gaat.

Zit het kiezen van de juiste kite op het randje tussen overpowered en niet overpowered?
Nee dat was wel zo, het ligt heel erg aan de situatie. Dat ligt heel erg aan welke baan. Het is dezelfde baan als elke zeilboot, maar bij het kiten ligt het eraan of hij 4 km ver weg is, dan vaar je het dubbele misschien wel meer. Vanaf de start recht upwind is dan 4 km. Met je kite maak je heel veel meter op zo een moment ben je altijd het randje overpowered, omdat je in een rechte lijn ga je het hardst. Upwind maakt het niet zo veel verschil, downwind maakt het alle verschil. Bij een kleine baan (800 meter), gaat het ook om de snelheid die je behoud in je tack en in je geip, dan ligt het meer aan je souplesse om de baan heen, het manoeuvreren dan pak je altijd een kleinere kite om dat goed te doen. Groot verschil in welke baan je hebt.

Wat betekend overpowered?
Overpowered betekent dat je 100% op het randje zit van wat je aan kan. Als je 1 of 2 knopen erbij krijgt dat je dan de lucht in vliegt. Op lange rakken wil je niet overpowered, maar net eronder zitten.
Waar gaat het stijve precies om in trapezs?
Het gaat puur om krachtenoverdracht, je wilt gelijk alles voelen voordat hij bijvoorbeeld vervormd.

Appendix C: Design sprint 1 questionnaire



Questionnaire (1/8) Climbing Manoeuvre

The image on the left shows where the areas are located. Please indicate per area your perceived level of **discomfort** in the table below. Only fill in one cell per row.

Area	Extremely uncomfortable	Very uncomfortable	Quite uncomfortable	Barely uncomfortable	Not uncomfortable
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

Interview Questions

Gender: man vrouw
Ervaring: ja nee

How did the harness feel while in the different positions?

____

How much did the harness move around?

____

How much did the harness block the blood flow to your legs?

____

How confident did you feel while wearing the harness?

____

How do you imagine these harnesses to feel during surfing?

____

Which harness do you prefer and why?

____

What improvement would you make to your preferred harness?

____

Notes

____

Appendix D: Design Sprint 2 & 3

Interview Questions

Which concept do you ultimately prefer for the manoeuvre positions and why?

____
____
____
____
____

Which concept do you ultimately prefer for the upwind positions and why?

____
____
____
____
____

How do you expect these concepts to hold up while on the water?

____
____
____
____
____

What are your main concerns with these concepts in the upwind position?

____
____
____
____
____

What are your main concerns with these concepts in the upwind position?

____
____
____
____
____

Compared to the ION Sonar, how would you estimate these concepts?

____
____
____
____
____

Notes

____
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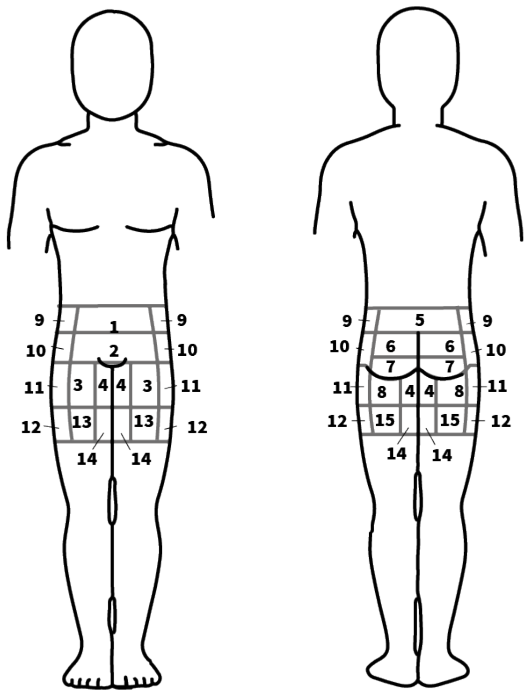
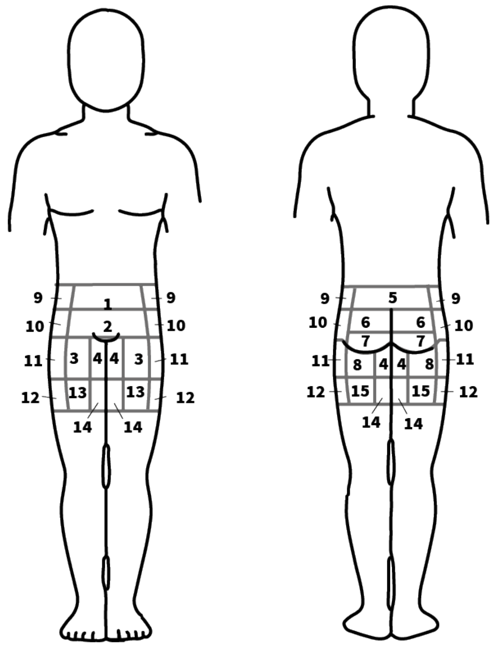


Questionnaire (1/14) Control manoeuvre

The image on the left shows where the areas are located. Please indicate per area your perceived level of **discomfort** in the table below. Only fill in one cell per row.

Area	Extremely uncomfortable	Very uncomfortable	Quite uncomfortable	Barely uncomfortable	Not uncomfortable
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					



Questionnaire (2/14) Control manoeuvre

The image on the left shows where the areas are located. Please indicate per area your perceived level of **support** in the table below. Only fill in one cell per row.

Area	Maximum support	A lot of support	Moderate support	Barely any support	No support
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

DESIGN SPRINT 2: RAW DATA

Perceived level of discomfort (1 = none, 5 = Extreme)

Concept	Participant	Area 1	Area 2	Area 5	Area 6	Area 7	Area 9	Area 10
Control	1	1	4	1	5	1	1	5
	2	1	1	2	1	1	1	4
	3	1	1	3	3	2	1	4
	Avg	1,0	2,0	2,0	3,0	1,3	1,0	4,3
	std	0,0	1,4	0,8	1,6	0,5	0,0	0,5
Force Distribution	1	1	1	1	2	1	1	4
	2	1	1	2	2	1	3	3
	3	1	1	3	3	2	4	4
	Avg	1,0	1,0	2,0	2,3	1,3	2,7	3,7
	std	0,0	0,0	0,8	0,5	0,5	1,2	0,5
Spreaderbar	1	1	1	1	4	1	1	5
	2	1	1	3	3	1	4	4
	3	1	1	2	2	2	3	3
	Avg	1,0	1,0	2,0	3,0	1,3	2,7	4,0
	std	0,0	0,0	0,8	0,8	0,5	1,2	0,8
Hard belt	1	1	1	1	3	1	1	3
	2	1	1	2	2	1	3	3
	3	1	1	3	2	2	3	2
	Avg	1,0	1,0	2,0	2,3	1,3	2,3	2,7
		0,0	0,0	0,8	0,5	0,5	0,9	0,5

Perceived level of Support (1 = none, 5 = Maximum)

Concept	Participant	Area 1	Area 2	Area 5	Area 6	Area 7	Area 9	Area 10
Control	1	1	1	4	4	1	4	4
	2	1	1	5	5	1	1	5
	3	2	2	3	3	3	2	5
	Avg	1,3	1,3	4,0	4,0	1,7	2,3	4,7
	std	0,5	0,5	0,8	0,8	0,9	1,2	0,5
Force Distribution	1	1	1	1	4	1	1	4
	2	1	1	5	5	4	5	5
	3	1	1	4	4	3	4	4
	Avg	1,0	1,0	3,3	4,3	2,7	3,3	4,3
	std	0,0	0,0	1,7	0,5	1,2	1,7	0,5
Spreaderbar	1	1	1	1	4	1	1	3
	2	1	1	5	5	1	4	4
	3	1	1	4	4	3	4	4
	Avg	1,0	1,0	3,3	4,3	1,7	3,0	3,7
	std	0,0	0,0	1,7	0,5	0,9	1,4	0,5
Hard belt	1	1	1	1	4	1	1	4
	2	1	1	5	5	1	5	5
	3	1	1	4	4	3	3	2
	Avg	1,0	1,0	3,3	4,3	1,7	3,0	3,7
	std	0,0	0,0	1,7	0,5	0,9	1,6	1,2

DESIGN SPRINT 3: RAW DATA

Perceived level of discomfort (1 = none, 5 = Extreme)

Concept	Participant	Area 3	Area 4	Area 8	Area 11	Area 12	Area 13	Area 14	Area 15
Control	1	1	3	1	2	1	1	1	1
	2	1	3	2	1	1	1	1	2
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Average	1,0	3,0	1,5	1,5	1,0	1,0	1,0	1,5
	std	0,0	0,0	0,5	0,5	0,0	0,0	0,0	0,5
Extra padding	1	1	4	1	2	1	1	1	1
	2	1	5	1	2	2	1	4	1
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Average	1,0	4,5	1,0	2,0	1,5	1,0	2,5	1,0
	std	0,0	0,5	0,0	0,0	0,5	0,0	1,5	0,0
Bigger legstraps	1	1	1	1	1	3	3	3	3
	2	1	1	1	1	1	1	1	1
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Average	1,0	1,0	1,0	1,0	2,0	2,0	2,0	2,0
		0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0

Perceived level of Support (1 = none, 5 = Maximum)

Concept	Participant	Area 3	Area 4	Area 8	Area 11	Area 12	Area 13	Area 14	Area 15
Control	1	1	3	3	3	1	1	1	1
	2	1	1	2	4	4	1	3	5
	3	2	4	3	3	4	1	2	4
	Average	1,3	2,7	2,7	3,3	3,0	1,0	2,0	3,3
	std	0,5	1,2	0,5	0,5	1,4	0,0	0,8	1,7
Extra padding	1	1	4	3	3	1	1	1	1
	2	1	5	2	2	3	1	5	2
	3	1	4	3	3	2	1	2	1
	Average	1,0	4,3	2,7	2,7	2,0	1,0	2,7	1,3
	std	0,0	0,5	0,5	0,5	0,8	0,0	1,7	0,5
Bigger legstraps	1	1	1	1	1	4	4	4	4
	2	1	1	2	1	5	5	5	5
	3	3	2	2	3	4	4	4	4
	Average	1,7	1,3	1,7	1,7	4,3	4,3	4,3	4,3
		0,9	0,5	0,5	0,9	0,5	0,5	0,5	0,5

Appendix E: Building the prototype

This appendix descibes the process that was used to build the final prototype.

1) Make the mould. The process to get the measurements of the athletes is already described in chapter **"Chapter 10 Hip Pressure"**. A vector with a known length is put into the same image as the created profile in Paraview. This image was imported into SolidWorks (**Figure 1)**, traced & offset by 10 mm (for the EVA foam) (**Figure 2**) and extruded **Figure 3**.

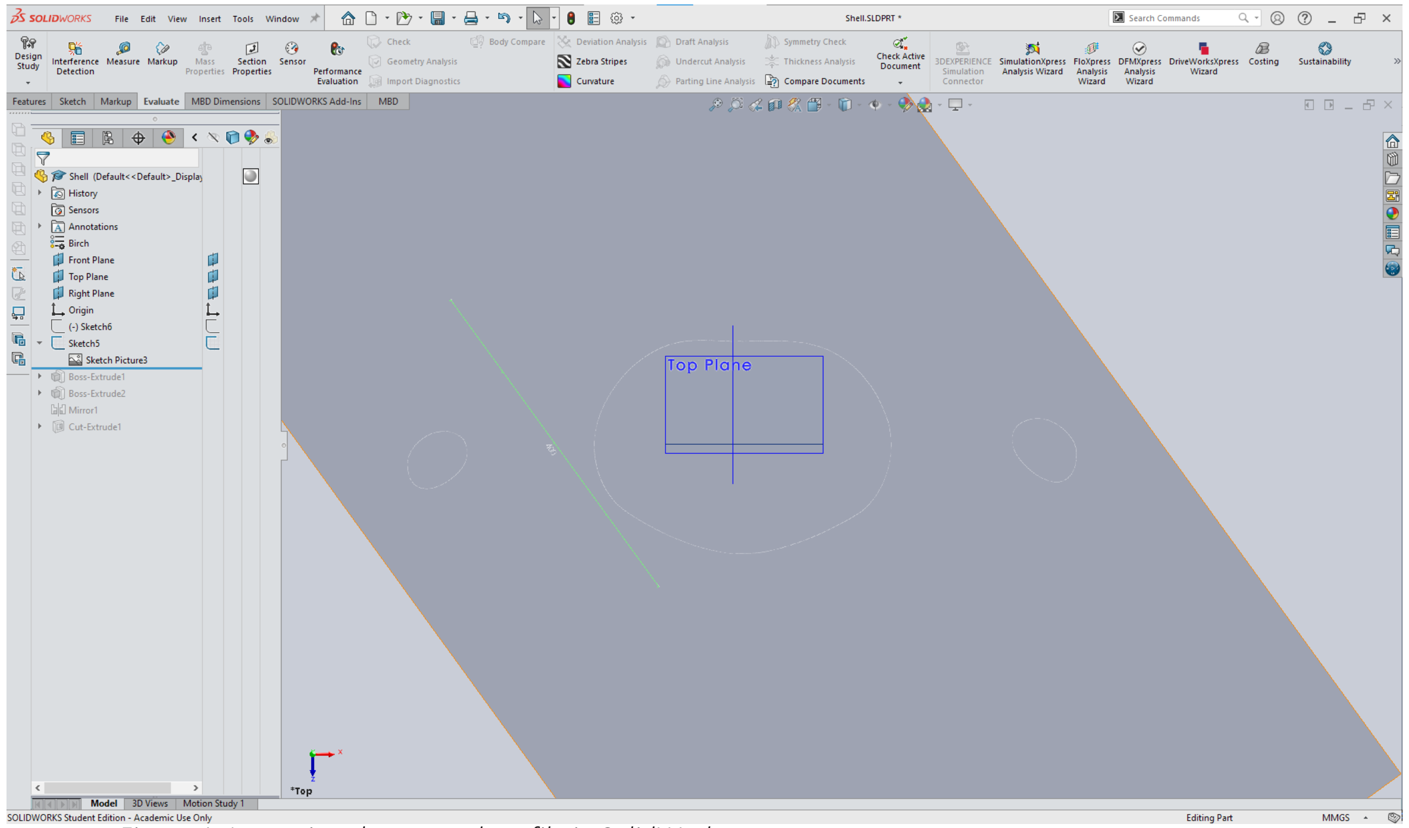


Figure 1: Importing the created profile in SolidWorks

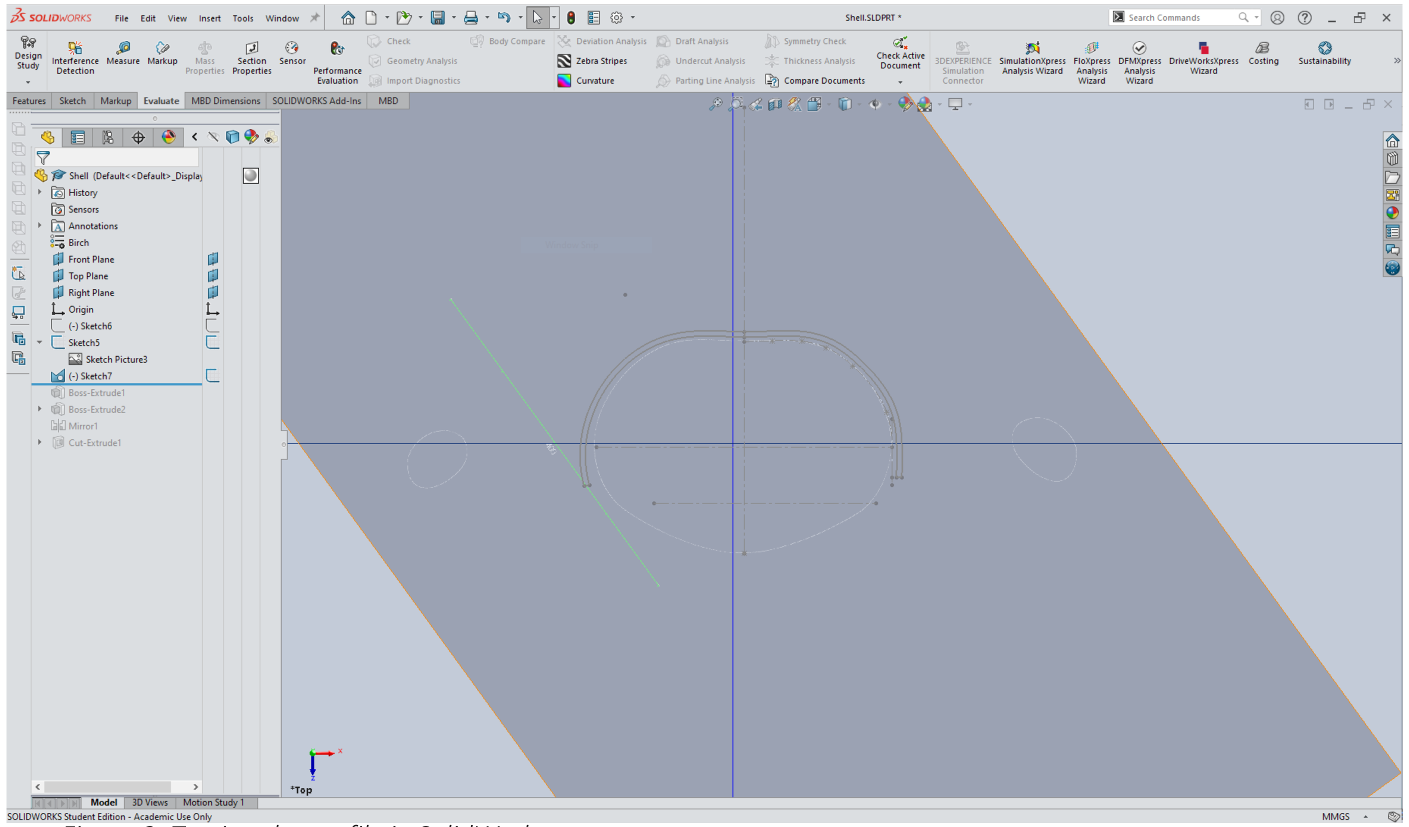


Figure 2: Tracing the profile in SolidWorks

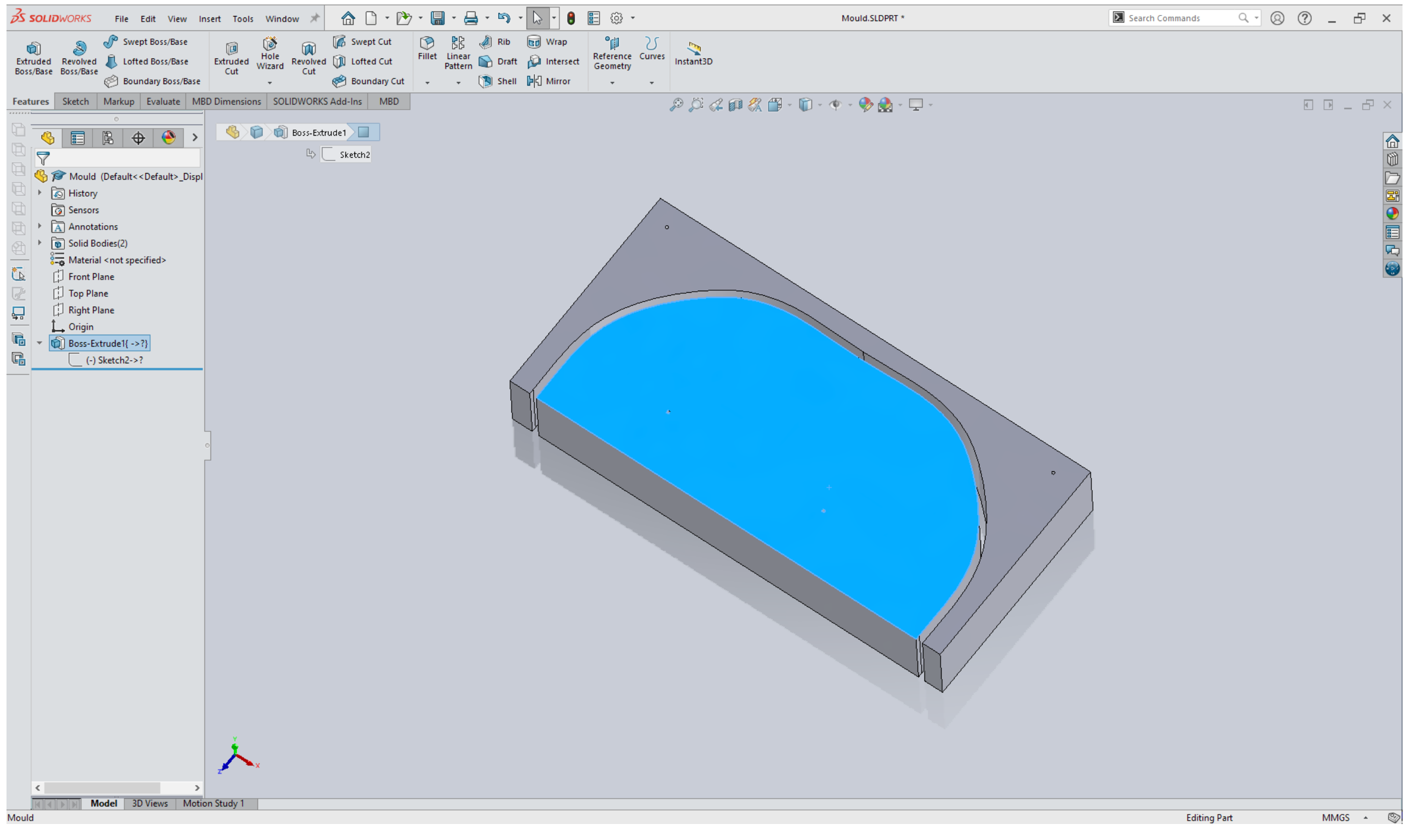


Figure 3: Extruding the sketches to create the mould

For precision purposes, the mould pieces were then lasercut (**Figure 4)** and glued together. Then the 1 mm airplane triplex was cut to shape, glued up and put inbetween the mould (**Figure 6**).
Then the attachment point was designed in SolidWorks, built and

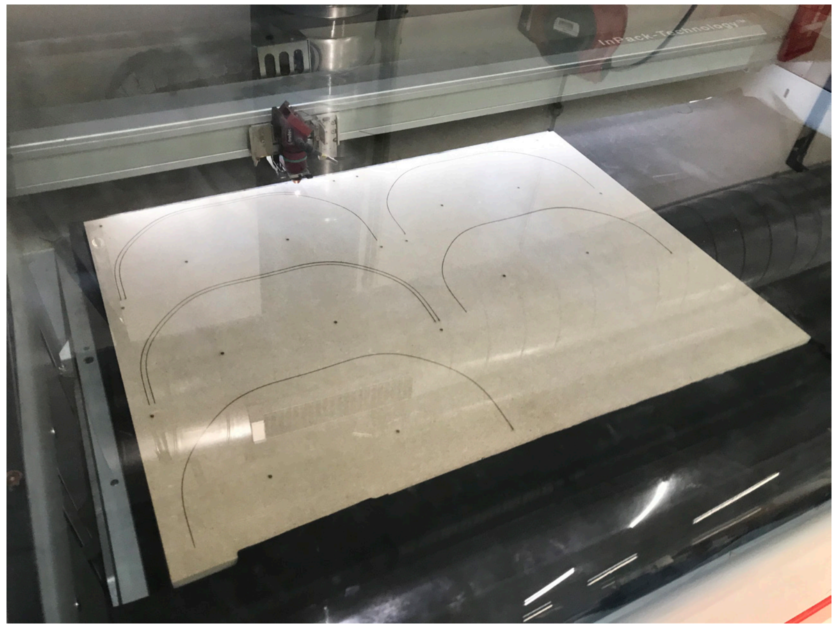
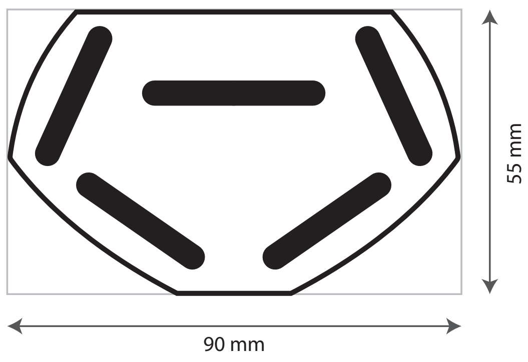


Figure 4: Lasercutting

Figure 5: the lasercut mould parts glued together

Figure 6: The airplane triplex inbetween the mould



welded (**Figure 7 and Figure 8**).

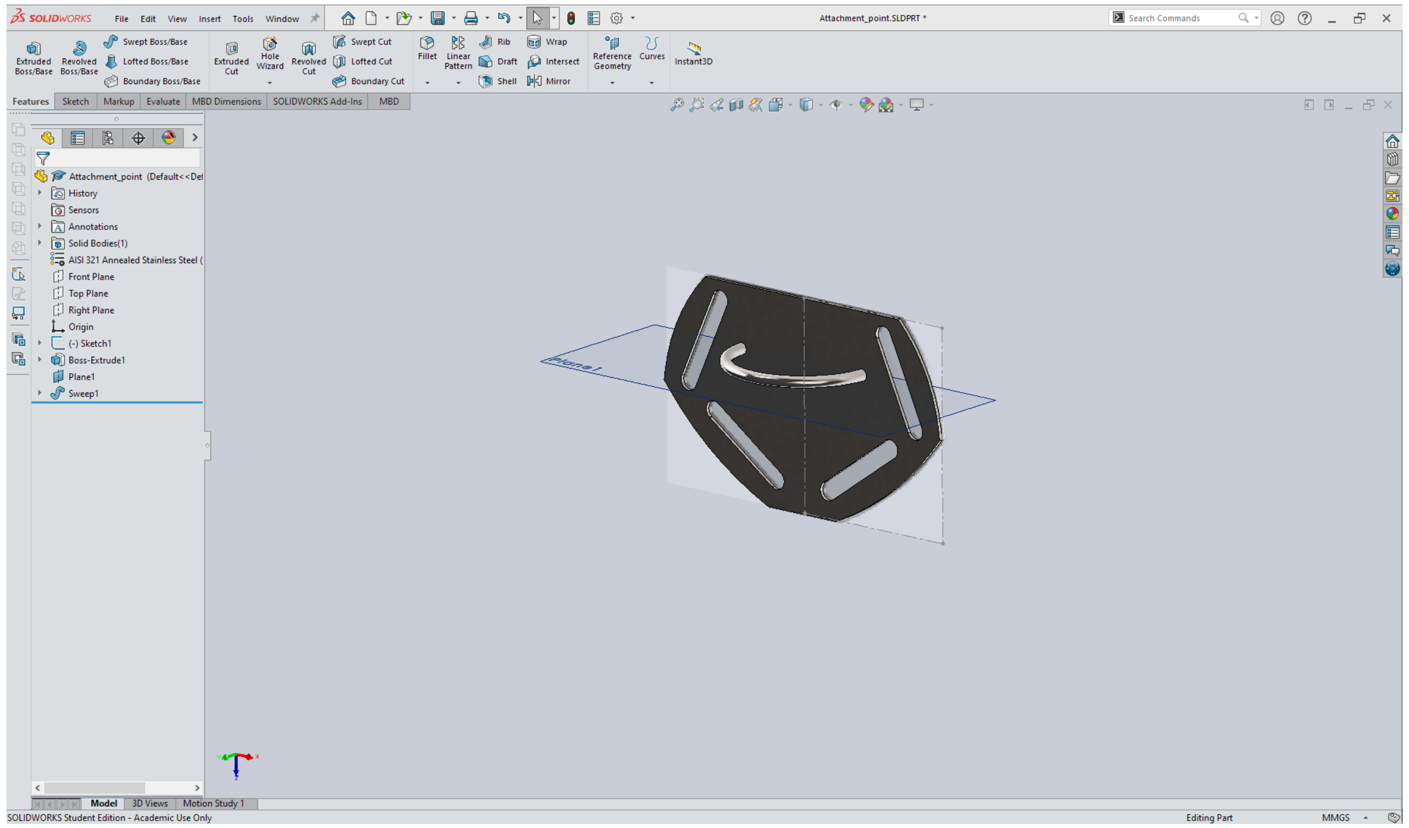


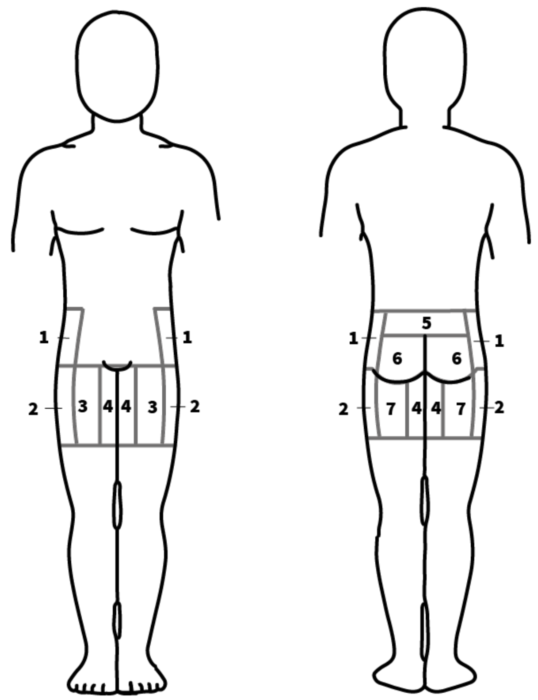
Figure 7: The attachment point in Solidworks

Figure 8: The attachment point built

Appendix F: 3D Scanning products

Technology	***Device***	***Description***	***Advantages***	***Disadvantages***	***Costs***	***Fit with project***
Structured light	Artec Eva Lite	A handheld device created to scan geometrically rich objects like the human body	"Portable Suited for human body scans (object sizes between 50 cm and 200 cm)"	"Expensive Might be too detailed"	€ 6.700,00	-
Photogrammetry	3dMDhead	A setup that can record and capture the different postures of the human face using photogrammetry up to 60 frames per second	High accuracy	Expensive	€10.000,00 +	-
Photogrammetry	3dMDbody	Full body scanner that uses photogrammetry at a rate up to 120 frames per second. The baselane model can record people in the A - posture but can be expanded to accommodate different needs	"Capable of scanning complete humans instantly Capable of capturing motion"	"Takes up a lot of space Can scan the entire body, which is not necessary"	Unknown	-
LiDAR & Photogrammetry	iPad or iPhone with LiDAR sensor	The newest iPads offer next to a high resolution camera also a LIDAR sensor, which can sense the distance between the sensor and the object in front. The iPad can use this data in combination with images to generate a 3d model.	"Portable Cheap"	"Not as high accuracy as dedicated industrial devices Reliant on app developers"	€ 900,00	+
Structured light	Structure sensor mark II	Accessory for the iPad that can be clipped on it. It uses structured light IR projector and combines it with a depth sensor. Compatible with iPads going back to 2014.	"Portable Good accuracy Relatively cheap"	Requires an iPad	€441,36 + iPad costs	++
Photogrammetry	Software: 3DF Zephyr Free	Photogrammetry software that creates a 3D model based on overlapping images. The free program allows up to 50 images, while the paid version allows up to 500 images for increased accuracy	"No hardware needed other than a good camera Allows remote customers to send in pictures for a custom mould"	"Quality may be lower than dedicated devices Quality dependent on the quality of the pictures Free version only allows for 50 images"	" Free, 3DF Zephyr Lite €150 "	++

Appendix G: Final Test Questionnaire



Area	Extremely uncomfortable		Very uncomfortable		Quite uncomfortable		Barely uncomfortable		Not uncomfortable	
	Design 1	Design 2	Design 1	Design 2	Design 1	Design 2	Design 1	Design 2	Design 1	Design 2
1	O	O	O	O	O	O	O	O	O	O
2	O	O	O	O	O	O	O	O	O	O
3	O	O	O	O	O	O	O	O	O	O
4	O	O	O	O	O	O	O	O	O	O
5	O	O	O	O	O	O	O	O	O	O
6	O	O	O	O	O	O	O	O	O	O
7	O	O	O	O	O	O	O	O	O	O

Area	Maximum support		A lot of support		Moderate support		Barely any support		No support	
	Design 1	Design 2	Design 1	Design 2	Design 1	Design 2	Design 1	Design 2	Design 1	Design 2
1	O	O	O	O	O	O	O	O	O	O
2	O	O	O	O	O	O	O	O	O	O
3	O	O	O	O	O	O	O	O	O	O
4	O	O	O	O	O	O	O	O	O	O
5	O	O	O	O	O	O	O	O	O	O
6	O	O	O	O	O	O	O	O	O	O
7	O	O	O	O	O	O	O	O	O	O

De trapeze blijft op zijn plek zitten

O	O	O	O	O
Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens

Ik moet van houding wisselen vanwege discomfort

O	O	O	O	O
Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens

Het aanknopingspunt tussen de vlieger en de trapeze is ter hoogte van het kruis

O	O	O	O	O
Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens

Het aanknopingspunt tussen de vlieger en de trapeze blijft op zijn plek zitten

O	O	O	O	O
Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens

De trapeze plaatst de krachten van de vlieger op de juiste plek van het lichaam

O	O	O	O	O
Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens

Ik kan me vrij bewegen in de trapeze

O	O	O	O	O
Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens

Ik kan de trapeze afstellen zoals ik wil

O	O	O	O	O
Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens