KITE SEAT

Design of a kite seat with optimal ergonomic fit, for use in surfschools

TU Delft

WILLEM HOOFT FOUNDATION

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Master Thesis - Msc. Integrated Product Design
March 2022

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IKO International Kiteboarding Organisation
PASA Professional Air Sports Association
WHF Willem Hooft Foundation
SCI Spinal Cord Injury
UPPS Ultra Personalised Products and Systems (fieldlab TU Delft)

SF Safety Factor
BPD Buttock Popliteal Depth
FBD Free Body Diagram
RQ Research Question

ACKNOWLEDGEMENT

This thesis is the final part of my studies at the faculty of Industrial Design Engineering (TU Delft). Although this was an individual project, the help of the people around me made it possible to bring this to the right end, but also in such a way that it remained fun.

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A very special thank you to all the participants who came to the faculty. Some drove a few hours or took a day off work to help me out setting up a 3D-database of the sit-kite target group. Talking to them made me, even more, enthusiastic about this project and willing to find the right solution.

I would like to thank my friend and housemate Jacoba Seminck, who was always open to helping me out and making me find solutions when problems appeared (and fun times). But most of all, I would like to thank my parents and my brother for their endless help in good and bad moments. I think after my studies, they know the field of Industrial Design in and out ;)

Marinke Callens
Delft, March 2022.

ABSTRACT

The goal of this thesis is to design a kite seat with optimal ergonomic fit for beginners in kite schools. Before designing, it is important to understand the context and create anthropometric guidelines for the target group.

The seat will be used for sit-kitesurfing, which originates from the sport kitesurfing. Its target group focuses on people with a physical disability such as SCI, amputees or spina bifida. The difference with kitesurfing is that the setup exists of a seat mounted on an aluminium frame. This frame goes onto a specially designed board for this purpose.

The project has been set up in cooperation with the Willem Hooft Foundation. This is an organisation aimed at improving the accessibility of adapted watersports, with a focus on kitesurfing. Research shows that accessibility to sports in general is lower for people with a physical disability. However, this is expected to be even lower for sit-kitesurfing. Currently, the availability of adapted courses is limited and people are left to themselves. This means buying all the gear before even trying the sport and learning the sport without qualified instructors. Improving the accessibility is done in cooperation with kiteschools offering adapted courses, where beginners can try out the sport in a safe environment.

What stops most kiteschools from offering these courses is the relatively high cost of the specialised gear. Currently, the biggest part of the costs consists of the kite seats. At least four out of seven different seat sizes are necessary to organise kite courses. Replacing those four to seven seats by a single, adaptable seat will greatly reduce the cost for kiteschools. Next to the financial aspect, there are practical and ergonomical benefits. An example is the time-consuming and difficult task of changing the right seat size to the frame. Ergonomically, the fit of these seats is often not optimised for the beginning kitesurfer of the target group.

The context, literature and desktop research resulted in key insights and points of improvement. Where information was still lacking, additional user or expert interviews were performed. Anthropometric data has been gathered through existing datasets on DINED. However, this information was not specific for the target group. Additional manual measurements and 3D-scans are performed with 9 people fitting the target group. This pointed out the differences between the target group and the existing datasets, but also provided lacking anthropometric data such as thigh width and location of the trochanter. Next to that the difficulties became clear, as everybody is different. The main design goals gathered from the research are improving pressure distribution through an optimal and tight fit. Challenges are the varying location of the trochanter, shape of the buttocks and the thighs.

The final design is an adjustable seat, reducing the amount of needed kite seats from at least four to one. This will greatly decrease investment costs, effort, time and storage. The project's outcome includes anthropometric design guidelines for a kite seat and a 1:1 prototype to test the concept.

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PART A

ANALYSIS

SOURCE: WHF - ROMANTSOVA PHOTO

In this part, research has been performed prior to designing. This is needed to create a better view of the situation and its challenges. Eventually this will lead to an updated problem definition and design requirements, which is the starting point for the ideation. The steps to get there can be found in the figure below.

1 PRODUCT CONTEXT

1.1 SIT-KITE THE SPORT

1.1.1 Introduction

Figure A-1.1: sit-kitesurf
Source: WHF

Sit-kiteboarding is a sport derived from the better-known sport kitesurfing. It is meant for people with a physical disability. More than 15 years ago, the first sit-kiter went on the water (Keep Seated, 2019). The difference to kiteboarding is that the athlete is seated on the board. To perform the sport, muscles in the legs are not needed, which makes the sport suitable for people paralysed in the legs (eg. due to spinal cord injury) or missing one or both legs. However, at least a part of the upper thighs is needed to clamp the athlete into the seat.

The setup exists out of a unidirectional board (means there is a front/back and can not be used in both directions), a frame and a seat with backrest and spreaderbar (see image A-1.2). In this project, the focus will be laid on the seat.

The sport can be performed on lakes, calm and wild seas. It is performed all over the world and is getting more awareness, which can be seen by the increasing numbers of athletes. However, this amount is still small due to a lack of accessibility to adapted courses. In the Netherlands, there are around five people actively performing the sport (WHF, 2021). Worldwide, there are five kiteschools offering these lessons, located in Germany, Greece, France and Italy. Of which only one, AltoGarda Kite Italy, is considered as experienced and are only taking a limited amount of students per season.

Another option in the direction of kitesurfing is tandem-kitesurf (see figure A-1.3). Here the student is attached to the instructor through the harness. However, this can not be done independently but gives an image about the feeling while kitesurfing. There is also the option of cata-kite, where the kitesurfer is seated on a catamaran whilst steering the boat with a kite.

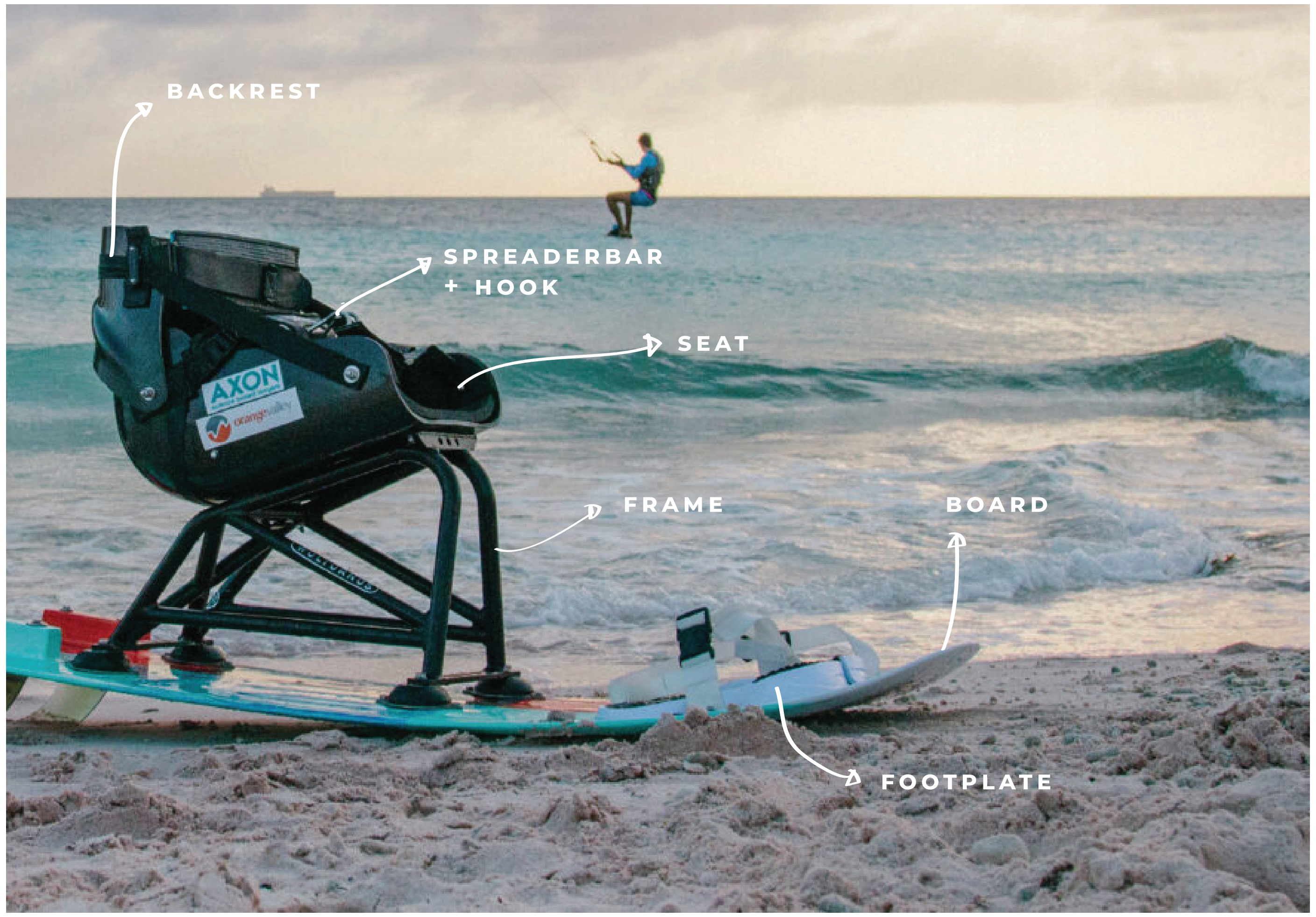


Figure A-1.2: Annotated view of current set-up
Source: WHF (without annotations)

The spreaderbar (see figure A-1.3) has as function to connect the kite to the person. This is done by attaching the chickenloop of the kite to the hook that is on the spreader bar. In sit-kitesurfing the spreaderbar is attached to a strap that goes all around the kiteseat.

Figure A-1.3: Spreaderbar on current setup

Similar sports are sit-ski (figure A-1.6), sit-snowboard and sit-wake (figure A-1.5), with skiing being most known and most performed. The seats currently used by most sit-kiters are the same as sit-ski.

Figure A-1.4: tandem-kitesurf
Source: blog.surf-prevention.com

Figure A-1.5: sit-wake
Source: pl.youcanwake.com

Figure A-1.6 sit-ski
Source: rockymountainadaptive.com

1.1.2 Kitesurfing

Figure A-1.7: Kitesurfing
Source: theriderexperience.com (left) & airush.com (right)

Kitesurfing is a water sport that has existed since around 1995 (Kitesurfing Handbook, n.d.). The kitesurfer uses wind power to be pulled out of the water and uses this power to go forward. It is a combination of different water sports, such as surfing, windsurfing and wakeboarding. The material exists out of a kite (most used sizes: 5m2-16m2), a bar with lines (average length 20-27m), a harness and a small board. Kitesurfers can ride with speeds of up to 35 knots (Bourgois et al., 2013), but will most likely ride between 12 and 22 knots. There are many influencing factors when a kitesurfer can go on the water, including wind speed, kite type and size in relation to your weight and technique (Kitesurfist, 2018). Nowadays the sport has evolved to different disciplines such as freestyle, wave and race with many different types of boards and kites, depending on the discipline. A term that will be often used in the report is edging. This is different to most other watersports and is needed to control the speed and direction. It can be achieved by putting the board at an angle. This allows the kitesurfer to ride upwind (see figure A-1.8), which means riding nearly directly against the wind or, in other words, zigzagging across the wind (Surfertoday, 2021). This skill is also what differentiates a beginner from a more advanced kitesurfer.

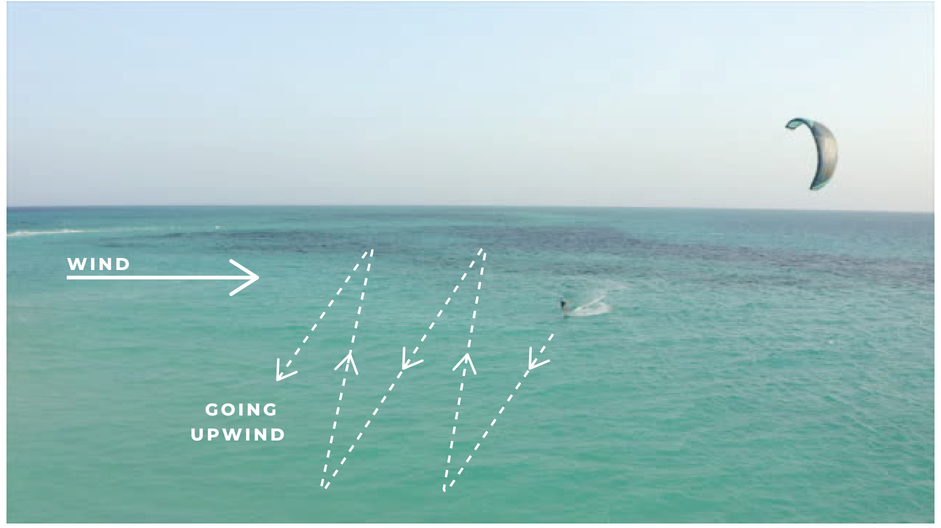


Figure A-1.8: riding upwind
Source: Gettyimages.dk (image without annotations)

An important aspect is the safety system connected to the bar, called the quick-release (see figure A-1.9). When pulling this, it makes sure power is removed from the kite and the kitesurfer has time to detach himself from the seat. The quick-release is attached to the chickenloop, which is connected while riding to the hook (which is part of the harness). In an extreme situation, it could happen that a kite line is stuck behind an object in the water or around the seat. If the situation is too dangerous, a kite knife (see figure A-1.10) can be used to cut one of the lines.

Figure A-1.9: Safety system - quick-release (in red) attached to the bar, should be pulled upwards for pressure release of kite
Source: Kitemana.nl (image without annotations)

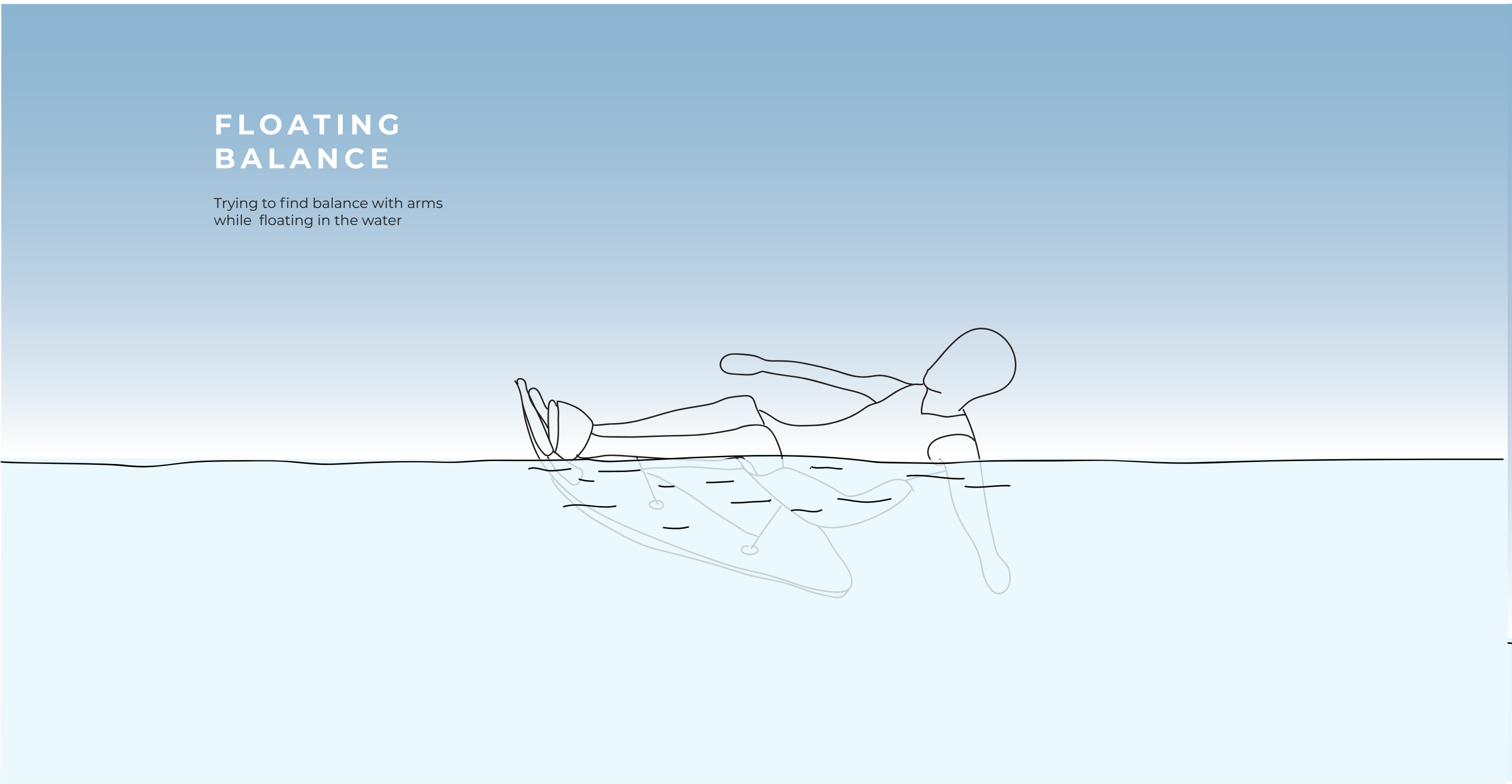
Figure A-1.10: Kite knife
Source: Kitemana.nl (Manera)

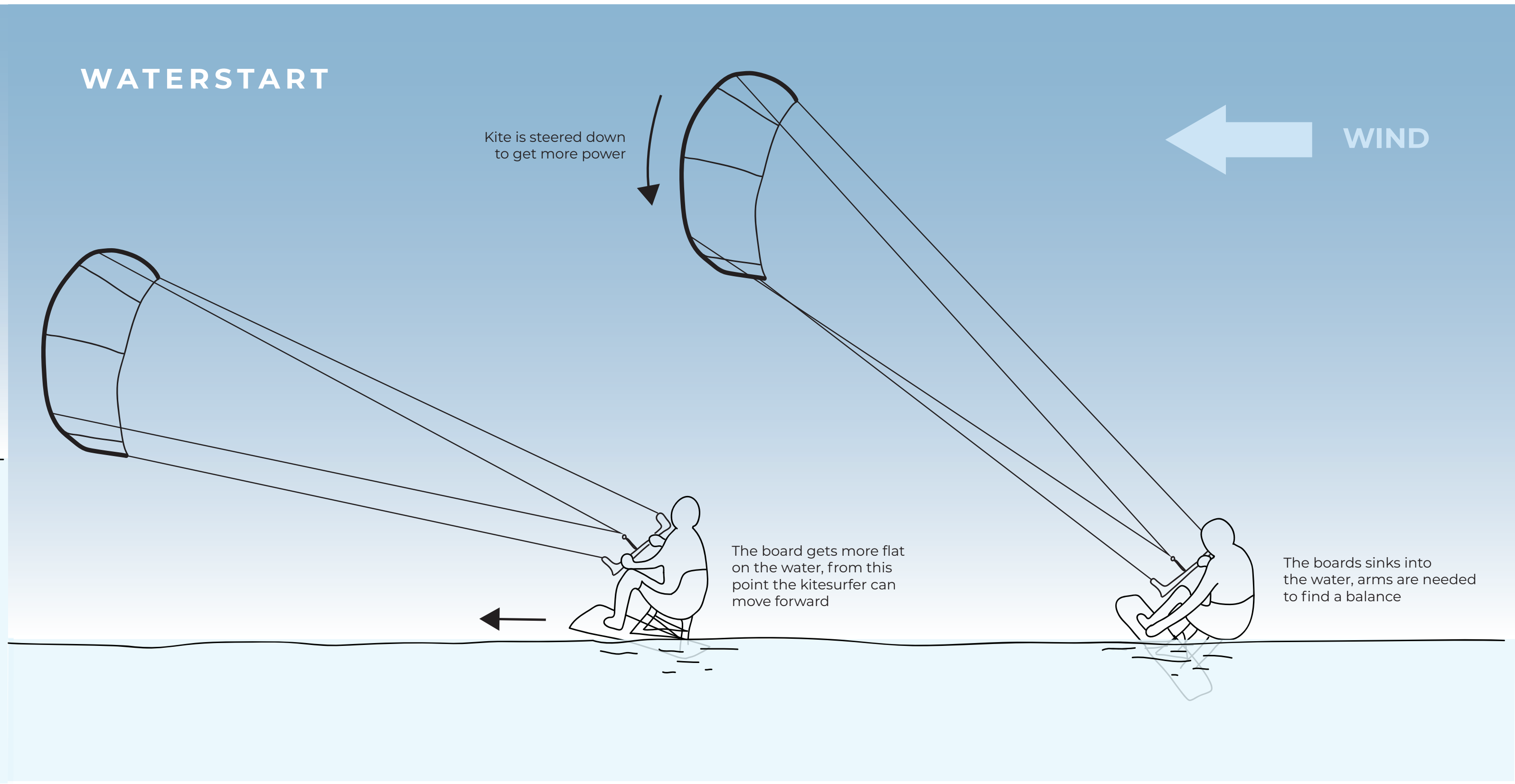
1.1.3 Technique and skills

There are multiple key skills in sit-kitesurfing, which results in different forces acting on the seat. Analysing these is essential for a better understanding of the use of the seat in real-life situations. A more precise analysis of the forces can be found in Chapter 6. Environmental Forces.

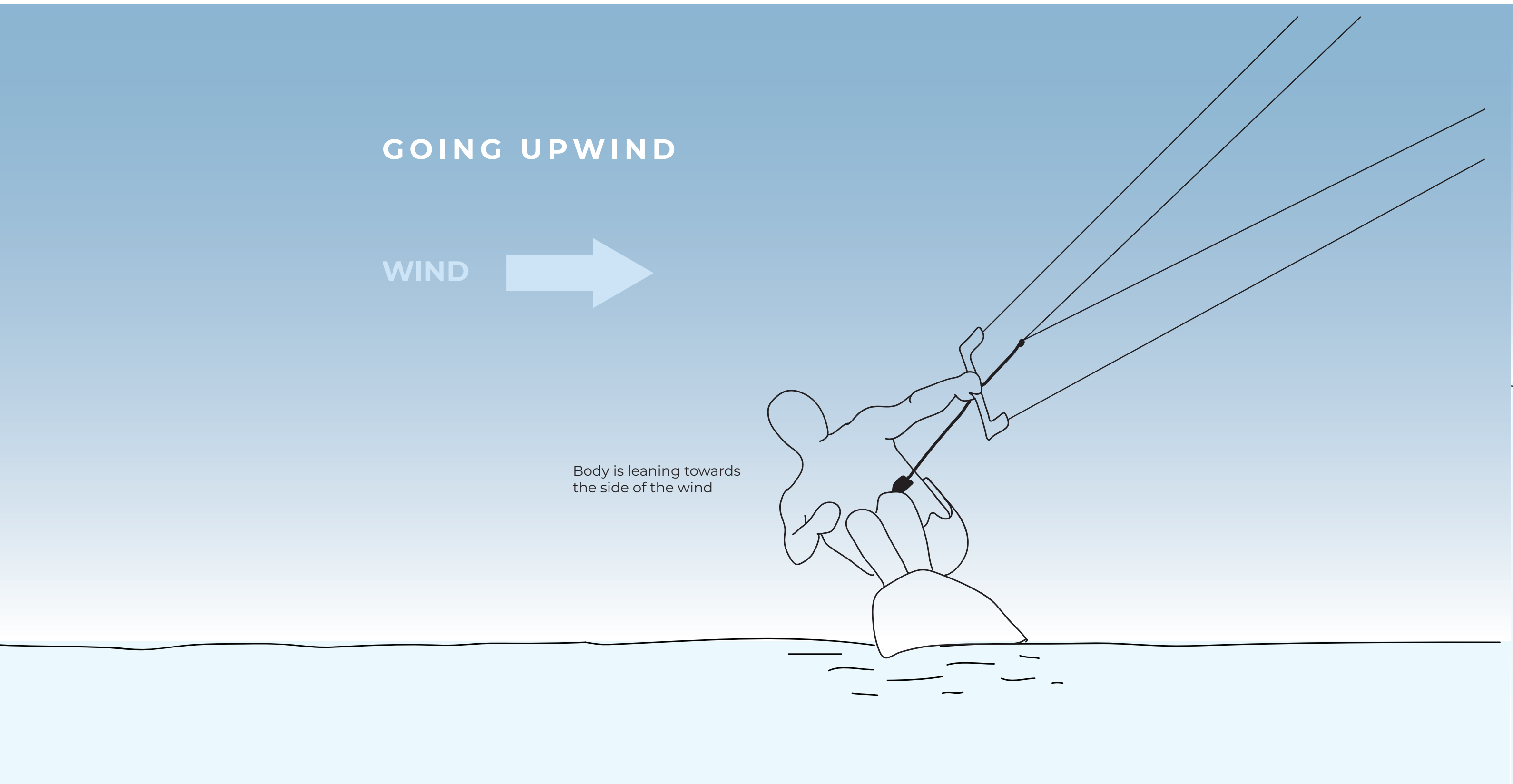
The first one is learning to find balance while floating by using the arms. Most of the board is underwater, only the shoulders and head are above water. The buoyancy comes from the life vest on the upper body, and not from the material (see figure below). If the buoyancy comes from the material, the kitesurfer could float head down which leads to a dangerous situation.

After this, the waterstart will be a key skill. This allows the kitesurfer to get out of the water, and ride on the water surface. As can be seen on the figure below, the sit-kiter will first lie in the water with most of the board under water. Then he steers the kite downwards, which will create extra power to perform the waterstart. The kitesurfer is pulled forward and the person leans forward as well. This allows the board to turn flat on the water. When started, the person can steer the kite upwards without sinking down again (if there is enough wind for the kiter)

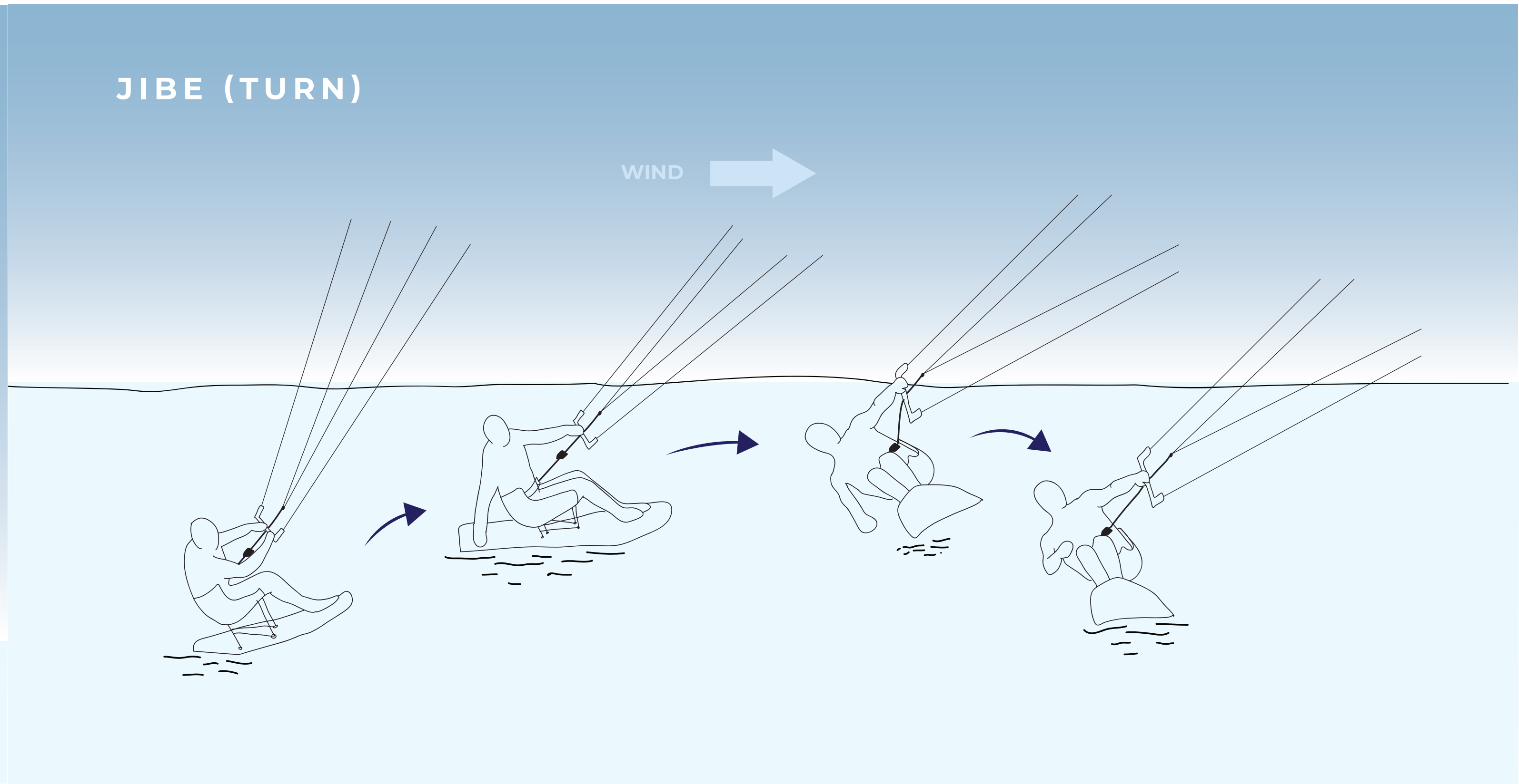




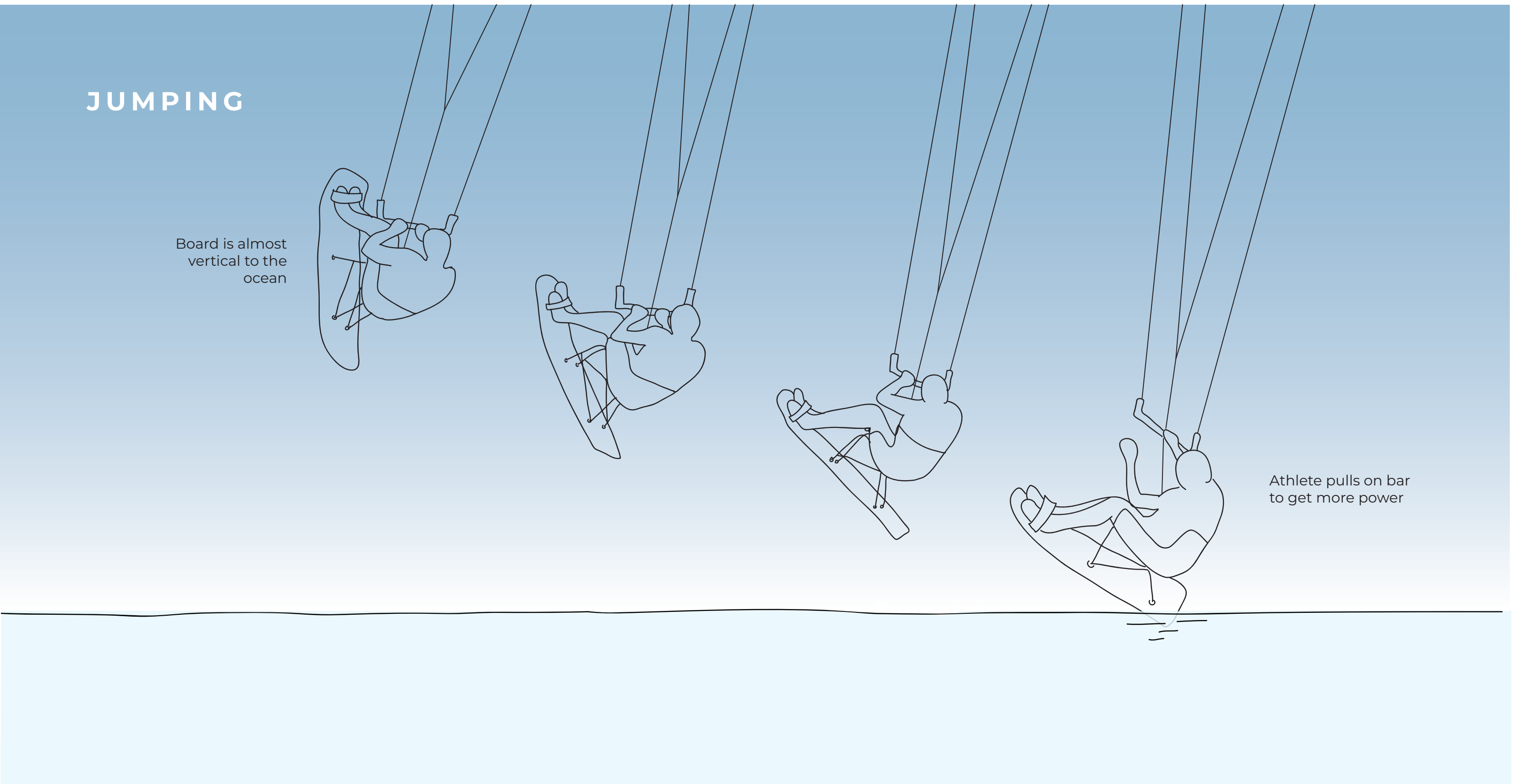
In order to be able to get back to the starting position, going upwind is important. The technique is to push the body against the side of the wind until the board is at angle with the water (also called edging).



Turning is done by performing a jibe. Which means the athlete turns the kite to the other side, presses his body against the wind in order to turn the board. This manoeuvre is a downwind turn (in direction where the wind blows to). In this step it is important to have a good force transition by having a tight fit close to the body. If the jibe is not done correctly, the board will pull the person in another direction than the kite. This is why a tight fit is also important, to not get pulled out of the seat. As the backrest is connected to the seat and body, every move made from the abdominals or back are directly transmitted to the board. A jibe can be done differently using different techniques, mostly variable in speed or pressure against the wind (edging).

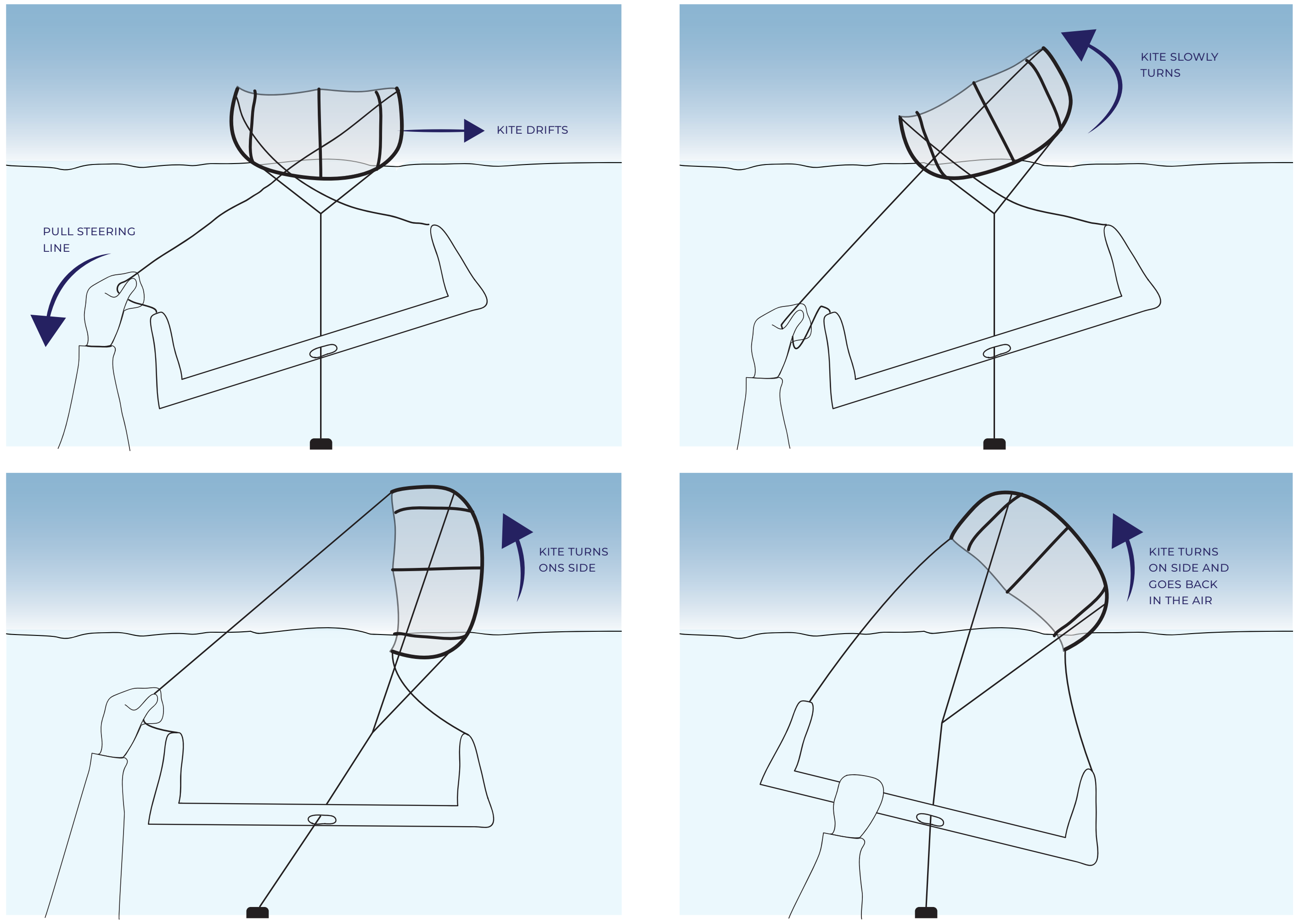


For more experienced kitesurfers, jumps can be practised. Here it is important the person pulls the bar towards its body, this will create more power into the kite (see figure below).



If the person crashes, the kitesurfer could be on their side and will need to turn on their back and find balance before performing the waterstart again. This is not an easy action, and is something beginners often struggle with. However to be an independent rider, this is a critical skill.

It could also happen that the kite crashes, which is not a comfortable position. The kitesurfer will need to be able to relaunch the kite. This is important to get the kite back up in the air after a crash (see figure below).



1.2 STAKEHOLDERS

Stakeholders of the project are analysed, and their roles or levels of interest are explained. An overview can be seen on figure A-1.11, a more detailed explanation can be found on the next page.

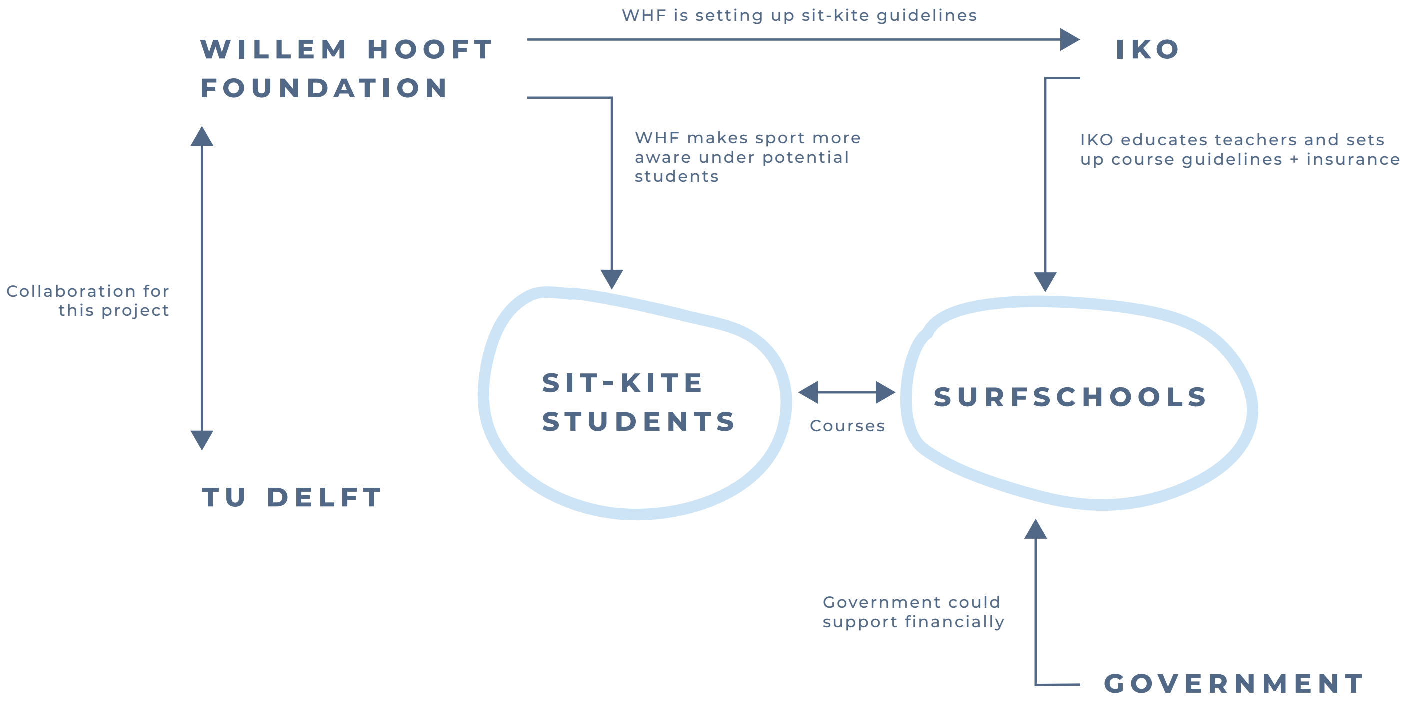


Figure A-1.11: Stakeholders overview

Sit-kite students
The students will be the user of the seat which makes them the most important stakeholder and is considered as the target group (further explained in 1.3 Target group). Their interest in this project lies in better accessibility to the sport, better safety and higher performance. Out of research by Wu and Williams (2001), the main reasons for athletes with SCI who participated in sports after injury were for fitness, fun, health, and competition.

Surfschools
Surfschools, and their instructors, are important stakeholders in this project. The design will be made for beginners to use in surfschools. In kitesurfing, it is important to learn theoretical and practical matters from an experienced instructor (IKO, 2018). Without knowing the right safety rules and procedures you could be a danger to yourself and others. This goes for both the traditional and adapted kitesurfing.

Offering sit-kite
For kiteschools already offering sit-kite courses, this project is of interest for improving their lessons and materials. They already have knowledge due to their experience in teaching and working with sit-kiters. There are currently five schools worldwide offering/having offered seated kitesurfing:

- Nieblumer Wassersport Schule – Germany
- Surf Club Keros – Greece
- Handikite DFC – France
- Altogarda – KITE ASD – Italy
- Sail United e.V. – Germany

Not yet offering sit-kite
The kiteschools, who are not yet offering sit-kite lessons, are also important stakeholders for this project. By getting them involved in the sport, it is getting easier to make the sport accessible for people with a disability. Finding out what is holding them back is an important aspect to research.

Willem Hooft Foundation
The project has been set up in cooperation with Willem Hooft Foundation (willemhooftfoundation.com). This is a Dutch foundation that promotes seated watersports for people with physical disabilities, with a focus on sit-kitesurfing. They have a goal to make sit-kiting easier accessible and safer. By organising introduction days and setting up product development projects, they try to achieve this goal.

TU Delft / UPPS Fieldlab
The project is part of a master thesis Integrated Product Design at the faculty Industrial Design Engineering at the TU Delft. Next to that will the UPPS Fiedlab facilities be used, in regards to 3D-scanning and manual measurements.

International Kiteboarding Organisation (IKO)
IKO is the largest kiteboarding organization in the world, with an active community of more than 600 000 kitesurfers, 5000 certified instructors and 350 affiliated centres in more than 60 countries (IKO, 2021). It is important to include them as a stakeholder, as they are most likely to guide instructors through the sit-kite process and guidelines in order to offer safe courses.

Government
Initiatives like this could be subsidized from a government or local authority.

1.3 TARGET GROUP

The target group are people with a physical disability, who have good core stability, hand and arm function. This is needed for controlling the kite and board. Next to that, is physical fitness important for performing the sport. People from the following paralympic classifications, depending on the level of severity of their injury, could be part of the target group: spinal cord injuries (ISMWSF) and orthopaedic conditions/ amputees (ISOD). Also people with knee or hip problems can be included in the target group, if there is enough flexibility of the knee joint. As sit-ski, it can be performed by individuals with bilateral lower limb functional impairments, including persons with spinal cord injuries, spina bifida, or bilateral lower extremity amputations (De Luigi & Cooper, 2014).
This variety of potential users also creates challenges while designing an optimal ergonomic fitting seat. More specifically will the thigh width have large differences between people with and without muscle strength in the legs. Other potential anthropometric factors will be determined in this project.

Since the seat will be re-designed for kiteschools, the project will tackle the design of a seat for beginners, rather than for advanced sit-kiters. This does not mean advanced kitesurfers can not use the seat, but they could have other personal desires about the material when improving in the sport. This is also something that is visible in the current group of experienced sit-kitesurfers, where no setup is exactly the same. A beginner's target group will demand additional requirements.
For this project, there will be looked at adult users only but can later be extended to children. As the athlete requires additional help compared to standard kite lessons, it is important to include the instructor as a user as well. He/she will also play a role in setting up the gear. It is also crucial to understand how a course is given, to understand the whole context. Designing the lessons will not be the focus of the project. However, the design can include suggestions for this.

1.3.1 Spinal Cord Injury

As the biggest part of the current and interested sit-kiters have a SCI, more research has been done to specify this better. Depending on the height of the paralysis, the seat and backrest are vital for stability and for the ability to put weight onto one side of the board to be able to go upwind. A SCI is a damage to the spinal cord that results in a loss of function, such as mobility and/or feeling (see figure A-1.12). In general, there will be more experienced dysfunctions if the injury occurs higher in the spinal column. Divided into four categories: cervical, thoracic, lumbar and sacral; and two types: complete and incomplete. To be able to perform sit-kiting, full arm function and core stability are needed for controlling the kite and board. This means that not all SCI-patients will be able to perform sit-kiting. According to the Willem Hooft Foundation, patients with a SCI on a thoracic (T4-T12) level could be part of the target group, with T4 being the limit and everything higher (in number) is considered more easy. The lower in the spinal cord that the damage occurs, the more function can be expected (Spinal Cord, Inc., 2020). This group will mostly exist out of more men, as SCI is affecting more men than women (Shepherd Center, 2021). Furthermore, kitesurfing is still mostly dominated by men. In 2014, 90% of the riders in the US were male (TheKiteboarder, 2014), it is expected that this number has decreased but will still be dominated by men. More information about SCI can be found in Appendix VI.

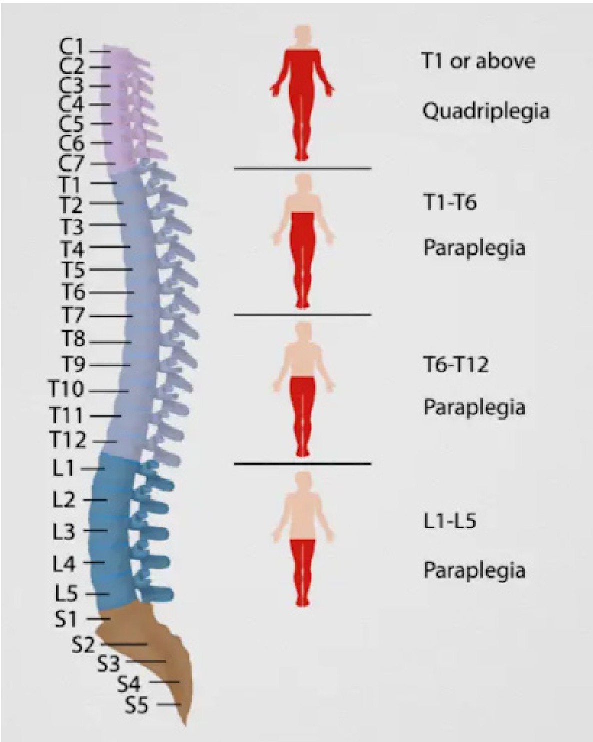


Figure A-1.12: levels of SCI
Source: Alila Medical Images

2

CONTEXT RESEARCH

2.1 RESEARCH PLAN

Goal
The goal of the research is to understand the context of sit-kiting and create design and anthropometric guidelines for a kite seat for beginners. Additional research will be done about the accessibility to the sport and to verify and/or sharpen the problem definition.

Research questions
1. How does the current setup of equipment and courses work?
2. What are the reasons for low integration of the sport in kiteschools?
3. What are the important aspects (anthropometric, usability, comfort and safety) while designing a seat for sit-kite beginners in schools?
4. What are the points of improvement of the current kite seat?

Method
Desktop and literature research
- Research about existing kite and ski seats, market, desirability, ...
- Context research

Customer journey / Storyboard
- Clear overview of steps (can help during interviews with schools and understanding the process).
- Where are the points of improvement + what has to be taken into account designing the seat?

Qualitative research / User interviews
- Instructors and schools: better image of way of working, sharing of experience, where do they see improvement, specifically about seat
- Experienced sit-kiters: as expert user of the seat

Quantitative research
- Questionnaire (schools not offering sit-kite: familiarity of the sport, what is holding them back, market research)

2.2 DESKTOP AND LITERATURE RESEARCH

General desktop and literature research has been performed to find out existing knowledge relevant to the project. This research is not limited to one research question, but tries to find answers for all and find out where information is missing. The method for the literature research was rather spontaneous, and was further completed during the ideation whenever knowledge was lacking. Important keywords used during the research are written in the beginning of each topic. Most literature has been found using Google Scholar and ResearchGate using these keywords.

General
[ski seat, adaptive sports, sit-ski, sit-snowboard]

As research about kite seats is limited so far to trial-and-error prototypes, literature research has been done on existing literature about sit-ski. Furthermore, the current kite seats are directly used from sit-ski, which makes it useful to dive deeper into it. However, most research had a clear engineering focus of the whole system, such as the influence of the centre of mass on ski performance (Langelier et al., 2013) and vibrations acting on the material. There has been research at TU Delft - faculty Mechanical Engineering about sit-snowboard. But also this was rather focussed on the frame system and did not deliver any solutions or insights regarding the seat.

Desirability
[adaptive sports, inclusive sport, sport participation SCI]

People with disabilities face numerous barriers to participate in adaptive sports including accessibility, transportation, awareness and finances. These barriers are potentially even bigger for kitesurfing. Regular sports participation has shown to have a positive association with, among others, improvements in quality of life, life satisfaction and community reintegration (Diaz et al., 2019). Making kitesurfing for people with a physical disability more accessible will therefore contribute to these above mentioned things.

Seat
[ski seat, sit-ski, backrest ski seat, ski bucket]

The ski seat can be a standard size seat or a custom-molded seat which adds to the performance. They are also equipped with a removable hard external shell to protect against injuries (De Luigi & Cooper, 2014). A custom-molded seat is usually prefered (Juriga et al., 2017). There are three main ski seats: plastic bucket seat, seat bench and a composite seat (see Table A-2.1). The bucket seat is considered most comfortable, but it does not allow larger riders to fit comfortably. On the other side, smaller skiers will need extra padding for a tight fit which adds weight. While a bench seat is more suitable for larger riders, it decreases the perceived comfort and security (due to the straps around shins, thighs and feet). Finally the composite seat is considered as the best in performance and lightweight. But it is more difficult and expensive to manufacture (Bissonnette et al., 2021), however it is the one being used for kitesurfing.

Plastic bucket	Bench seat	Composite/Gelcoat
		
+ Highest perceived comfort	+ Suitable for wide variety of body shapes	+ Highest performance Lightweight
- Not suitable for large riders	- Less security Less comfort	- Expensive and difficult manufacturing

Table A-2.1: different types of ski-seats

The backrest of a ski seat should be adjustable in height to facilitate a wide range of disabilities. For example, riders with a low SCI will feel that a high seat is limiting their range of motion in the upper body (Bissonnette et al., 2021). However for sit-kitesurf this is different as, in contrast to skiing, they can not use outriggers for turning (De Luigi & Cooper, 2014), and will need their upper body for edging, turning and riding upwind. This is depending on the level of SCI. People with enough upper body muscle might prefer no backrest which improves their freedom of movement. According to Willem Hooft, kitesurfers will need a higher backrest with the same SCI level compared to skiing.

Ergonomics
[seat comfort, sitting support]

Research about vehicle seat comfort by Kochem and Zimmer (2004), states that surfaces of the back and buttocks were important for actual seating comfort and correct support. No research has been found if this is similar for ski-seats. This means further research is required to find out if this is also the case for kite seats (see Chapter 4.Discomfort).

Market
[kitesurfing, adaptive sports, adaptive winter sports]

To get a better image about the potential of sit-kiting, there has been looked at the current market of similar adapted sports such as sit-skiing. The growth potential of the sport will have an influence on the accessibility, production possibilities and costs.

During the 2016 paralympic games in South Korea, more than 500 athletes out of 49 countries participated in 6 wintersport disciplines. Out of 130 Nordic skiers at the 2010 Winter games, there were 53 sit-skiers. There is still an increasing number in interest for adaptive wintersport (Oh et al., 2019). However, there are no exact numbers available of the amount of sit-skiers.

Worldwide there are around 350 kite centers registered at IKO. The actual number of schools will be higher as not all schools are connected to IKO. However, only five kite schools are known to be offering sit-kite, which shows opportunity for further integration of the sport at other schools. If you compare the numbers with ski schools, there are many more offering sit-skiing courses. In 2012, there were already 150 ski schools in France offering handiski instruction and hire (ENAT, 2012). In Europe, there are 18 ski resorts specifically accessible for people with SCI. However, the numbers between ski and kite are not directly comparable, as the amount of people skiing is much higher. In 2012, it is estimated that the amount of kitesurfers worldwide was 1.5 million people (International Sailing Federation, 2012), and it has continued to grow. The amount of skiers and snowboarders worldwide are estimated at 125 million (Snowsports Industries America, 2016). With this data, it can be estimated that sit-kite will not get more popular than sit-ski but definitely still has potential to grow and be included in more kiteschools worldwide if the sport gets more awareness and becomes more accessible.

After contacting F-One in October 2021, the producer of the sit-kite boards, they mentioned having sold 12 boards since December 2020. They see this as a good number, and would normally sell around 10 boards a year without any marketing.

Contacting Tessier, producer of the used ski-seats, they mention not having any data on the sit-ski market because it is niche. They could only tell that they sell around 350 seats each year, in all of their products (including ski and wake). They have thought of an adaptable seat before, but found it difficult to get rigidity allowing the same performances.

2.3 STORYBOARD

To understand the context of the course and sport better, an overviewing storyboard has been set up of the course program. This could point out the aspects of improvement and/or the role the kite seat plays in the process. This storyboard is discussed with WHF, sitkiters and kiteschools. According to the Delft Design Guide, a story board (also known as customer journey mapping) helps to gain insight into all stages a customer goes through while using the product (Van Boeijen et al., 2014). The goal of this method is to answer mainly research question 1 ("How does the current setup of equipment and courses work?").

The structure and the content of a standard kite course differ between schools and instructors, but if learnt at a school, it should be standardised such as IKO or PASA (IKO, 2019). The course can be given privately (one student per instructor), semi-privately (2 students per instructor) or in a group (>2 students per instructor). A sit-kite course is currently not standardised yet, but WHF is setting up guidelines for IKO.
On page 28 written text can help understanding the storyboard (figure A-2.1).

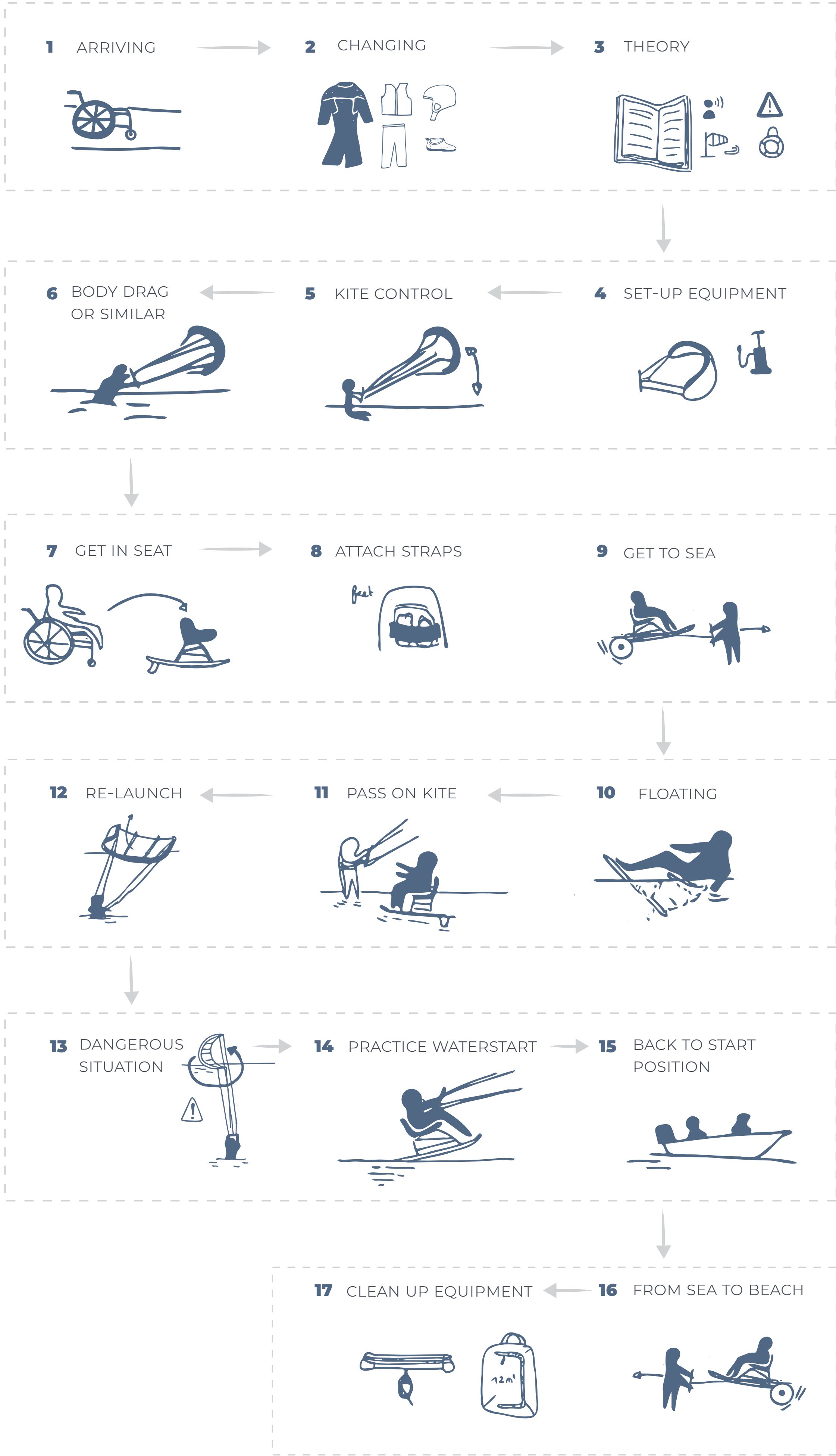


Figure A-2.1: Storyboard

1
The student arrives at the surfschool with their wheelchair, which means the school should be adapted to this.

2
After some information and possible administration, it is time for the student to change into the right clothing. This means a wetsuit for warmth and protection against the seat. In warmer locations, a wetsuit can be changed for long pants to ensure protection against material and environment. Other equipment that will need to be worn are an impact or life vest, a helmet and shoes.

3
After that, theory will be given about different wind conditions, safety rules, way of communicating and how to analyse a spot.

4
Then it is time to try out the kite and learn kite control, this will most likely be done on the beach but it can also be in the water. In setting up the equipment, a sit-kite student might need additional help in pumping up the kite and laying out the lines, as this can be tricky out of a wheelchair on the beach.

5
The next step is about kite control. A bodydrag can be performed, but this depends on the facilities of the surfschool.

Source: AltoGarda Kite

6
After this the student is ready to try the seat. Already on the beach, the person will get in the seat. Some can do this independently, some will need help.

7
When in the seat, straps need to be attached. One around the feet, two at the seat and finally one at the back (depending which set-up is used).

8
In most situations, the sit-kiter (with the equipment) will be placed on a trailer and will be pulled forward by an instructor on the beach to the sea.

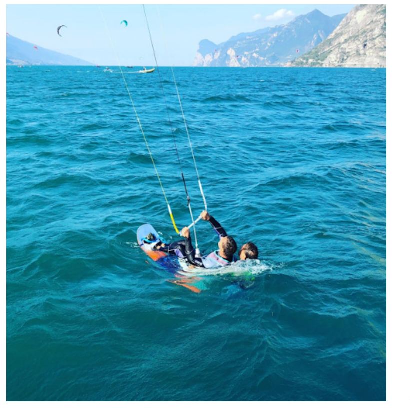
Source: WHF

9
Before actually riding, the student will be teached how to float and how to use its body to turn when fallen on his side. This is practised by laying in the water with the arms wide open, the equipment will be under the person and under water.

10
After this, an instructor will launch the kite from the beach and will pass it on to the student in the water.

11
Before actually practising the waterstart, it is important to learn a re-launch while in the water. This is important as you need to be able to get the kite back in the air when fallen into the water.

12
When succeeded, the student can learn his waterstart. This will take some trial-and-error, while the instructors keep closeby with the boat or in the water in case something goes wrong (not being able to turn on back).



Source: AltoGarda Kite

13
When finished, the student will be brought back to its start position as he will not be able to ride upwind and will be dragged down in the direction of the wind. In a course, it is most likely the boat will pick them up and bring them back to the beach where the trailer is ready.

The differences between a standard kitesurf course and an adapted sit-kitesurf course are listed below, using the steps of the storyboard.

	Standard kitesurf	Sit-kitesurf
Standard	**Safety measures** which contains the kite-release (getting power out of kite) and safety release (detaching kite from person)	Additional safety measures: different steps when in trouble (first kite-release, then out of seat) + how to get out of seat + how turn on back
Kite control	Teached while sitting and standing on the beach, after that a **bodydrag** is performed (being dragged by a kite on the water without a board). This is also essential as the kitesurfer will often lose his board and needs to be able to bodydrag back to the board.	Teaching kite control depends on the facilities of the surfschool. A bodydrag can still be performed to feel the power of the kite. However this is not an essential skill as the kitesurfer will always be attached to the board and will not lose it. Or, as a school in Italy, the student is fixed on a boat which is being pulled forward by the movements of the kite.
Get to sea	Student will launch the kite himself and walk to the sea with the kite in the air.	Person is dragged on a **trailer** (without the kite) to the sea. Teacher will launch kite and pass it on to the student in the water.
Waterstart	**Instructor** can stay **on the beach** while the student is practising on the waterstart. There is often communication through a microphone in the helmet.	Student can struggle with turning on back, instructors will need to be close (on boat) to assist if needed
Back to start position	Student will walk back with the kite in the air	Student will be **picked up by a boat** or gets back to the beach and is being pulled back using a trailer

Table A-2.2: Differences sit-kitesurf lessons VS standard kitesurf lessons

Conclusion

Compared to a standard course there are some fundamental differences, such as the group size and points of attention for the kite instructor, mainly about safety. A sit-kite course needs more preparation and time during the course. Certain steps should be done differently in the process, mostly regarding the transportation of the student and material set-up.

2.4 INTERVIEWS

Interviews are performed to find answers on all 4 research questions. They will be held with experienced sit-kiters as well as surfschools offering sit-kite lessons. Following the method in the Delft Design Guide, this will help in obtaining contextual information about product use and issues, as well as expert opinions (Van Boeijen et al., 2014).

Interviewed people:

Willem H.
Willem Hooft is the founder of WHF, and he is a professional sit-kitesurfer. His expertise can be used to answer research questions 3+4.

Markus P.
Markus is an experienced sit-kitesurfer from Switserland who did explorations to better equipment for himself. His expertise can be used to answer research questions 3+4. Contact is suggested by WHF.

Nicolas L.
Nicolas is an experienced sit-kitesurfer from France, living on the Canary Islands. His expertise can be used to answer research questions 3+4. Contact is suggested by WHF.

Mark
Mark is an experienced kitesurf instructor in Mallorca for many years, but not yet experienced with sit-kitesurfing. He started this summer with helping out a person who wanted to learn sit-kitesurfing and figuring everything out. His expertise can be used to answer research questions 1-4. Interviewee is found through Instagram on search term #sitkite.

Luc F.
Luc is a material expert and ski-teacher from a sit-ski organisation in the Netherlands. He is very experienced with using the seats himself and adjusting it for other people. His expertise can be used to answer research questions 3+4. Contact is suggested by WHF and is approached through email.

Andreas A.
Andreas is an experienced (sit-)kite instructor from Greece. He is starting up his own organisation to promote sit-kitesurfing. His expertise can be used to answer research questions 1-4. Contact is suggested by WHF.

Method:

The questions (see Appendix II.A) have been divided by categories: general, courses, equipment, seat and the project. They are left open, as far as possible, to not force the interviewees into a direction or limit them in their answers. The questions mainly work as a leading document, rather than an exact transcript.

The main takeaways of the interviews are visualised in mindmaps, with a distinction between answers of an experienced sit-kiter (orange), sit-skier (blue) and sit-kite instructor (green). Together with the interview notes this can be found in Appendix II.B and III.

Conclusion

From the interviews it can be concluded that there are different preferences depending on the person and/or the disability. Especially the required or desired help and the use of a backrest. Interviewing surfschools next to experienced sit-kiters, showed to be beneficial to get a better image of beginners and their desires and obstacles.

Furthermore some conclusions or design requirements for the design can be drawn, which can be found below:

Design req.: *Backrest should be removable*

Design req.: *Backrest should not restrict freedom of movement*

Design req.: *Adapting size of seat should take less time than changing to another frame*

Design req.: *Seat should be stiff for performance and support*

Key insight: *Maximum used hip width in sit-kite is 390mm*

Key insight: *Main issues lie in setting up the equipment (time)*

2.5 QUESTIONNAIRE

A questionnaire has been set up for kiteschools that are not yet offering sit-kite lessons. The goal is to verify the problem and dive deeper into the low accessibility/integration of the sport, which corresponds with research question 2. Answers can be found in Appendix IV.

Six kiteschools in Belgium and the Netherlands answered the questions (see Appendix IV). Only two out of six have considered including sitkite in their offered courses, while half of them already had direct demands about adaptive kitesurfing. The main reason it is not integrated yet is mostly cost-related and viability. As well as the lack of experienced instructors.

Limitations: as most schools have not yet even considered including sit-kiting in their program, they might not be aware of the possibilities and challenges. It would be more interesting to interview schools that have already considered including it, but did not proceed for certain reasons.

3 PRODUCT ANALYSIS

In addition to subjective feedback of users and kiteschools, the current system has been analysed to understand its working, strengths and weaknesses. This research helps in answering research question 1 ("How does the current setup of equipment and courses work?") and will deliver insights that are less prone to biases.

3.1 CURRENT ANALYSIS

Figure A-3.1: current set-up
Source: AltoGarda Kite

Currently, there are a few kite schools equipped to teach people with disabilities. Some have adapted and modified the material such as wide windsurfing boards, inflatable chairs or catamarans powered by a kite (IKO, 2017).

The current setup used in schools exists out of an aluminium frame (brand Wolturnus) with a carbon/glass epoxy seat (brand: Tessier) on an adapted board (brand: F-One) (see figure A-3.1). Especially the combination between the Wolturnus frame and F-One board is preferred. There are definitely variations on this equipment, for example a kitesurf harness instead of a hard backrest or different frames. However, it is a design requirement that the seat will need to be suitable for the Wolturnus frame.

The seat has two straps around the legs and one around the backrest (figure A-3.2). This is to make sure the kitesurfer is entirely attached to the seat and can not be thrown out when the kite is going into another direction. In addition to these straps, there is another one around the feet and the spreaderbar will be attached as well. A more detailed overview of the parts can be found in Appendix V.

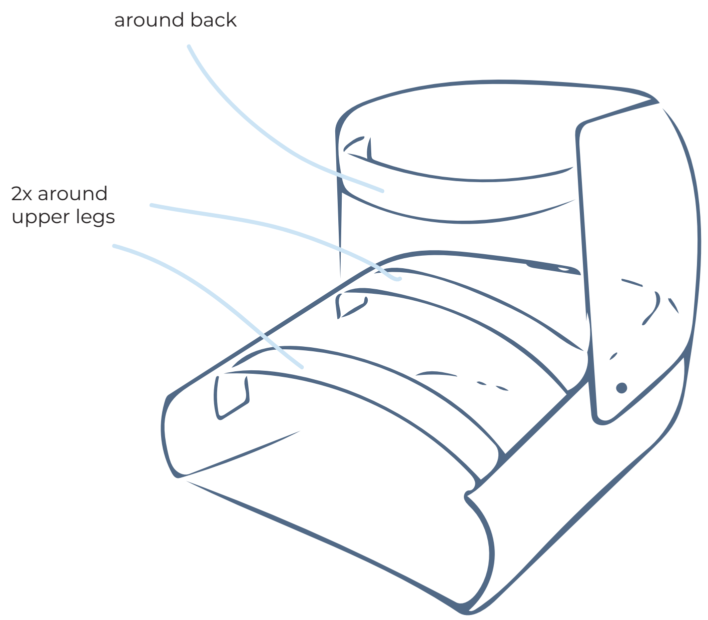


Figure A-3.2: straps

3.2 SIMILAR EQUPMENT

Research has been done on existing products in sports that show similarities to sit-kite. This will give an image about material choice, production, sizes/dimensions and problems solved in other products. Or just simply to draw inspiration from in the ideation phase.

Kitebuggy - Aeroseat	Water Ski Seat
 • Material: durable cordura, the lower is from water-resistant bisonyl (PVC) • Rigid outer-frame with textile in between • Source: MG-kites, 2011	 • Target group not for disabilities • No backrest
Kayak Seat	Adaptive waterski - Sitski
 • Carbon– Kevlar seat design • Wider legs positioning gives more stability - in sitkite this would mean a wider board needed • Gel padding - ensures scratch and pressure-free sitting • Interesting locking system: quick release four-point fastening system	 • With or without backrest • Backrest rather for not falling out then performance • Source: Numotion

Table A-3.1: similar equipment

4

(DIS)COMFORT

After performing the interviews, some interviewees mentioned the importance of comfort of the seat. The reasons why are further researched in this chapter. This will also help in creating insights for research questions 3 ("What are the important aspects while designing a seat for sit-kite beginners in schools") and 4 ("What are the points of improvement of the current kite seat?"). Research has been done through literature research and a survey for sit-kitesurfers.

4.1 SEATING POSITION AND SUPPORT

[pressure distribution seat, postural support SCI, lumbar support, wheelchair positioning]

As some interviewees mentioned the importance of the backrest, further research on this has been done. Next to that, it is known that people with a SCI might need additional postural support in some situations.

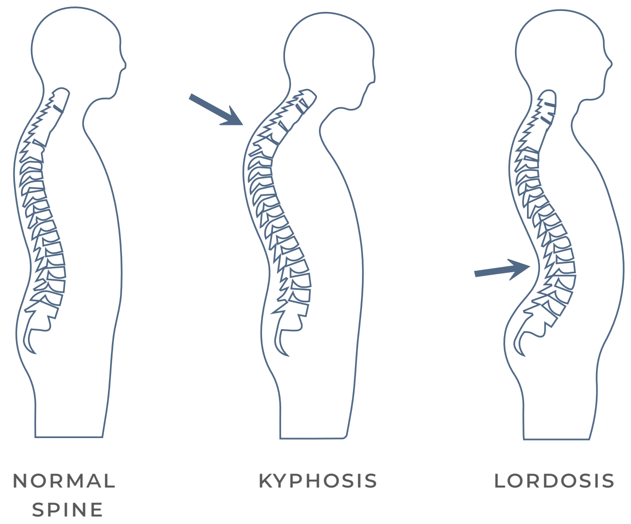


Figure A-4.1: body postures
Source: www.sportsinjuryclinic.net

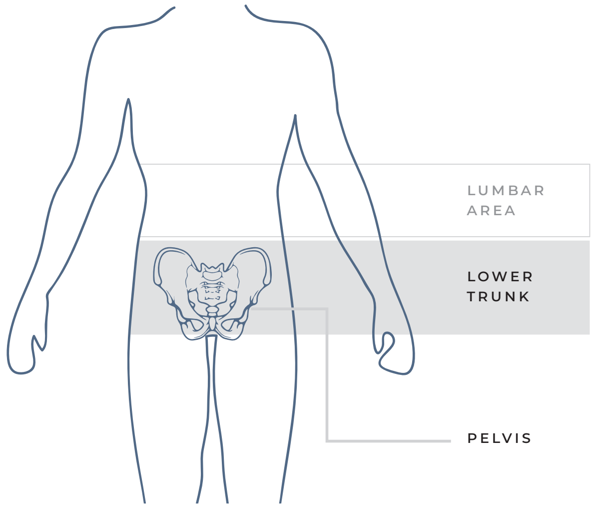


Figure A-4.2: lower trunk and pelvis

As mentioned earlier, pressure distribution on the seat is important. For people with limited mobility, body repositioning is the only way to change pressure distribution at the body-seat interface while in a wheelchair (Aissaoui et al., 1997). The current kite seat is developed by athletes for optimal performance, with an average angle backrest-seat of 80 degrees. The more the seat is tilted backwards, the more balance the kitesurfer will have. However, this backward tilt is restricted to 20 degrees as it would otherwise interfere with the kite lines. A lumbar support increases lordosis, which is not desired as it increases the load on the back (Makhsous et al., 2003) (Andersson et al., 1979).

On the other hand, will an encouraged kyphotic posture (see figure A-4.1) cause discomfort in both disabled and non-disabled subjects (Harms, 1990). Translating this to the project, it is important to minimize the chances of lordosis or kyphosis and not work with lumbar support.

It is therefore necessary to support a normal spine posture. Research by Hastings et al. (2003) states that by providing postural support for the pelvis and lower trunk (see figure A-4.2), a better upright position can be maintained even with muscle paralysis.

Important to notice, Willem Hooft states that the backrest's main function is to translate the sideward forces of the upper body to the board. While riding, the back is most of the time free from the backrest, which is desired for freedom of movement. The support and fit is therefore less important in the backrest than in the seat itself.

***Design req.:** The seat should support a normal spine posture by supporting the pelvis and lower trunk (avoid kyphosis and lordosis)*

4.2 DECUBITUS

[pressure sores, decubitus, pressure injury, decubitus wheelchair, decubitus SCI]

Everyone with a SCI who is wheelchair dependent, has an increased risk of getting decubitus on the seating area (Ash, 2002) (Byrne & Salzberg, 1996). Decubitus is an open skin wound formed by prolonged pressure from the body's weight against a surface. But it is also a consequence of friction (especially when the body is moist) and shear. This mostly occurs on skin that covers bony areas, such as the tailbone and buttocks. Decubitus is also known as pressure ulcer or pressure sore (WoundSource, 2016)(Mayo Clinic, 2020)(Edsberg et al., 2016)(Mendes et al., 2018). Research performed by Valent et al. (2019) in The Netherlands, concluded that out of the people who have a SCI for over 10 years, 22% (of the 265 people) could not sit the past year for an average of 55 days because of decubitus and its treatment. As mentioned before, higher pressure is related to a higher prevalence of decubitus. However, there is no set threshold for pressure due to individual variations in factors, such as mobility and body composition (Reenalda et al., 2009). As pressure is dependent on a unit area, the more the body is supported by the seat, the better for decreasing the chance of pressure injuries as it will be better distributed. In regard to decubitus, comfort means comfortable pressure and safety, but also the possibility to still perform an activity (Richtlijnendatabase, 2018). The foam that is currently used in the kite seats is the same for skiing, and is considered as good for the target group concerning the prevention of pressure sores. However there are still athletes adding additional foam or cushioning.

***Design req.:** The design should minimize changes in pressure injuries, by minimising shear and friction; and maximizing pressure distribution*

Next to the unit area, the factor of time is also important. Willem Hooft mentions that most sessions last around 1.5-2 hours. If it would last longer, this would create discomfort related to decubitus. Research by Kenedi et al. (1976) shows the maximum suggested pressure over time over bony prominences (see figure A-4.3). Imaging a kite-session of +-2 hours, a maximum value of around 200 mmHg (=2665 Pa =2.67N/cm2) is acceptable. There can be played with different foams as the pressure while sitting is affected by the type of cushioning material at the surface (Gutierrez et al., 2003). However, as mentioned before, the sensitivity of generating decubitus is person dependent. This makes using hard numbers as a guarantee to prevent decubitus, not trustworthy.

A higher comfortability in this project can be achieved by having an optimal fit of the seat to the body, this way minimizing the shear and friction, and maximizing pressure distribution. But also being aware of the time in the seat is important.

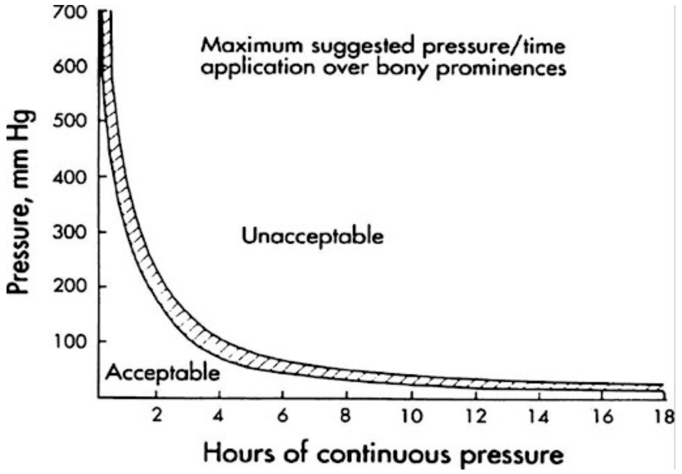


Figure A-4.3: Maximum suggested pressure over time
Source: Kenedi et al., 1976

4.3 PRESSURE ISCHIAL TUBEROSITIES

[ischial tuberosities, sitting pressure, seating bones, pressure distribution wheelchair]

Specifically pressure on the ischial tuberosities (see figure A-4.4) is important to take in mind, as this is a common point of discomfort in other seating products. It should be taken into account that no hard parts, eg. screws, are located where the ischial tuberosities are.

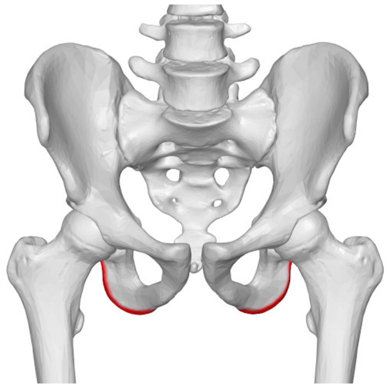


Figure A-4.4: ischial tuberosities marked in red
Source: BodyParts3D

Pinto Da Silva (2011) did research about pressure distribution while seated on a wheelchair. On figure 4-4.5 a visual representation can be found of this pressure distribution. The area with a higher load (green area) is located around the ischial tuberosities. It should be noted that the pressure is measured in an upright position. Research shows that forward leaning for SCI patients are accompanied with pressure relief on the ischial tuberosities (Henderson et al., 1994). As the standard posture while kitesurfing is 80 degrees, it can be assumed that pressure will be more widely distributed while kitesurfing compared to figure A-4.5.

Research by Park and Jang (2011) showed that there is no significant difference between patients with and without a SCI on the pressures of the ischial tuberosities area. This means research about pressure distribution of the buttocks does not have to be specific for people with SCI.

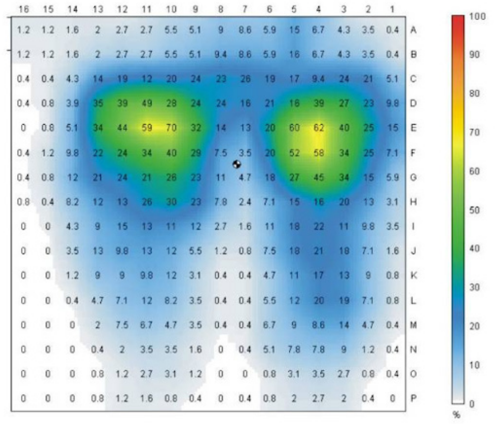


Figure A-4.5: Pressure distribution standard foam on wheelchair
Source: Pinto Da Silva, 2011

Ischial tuberosity width is related to the hip circumference for both men and women. In general this width was greater for women than for men, with an average of 13mm (Chen, 2021). The research by Chen also stated that the width is variable according to the seating angle. When the seating angle increased, the ischial tuberosity width increased as well. They measured the difference between 60 and 105 degrees seating angle, which led to a width difference of 11mm. It can be assumed that during kitesurfing the location of the ischial tuberosities will most likely change as well and that the average width will be gender-dependent.

Due to these insights, there has been chosen for a flat bottom surface to prevent misplaced protrusion or gaps, as the ischial tuberosities are never on the same spot for every person or sitting angle. This could lead to an increase in perceived discomfort and chances of decubitus.

***Design req.:** The surface touching the buttocks should be flat*

4.4 PERCEIVED DISCOMFORT

[comfort, discomfort, measuring discomfort]

Oxford dictionary defines discomfort as "a feeling of slight pain or being physically uncomfortable" (Oxford Learners' Dictionaries, n.d.). While Ashkenazy & Dekeyser (2019), define discomfort as "Something that can be physical or psychological and is characterised by an unpleasant feeling. Pain can be a cause for discomfort, but not every discomfort can be attributed to pain". It can be stated that comfort and discomfort do not have a fixed definition, and it depends on the literature or context. Therefore it is important to clarify this term, as clear as possible to the interviewee. Also, the Delft Design Guide (Zijlstra & Daalhuizen, 2020) states that there are many definitions for comfort, but that there are some that are generally accepted:

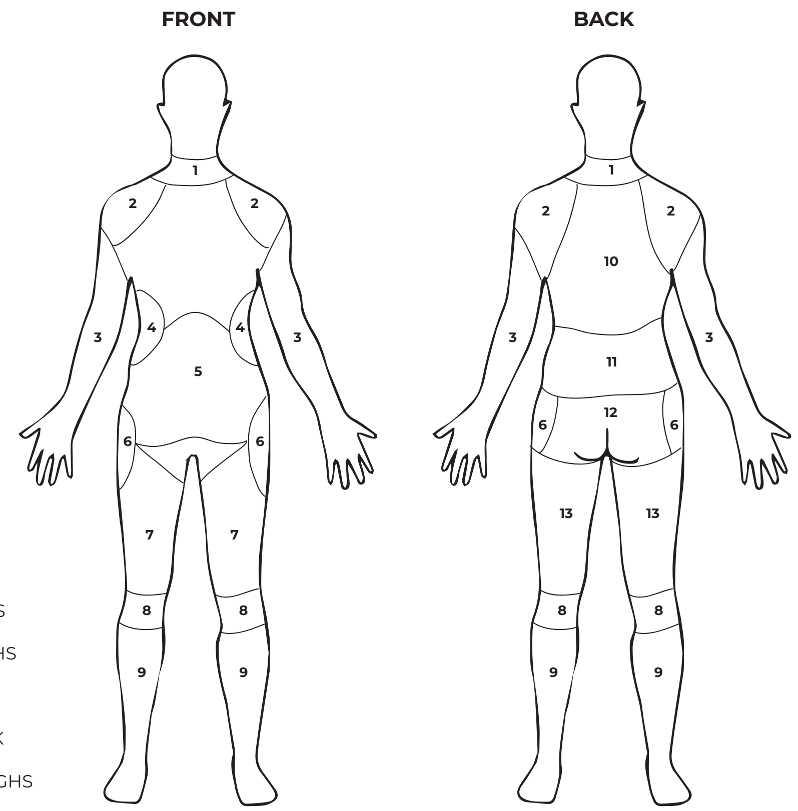
- Comfort is a construct of subjectively defined personal nature
- Affected by physical, physiologic and psychological factors
- Reaction of a person interacting in the environment

People often and naturally differentiate levels of subjective responses across a continuum from strongly positive to strongly negative (Richards, 1980). However, further research by de Looze et al. (2003) revealed that comfort and discomfort are based on independent factors. For example discomfort is more related to physical factors such as pain and soreness, while comfort is closer to a feeling of relaxation and well-being. It might be useful to take comfort and discomfort apart, since there are different underlying factors (Zhang et al., 1996). Because of this, discomfort will be seen as something not correlated to comfort in the survey (see chapter 4.4 Perceived Discomfort). Answers about discomfort should be given on a numeric rating scale as an analogue one can have difficulties while interpreting (Oborne and Clark, 1975).

4.4.1 Survey

As there is a limited number of sit-kitesurfers in the Netherlands and the others are scattered around the world, it is not possible to conduct user tests with the target group. Furthermore, would a user test be dependent on wind, weather and location. Because of this, a survey has been set up for sit-kitesurfers, to analyse the perceived (dis)comfort during the current situation while kitesurfing. They are asked to analyse their use of the kite seat during a session. As some sit-kitesurfers do not practise the sport often (eg. live far from a lake or ocean), they should also be given the option to fill in the questionnaire without riding. Here it is important they keep past sessions in mind while answering the questions. This is because of limited time in this project.
The survey can be found in Appendix XII. It has been set up while keeping the Localised Postural Discomfort (LPD) method in mind. Participants are asked to rank their sense of discomfort from 1-7, during the first 5' in the seat, during kitesurfing and within 30' after the session. In addition to this, they are asked to indicate where they perceive discomfort (see figure A-4.6). The goal is to find out where discomfort is perceived with the current existing kite seats. This way, there can be anticipated on the findings with the new concept.

Results
All results can be found in Appendix XII.



1. NECK
2. SHOULDERS
3. ARMS
4. RIBS
5. ABDOMINALS
6. HIPS
7. UPPER THIGHS
8. KNEES
9. LEGS
10. UPPER BACK
11. LOWER BACK
12. BUTTOCKS
13. BOTTOM THIGHS

Figure A-4.6: image used for allocation discomfort

Main findings

Questions were filled in by seven sit-kiters of which six had a SCI from L1, L2, TH12 to TH10. Five out of seven are using a backrest, of which four the standard hard one (three low version - one high version) and the other a harness. Two out of seven are using the Tessier seat.

Four indicate that the seat fits almost perfectly, while for the three others (all three using a self-manufactured seat) it does not fit their desires.

Perceived discomfort depends on the location and level of the person. But the most perceived discomfort is during kitesurfing, of which four out of seven participants locate the discomfort on the ribs. Before and after kitesurfing, the discomfort is not directly related to the seat but rather to the intensity of the performance (eg. arms and shoulders).

Four out of seven mentioned differences in discomfort depending on the weather, especially higher discomfort in higher wind speeds and choppy water.

One participant also mentions that he feels big differences according to which wetsuit he is wearing. When wearing a 4mm neoprene (autumn/spring/winter) it fits perfectly, while a 2mm (summer) is too loose and a 5mm (cold winter) is too tight.

One person mentions that a good grip between the neoprene and the cushioning is important for improving comfort.

No person had experienced pressure sores due to kitesurfing, and only one felt like their seat was lacking postural support.

There are no clear differences between beginners and experienced sit-kitesurfers. Three out of seven are beginners, and mention (as only ones) that they feel no differences in discomfort depending on weather situation or clothing, while all others participants do. This could be due to the lack of experience in those different situations.

Design insight: *The design should prevent sliding of the seat, either by creating grip or by an optimal fit*

Design req.: *Backrest should be removable.*

4.5 CONCLUSIONS

Multiple insights are gathered during the (dis-) comfort research. An important one is that the seat should support a normal spine posture, which can be achieved by supporting the pelvis and lower trunk in an upright position. This means the support should come from the seat and not the backrest. User research showed that the backrest's main function is to translate the forces of the upper body towards to board and not to give support. The reason is that the athlete has an active posture where the back seldom touches the backrest, as there is a constant change of sitting angle. Furthermore it shows that a backrest is not necessary for all athletes, as it depends on the available trunk muscle. It can be concluded that the use of a backrest is dependable on the level of disability and/or personal desires. The backrest should therefore have the option to be removable.

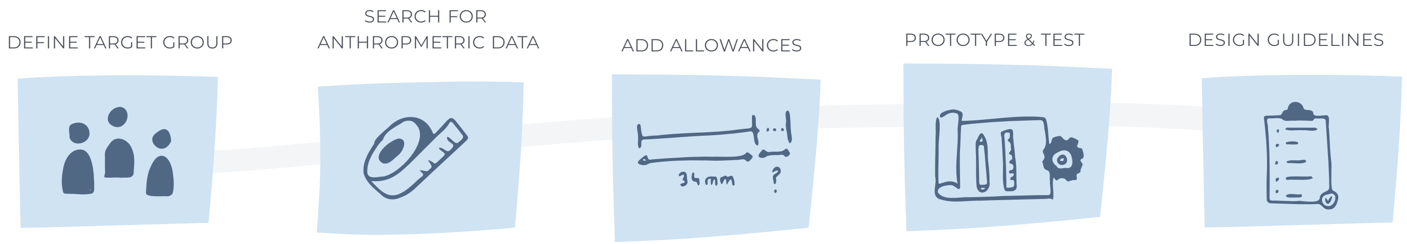
Secondly, decubitus should be minimised for comfort and safety reasons. This can be achieved by looking for an optimal pressure distribution that minimises shear and friction. The current setup is not problematic for most users, but can be improved by having an optimal fit for the user. Furthermore, the need to avoid decubitus depends on the person and could be adapted by the person itself which has an influence on the innersize of the seat.

Interviewees mentioned the influence of the type of wetsuit that is being worn on the comfort and performance. A summer neoprene (3mm) shows noticeable difference to a winter wetsuit (5mm) in terms of the fit of the seat. This shows that a continuous sizing system is important so no one has a tolerance of 2mm or larger.

5 ANTHROPOMETRIC DATA

As concluded in chapter 4.(Dis)comfort and interviews, a tight fit is necessary for performing the sport in a safe and comfortable way. As the seat will be used in surfschools by a range of different people, gathering and understanding the corresponding anthropometric data of the target group is important. In this chapter, data will be collected through desktop and literature research and analysed by performing 3D-scans and manual measurements of the target group (+- 10 participants).

5.1 INTRODUCTION



During the project, the approach Anthropometric Design from the Delft Design Guide will be used. This will guide the design towards an optimal fit of the seat to the target group. It will help in decision making on adjustability, size and shape (Delft Design Guide, 2020). The target group is already described in Chapter 1.3 Target Group, but a summary is given below.

Summary target group (important for data collection)

- Adults (18-60)
- Mixed: men + women
- International
- Physical disability in the lower body
- In case of SCI: L5-L1 and T12 - T4 (max.)

It has to be noted that the dimensions include the foam, which can be easily compressed up to 10mm and has the potential to cover more (larger) people.

Seat size	Seat width	Backrest width
1	330 mm	290/340 mm
2	350 mm	310/370 mm
3	370 mm	320/340 mm
4	390 mm	330/340 mm
5	410 mm	340/350 mm
6	450 mm	390 mm

Table A-5.1: Existing dimension seat width and backrest width

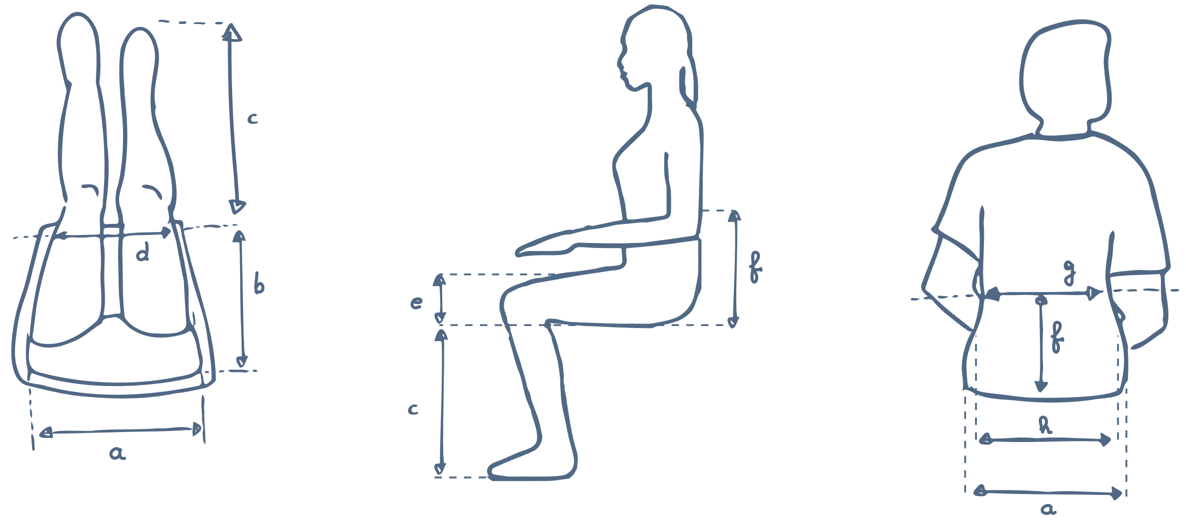
Height backrest	Seat depth
350/420 mm	420mm

Table A-5.2: Existing dimensions backrest and seat depth

Importance and dimensions needed

Multiple dimensions are needed for a tight fit of the body to the seat, as well as performance (eg. riding upwind) and support (depending on level SCI). Next to that, it is known that pressure injuries (see chapter 40 (Dis)comfort) are common complications for people with SCI (Trewartha & Stiller, 2011).

Dimensions should not be measured in the standard position. It is important to measure in the right sitting position similar to sit-kiting. Together with UPPS fieldlab measurements are performed. Although hip-width can be found, results will be compared to check if there are any differences between people with SCI and accessible data. In table A-5.3 the important dimensions are noted down. Further in the chapter, explanation and further research about them can be found.



	What	Where to get
a	Hip width (seat width)	DINED + Manual + 3D measurements
b	Buttock popliteal depth (seat depth)	DINED + Manual
c	Popliteal height	DINED + Manual
d	Thigh width	Manual + 3D measurements
e	Thigh height/clearance	Manual + 3D measurements
f	Backrest height	Research + existing backrest
g	Back waists (at backrest height)	Manual + 3D measurements
h	Pelvis width	Manual + 3D measurements

Table A-5.3: Needed measurements

5.2 DESKTOP AND LITERATURE RESEARCH

5.2.1 Seating position

The way someone is positioned can have an influence on a measured dimension of a body part. Choi and Ashdown (2010) performed scan measurements in active postures compared to a standing scan. They concluded that a sitting posture showed the most changes compared to other active postures. Under which the leg length and hip width showed most differences compared to a standing posture.

In figure A-5.1, a representation of the seating position while kitesurfing can be found. It has to be noted that the current seat design allows the user to adjust the sitting angle by changing the position of the backrest. This position is thus not fixed, but only more experienced riders will change this angle during riding. When riding upwind, the person will lean more forward. While going downwind or riding a wave, the athlete will lean more to the back. However, the most common and average angle is 80°. More information about this has already been described in Chapter 4.1 Seating position and support.

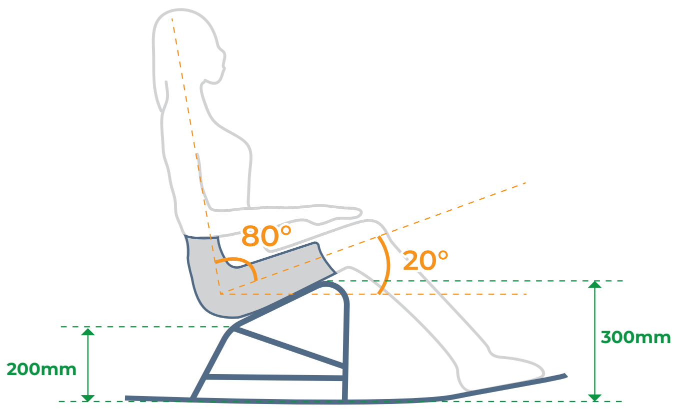


Figure A-5.1: Seat is positioned at an angle of 20 degrees, thighs should touch the seat surface.

There are some sit-kiters who are seated on their knees (kneeing) while kitesurfing. Research by Lajunen et al. (2020) found that kneeing (seated on knees) was found to deliver better performances in terms of oxygen consumption than knee-high (pelvis lower than knees) while skiing. However for people with low SCI this means no support around the hips and lower back, which is not possible. A part of the current sitting angle is determined by the frame. In, for example, wakeboarding the seating angle is adaptable depending on the skill and desires of the rider. For kitesurfers this angle is fixed at 20° and is not adaptable. It should be taken into account that with a fixed seat depth and location of the footrest, the actual sitting position could change (see figure A-5.2).

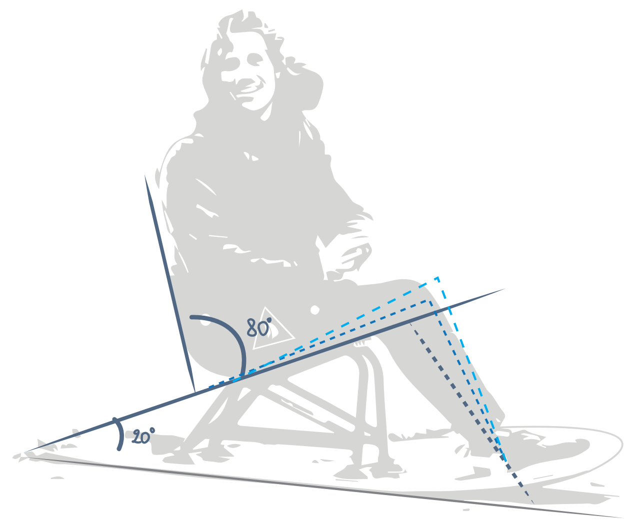


Figure A-5.2: change in seating position according the BPD and popliteal length

Design req.: *The thighs should always have contact with the seat for optimal pressure distribution and avoidance of decubitus, in such a way that a sitting angle of 20° can be respected.*

5.2a Hip width / Seat width

The current seats, based on the seat depth and width, covers 95% of the Dutch adults (Dined, 2004), as can be seen on figure A-5.3. After contacting Tessier, producer of the seats, the most sold sizes in sit-wake are size 2,3 and 4. They also mention that this demand depends on the sport and that it will be different for sit-ski. As mentioned before, it is known from AltoGarda Kiteschool that only sizes 1-4 are being used, with 1 and 2 the most frequent. According to Dined, if only sizes 1-4 are used, this covers 39% of the population (+- P40 hip width). However, when looking at the Dutch student dataset (Dined, 2016), sizes 1-4 cover 70%. This is a large difference and sounds more logical. According to Johan Molenbroek, who lead this research in 2004 and 2016, the reason for these differences could be that there is still a growing obese population.

There will be differences with the international database (target group), but the Dined ellipse tool is not possible with that data. For the hip width, the available data might not be useful for this project and additional dimensions of the target group will need to be measured. Also, one of the reasons that only the lower end of the curve is reached, could be due to a sportive and fit user group.

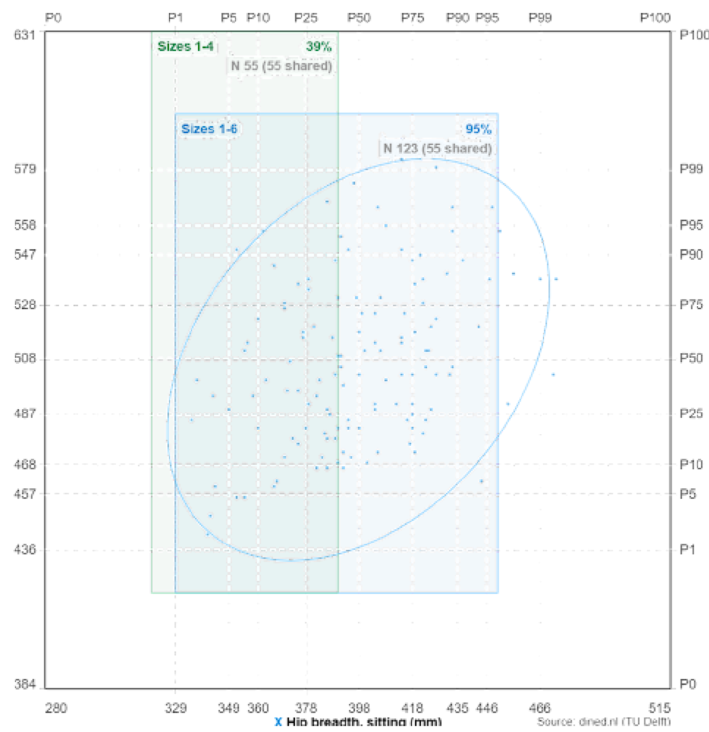


Figure A-5.3: Correlation Dutch population (age 20-50) hip breadth and BPD - 2004

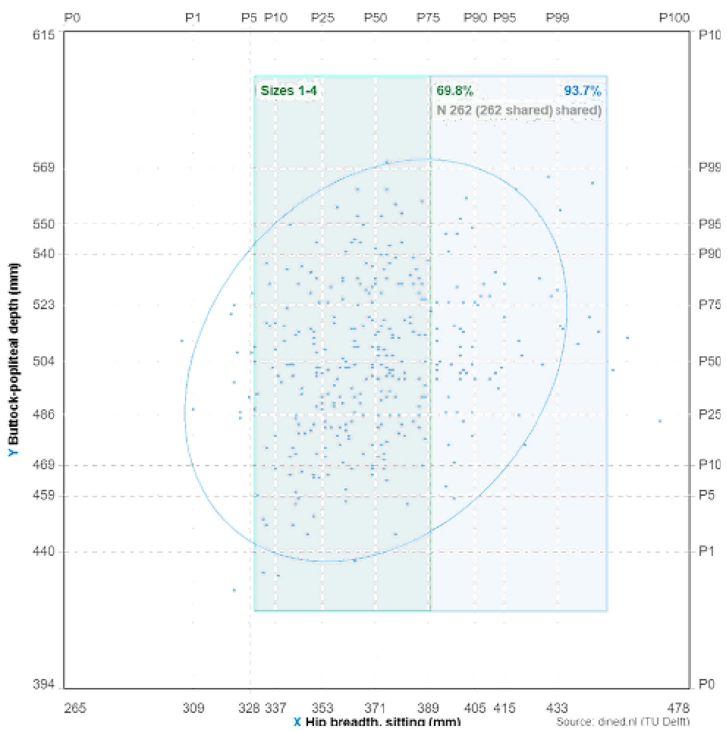


Figure A-5.4: Correlation Dutch students (age 17-27) hip breadth and BPD - 2016

Existing ski seats and the sizes offered have been analysed. In most cases, the only given dimension is the seat width (see table A-5.4). This has been done to analyse the comparison of the data found on Dined and used in real life. It has to be kept in mind that in a ski seat allowances of the clothing will be added (thick winter clothing).

Out of an interview with an experienced sit-kitesurfschool, it can be concluded that only sizes 1 to 4 (brand Tessier) are being used and are covering all of their students. This means a range in seat width from 330 to 390mm. Looking at the international database of Dined, this corresponds with the hip width of P35-P78. In the Dutch student dataset this corresponds with P5-P75 (Dined, 2004). But as mentioned before, Dined might not be valuable for this target group. In table A-5.6 an overview of measured hip breadths, according to the NEN-ISO 7250 standards can be found together with the data found on Dined.

	Seat width range (smallest - largest size)
Praschberger Monoski	Size 1 - 34 cm Size 2 - 36 cm Size 3 - 38 cm Size 4 - 40 cm Size 5 - 42 cm Size 6 - 44 cm
Aspen Seating System	S - 33 cm M- 38 cm L - 43 cm
DS lock seat	S - 34 cm M- 39 cm L - 44 cm
Tessier dualski seat	Size 1 - 33 cm Size 2 - 35 cm Size 3 - 37 cm Size 4 - 39 cm Size 5 - 41 cm Size 6 - 45 cm
Tessier Nordic Seat	S - 33 to 37 cm L - 38 to 41 cm
Mogul Master Sitski	S - 33 cm M - 36 cm L - 38 cm
Dynamique Bi Ski	S - 33 cm M - 38 cm L - 43 cm
Range	**Smallest: 33 cm** **Largest: 45 cm**

Table A-5.4: ski seat range seat width

Seat size	Seat width
Ski seat range	330-450 mm
Current seats: sized 1-6	330-450 mm
Current used seats: sized 1-4	330-390 mm

Table A-5.5: comparison ski seats

Hip breadth datasets	P1	P5	P95	P99
NEN-ISO 7250 measurements Italy	288	308	410	450
NEN-ISO 7250 measurements China	303	316	395	417
NEN-ISO 7250 measurements Kenia	n.a.	308	453	472
Dined 2016 Dutch students	309	328	416	435
Dined 2016 Internationals	229	264	436	471

Table A-5.6: comparison database hip breadth

Important to notice, is that the athlete wants to be clamped in the seat. For example, figure A-5.5, shows where Willem Hooft cutted the foam and a part of the carbon so other body parts would be more tight and not only around the hips. He is actually a size 3 (37cm), but uses a size 1 (33cm). Measurements will be done without pressing into the flesh of the hips, but the actual needed seat width will need to be smaller than this to be sure the athlete is clamped. For this reason, two measurements will be taken. One according to the NEN-ISO guidelines (no pressing into flesh) and another pressing into the flesh.

Figure A-5.5: Kite seat Willem Hooft with cut-out foam + carbon for tighter fit

***Key insight:** The current seat width starts at 330mm, but should correspond to P5 of the internationals, which is +- 315mm. The ultimate needed width is known and is 390mm but has to be checked with manual measurements of the target group.*

5.2B Seat depth

Research by Bahrampour et al. (2019) stated that the appropriate seat depth for desk chairs can be recommended on P5 buttock-popliteal depth (BPD) of a population, this caused the least discomfort in his target population, university students. However, they mention that the optimal seat depth design varies greatly between different standards and countries. In this research 402 mm was an optimal, while the P5 for Dutch adults is fixed on 457 mm (DINED, 2004). In another research about wheelchairs, it is concluded that seat depth should be 2-5cm less than the P5 value of the BPD of the disabled group (Goswami et al., 1986), which would be 407-437 mm for the Dutch adults (no data available international dataset). However, no research has been found on ski or kite seats, so no direct conclusions can be drawn. It has to be taken into account that the seating position for sit-kitesurf will differ. The current seat depth of the Tessier seats is 420mm, which lies within this range. Willem Hooft also stated that a short seat depth is not an issue, but rather a seat depth that is too large as this will increase the chance of pressure injuries (against the calves).
Important to note, is that there is not much room for reducing the seat depth as the seat should still fit on the frame. Currently, there is only 35mm space between the end of the seat and the first bolts (see image A-5.6).

Figure A-5.6: distance between bolts and end of seat (35mm, measured from center of hole)

BPD	
Dined range Dutch mixed adults 2-60 P1-P99	438-572 mm
Dined range Dutch students 2016 P1-P99	440-566 mm
Seat depth	
Current seat depth (Tessier)	420 mm

Table A-5.7: comparison DINED, literature and current seat

Design req.: *Seat depth can stay the same, 420mm, but can be maximum 438mm to make sure no one is touching the end of seat with their knee pit.*

5.2C Popliteal height

Together with the BPD, the popliteal height has an influence on the contact made between the thighs and the seat. If legs are longer (BPD and popliteal height), thighs can get lifted which means there is less contact with the seat. As mentioned before, it is important to have a good pressure distribution to avoid pressure points and improve performance.

Currently, if legs are too long, it could happen that the thighs are lifted off from the seat, due to the fixed position of the footrest/seat depth (see figure A-5.7). In all situations, the upper legs should be parallel to the seat surface for optimal performance and pressure distribution (see figure A-5.8). In order to keep this angle the same, and thus keep the thighs connected to the seat, calculations are done (see Appendix VIII). A comparison is made between dimensions of P1 and P99 (Internationals: popliteal height). If the same sitting angles are used, the difference in distance of the feet will be 181mm (distance dark blue and light blue line in figure A-5.8).

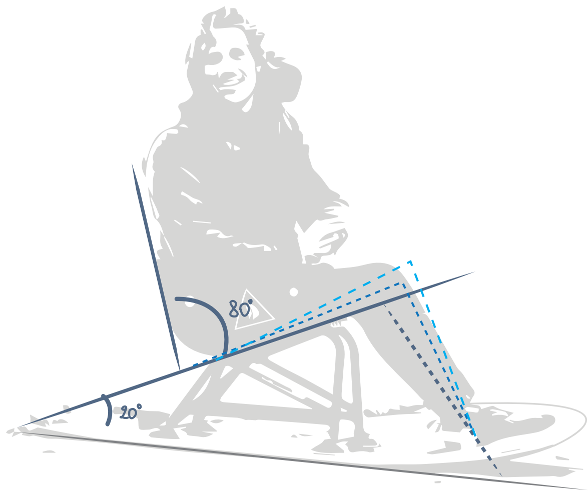


Figure A-5.7: Current situation - if legs too large, bottom thighs lifting off the seat

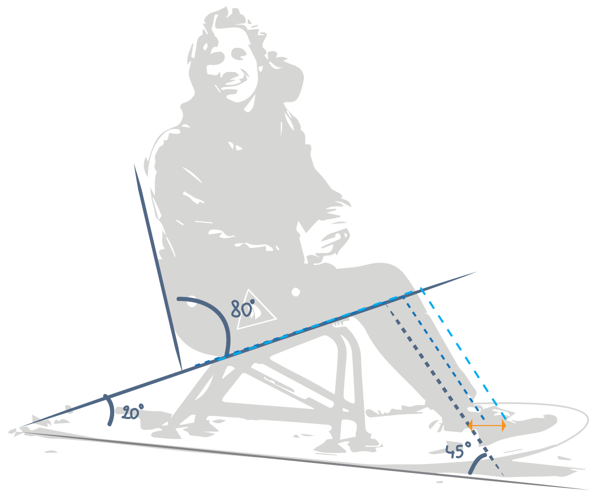


Figure A-5.8: Desirable situation - changing footrest position or seat depth to keep the thighs

Popliteal height	
Dined International P1-P99	285-541 mm
Dined Dutch students 2016 P1-P99	392-554 mm

Table A-5.8: popliteal height

Design req.: *Either seat depth or location of footrest should be adaptable (+-18cm), in order to have a close contact of the bottom-thighs with the seat.*

5.2D Thigh width

In the current seats, the thigh width varies according to the seat. For example, seat size 1 has a thigh width of 250mm, while size 3 is 275mm wide (own measurements - no data available). According to Willem Hooft, the seat with the right seat width has a thigh width (at seat depth 420mm) that is too wide for him. As a large part of the target group are people with SCI, it has to be taken into account that there is muscle loss in the legs. Six weeks after the SCI, there may be up to 45% reduction of thigh muscle in the cross-sectional area (Invernizzi et al., 2021). This leads to differences between the measured population on Dined, but will be important to include in the range of adaptability of the seat. Again for good performance and pressure distribution.
However, in this case, too tight is not good as this will make sure the knees are pressed against each other. As these are bony areas, the change on decubitus will be increased.

On figure A-5.9 a topview of a 3D-scanned subject placed in a kiteseat can be seen. Remarkable is the overall good fit around the hips, but the empty space at the end of the seat between the thighs and the side of the seat. Also the widest part of the seat does not correspond with the widest part of the person.

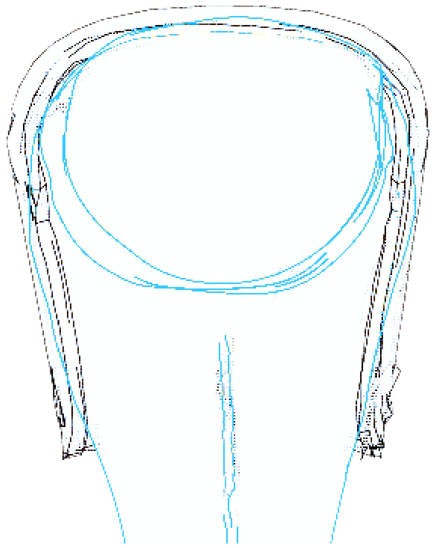


Figure A-5.9: topview of outlines 3D-scanned subject (blue) placed into current kiteseat (black)

5.2E Thigh clearance

As can be seen on figure A-5.10, the sides around the upper legs are not straight but are bent to support the thighs. This is again important for a tight fit. As the thigh width, it is expected to have a large difference between people with SCI and the datasets of the non-injured population now available. Furthermore, this data is measured at a vertical distance from the seat to the highest point on the superior surface of the thigh at the abdominal-thigh junction. In this project, it is valuable to know the thigh clearance at seat depth 420mm.

This should therefore be measured during the tests together with UPPS Fieldlab.

Thigh clearance (mm)	P1	P99
Dined Dutch Students 2016	111	177
Dined Dutch adults 20-30 2004	118	188
Dined Internationals	n.a.	

Table A-5.9: thigh clearance data

Figure A-5.10: front view of seat showing the curved edges around upper legs

5.2F Height of backrest

The current backrests are available in two sizes 350 to 420mm (according to the size guide of Tessier). Currently, the high backrest is seldom used by experienced users. But when talking to the Italian kiteschool, experienced in sit-kite, they mention both heights of backrests are used. This depends on the level of SCI but also the height of the rider. When a student becomes more experienced, he/she might feel less need for a higher backrest.

***Key insight:** The backrest should be adaptable in height, and at least fixable at 350mm and 420mm (current sizes).*

5.2G Backrest width

The current backrests are available in two sizes 350 to 420mm (according to the size guide of Tessier). Currently, the high backrest is seldom used by experienced users. But when talking to the Italian kiteschool, experienced in sit-kite, they mention both heights of backrests are used. This depends on the level of SCI but also the height of the rider. When a student becomes more experienced, he/she might feel less need for a higher backrest.

Backrest width (closed backrest)	
Current available seats: size 1-6	290-390 mm
Current used seats: size 1-4	290-350 mm

Table A-5.10: backrest width Tessier

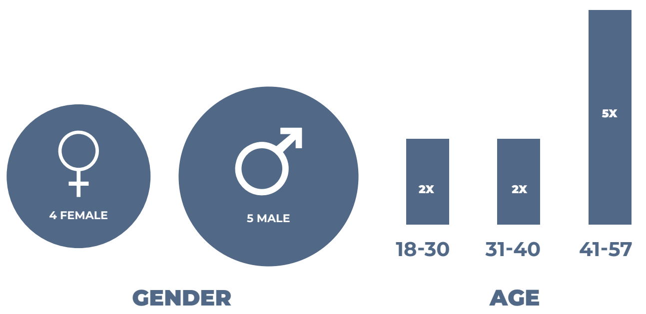
5.3 MEASURING TARGET GROUP AND 3D-SCANNING

There are still some specific measurements that can not be found online or in prior research. Or there are expected differences between the existing data and the one from the target group. These measurements will be done by hand and through 3D-scanning. Together with fieldlab UPPS 3D-scans will be performed of the target group for an ultra-personalised seat, this data will be shared.

Different to previous desktop research, this target group will be focussed on Dutch adults (wheelchair users) only. This is due to the limited access of internationals of this target group. The data of the subject group will be compared to the Dutch dataset, to detect where they are on the curve, and to determine if there are some particular differences.

For both the manual measurements and 3D-scanning, tight clothing is necessary. After performing the pilot, it was clear that dark-coloured clothes create difficulties in the 3D-scans, as there is less contrast. This leaves the scan with holes (parts where the object is not registered by the scanner) around the hip area, which is an important area to register for this project. Therefore, light colours will be necessary.

5.3.1 Overview subjects

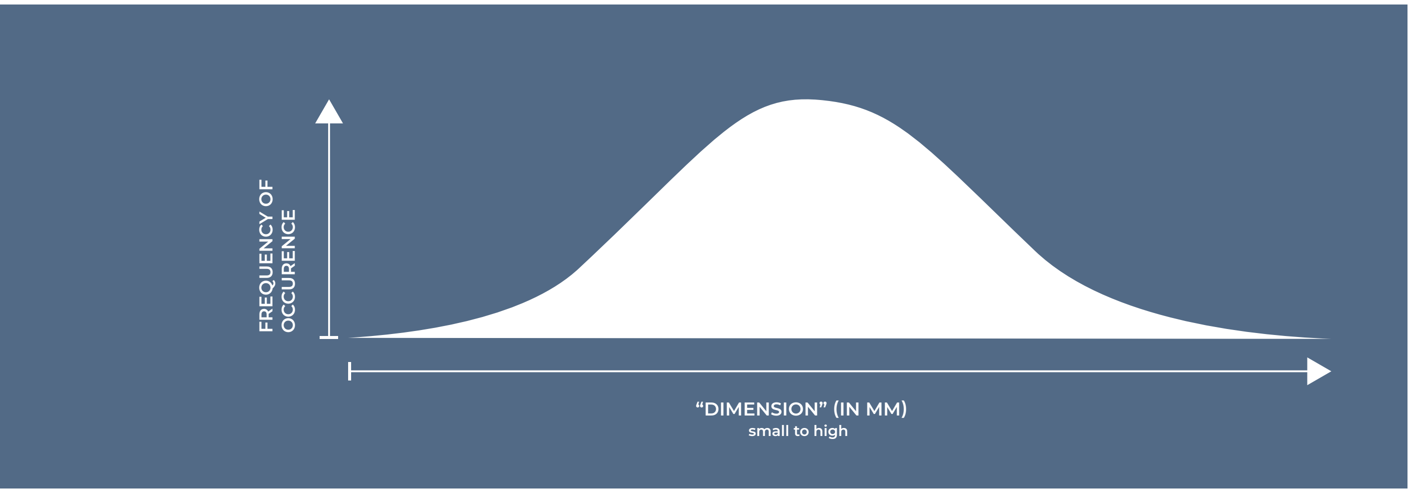


Nine subjects, belonging to the target group, came to the faculty of Industrial Design Engineering at TU Delft. The manual measurements and 3D-scans were performed on all subjects. The group consisted of 4 female and 5 male subjects, aged between 18 and 57, with the following disabilities:

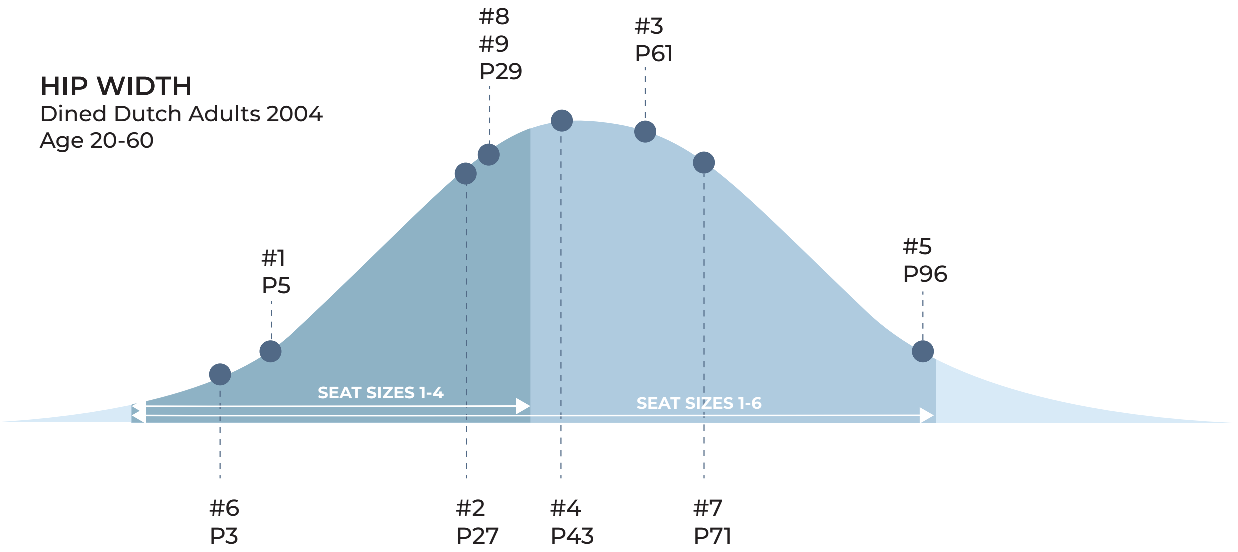
- SCI (4x)
- Decreased communication between brain and legs (2x)
- Disturbed nervous system; decreased leg muscles
- Amputation of legs
- No function below pelvis

On the next page a visual overview of the spread of this measured group can be found based on the hip width, thigh clearance, BPD and popliteal height. This information is gathered from the database DIined Dutch Adults 2004, age 20-60. Looking at the hip width, the subjects show a great spread on the curve, which is favourable for this project. The figures for BPD and popliteal height are included as well, to create a general overview of the spread. It should be taken into account that a Dutch dataset is used which varies to the international datasets. The hip width for the international population will generally be smaller. This is due to the fact that Dutch people are on average larger than other populations. As the design should be suited for an international population, this takeaway should be kept in mind while designing.

All results can be found in Appendix XIII.

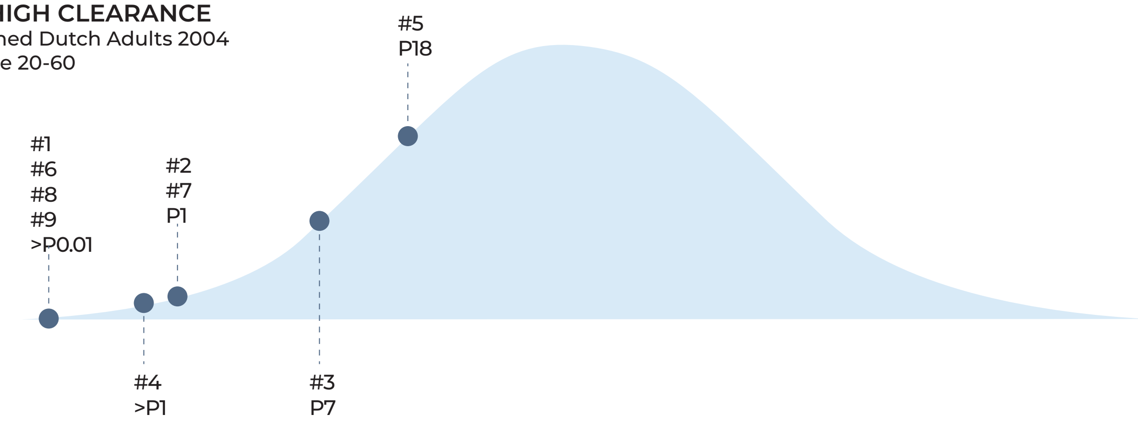


HIP WIDTH
Dined Dutch Adults 2004
Age 20-60



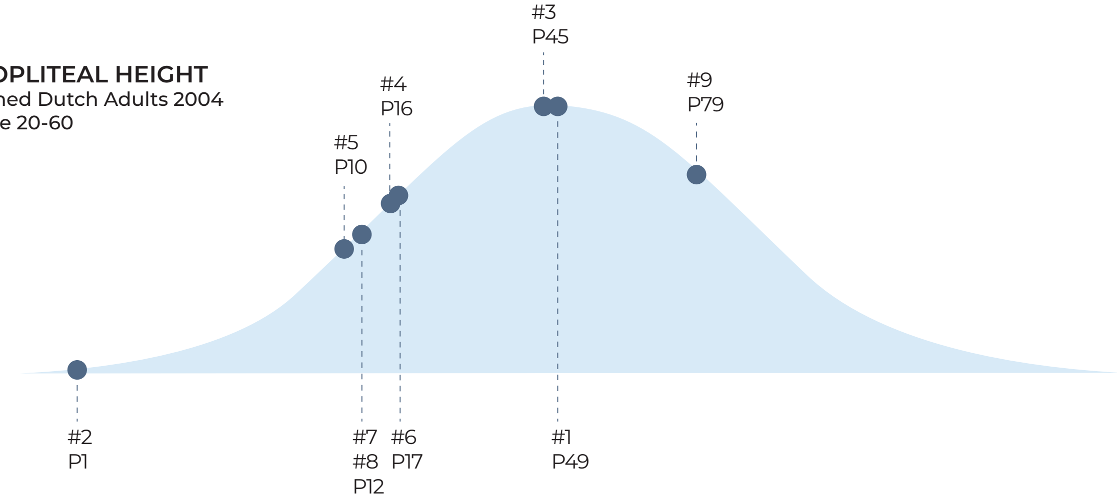
*Remark:
The Tessier seat sizes are also visualised on the graph. Seat sizes 1-4 are the only kite seats used at kiteschools. It should be noted that the seat width will be smaller than hip width.

THIGH CLEARANCE
Dined Dutch Adults 2004
Age 20-60

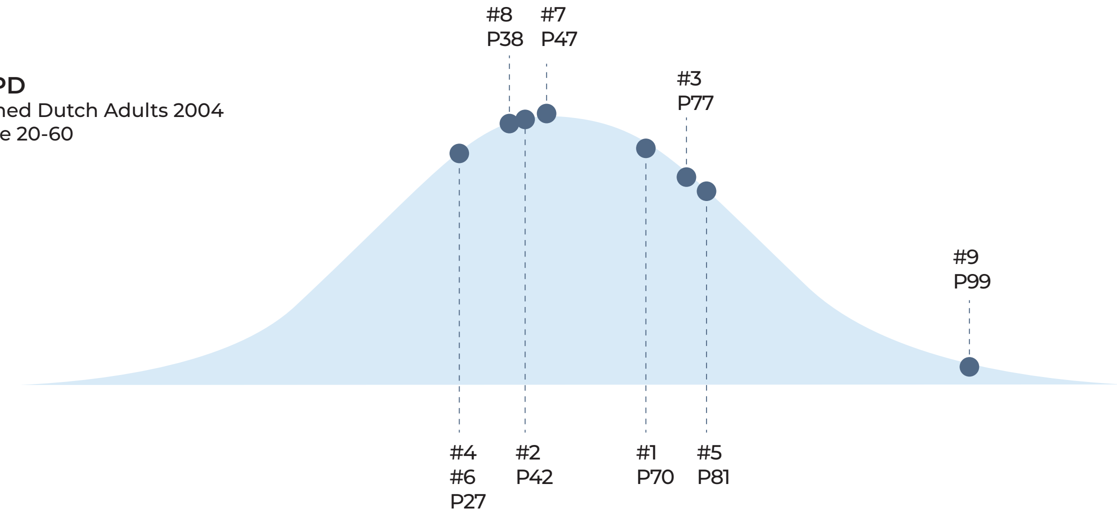


*Remark:
It should be noted that measurements of the thigh clearance of the target group are made at a distance of 420mm from the back. This could influence the reliability of the results. However, it is expected that the target group will be on the lower side of the curve due to leg muscle loss.

POPLITEAL HEIGHT
Dined Dutch Adults 2004
Age 20-60



BPD
Dined Dutch Adults 2004
Age 20-60



5.3.1 Manual measurements

Manual measurements are done in order to compare the measured target group with datasets already available of the population, and analyse where they are on the curve. It is important to have a consequent method of measuring with the right equipment. For this reason, the ISO 7250-1:2017 is used. Each measurement is repeated at least three times. In case there is a large difference, an additional measurement is done. An average of the measurement will be taken. In case of an extreme outlier in the measurements, this will not be included in calculating the average. There are also measurements needed that do not have an instruction according to the NEN-ISO guidelines, or will be done differently due to practical reasons. For these dimensions, the same method of similar dimensions is used. An overview can be found in Appendix XI.

For the manual measurements, the subject is seated on a measuring chair designed by the body lab (see figure A-5.11). Measurements are done using a sliding caliper (see table A-5.11).

Source: qts.tools

Sliding and spreading calipers
For measuring the breadth and depth of body segments, as well as the distances between reference marks.
(ISO, 2017)

Table A-5.11: needed instrument manual measurements

Figure A-5.11: measuring chair

5.3.1 3D-scanning

Research performed by Choi and Ashdown (2010) concluded that 3D scans provide a reliable method for measurements of active body positions, which would be impractical to measure using standard anthropometric methods. Research also shows that 3D scans are valuable for creating a database of different body shapes wearing one size (Ashdown et al., 2004), which could be the adaptable kite seat. These scans will also give insights about the shape from the buttocks until the needed backrest height. Finding out the differences in this shape will be important to see if a universal size for the backrest can be chosen or if it needs to be adaptable as well (and in which way). Furthermore, as the 3D-scans are performed in the first part of the project it can be used to retrieve a particular dimension in case it has not been measured manually. This helps the project to move further as there is limited time. 3D-scans will be performed in the same sitting angle while kitesurfing (see figure A-5.12) and will be verified with a goniometer before scanning.

Measurements are often defined with respect to anthropometric landmarks. These marks are drawn on the body prior to taking the measurements or 3D-scanning (ISO, 2017). This is also part of the 3D-scanning procedure, with stickers used as landmarks on the trochanter and pelvis bones.

A pilot has been performed prior to the tests together with Willem Hooft and Laura Ahsmann from the UPPS fieldlab. This was done to check the method and points of improvement. The procedure and insights of this pilot can be found in Appendix IX.

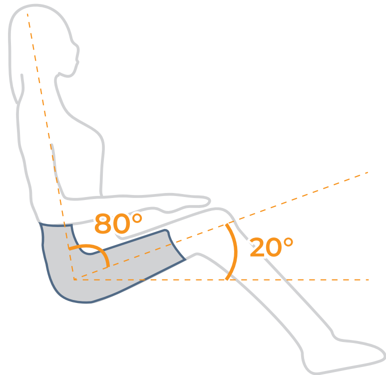


Figure A-5.12: kitesurf position

Set-up
The procedure of the measurements can be found in Appendix X. However, a short overview of the set-up is explained below.

The subject will take place in the vacuumbag, which is placed over a chair in the right sitting angle. Legs are strapped together. A vacuum machine will be connected to the bag, and air will be drawn out of the bag. The researcher will use the Arctec 3D-scanner, connected to the Arctec Studio 3D Software, for registering the scan (see figure A-5.13). This takes around two minutes.

After this, the subject can leave the vacuum bag but the vacuum machine stays on in order to remain its shape. The researcher does another 3D-scan, this time only of the shape of the bag (see figure A-5.14).

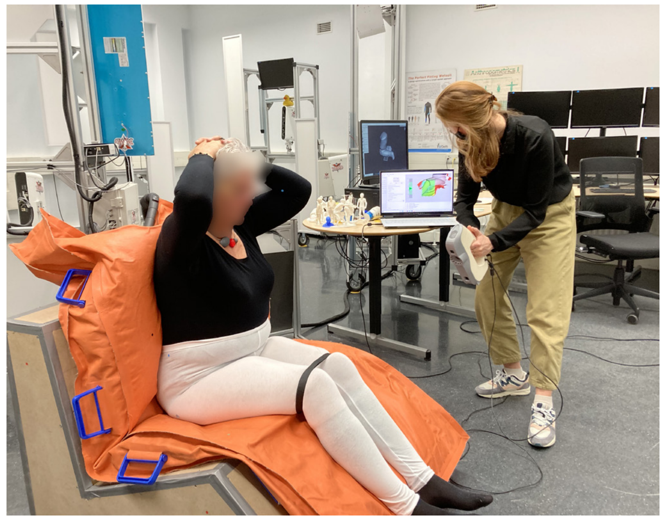


Figure A-5.13: set up scan

Figure A-5.14: second scan

5.3.2 Processing of scans

Software and processing
3D-scans are directly registered on Artec Studio 3D software. For each subject, two scans are done: one from the body while sitting in the beanbag and one of the shape that is left behind (see figure A-5.15).

The two scans are first processed separately from each other before aligning both with each other. Rest material can be removed using the erase function on Artec (see figure A-5.16).

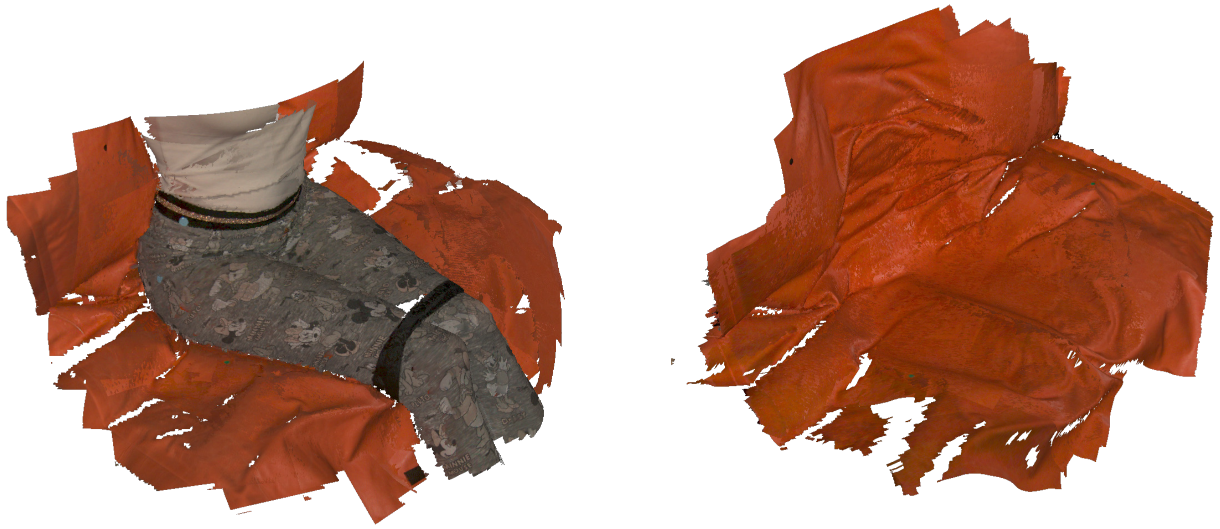


Figure A-5.15: non-processed scans (left:person; right:beanbag)

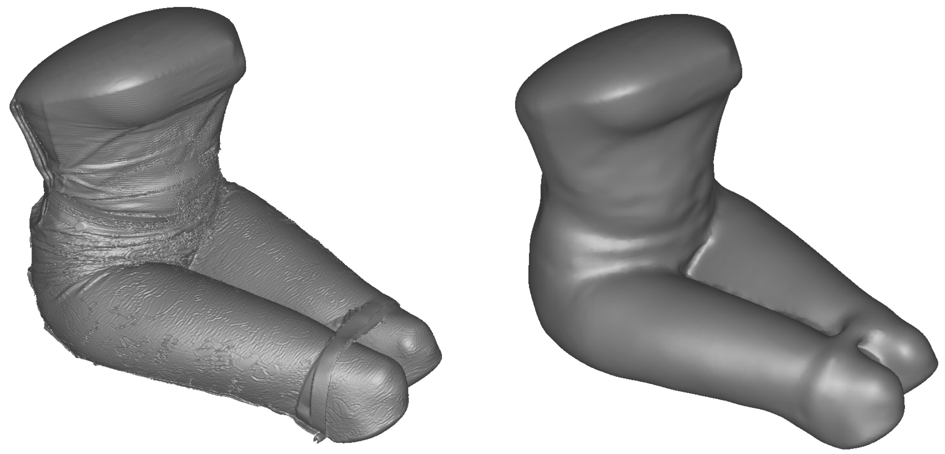


Figure A-5.16: non-processed scans (left:person; right:beanbag)

After global alignment and cleaning the area around the body, further smoothening is done on Autodesk Meshmixer. This step is important to use the shape for embodiment of the seat. The differences of these versions are analysed using a heatmap in Artec Studio (see figure A-5.17). The largest differences measured are the areas with folds, but critical areas such as hip and thigh have differences between 0.1 and 1.5mm. Although this is small, it is suggested to measure the dimensions using the rough scan, but being aware of the location of the folds and imperfections.

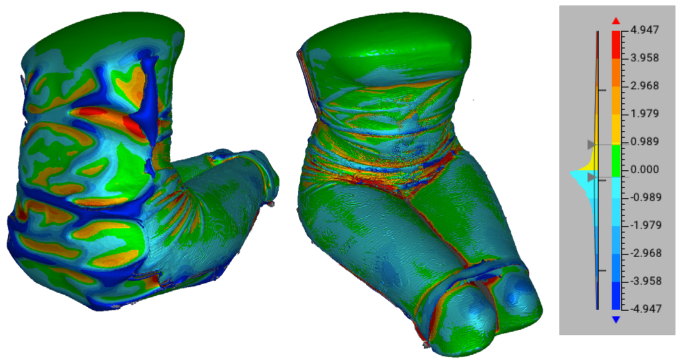


Figure A-5.17: Heatmap showing differences rough and smooth layer (participant 6)

Measurements from the 3D-scans are taken in the software Artec Studio. This is not automated and has to be done manually using the linear measurement tool. This tool can draw lines from one point to another, while measuring the distance of these lines. It also shows the XYZ-coordinates of the chosen points.

5.3.3 Different set-up

Through WHF, there was contact with the company Perteon based in The Netherlands. They produce sit and lie-orthoses for people who need additional support. They have been performing 3D-scans for an optimal ergonomic fit in their products since 2007, and have been working on improvement of the scanning system. They have a different method, which will most likely give differences in results and precision in the scans. Perteon offered to lend out their chair and expertise. For one person, a 3D-scan will be performed of the TU Delft setup and one using the method of Perteon (see figure A-5.18) to check for the biggest differences. The goal is to find out the most reliable method and understand their procedure from scan to product.

Figure A-5.18: Set-up of Perteon

A test subject has been scanned using both set-ups to compare to results. The chair has been used by the company Perteon, which consists of 3 vacuum bags with smaller polystyrene balls covered by a more stretch material than the fieldlab setup. It was expected that the scans would have less folds. On figure A-5.19, both scans can be seen next to each other (red=Perteon; blue=fieldlab). The Perteon (red) scans show more adaptability of the material around the body, compared to the more stiff material of the fieldlab beanbag. This becomes clear by looking at the outline of the buttocks, which is flatter in the fieldlab setup. However, aligning the body and vacuum bag scans were harder for the Perteon setup.

Important takeaways are that a more flexible material in combination with smaller polystyrene balls allow for greater adaptability of the body shape. This can be taken into account for further research, or for the design itself. For example looking for a material that adapts more to the body in order to provide optimised pressure distribution.

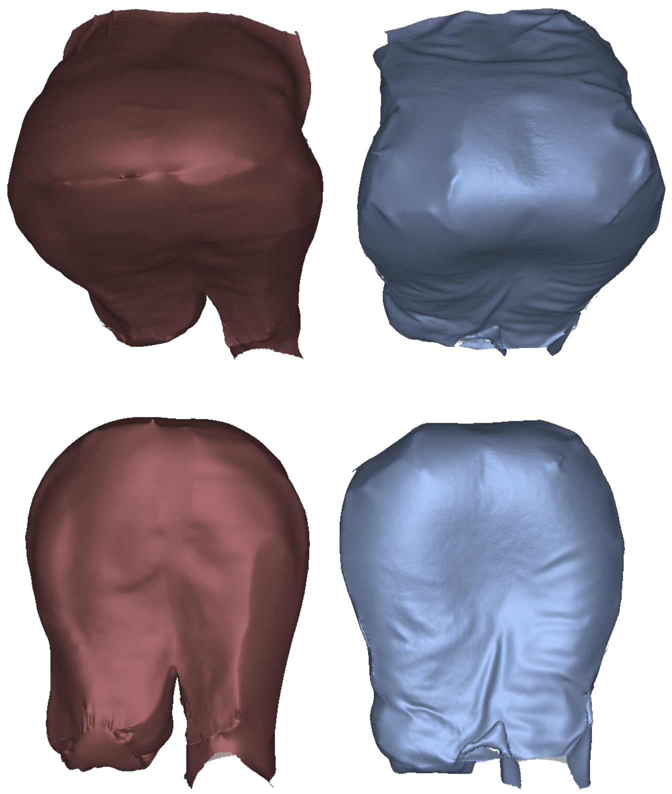


Figure A-5.19: setup Perteon (red) vs fiedlab (blue)

5.3.4 Conclusion

Nine Dutch adults (age 18-57) fitting the target group have been measured and 3D-scanned at the faculty Industrial Design Engineering at TU Delft. They all fitted in the target group, and had different levels of injuries or disabilities. Concerning the hip width, the participants were scattered between P3 and P96 on the DINED Dutch Adults dataset. While on the international database, it covered P47 to P97. It can also be stated that the target group does not have large differences regarding the hip width compared to the datasets available on DINED.

DINED data can not be directly used for deciding on the seat width. This is due to the fact that the actual seat width will be smaller than the measured hip width. This depends on the compressibility of the hip flesh, which is different for every person. But generally larger for wider people.

There is no data available of the thigh width in the standard population. This means no comparison can be made with the target group. However, it is assumed that the thigh width shows a large difference between the target group and standard population. This is because of muscle loss in the legs. Looking at the data of the test subjects, the smallest thigh width can be found with the participants with total muscle loss in the legs. For this reason, data of the thigh width will be used from the scans. A margin will be added to the smallest and widest thigh measured. Comparing the data of the thigh height, the measured subjects are at the lower end of the curve. Participant 1, 6 and 9 are even smaller than P1. All of the three participants had no muscles in the legs (SCI). There can be assumed that this dimension will be in general smaller for the target group.
Also data about the backwidth at the needed heights were not available and is gathered from the 3D-scans. Data can be found in Appendix XIII.

Findings:
The largest differences (>10cm) between subjects were found to be hip and thigh width, as well as popliteal height. Medium differences (7-9cm) were back width and hip width on bone. While the smallest differences (<5cm) were thigh and pelvis height, and BPD. It has been decided to continue with the hip, thigh and back width to be adjustable as they show larger differences between subjects and are of great importance for good performance of the seat (eg. edging).

Some measurements show large differences (>15mm) compared to the 3D-scans, especially hip width and thigh width. Explanations could be:

- These are areas with generally more fat tissue, where an anthropometer can be pressed more into the flesh. It shows that the difference is bigger for people with more fat tissue.
- The posture is not the same on the measuring chair (90°) and beanbag (80°) which could influence the dimensions
- Difference in how close the thighs are in each measurement

3d-scans are a good method as they take these possibilities of differences away. However, a kitesurfer will need to be tight in the seat and the maximum measured hip width will be too large. Two subjects mentioned that their ski seat size corresponds to the measured hip width pressed into flesh, and wheelchair cushion size corresponds to maximum hip width measured. Measuring by hand is also valuable to compare with existing datasets, but is not essential as the largest differences are already known due to this project. Therefore it is recommended to continue with 3D-scanning without manual measurements, as this provides all required information. Only the hip width while pressing into the flesh is not possible with the scan

and the researcher should be aware of this. However, for an ultra personalised seat, manual measurements are required as it is important to find the measurement while pressed into the flesh for a tight fit in the seat. The setup as it is now, works sufficiently but can, if desired, be improved by choosing a more flexible material for the vacuumbag, as well as smaller polystyrene balls.
As the target group also includes amputees, there might be remarkable differences between the width of each thigh. This leads to asymmetry and should be taken into account when designing.

People with less fat around the thighs have a more straight line from trochanter to knee, while people with more fat have a more round outline (see figure A-5.20).

Furthermore, the form of the thighs (width and height) are variable for people with less leg muscles as flesh is pressed outwards. This means that in some cases the body scans were very thin around the thighs. A visual comparison can be found on figure A-5.21 and A-5.22.

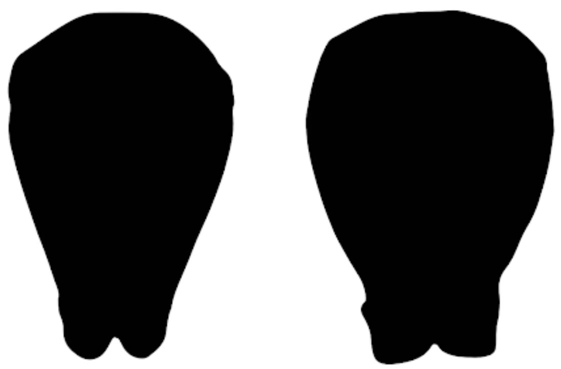


Figure A-5.20: outline bottom thighs - right: more curved

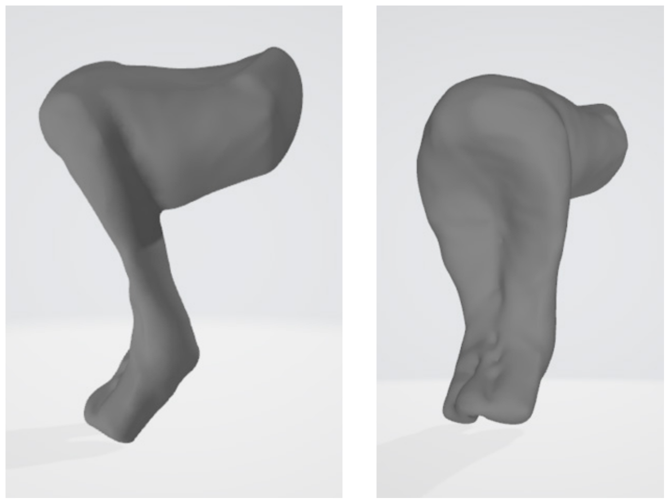


Figure A-5.21: scan of SCI T7

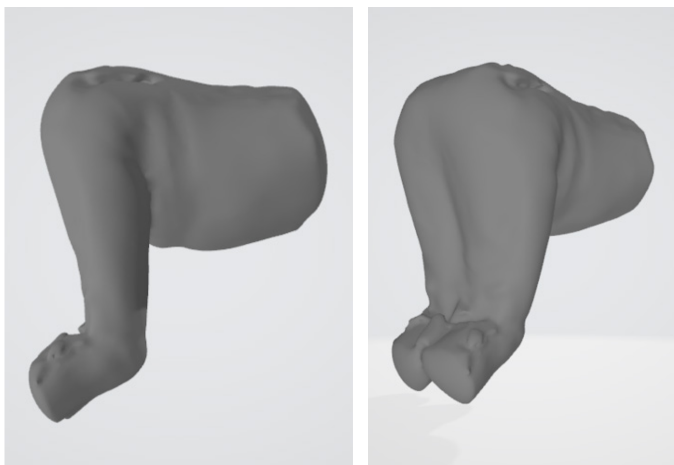


Figure A-5.22: scan of person with leg muscles

Insights setup:
Measuring chair
- Too high for easy transition with wheelchair
- Hard to sit straight for some people
- Handle on chair might help to get in easier

Manual measurements
- Hip width showed the largest differences between manual measurements and 3D-scans: hard to measure it exactly right

3D-scans
- Stickers/markers are critical for good alignment and 3D-measuring of hip and pelvis width
- Make vacuumbag hard before letting the person enter, this makes the transition from wheelchair easier

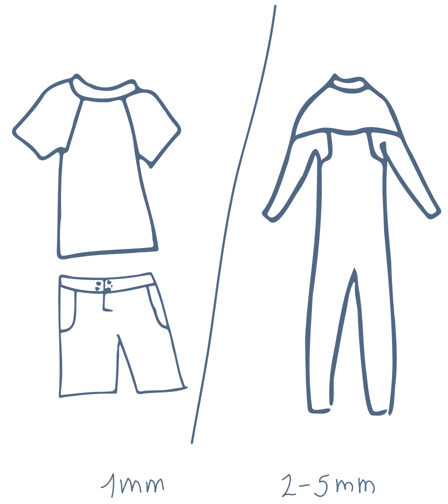
Design req.: *The design should fit people with different widths in each thigh.*

Design req.: *The design should be adaptable in hip and thigh width, back width should adapt with hip width if chosen for a closed backrest.*

Key insight: *The needed hip width for the kite seat is smaller than the actual hip width measured without pressing into the flesh.*

5.4 ALLOWANCES

While sit-kiting it is usual to wear a lycra and shorts (+-1mm) or a wetsuit (ranging from 2mm to 5mm, depending on the season). It is also necessary to wear an impact vest or life vest for safety reasons. However, the last mentioned will most likely be worn over the seat and should not be included in the allowances. This means the allowances can range from 1 to 5mm (see figure below). Willem Hooft also stated that he feels a big difference while wearing a wetsuit or a swimming trunk in how fixed he is in the seat. Also a participant of the survey mentioned this.



5.5 CONCLUDING DIMENSIONS

On figure A-5.23 a visual can be found that shows the ranges of dimensions needed to fit the students of a kiteschool. It should be taken into account that these dimensions are based on existing anthropometric data and missing data is based on the test subjects, which was limited to 9 people (+ 1 pilot). Tolerances are added to the minimum and maximum to accommodate a larger group. Further research, scanning and analysing more subjects of the target group, is recommended for more reliable results.

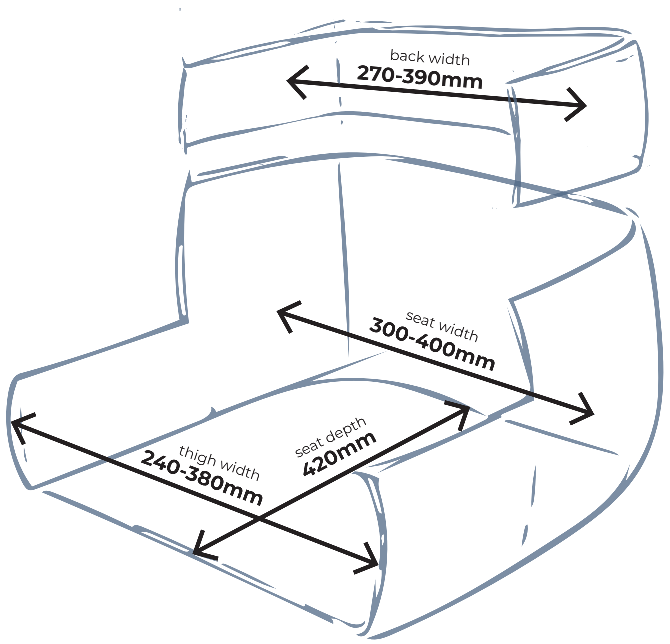


Figure A-5.23: concluding dimensions

Figure A-5.24 shows the range of hip widths of the international population of the Tessier seats (used sizes 1-4) and the new kite seat. Although the new kite seat does not cover the smallest 15%, it has been decided to not go smaller than 30cm as other problems in the setup will arise as well (eg. smaller board needed). This was in consultation with WHF. Note that people with a wider hip width than 40cm will still fit in smaller seats as flesh will be pressed together, which is not measured in the Dined datasets.

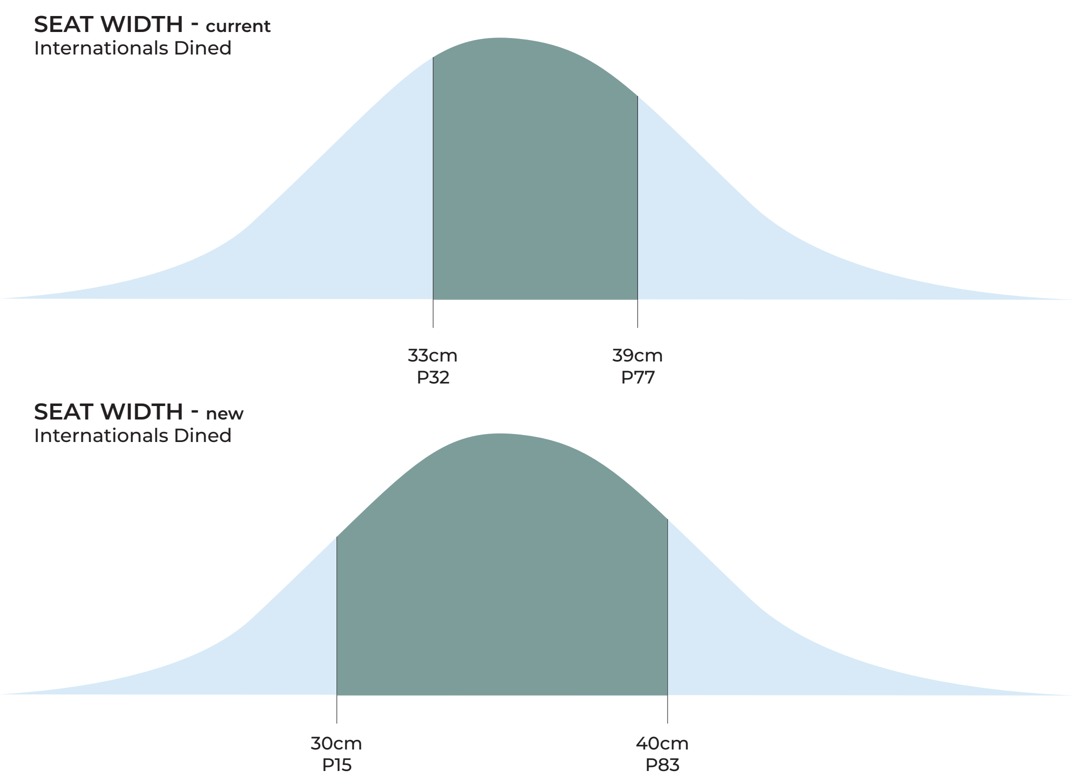
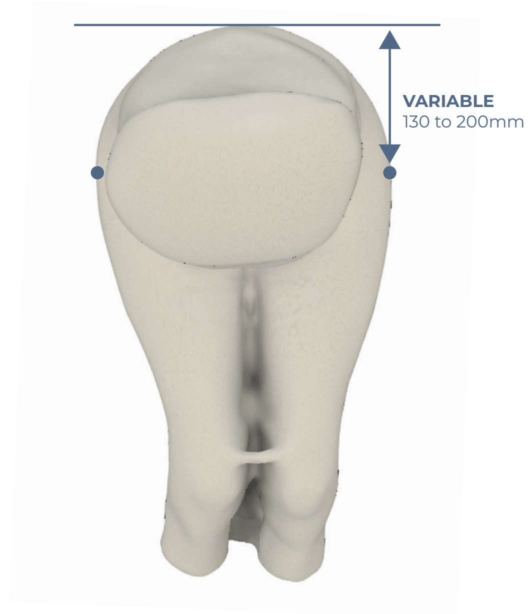


Figure A-5.24: representation range international database

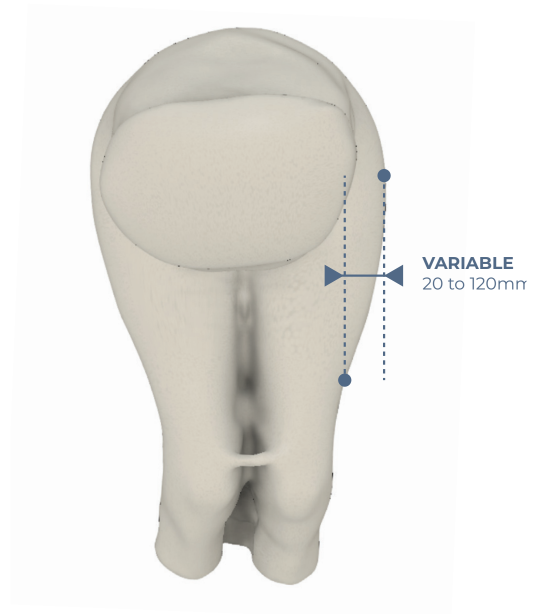
Hip width: 300 - 400 mm
- The seat should sit tight, leading to a smaller seat width than the actual hip breadth.
- All test subjects would fit in a seat width of 390mm (when pressing into the flesh) even participant with hip breadth P97 (DINED Internationals)
- Allowance of thickest wetsuit is 10mm (5mm at each side)
- If going smaller than this, the person's weight will be lower as well and hitting a limit for the used material (other board with less volume needed and/or other frame) and is left out of scope



Seat depth: 420 mm
- No issue with current seat depth
- Not too large for P1 (DINED Internationals)

Thigh width: 240 - 380 mm
- Large differences depending on leg muscles and body fat
- Thigh width is never larger than hip width (20 - 120mm smaller)
- Allowance of thickest wetsuit is 10mm (5mm at each side)
- Thigh width should be adjustable at both sides, to allow asymmetry in the thighs (eg. amputees, muscle loss in only one leg, ...)

Back width: 270 - 390mm
- Backwidth always smaller than hip width (25 - 70mm smaller)
- Allowance of thickest wetsuit is 10mm (5mm at each side)



Key insight
Thigh width also changes with the hip width. It is minimum 20mm smaller and maximum 120mm smaller than the hip width. However there is a minimum dimension of thigh width of 240mm. The new seat design should be adaptable within this range.

Important to notice is that the trochanter is situated at 130 to 200mm distance to the back. Only from that point the width of the seat can get narrower according to the thigh width. This point can be generalised and taken as maximum 200mm (see figure A-5.25).

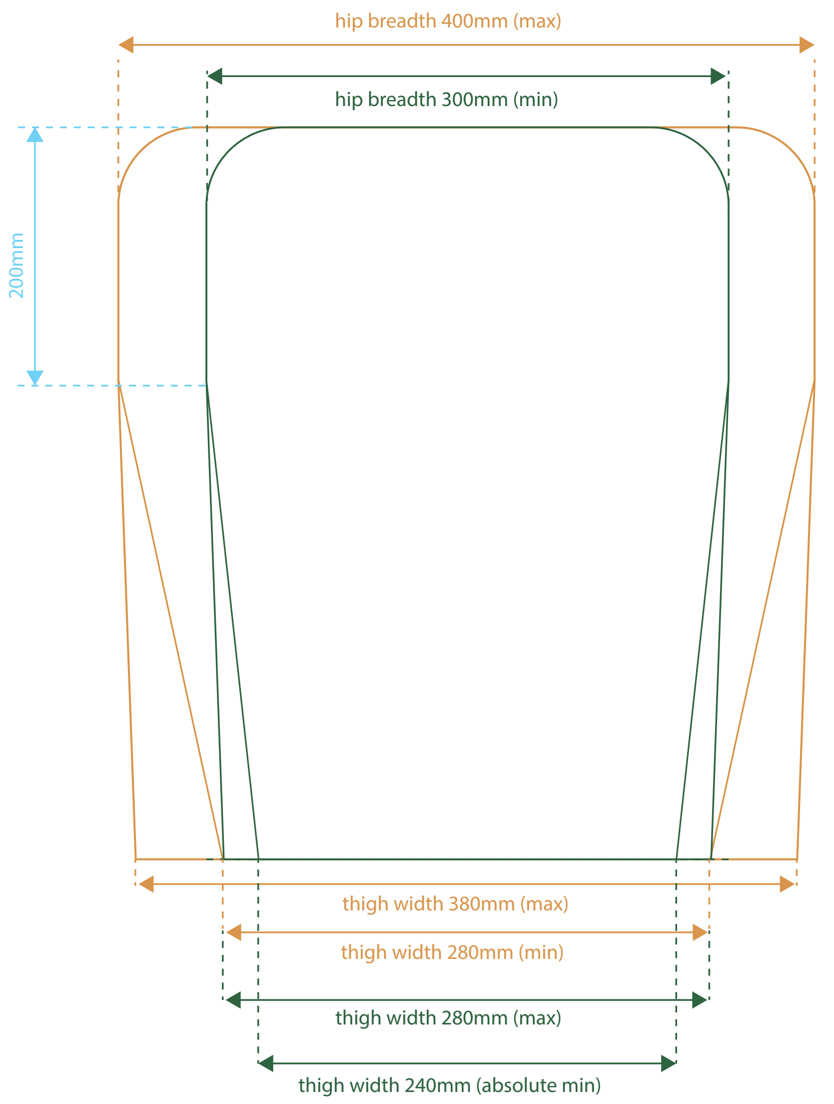


Figure A-5.25: smallest (green) and largest (orange) needed hip width compared

6 ENVIRONMENTAL FORCES

It is important to understand the forces acting on the sit-kiter and the material in order to design a safe product, even in extreme situations. The way someone is seated will also have an influence on the force distribution and is therefore analysed.

Introduction

A sailing boat will use its keel (see figure A-6.1) to create resistance which helps to not just be blown away by the direction of the wind (Fossati, 2009). This means there is a centre of lateral resistance (CLR) underwater which creates resistance to the centre of effort (CE). Overall, there are two important forces to remember, which is the resultant of aerodynamic force FA and resultant of hydrodynamic force FI (see figure A-6.2).

A sit-kitesurfer does not have a keel and will create this resistance by putting the board at an angle towards the water (edging). This leads to a centre of lateral resistance (CLR) that is much closer to the person. But also the sail is replaced by a kite with lines, which changes the place of the centre of effort (CE) to the connection of the kite to the person, which is the chickenloop (see figure A-6.3). As the backrest is tightly connected to the body and to the rigid seat, the athlete will move as a "block", and hips will be in a straight line with the back.

Figure A-6.1: sailboat with keel underwater
Source: Sailingworld.com

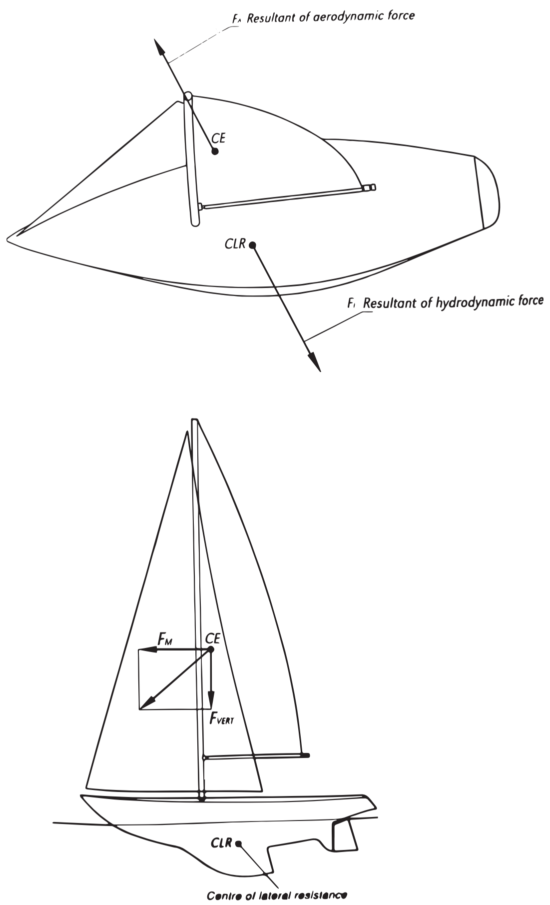


Figure A-6.2: alignment of the aerodynamic and hydrodynamic forces and centres
Source: Aero-hydrodynamics and the performance of sailing yachts - Fabio Fossati

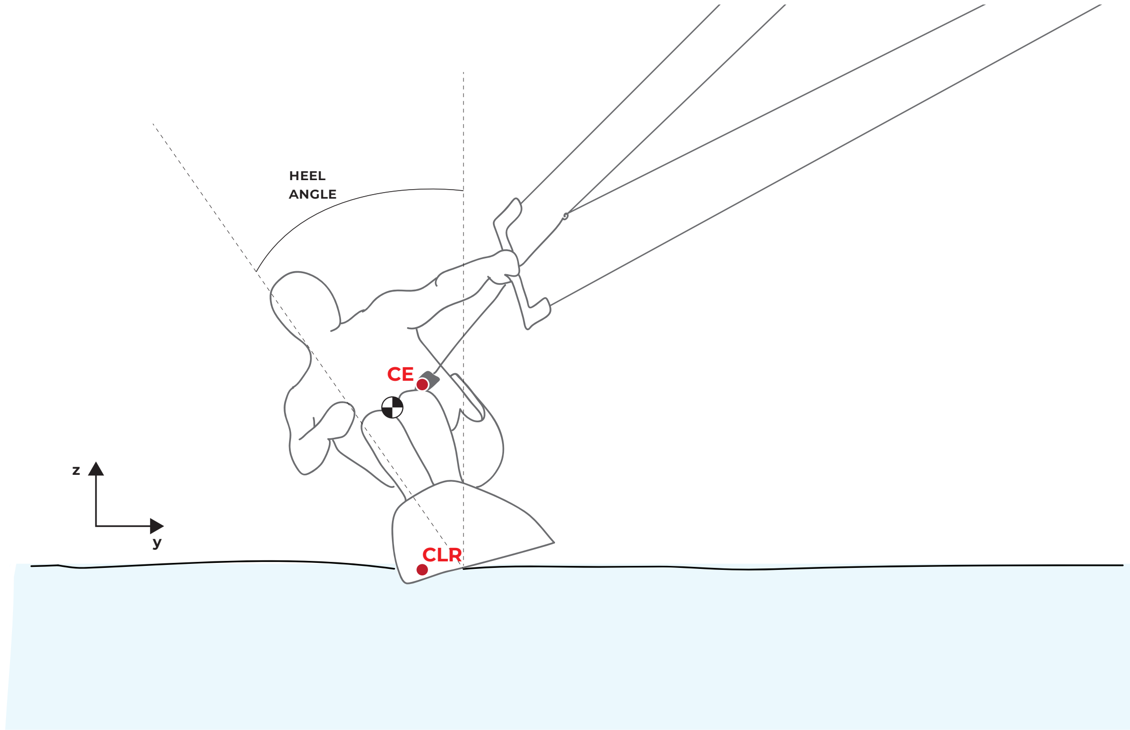


Figure A-6.3: centre of effort (CE) and lateral resistance (CLR) sit-kitesurf

Below, a more detailed FBD can be found of the forces acting on the athlete while riding.

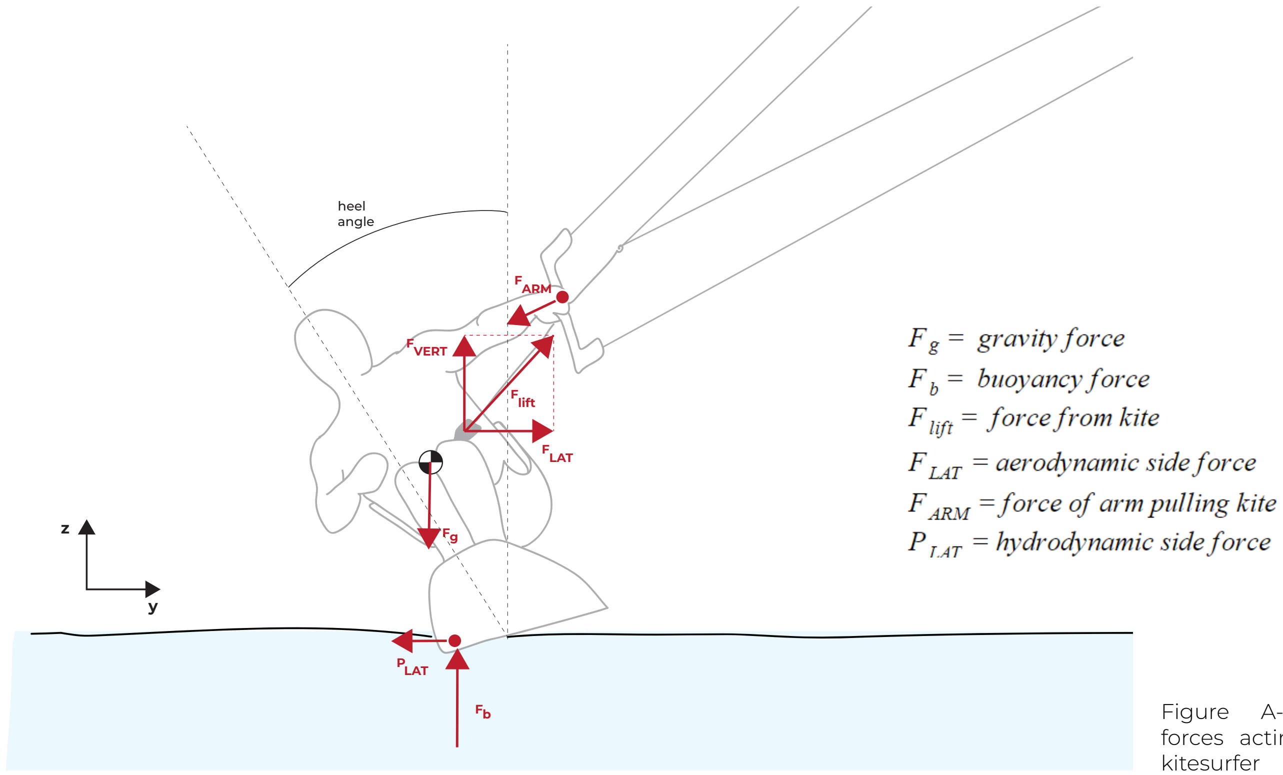


Figure A-6.4: FBD forces acting on sit-kitesurfer

Willem Hooft did some experiments while riding, by loosening the straps around the thighs to find out the impact. He experienced that there is a strong upward force that is exerted on the strap. But not on the sides of the seat as was expected.

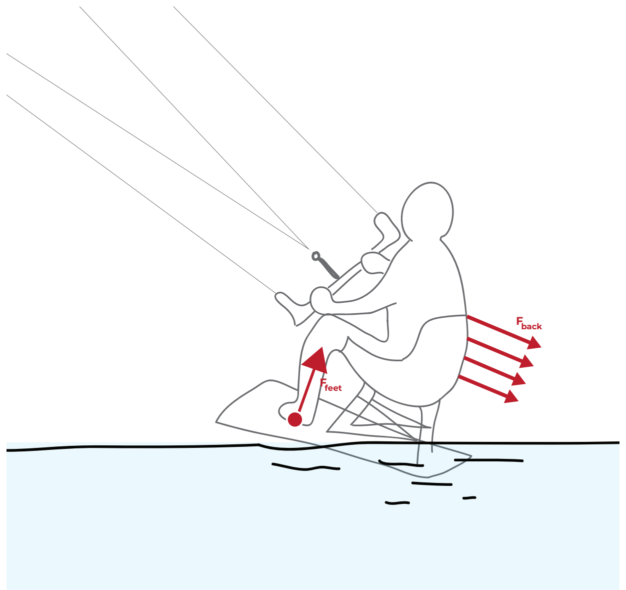


Figure A-6.5: forces on material while riding

When performing a turn/jibe in the current situation, there will be more pressure towards one side of the seat (see figure A-6.6). If a backrest is used, it is important to notice that the main pressure will be on one side of the backrest. It should be stated that the current seat is not a perfect fit, and allows some sliding.

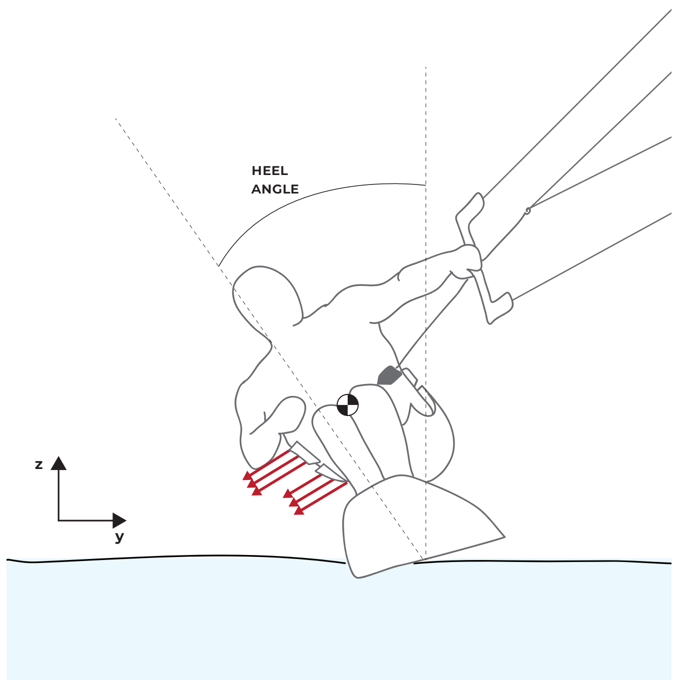
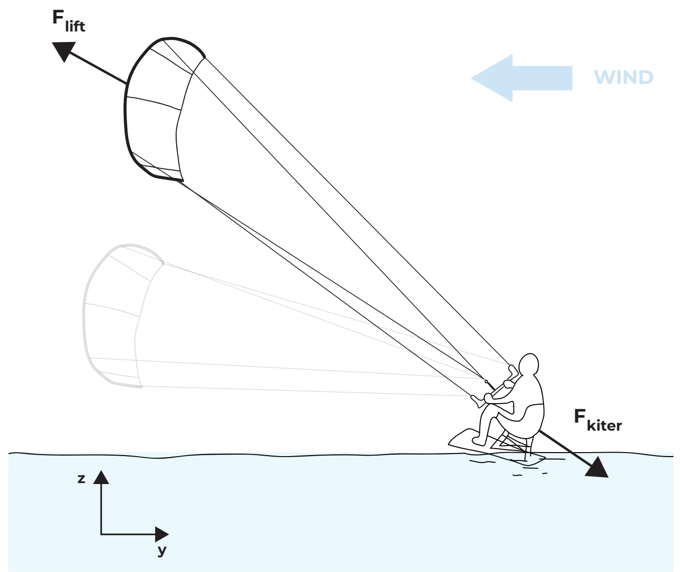


Figure A-6.6: pressure on seat during a turn

Environmental forces

The size of the kite depends on the weight and ability of the kitesurfer, as well as the wind conditions. However, a kitesurfer will always ride at an average speed. If the wind decreases, the kite size increases. As the lift force is the force pulling the kite forward, this formula can be used:

$$F_{lift} = 1/2 * \rho * C_L * V^2 * S$$



ρ = *air density* = 1.2 kg/m^3
C_L = *lift coefficient* = 1
V = *velocity or wind speed* = 23 *kts*
S = *size of kite* = $9m^2$

$$F_{lift} = 1/2 * 1.2 * 1 * 12^2 * 9 = 777.6\ [N]$$

However, this value of 778N is when riding and does not include any crashes or jump landings. The Innosport lab in The Hague did tests in the past in cooperation with Thierry Schmitter (experienced Dutch sit-kiter) using an accelerometer. This showed that at landing with the board flat on the water a force of around 500kg (+- 5000N) is applied on the equipment (body + equipment weight +- 80kg). Technique will play a large role in the force generated when landing on the water. Experienced kitesurfers can minimise this impact by steering their kite in a certain way just before hitting the water. Most beginners will not jump yet at schools, but a crash is definitely possible.

Looking at the lines, to fly safely and have optimal control over your kite it is recommended to use lines that can withstand up to 300kg (Vector Kitelines, n.d.). As there are 4 lines, the kite bar is designed to withstand four times 300 kg, which is 1200kg/12000N. This can be considered as the most extreme situation. Applying a SF of 2 on the force while landing, this comes close to the force the lines are designed to withstand.

Force on hook while riding	777.6 N (155 N with SF)
Force on material while landing after jump	5000 N (10 000 N with SF)
Extreme force used for designing kitebar *(already including SF)*	12 000 N

Table A-6.1: overview forces

Conclusion

Depending on the situation (eg. wind speed, riding style, ...) there will be different forces acting on the material, with an extreme force of 12000N (including SF). However, kitesurfing is a dynamic sport with a constant difference in location of the peak force of that moment. If this is combined with a composite material, FEA becomes too complex for this project. It is recommended to analyse through trial-and-error.

7 CONCLUSIONS

In this chapter the performed research will be analysed, in order to create insights and connections. The methods used for making connections are mindmaps and looking for clusters by rearranging post-its. Pictures of this process can be found in Appendix IXX. This will result in an updated problem definition and design requirements.

7.1 DISCUSSION AND RESULTS

Looking back at the RQ, they are all covered:

1. How does the current setup of equipment and courses work?
   Covered in chapter 2. Context research and 3. Product analysis

2. What are the reasons for low integration of the sport in kiteschools?
   Covered in chapter 2. Context research

3. What are the important aspects (anthropometric, usability, comfort and safety) while designing a seat for sit-kite beginners in schools?
   Researched in chapters 2 to 6, and concluded in the following chapter 8. Design requirements

4. What are the points of improvement of the current kite seat?
   Researched in chapters 2 to 6, and concluded together with research question 3 in the following chapter 8. Design requirements

In order to define the problem and determine the design requirements, the performed research has to be analysed. This has been done by combining the insights of the interviews with the desktop and literature research, as well as the anthropometric data gathered. There has been searched for relations between all the insights, which shows in the mindmaps below. But also by rearranging post-its, trying to find connections and interrelations (see Appendix IXX). This leads to clusters in the following themes and will be further explained in the discussion:

Comfort
Schools & accessibility
Person dependent
Size
Material
Backrest
Adaptability
Pressure distribution
Help external person

Written discussion:
In order to perform sit-kitesurfing, it is important to have a kite seat fitting to the athlete's body type. This is needed to be able to edge (putting board at an angle to the water in order to control speed and direction), and this is done by pressing the body against the seat. Currently there are 6 different adult sizes on the market, ranging from a hip width 33-46cm. Only sizes 33-39cm are currently being used in a specialised kiteschool. An individual set exists out of a frame, board and a seat. It is needed to have multiple sizes to cover the potential students. Each of these seats come at a high price, which results in high investment cost for kiteschools. Next to that, it requires time and effort to change the right seat to the frame. Even to such an extent that a current kiteschool is purchasing multiple frames to be able to leave the seat on it and in this way saving time. However, such a frame costs above 2000 euro. Without external financial support this is not possible, as a sit-kite course requires more effort next to the same price asked to students. An adaptable seat, lowering the investment costs and requiring less time to adapt sizes compared to changing seat to frame, can be a solution to make the sport more accessible to kite schools. This will also save space in the kitesurf schools, which most of the time only have one storage container or some are even mobile.

Looking back at the storyboard, the biggest issue is in the material setup. The issues concerning the material setup are related to time and effort. As mentioned before, it takes too much time for instructors to change the right seat to the frame. Another point of attention is the dangerous situation, which could be when a kite crashes but keeps looping across the water (the kite keeps turning which creates a lot of power on the kitesurfer who is being pulled forward). There is a lot of pressure on the person, which makes it hard to open the straps. The quick-release of the kite should be used (and thus reachable), so the kitesurfer has time to detach himself from the seat after pressure is removed from the kite. Furthermore, the material should not float when the kitesurfer is attached, as this could lead to a situation where the person turns head down towards the water.

The seat itself has no other major issues, and users are satisfied with its performance. There is discomfort among different users around the hips while performing the sport. The points of improvement are thus an optimal fit, adjustability for schools in order to reduce costs and time while not decreasing on safety.

The forces acting on the seat depends on the weather condition, the riding style and/or discipline of the kitesurfer. However, the seat should be able to withstand 12000N (extreme situation with SF) distributed through the spreaderbar which is connected to the seat.

Talking about comfort, the seat should support the pelvis and lower trunk for a normal spine posture. Next to that, should the seat have an optimal pressure distribution in order to minimise the chances of decubitus, which is common for people with SCI. This should be achieved by an optimal, tight fit that adjusts to the person. Important places with the largest differences among the target group are thigh and hip width. Currently seats are chosen depending on the person's hip breadth, which leaves space around the thighs for some users. This results in less controlled pressure distribution, more friction and worse performance due to bad force transition. Furthermore was the smallest seat width of the available seats 33cm, which does not cover the lower end (<P35) of the international target group. On top of that will the needed seat width be smaller than the actual hip width due to the tight fit. Also the seating height/popliteal height is not taken into account in the current setup, which leads to lost contact between the bottom of the thighs and the seat for taller people. It has been decided that the footrest should be adjustable in position to solve this issue and will not be involved in the design of the kiteseat.

Looking at the different scanned bodies, another big difference is the thighs and buttocks among the subjects, both in width as in form. A challenge is to accommodate all body shapes of the target group. For this the 3D-scans can be used to verify as they cover a wide range of the target group. Also the distance from the back to the trochanter varies, which influences the location of the widest point.

The needed dimensions for the seat are gathered by doing literature research, 3D-scanning and manual measurements and can be summarised in the picture below. It should be taken into account that thigh and back width are always smaller than hip width, and are therefore related to that dimension.

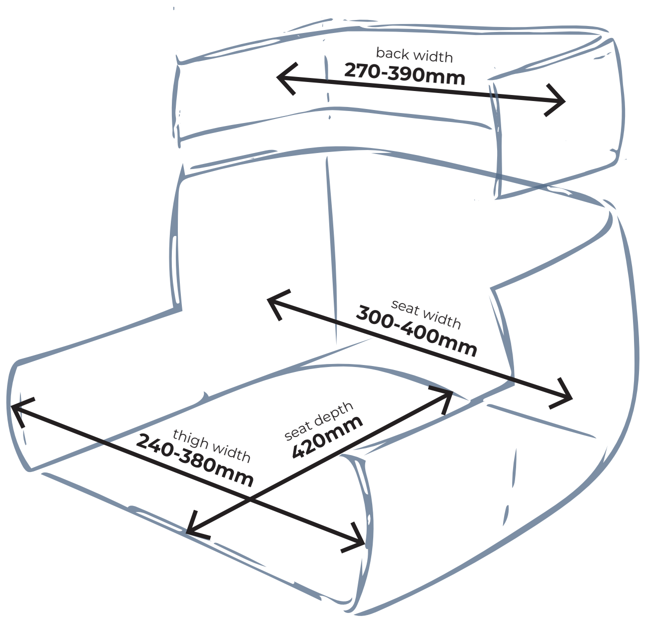


Figure A-7.1: desired dimensions kiteseat

Limitations and recommendations

The research was now limited to time and the connections of WHF, and is performed with 9 test subjects. In the future, it is recommended to measure more subjects of the target group, to verify the anthropometric conclusions.

While performing the 3D-scans, it is valuable to use markers on important measurement points (eg. trochanter and pelvis) and on the vacuumbag for easier post-processing. The scans can also be improved by using a more flexible material for the vacuumbag and smaller polystyrene balls. This allows for better adaptability to the body and less folds.

The research was limited due to the amount of experienced sit-kiters and schools able to contact. The community is still rather small, but is enlarging every year. This means that for further research, it could be easier to find interviewees or sit-kiters to observe.

7.2 PROBLEM DEFINITION

With these insights the problem definition can be updated and there can be decided on the design requirements. This has been developed using the Problem Definition method as described in the Delft Design Guide (Van Boeijen et al., 2014).

"The current kite seat needs too much time and effort to change a student's right seat size to the frame, while it does not fit correctly to the target group which decreases comfort and performance."

The general problem is the accessibility for disabled people to learn sit-kitesurfing. More specifically the problem lies with kitesurf schools who are not offering the sport, due to high investment costs and lack of knowledge. The needed material comes at a high price compared to the demand for the sport. One surfschool-setup exists out of a board, frame and at least 4 seats in different sizes. Schools who are currently offering the sport, struggle with the high prices and the lost time changing the right size of seat to the frame and board. The goal is to solve this struggle by developing an adjustable seat. This should save time and reduce initial costs for schools. The main users will be people with a physical disability in the legs, eg. spinal cord injury or amputees. A side effect to be avoided are pressure injuries due to a bad fit and material choice. Important factors while designing a kite seat for this target group are performance, comfort and safety. While the main factors for kitesurf schools will be ease of use and costs.

7.3 DESIGN REQUIREMENTS

A. Environment
A1. The design should be able to withstand salt and freshwater

A2. The design should be able to withstand UV radiation

A3. The product should not release toxic materials into the water

B. Modularity
B1. The seat should be attachable to the Wolturnus aluminium frame

B2. The backrest should be removable

B3. Broken parts should be replaceable

C. Safety
C1. The seat should be designed to withstand 12000N (distributed through spreaderbar).

C2. The quick-release should be easy to reach, even when fully depowered

C3. The seat should sink while the kitesurfer is in the seat, allowing easy rotation

C4.The design should minimize chances on pressure injuries, by minimising shear and friction; and maximizing pressure distribution

C5. The user should be able to exit the seat in the water in case of emergency in the same or less time as the current situation

C6. The design should limit the chance of kitelines getting stuck

D. Performance
D1. Water should be able to leave the seat

D2. Strong and stiff enough for riding on choppy water, transport in cars and jumps on the water (+-2m)

D3. Stiff enough (while riding) for efficient force transition of body to board through the seat

D4. The foam should not be able to move while riding

E. Ease of use
E1. Easy to adjust sizes

- Changing to the right size should take less time compared to changing the current seat to another frame
- If chosen for multiple sizes: the seat should be easy to interchange

F. Target product costs
F1. 50% less investments costs for schools than 4 adults seats (<3000 EUR)

F2. Less storage room needed than the current situation, which are (minimum) four seats with a frame and board.

G. Anthropometry
G1. The hip width should be adjustable and cover a range of 30-40cm.

G2. The seat depth is a fixed dimension at 42cm

G3. The thigh width of the seat should be adjustable and cover a range of 24-38cm, but will always be smaller than the hip width.

G4. The design should fit people with different widths in each thigh. Which means the part around the thighs should have the option to be asymmetrical, but still have a width within the range as mentioned in G3.

G5. The backrest should be adaptable in width when chosen for a closed backrest within a range of 27-39cm, but will always be smaller than the hip width.

H. Comfort
H1. The seat should support a normal spine posture by supporting the pelvis and lower trunk (avoid kyphosis and lordosis)

H2. User should not touch any bolts or hard material with its body while seated

PART B

IDEATION

After finalising the problem definition and design requirements, ideation can be started while keeping these insights in mind. The ideation exists out of design sprints which lead to three main idea directions which are developed to potential concepts. In consultation with WHF, it has been decided to focus on the seat itself rather than on the backrest.

SOURCE: WHF

1

DESIGN SPRINTS

The ideation will be stimulated by doing short brainstorm sessions in between research. Alternating between these two, with a short and powerful session, has proven to work best for me as a designer.

Important features to take into account:
- *Comfort and pressure distribution*
- *Rigidity*
- *Adaptability*

DESIGN SPRINT A

Brainstorm session
A brainstorm session has been organised with four participants. They were asked to first think about existing products that can be adjusted in size, height or similar. This with the goal to stimulate the creative mind. After this they were asked to draw or write answers to “How can you adjust sizes?”, “How can you adapt something to a changing hip and thigh width?” and “How can you change a backrest in width?”. The ideas were written down on a paper and passed around three times.

The results created new idea directions and insights, as well as thinking into a different direction than I had done so far. The first design sprints continuing on this brainstorm session can be found in Appendix XXI.A.

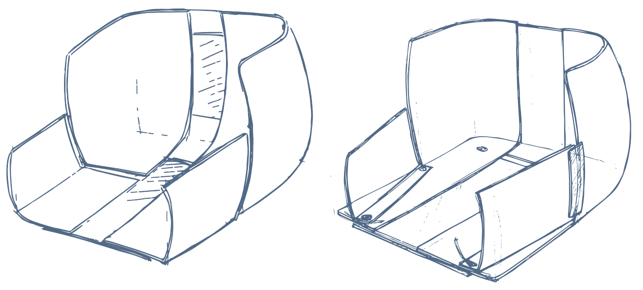
Moodboard
Before brainstorming, a moodboard is created existing out of current applications where dimensions can be adjusted. This will help as a lead during the creative sessions. In the Delft Design Guide this is called ‘Analogies & Metaphors’ and is considered helpful during idea generation. It should exist out of close and distant domains (Van Boeijen et al., 2014).

DESIGN SPRINT B

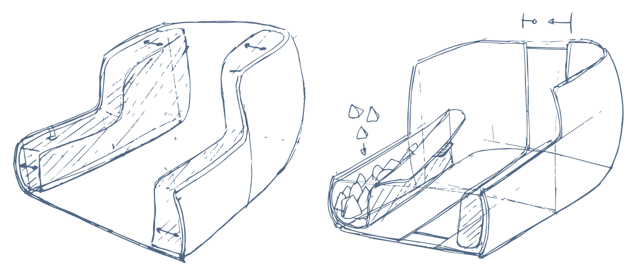
After the first design sprint, the idea sketches are categorised which lead to three main idea directions:
- Four parts and rails
- Outercase and inflatable/vacuum/filling;
- Two parts and changing sides.

A more elaborate visual of the directions can be found in Appendix XXI.B.

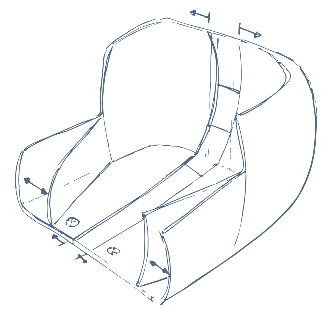
IDEA DIRECTION 1
Four parts and rails



IDEA DIRECTION 2
Outercase + inflatable/vacuum/filling



IDEA DIRECTION 3
Two parts + changing sides



DESIGN SPRINT C

More sketching has been done, this time with the information in mind of the collected anthropometric data. An obstacle turned out to be the changing shape and width of the thighs between the subjects. One rigid shape is almost impossible to adapt to the shape of the thighs. People with less fat around the thighs have a more straight line from trochanter to knee, while people with more fat generally have a more round outline (see figure B-1.1). This sprint led to ideas trying to solve this problem, for example by exploring different flexible but non-stretchable materials in the design.

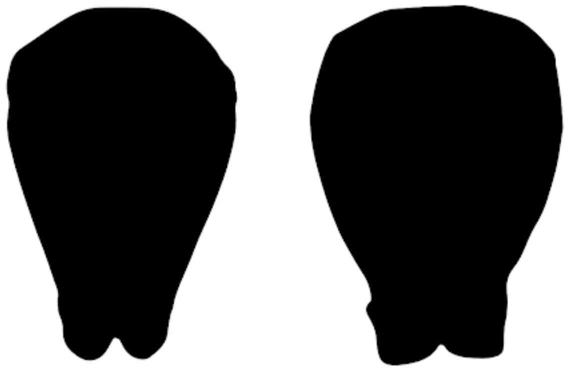


Figure B-1.1: outline bottom thighs - right: more curved

In Appendix XXI.C an overview of the sketches during design sprint 3 can be found.

2

ANALYSIS

ANALYSIS SKETCHES

Ideas of both design sprints are analysed. Instead of a typical way of presenting three concepts, it is more suitable in this situation to divide them into categories: system, straps and fix parts.
This follows the design method Morphological Chart. In the end, a combination is decided on as a final concept. In figure B-2.1 an overview can be found of the chosen concepts in each category.

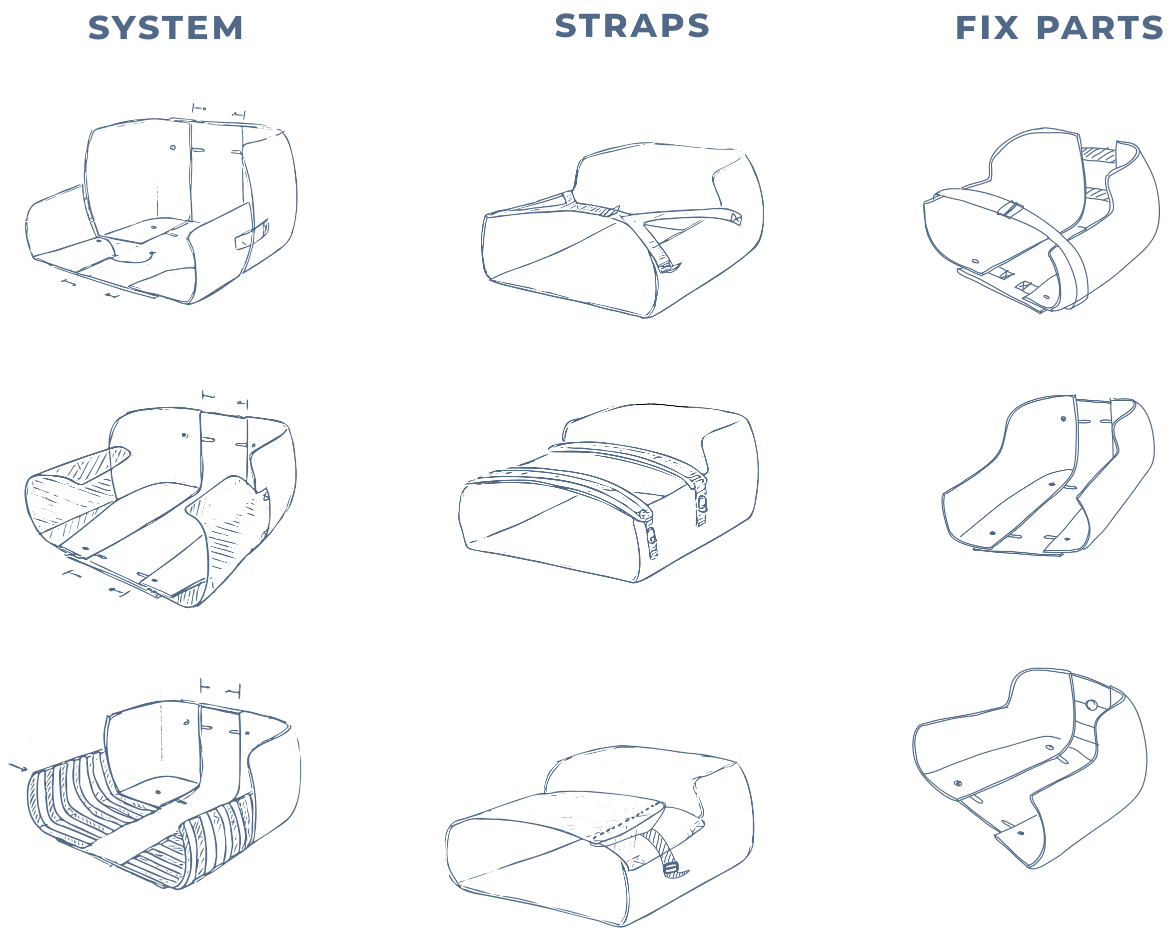
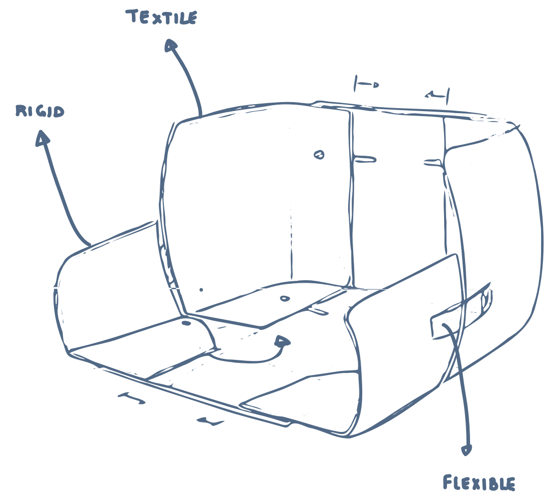
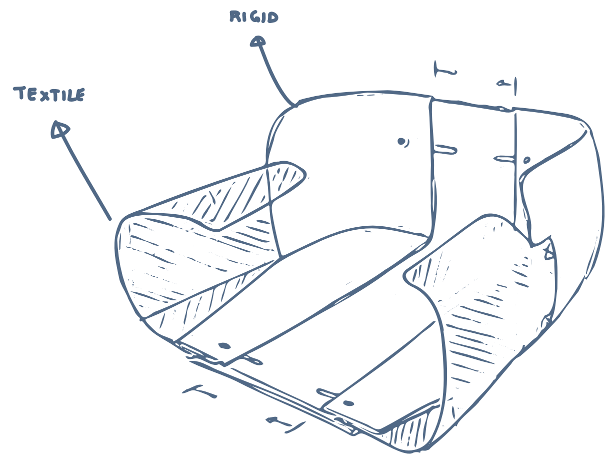


Figure B-2.1: overview chosen categories and concepts

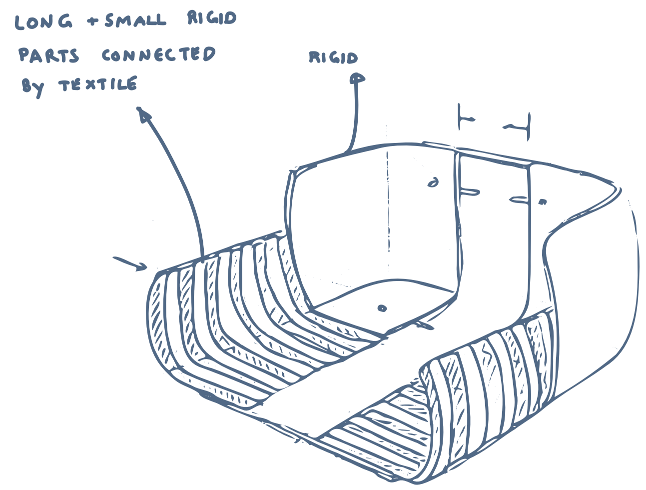
SYSTEM



Concept A1
RIGID
System consists out of four stiff parts attached to a baseplate. Thigh and hip parts are connected by a non-stretchable strap, which makes sure the sides can be adapted to the right thigh width. This concept is closest to the current feeling of the seat.

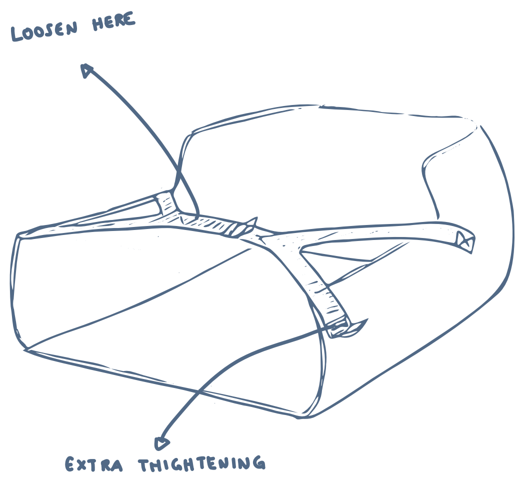


Concept A2
TEXTILE
System consists out of two stiff parts around the hips. Thighs are clamped by a large textile part which is stiff when connected with a strap. The textile can easily adapt to the shape of the upperlegs.

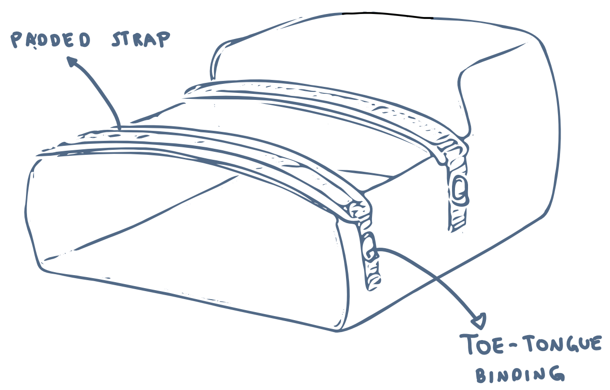


Concept A3
SAIL BATTEN
System consists out of two stiff parts around the hips. Around the thighs there is a large neoprene part which surrounds rigid parts connected by non-stretchable textile. This concept is in between the first two.

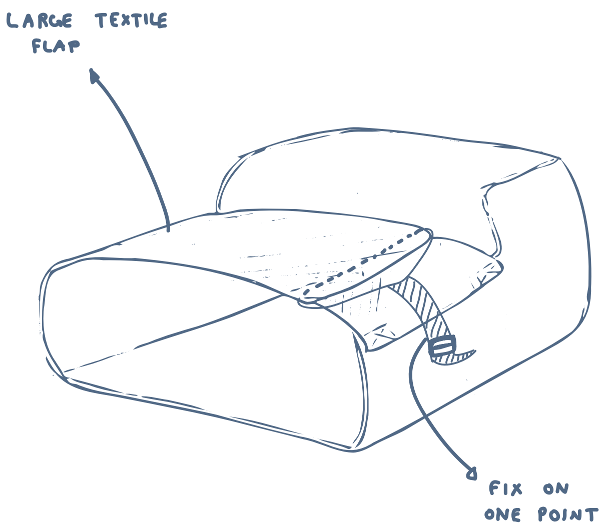
STRAPS



Concept B1
ONE POINT
Instead of two straps that needs to be opened in an emergency, the straps are combined in one point.

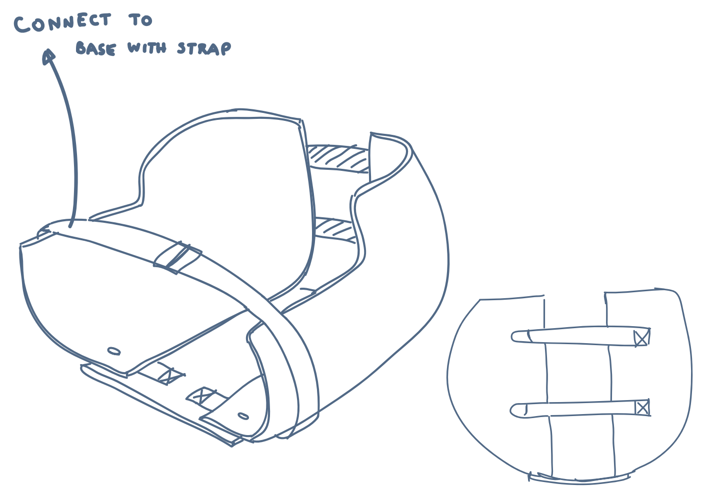


Concept B2
CLICK-CLACK
Close to traditional idea, but closed with a system similar to snowboard/ski-boots, called toe tongue binding. This allows for auditive feedback when thightening and easy release.

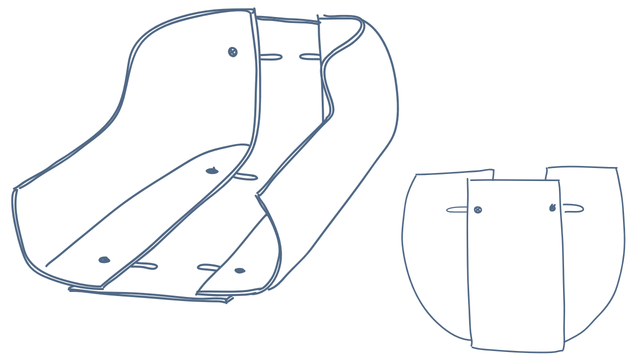


Concept B3
FLAP
The original two straps are replaced by one bigger textile flap. This covers the whole area of the upper legs.

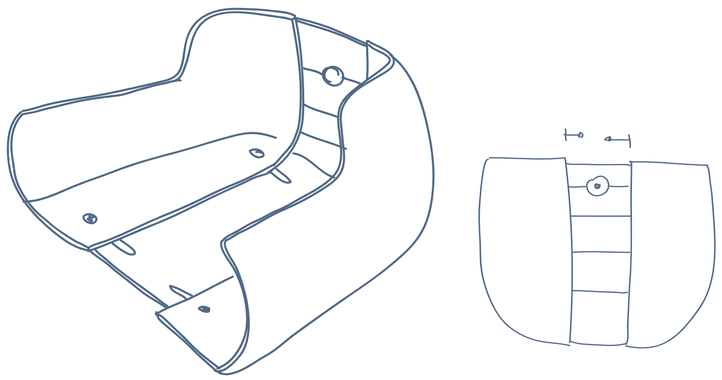
FIX PARTS



Concept C1
STRAPS
Hip width is thightened by adjusting the straps, which is similar to kitesurfing harnesses.



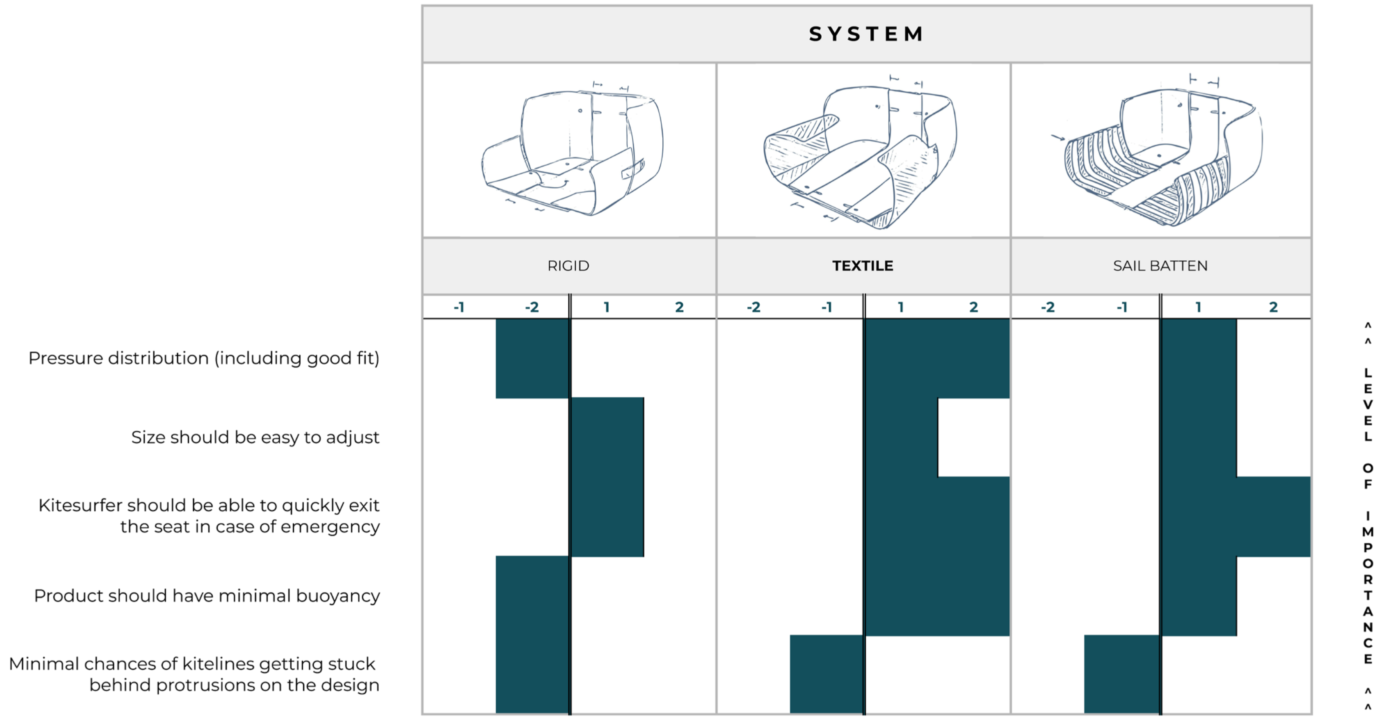
Concept C2
RAILS
Rigid parts are both connected to a base plate through a bolt. The back has a turning knob which loosens/thightens the connection between both.



Concept C3
BOA SYSTEM
Parts have rails on the base plate, but are thightened using the boa fit system which is used to close, for example, snowboard boots.

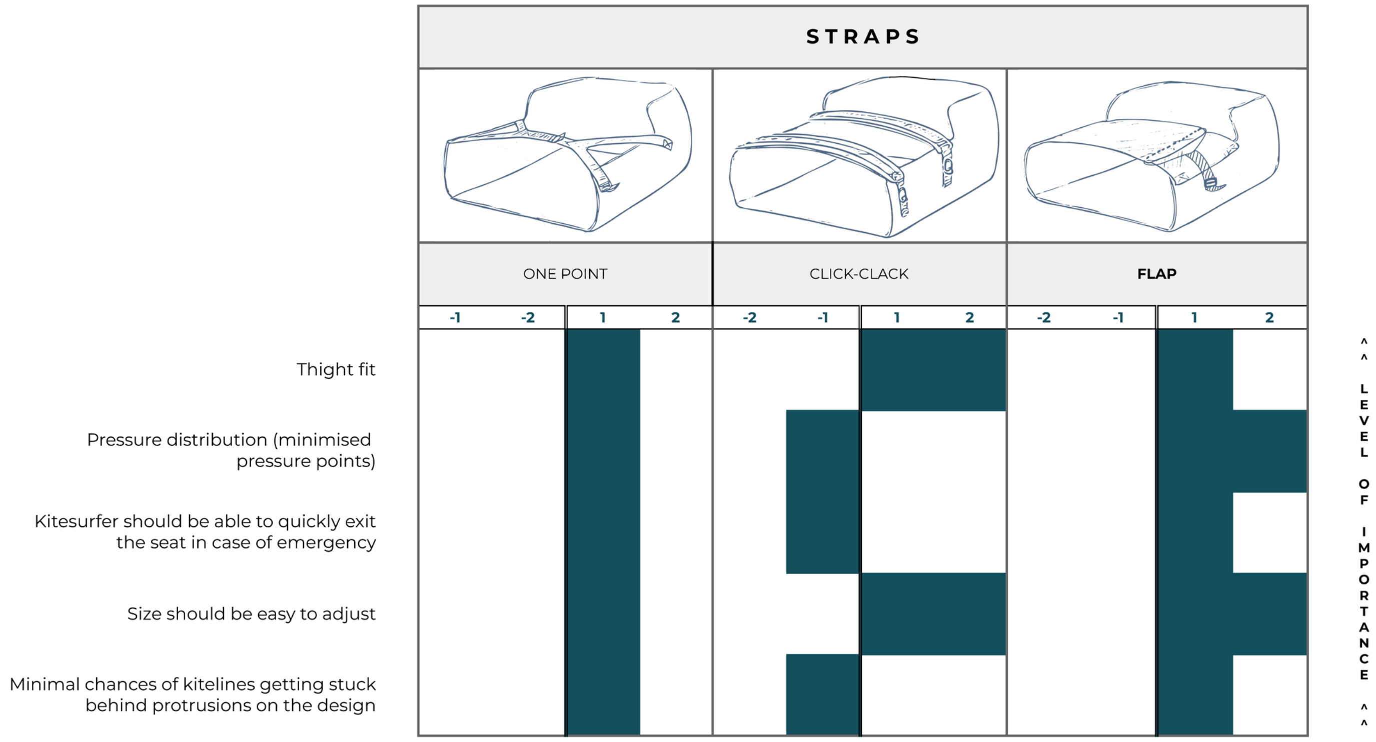
For analysing the concept and help in concept choice, the Harris Profile method as described in the Delft Design Guide is used. This allows evaluating the design alternatives using design criteria (Zijlstra & Daalhuizen, 2020). Criteria are set up on which the concepts are rated. These are not directly the same as the Design Requirements, as some are a hard require and can not be ranked (eg. resistance to UV, reachable quick-release, ...). As there are three concept categories, different Harris profiles are set up with varying criteria relevant to the category.

Important takeaways are that a more flexible material in combination with smaller polystyrene balls allow for greater adaptability of the body shape. This can be taken into account for further research, or for the design itself. For example looking for a material that adapts more to the body in order to provide optimised pressure distribution.



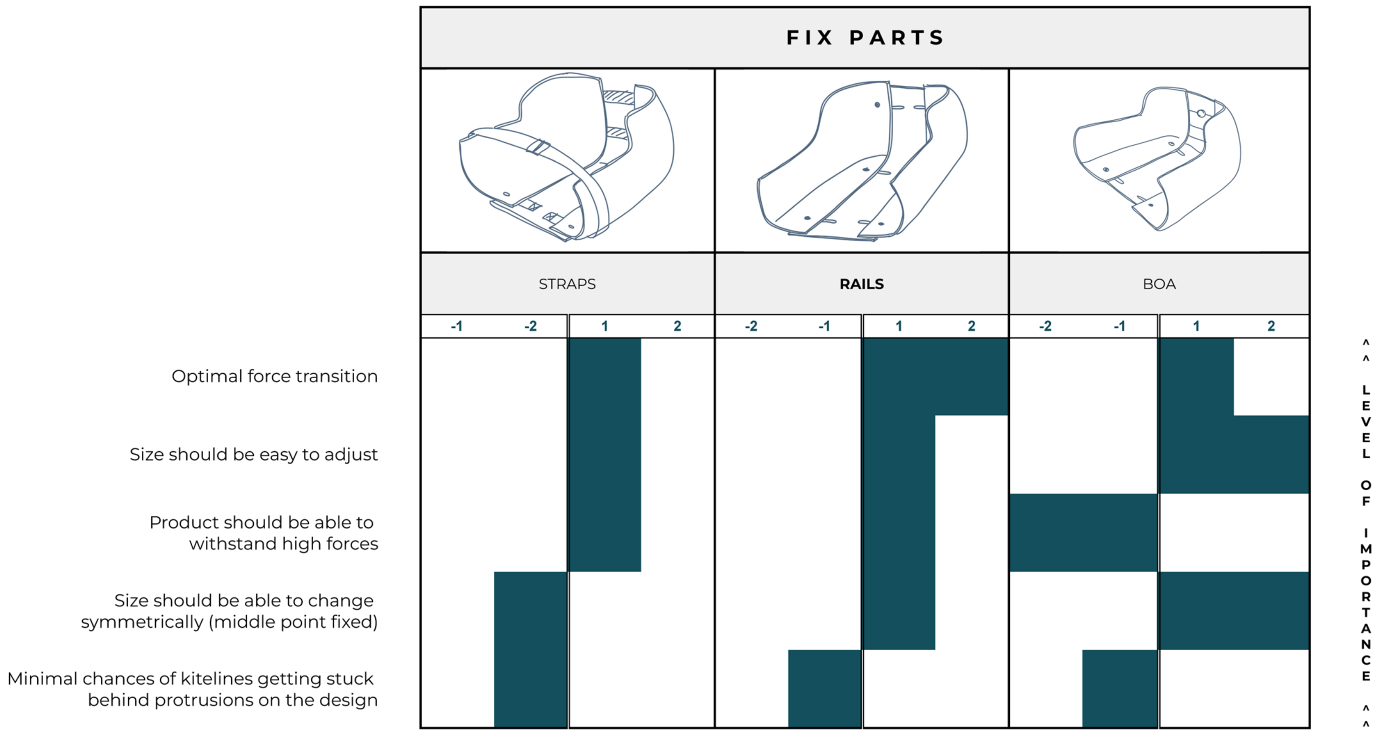
In this category, the "flap" concept comes out as the best option. A big plus is the pressure distribution, where the upward force, coming from the thighs, is distributed across a larger surface compared to the other options. This is also considered as one of the most important criteria. Only on the criteria of a tight fit, the "click-clack" concept scores better as it is known that it can be pulled on very tightly.

Furthermore can the "click-clack" also be more easily adjusted around the middle. However, the "flap" concept has only one connection point (as the "one point" concept) which allows less actions for adjustment and release out of the seat. This decision will be discussed with WHF, as there seems to be more than one suitable solution.



At a first glance, the concepts “rails” and “boa” seem to be most promising in the last category. However, a critical point for the “boa” concept is the ability to withstand high forces. There are currently no applications using the boa fit system with such high forces, and it is stated that the high power end can withstand up to 190kg (Williams, 2021). In the rail idea, the parts could be fixed with a clamping knob (see image B-2.2).

Source: Uxcell Store Amazon
Figure B-2.2: clamping knob



FINAL DESIGN SPRINT

In figure B-2.3 an overview of the most promising concepts in each category can be found. From this point, there will be another design sprint continuing on this combination. These sketches can be found in Appendix XXI.C.

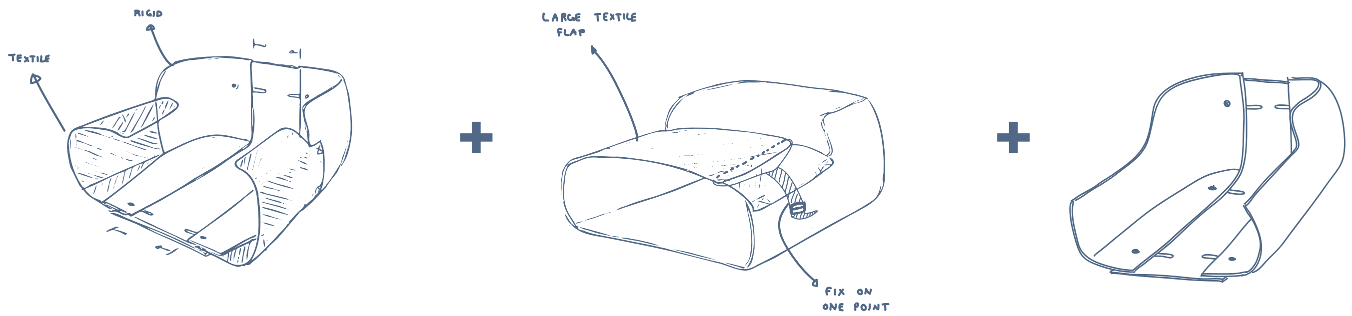


Figure B-2.3: chosen concepts per category

A quick test has been performed to analyse the textile concept further. Velcro was stitched onto a non-stretchable textile, and taped to a chair without arm rest.

Figure B-2.4: Set-up quick test

Two men and two women tried the prototype and it can be concluded that it fitted all four people. One point of attention is the angle at which the textile is laid. If it is connected straight to the seat, there will most likely be an area around the thighs that is not tight (see figure B-2.5).

Figure B-2.5: straight alignment (left), gap around thighs (right)

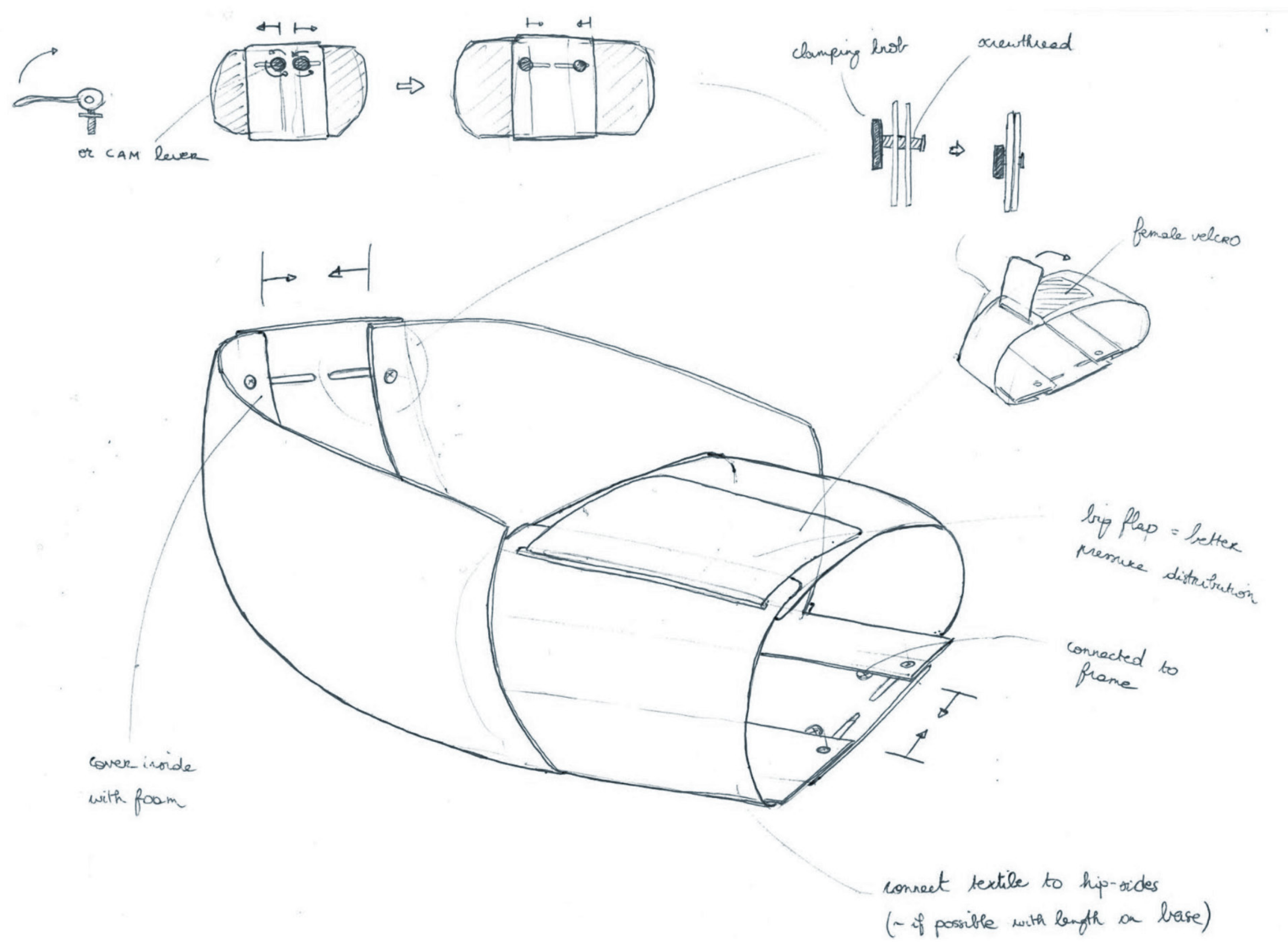


Figure B-2.6: annotated view chosen concept (strap/flap will later be decided)

After discussing the chosen concept with WHF, there was agreeability on the chosen system and fixtures. However on the large flap there are still some doubts, and will have to be tested once there is a prototype. Points of attention will be the tight fit and the ability of water to leave the seat. Willem Hooft also mentioned that the current pressure distribution coming from the straps does not create any pressure injuries and is therefore not seen as a necessary point of improvement.

PART C

FINAL DESIGN

SOURCE: WHF - SOULART

1

DESIGN EXPLANATION

After choosing the final concept, the technical details and its working have to be determined. This is done by making a CAD-model, printed 1:2 scale model and full scale 3D-print. But before diving into the details, an overview of the final design can be found in this chapter.

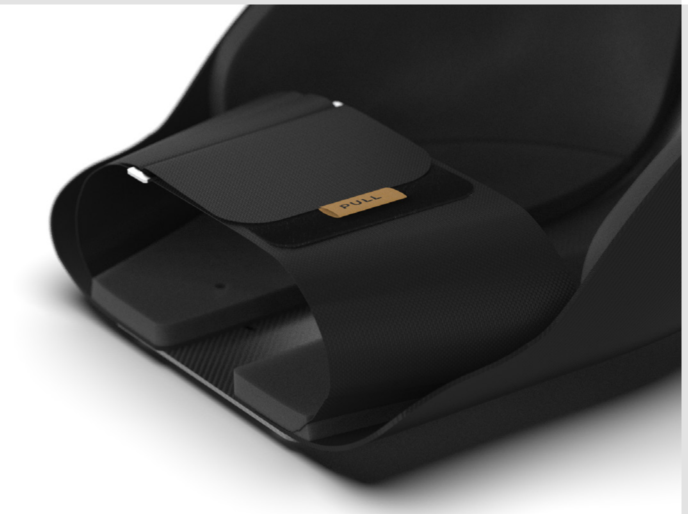
KEY FEATURES

The final design's main feature is an improved fit, which positively influences the force transition and pressure distribution. The seat is adjustable in seat width from 30 to 40cm. This easily covers over 70% of the international population. Note that this percentage will be higher, as the person needs to sit tight in the seat. This has as a consequence that the seat width will be smaller than their actual hip width, as flesh can be pressed in allowing for a smaller width.

The side parts slide over the base plate using a simple rail system.

The clamping knobs make sure the seat width is fixed at the right size. It also allows for easy adjustment without any additional tools.

The hard parts are covered with a 15mm closed-cell foam to minimise chances of decubitus. Compared to the original model, this design uses less foam which positively influences the design requirement of decreasing buoyancy.



The part around the thighs consist of a strong 600D Polyester textile, which adapts to different shapes of thighs. This makes sure the model is suitable for people with less or no leg muscles as well. Textile is fixed with a velcro connection, due to its reliability and durability in salt water.
A bright-coloured label has been added to the flap as usecue for easier loosening of the velcro.

It is important the spreaderbar is close to the body. The round cut-off above of the trochanter allows the spreaderbar to stay as close to the body as possible, even for the smaller and larger people.

2

EMBODIMENT

This part will give more clarity about the design choices made during the embodiment phase. Also the problems encountered and how they are solved.

2.1 FIT

To generate the right form of the seat, the 3D-scans are used to validate the shape. The 3D bodies are placed into the shape, and manually adapted using the control points to create a uniform outline (see figure C-2.1). This is still challenging as the trochanter's location varies a lot. Although the form seems to be fitting all scans, it is important to prototype the form to verify this.

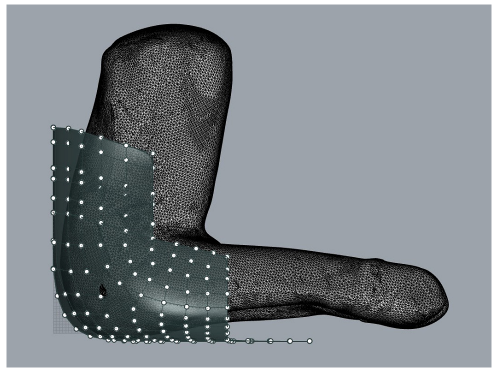


Figure C-2.1: adapting seat shape to 3D-scans

The different location of the trochanter can be seen in figure C-2.2, where a person with a smaller hip width (white) is placed over one with a larger size (orange). The black dots annotate the location of the trochanter. For the smaller person, the trochanter is located closer to the back.

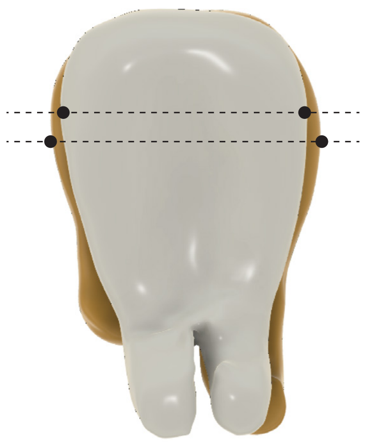


Figure C-2.2: person with small (white) placed over wider (orange) hipwidth

Remarkably, the original shape is flatter in the back than the new version (see figure C-2.3). The main reason is the location of the trochanter among different subjects, as this creates a different body shape. Out of the performed research it shows that smaller people often have a trochanter closer to the back than wider people. Among the test subjects the distance from the trochanter (widest part) to the back ranges from 130 to 200mm. Looking at the original kite seat, the distance of the back to the widest part of the seat is smaller than 130mm and is therefore not ideal.
On figure C-2.4 a visual can be found, showing a 3D-scanned body in the final prototype.

Figure C-2.3: original seat (left); new seat (right)

Figure C-2.4: 3D-scan placed in new seat

A 1:2 scale model is 3D-printed to verify its overall shape and rail system (see figure C-2.5). This model will also help to visualise certain problems better and make better decisions before printing on a 1:1 scale.

Figure C-2.5: 3D-scan of seat on scale 1:2

It is also tested if, in the smallest size, a kiteline could easily get stuck behind the base that is sticking out (figure C-2.6). It shows that with pressure in most directions, the lines set themselves free due to the flat surface. However there is still a chance of lines getting stuck. For this reason, the fillets of the upper corners of the base plate are increased (see figure C-2.7).

Figure C-2.6: prototype critical spot for lines getting stuck

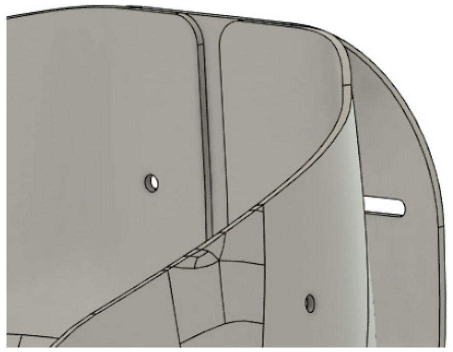


Figure C-2.7: improved critical spot

2.2 SHAPE

A first draft (v1) of the shape has been exported to Fusion360 to further develop it. After analysing this shape, a critical point has been found which is prone to breaking with the upward force from the feet (see figure C-2.8 - annotated in red).

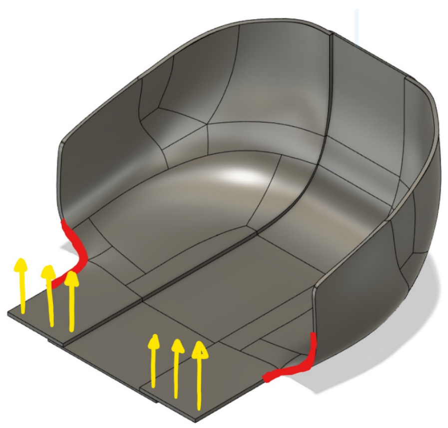


Figure C-2.8: critical point shape v1

An exploration has been done to find an aesthetic solution. Eventually, the point is made stronger by reducing the hard edges and using more round outlines in both horizontal as vertical directions (see figure C-2.9). A consequence of this design choice is that the textile part will have to be connected to the inside as it would not fit tightly around the smaller thighs.

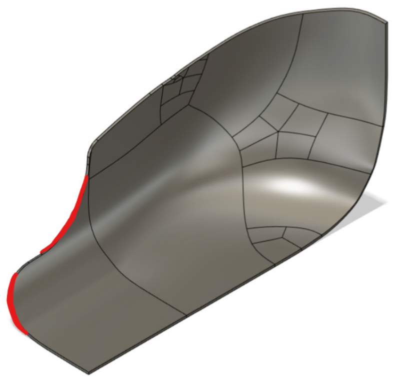


Figure C-2.9: fixed critical points shape v2

Another iteration has been made, specifically on this new shape. An important insight from the interviews was the ease of reaching the kitebar, even when fully depowered. This means that the spreaderbar should be as close as possible to the subject. For the smaller person, this requirement creates difficulty in shape v2 (see figure C-2.10 - red line shows location of strap spreaderbar). With the adapted shape v3, the strap of the spreaderbar can get more closely to the body. The more fluent outline allows for the possibility of different locations of the strap, as this location depends on the body type.

Figure C-2.10: shape v2

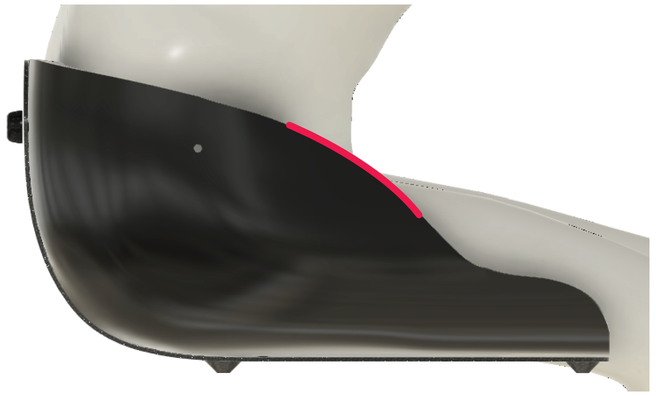


Figure C-2.11: shape v3

2.3 BACKREST

After analysing the 3D-model, the backrest still is a point of improvement. The base of the backrest is sticking out in the smaller sizes, which could be a possible spot of kitelines getting stuck. Furthermore, the curve of the backrest is too large for some people.

For these reasons the back of the backrest is made flatter. This allows the base to be located on the inside instead of the outside (see figure C-2.12). Also the fit follows the shape of the back better, as can be seen on figure C-2.13 and C-2.14. Also aesthetically it has a more clean and elegant appeal.

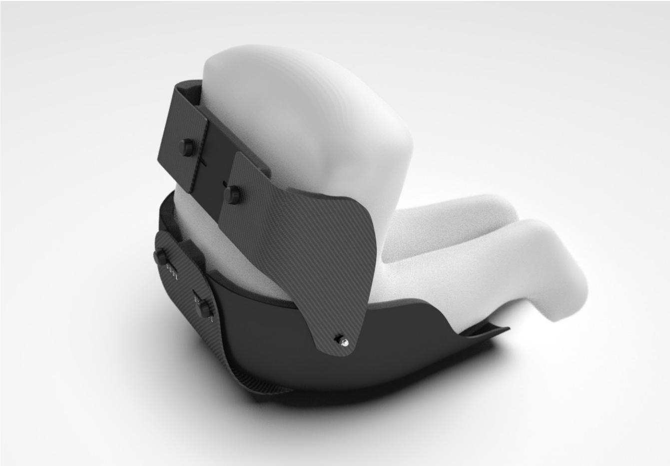


Figure C-2.14: backrest with 3D-scanned body

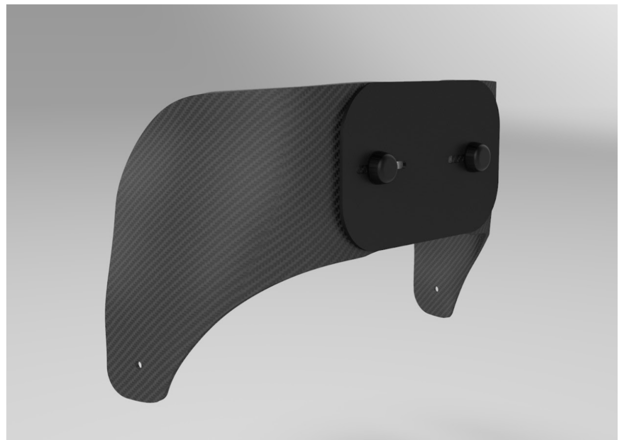


Figure C-2.12: backrest version 1

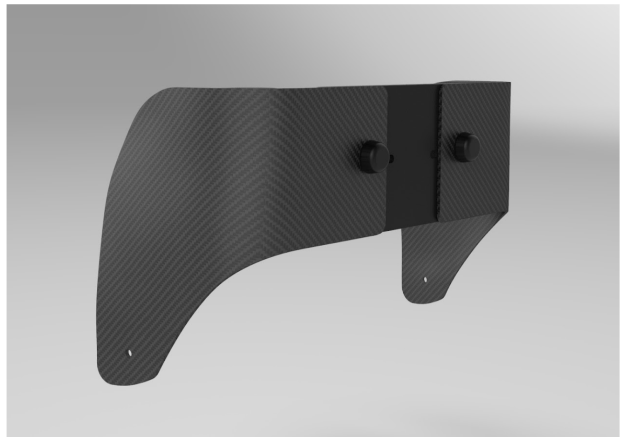


Figure C-2.13: backrest version 2

3 MANUFACTURING

In this chapter material and manufacturing choices are explained. Also the choice of fixtures can be found here.

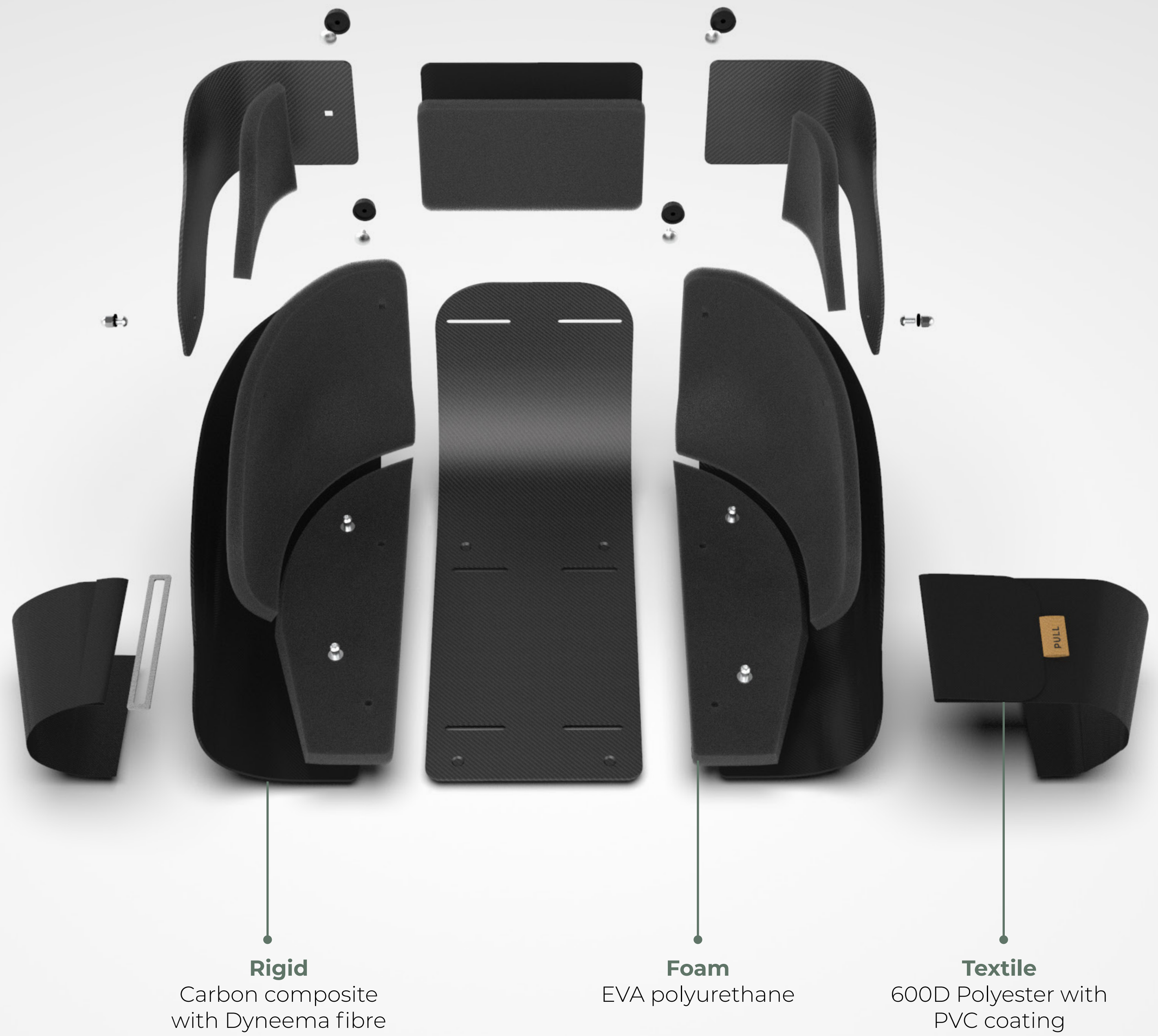


Figure C-3.1: overview parts

3.1 MATERIALS

The design will exist out of multiple parts and materials (see figure C-3.1). The two main categories are a flexible textile and a rigid material.

The textile is used for holding the thighs together. Main criteria are:

- Non-stretchable
- Strong enough to withstand shear and tension forces
- Feel soft to the skin (not causing rash)
- Resistance to UV and salt water

While the rigid material should have the following main criteria:

- Stiff
- Minimal buoyancy while maintaining minimal weight
- Resistance to UV and salt water

Rigid

The current material, glass fibre reinforced by carbon composite on the bottom, has proven its reliability. However, it is suggested to chose a carbon composite reinforced with Dyneema fibres. This combination improves shock absorption and provides more lightweight solutions. Furthermore, it has a much lower risk of shattering or splintering under a high impact, which improves the safety of the user (Dyneema Carbon, n.d.).
Next to that, the Chemelot campus of Brightlands will do further research in 2022 specifically about materials for a kitesurf seat. These insights can be applied in a later stage of this project.

Textile

The textile around the thighs needs to be strong and non-stretchable. The two most promising options are nylon or polyester. However, nylon fibres tend to be more stretchable which is not desired in this design, polyester dries quicker and is better resistant to UV (Jason Mills LLC, 2021). Looking at polyester options, a lower denier density means a more rough surface and less resistance to high forces and shear (Ruibag Factory, n.d.). 600D polyester is most suitable for the situation of a kiteseat. A final choice has to be made between a PVC and PU coating, of which both makes the material stronger. However, PVC is known to make the material more than two times stronger. On top of that it is also used for boat covers due to its water and mildew resistance (Metissagesbags, 2021).

Foam

There are two main types of foam, open and closed cell foam. In the current seat, a closed cell foam is used. In general, open cell foam is more soft as it allows air getting into the structure (Foam Factory, n.d.). As the foam will be used in water, it is important to minimise the risk of water damage like mold and bacteria. A closed cell foam structure is water tight and is therefore more suitable. Furthermore, this structure can withstand higher pressure (Polymer Technologies Inc., 2021).

EVA polyurethane foam is known to be resistant to UV and salt water, and is already widely used in the nautical industry (Flexform, 2020). It is therefore chosen as a good option for the kiteseat. The same thickness as the current foam will be used, which is 15mm. The foam will be glued onto the corresponding parts, but only in the middle so that the screws are still reachable, if needed.

However the downside is that a closed cell foam will always float due to its tiny air pockets, while an open structure will sink when water has entered. But once filled with water, it will also lead to a heavier product, which decreases the comfort and performance. It should be tested if the buoyancy creates any issue in a real-life prototype. It is expected that the main issue will lie in the hollow aluminium frame rather than in the seat.

3.2 PRODUCTION

Especially in the start, a big challenge for this project is the low-scale production. The amount of products made will be low as it will be part of an awareness program where the interest of the schools will most likely gradually increase. Laminating of carbon or fiberglass is known to be an expensive process where the molds are a large part of the costs. For this reason, different methods for production have been researched.

An interesting direction is laminating a 3D-print, which could decrease the investment costs of the molds. Research by Bere et al. (2020) explored this possibility by designing a bike saddle fabricated out of carbon-reinforced polymer. Starting from a 3D-print, using vacuum bag and oven curing. Tolerance on the produced models and the CAD-model was +-1mm. PLA turned out to be the best material in combination with oven curing and gel coat. In this project, it could be interesting to use this method for a ready-to-try prototype.

It should be taken into account that the current model is modelled at 3mm thickness. If opting for this production, the thickness of the 3D-print should be decreased to fit to desired seat width dimensions of 300-400mm. For standard printers, the parts can be too large but this can be fixed by printing them in two pieces and attaching them together using glue and the laminating process.

If after a certain time, the scale of production is increasing, there can be chosen for manufacturing a mould. This will take away the costs of 3D-printing per piece. Compared to seven original seat sizes, which each have an individual mold, this model could reduce manufacturing costs. The option of 3D-printing the molds can be explored as well.

3.3 FIXTURES

Sliding mechanism

There has been chosen for off-the-shelf screws to minimise costs concerning the small scale. Two types of fixtures, concerning bolts, are needed (see figure C-3.2).

Figure C-3.2: two types of fixtures (A-sliding; B-fixed)

In theory, the seat does not need to be clamped on all three locations of the rails. But the effectiveness will need to be tested, as the 1:2 scale model already showed some difficulties. To remain a smooth surface, the optimal situation is that the clamping knob is situated on the bottom. However, this will be an issue due to the frame underneath (see figure C-3.3). For this reason, the clamping knob will be placed on the back (type B). In the first 1:1 prototype, this will be tested.

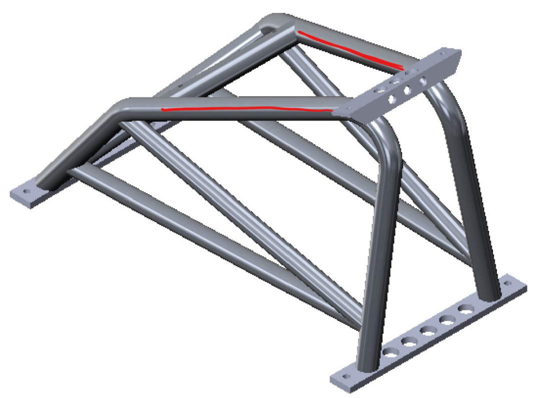


Figure C-3.3: frame tubes potentially obstructing the clamping knobs

Nonetheless, the type A bolts could still intersect with the frame. For this reason, an elevation is designed between the base and frame. This allows for free translation of the system. The elevation part can be integrated into the base plate or could be a separate part. For the 1:1 model, the back elevation follows the curve of the base plate. This will make the curved surface stronger, as the 3D-printing process will make it more brittle. In a later phase, this could be removed if the carbon composite shows enough stiffness and strength.

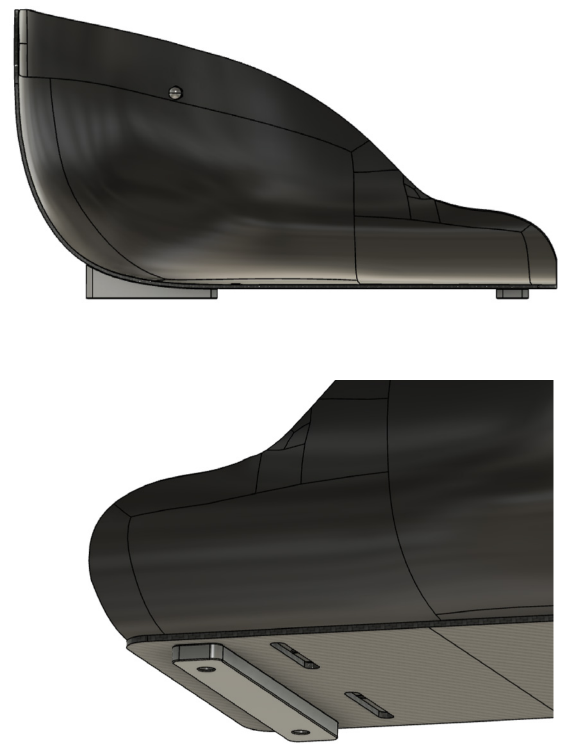


Figure C-3.4: elevation part

Type A

For type A, there has been chosen for a binding barrel as connection. In between, there are plastic washers for easier rotation and translation, as well as resistance to wear. Additionally, the added thickness of the washers allows for using a standardised size of binding barrel (10mm). Smaller is commonly not easy to access. These fixtures will be tightened once during installation, before inserting the foam.

Figure C-3.5: binding barrel with hex head
Source: BinifiMux Store

The largest force comes from the spreaderbar which is connected to the kite itself. However, this force does not directly have to go to the seat. There has been chosen to lead the strap of the spreaderbar around the frame (see figure C-3.6 - blue line). This will decrease the upward forces acting on the rail system.

The spreaderbar transmits a compressing force to the seat (see figure C-3.7). This force will have no influence on the fixation of the size, as the spreaderbar will be the last thing that is connected. Before that step occurs, the parts will already be locked onto each other. It needs to be tested in a real situation whether there is too much compression on the body of the athlete. If that is the case, an additional tube can be attached to the frame, which is wider than the seat, taking away the direct compression on the seat.

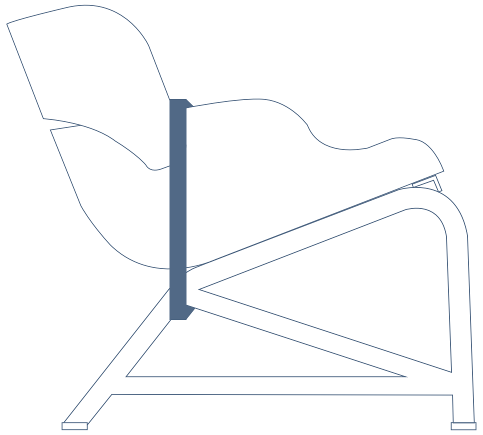


Figure C-3.6: spreaderbar all around frame

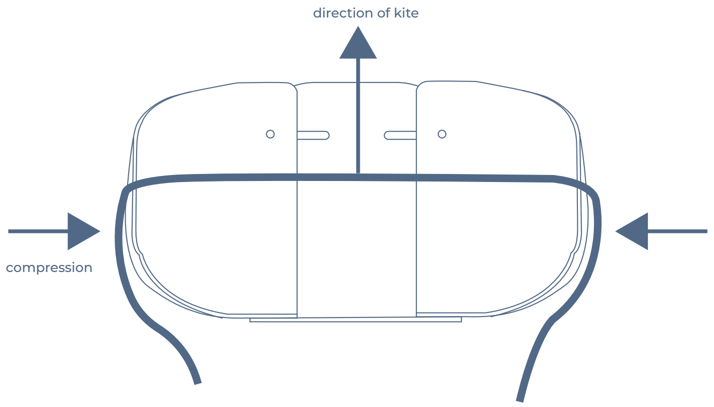


Figure C-3.7: compression on seat caused by spreaderbar/kite

Figure C-2.8: spreaderbar on original seat

Type B

Type B is more complicated as this one needs to be tightly fixed when adapting to the right size, while not interfering with the kite lines. This will need to be tested in a real-life situation whether there is any slipping during kitesurfing. For type B, carriage bolts (see figure C-3.9) will be used to allow easier fixation. The square neck makes sure that the bolt does not have to be fixed while tightening the bolt as the square shape restricts rotation.

Figure C-3.9: carriage bolts
Source: Shanghai G&T Industry

Spreaderbar

As mentioned before, the spreaderbar will be connected to the frame. Length of the strap can be adjusted using a buckle system. To guarantee its reliability, there has been chosen for aluminum buckles. In the past, plastic buckles on the spreaderbar of a kite seat have failed.

Figure C-3.10: aluminum buckle
Source: Nal Honindustrial

Textile

The textile part around the thighs could be fixed onto the seat, using the same bolts as the sliding mechanism in front. Another option is to glue the parts together. This is expected to have a better result, as the textile will be fixed over an entire length.

Figure C-3.11: indicating integration with side part

4 USE

4.1 SETTING THE SIZE

It is advised to set the hip width before the person is seated. To help choose the right size, a guide system can be found on the seat. The instructor should bear in mind that these dimensions are without wetsuits or clothes, as this depends on the situation.

While the person is seated, the side can still be pressed towards each other a few millimetres for an optimal fit. This means that the initial set size does not have to be exact. Nevertheless, marks are integrated into the knob and base part for easier adjustment (see figure C-4.1). These could also be replaced by a waterproof sticker to reduce costs.

There has been chosen for an angled knob, making sure if there are lines behind the knob, they will automatically slide off.

4.2 FOAM

On the largest size, there is a gap of 10cm without any padding. This can be solved by adding an additional piece of foam for all the seat widths larger than 35cm. It can be fixed with a velcro connection on the base plate.

In the middle of the bottom surface, foam could be removed to decrease buoyancy. The most important parts where foam should be present is around the trochanter, ischial tuberosities and the end of the seat.

It needs to be tested if no foam in the middle creates any discomfort or decubitus issues.

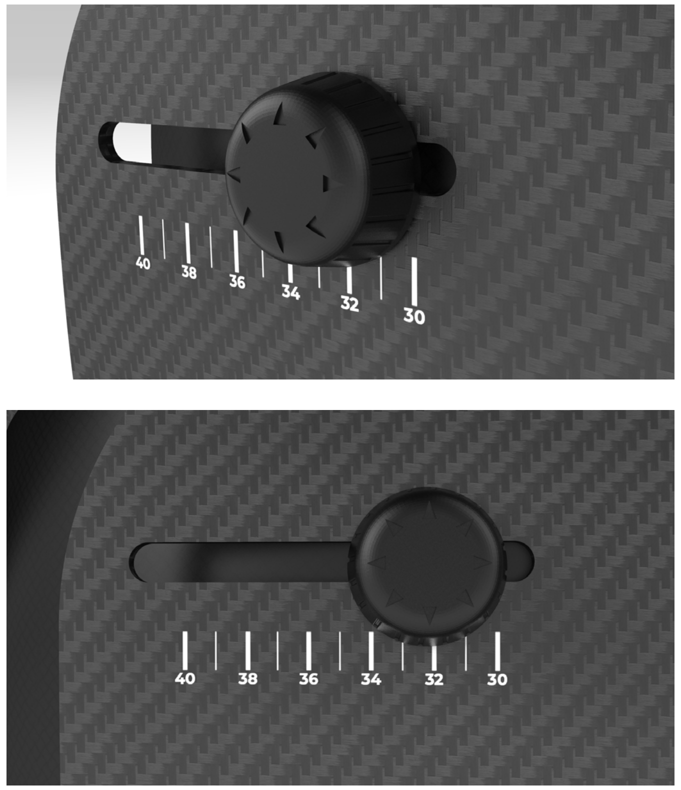


Figure C-4.1: marks on knob for easier setting of size

Figure C-4.2: additional piece of foam

5 VALIDATION

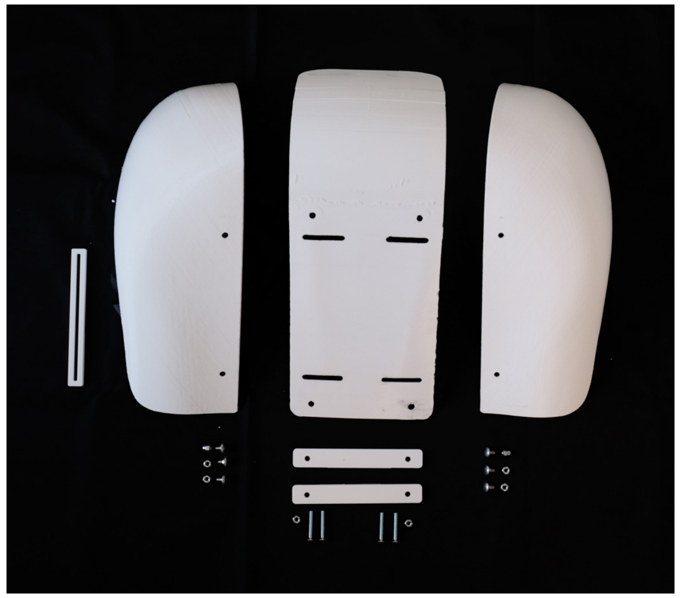
5.1 PROTOTYPE (1:1)

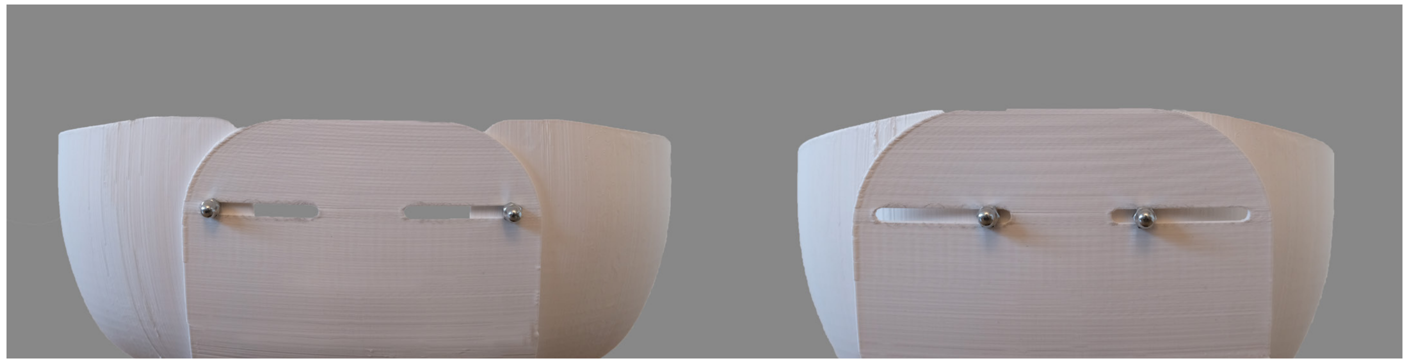
This prototype has been made on full scale, using 3D-printing. The material was intented to be reinforced with carbon fibre, resulting in a prototype that is strong enough to test in the sea. However, there were manufacturing issues which led to a choice of a lower quality printer and material (polyester). The Blackbelt printer of the Chemelot campus in Sittard has been used.

This is a bigger size printer, which allows for printing the parts in one go. However, problems still arose, because of the size of the print. One part of the print cools down while the warm nozzle is on the other side of the print. These temperature differences lead to warping and potentially breaking of the print. For an optimal result, it should be printed on a 3D-printer with a heated chamber.
Because of these reasons, only a test on land has been done. Later, the seat can be laminated with glass/carbon fibres for a test on the water.

Goal:
- Verify the rail system
- Mount on frame
- What problems arise, what works well, ...?

Pictures





4.1.2 Results and insights

Together with Willem Hooft, the seat has been mounted on the Wolturnus frame. This immediately gave some insights. It has been concluded that the design shows enough potential to pursue. However, some adaptions need to be made which are explained here and in the recommendations section.

It turned out the seat is situated more to the back on the frame compared to the original seat. This has a consequence that the back part is not supported by the frame and calves are too close to the frame. There has been chosen to move the position of the bolts 15mm backwards (see figure FIXME).

Figure C-4.FIXME: seat mounted on frame

What worked surprisingly well, is the use of a carriage bolt and a square hole instead of a standard round one (see figure FIXME). This allows for easy fastening. There has been decided to use this principle for the rails on the bottom as well. Especially these are harder to access because of the tubes underneath.

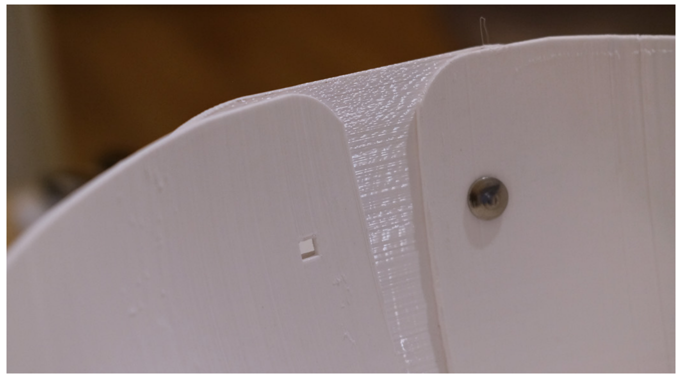


Figure C-4.FIXME: square neck/carriage bolt

Although the turning knobs turned out well and it is easy in use, there is still a safety concern. There is still a small chance of kite lines getting stuck behind. In consultation with Willem Hooft, there has been chosen to decrease on ease of use and replace the turning knobs by a rounded hex head. A tool will need to be used to fix the size.

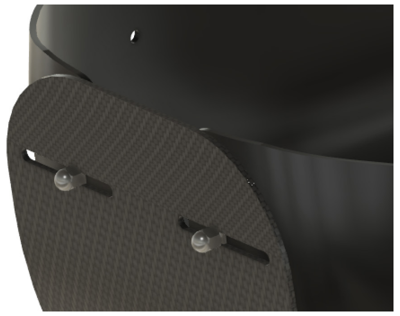


Figure C-4.FIXME: rounded head cap

When only the bolts on the back are fixed, the model has the intention to shift and not slide simultaneously (see figure FIXME). Sometimes the middle rails slide closer to each other. This could have multiple reasons. For example, the print is not entirely straight due to warping. Due to the tolerances of 3D-printing, the rails are not exactly the size of the bolts, which leaves some space for movement as well. What helped minimise this shifting effect, was using the square neck bolts here as well. This restricts the rotation movement. In a new prototype, this should be included and tested further.

Figure C-4.FIXME: shifting effect

Side should be a higher for better force transition

5.2 GENERAL RECOMMENDATIONS

Apart from the recommendations concerning the anthropometric data, these recommendations will cover the embodiment. The design will most likely have to go through some testing phases where aspects will need to be improved.

Currently, the side parts are lower than the original seat. The influence on the performance should be tested. There is a chance the **seat needs to come higher** and support more of the pelvis.

The current prototype can be reinforced for optimal strength and stiffness by **laminating** the parts with carbon. This will allow testing of the performance in a kite lesson setup. However, it is recommended to include the improvements and make a new 3D-print.

It is recommended to **reinforce the area around the rails and bolts** with an extra layer of carbon. It is expected that in these areas there will be a point load, which is more prone to break.

If it turns out that a **fixture** breaks during testing, the size or type of bolt can be easily adjusted. As mentioned in this thesis, predicting the behaviour of the forces on the material was too complex and time-consuming for this project. It would therefore be valuable to have someone with a mechanical engineering background further analyse the design. The **force analysis** that has been done in this project, can be used as a starting point. However, testing in a real-life situation will remain critical.

In terms of **sustainability**, laminating of a 3D-print is not optimal due to the post-processing difficulties. More specifically, separating the plastic print with the outer layer. However, for a functional prototype this might still be a good option.

Manual layup of carbon might be more labour intensive, but a good option once the volumes are large enough. As the mall is the same for all sizes, this can make sense and could be more economical than the current design with different sizes. In manual lay-up, it should be taken into account that fibres will need to be oriented in multiple directions. During kitesurfing, forces will act on the product from multiple directions, as the sport is dynamic. A uni-directional fibre is therefore not enough and the product will most likely break.

Regarding **prototyping**, it is recommended to print the next model on an Ultimaker with a carbon reinforced filament. This will make testing on the water possible (not performance, as stiffness is lower). But the principle can be tested, before spending a lot of money on a carbon composite material.

Due to the varying popliteal heights and BPD, it is recommended to have an **adjustable feet location**. This will make sure the thighs stay in close contact with the seat which allows optimal pressure distribution.

It is recommended to have another iteration on the **fixation of the rails**, in terms of rigidity and ease of use (eg. how best to fix bolts on the bottom between the tubes of the frame).

Although **the frame** was out of scope, it is recommended to have another look at this in further projects. There are points of improvement in terms of buoyancy and weight which could positively influence the whole set-up.

Apart from kitesurfing, the design has a big opportunity in **sit-wakeboard** as well. It could potentially be used without any additional adaptations. However, for sit-ski, the soft material around the thighs will create an issue in terms of protection during a crash on the ice.

5.3 FUTURE STEPS

Future steps are suggested on how to continue with the project. As the system is validated with a low-quality prototype, it is important to reinforce this model for a performance test on the water. This can be done by laminating it with glass fibres. After this, an iteration, if required, can be done. Together with the insights of the material project at Brightland's Chemelot Campus, a new prototype should be developed. From here, testing and iterating will be essential to get to the right strength, stiffness and performance.

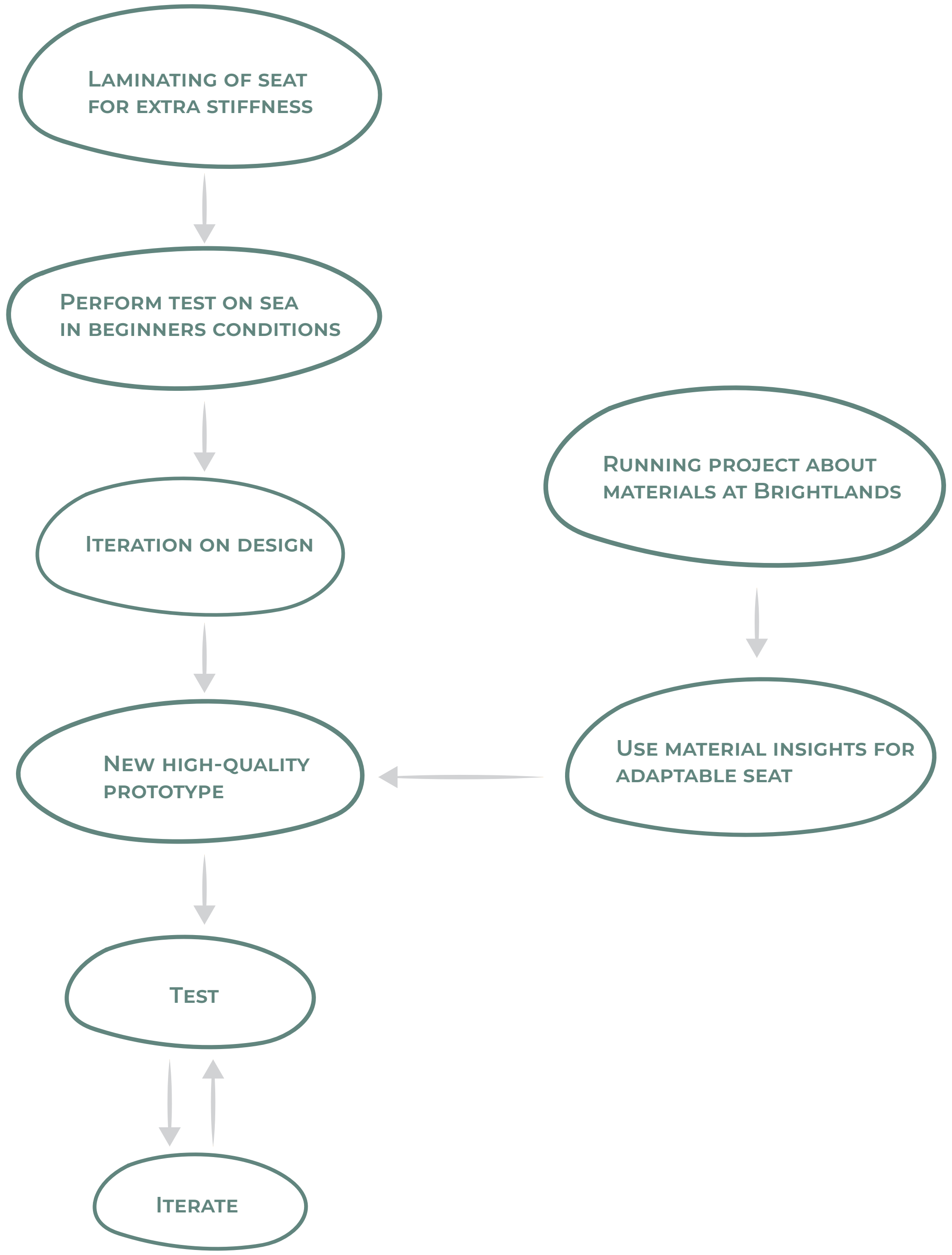


Figure C-5.FIXME: overview future steps

5.4 REFLECTION

At the start of the project, I struggled with how often and in which way I should update everyone involved. For me, this meant finding a balance between working independently and sharing with others. I think that in the beginning, I shared too little or not soon enough, but I believe this evolved positively during the project.

I am happy I started writing from the start, as this kept my work and mind organised. This also helped me in the later stages of the thesis to not get lost in all the written text.

I was planning to first make a low-fidelity 1:1 prototype to test its shape and form before making a functional prototype. However, I decided not to do this as Brightlands was able to print a functional prototype sooner than expected. Doing both of these steps was expected to take too long. However, the 3D-printing process got delayed by more than a month. This had an impact on the test and iterations I was able to perform, as the prints arrived only a week before my thesis deadline and in lower material quality than expected. In the end, I would have printed a low-fidelity prototype anyway as this would have been finished weeks earlier and I would have been able to have at least one decent iteration on shape and sizes.

Before the start of the project, I was worried I would struggle to work on this project by myself as all past projects were in a group. It turned out quite well and never felt I was on my own since I had my chair, mentor and Willem to help me out.

In the end, I am proud of the project I have worked on for the last 6 months. I have learned a lot of new skills and became more confident as a designer.

REFERENCE LIST

ABOUT THE IKO (n.d.). IKO. Retrieved 5 October 2021, from https://www.ikointl.com/about

Aissaoui, R., Dansereau, J., & Lemire, N. (1997). Effect of repositioning on seat and back pressure measurements and posture of able-bodied subjects. *Proceedings of the International Conference of Wheelchairs Seating.*

Anzeigen, A. B. V. K. (2019, November 10). A*dapted kitesurfing – a possible breakthrough?* KeepSeated. Retrieved 5 October 2021, from https://keepseated.com/2019/01/04/adapted-kitesurfing-a-possible-breakthrough/

Ash, D. (2002). An exploration of the occurrence of pressure ulcers in a British spinal injuries unit. *Journal of Clinical Nursing*, 11(4), 470–478. https://doi.org/10.1046/j.1365-2702.2002.00603.x

Ashdown, S., Schoenfelder, K., & Lyman-Clarke, L. (2004). Using 3D scans for fit analysis. *Journal of textilem apparel, technology and management, 4*(1).

Ashkenazy, S., & DeKeyser Ganz, F. (2019). The Differentiation Between Pain and Discomfort: A Concept Analysis of Discomfort. *Pain Management Nursing, 20*(6), 556–562. https://doi.org/10.1016/j.pmn.2019.05.003

Assisted Mountain Activities in Europe. (n.d.). Ski 2 Freedom Foundation. Retrieved 7 October 2021, from https://ski2freedom.com/en/locations-europe#accessible-resorts

Bahrampour, S., Nazari, J., Dianat, I., Asghari Jafarabadi, M., & Bazazan, A. (2019). Determining optimum seat depth using comfort and discomfort assessments. *International Journal of Occupational Safety and Ergonomics, 26*(3), 429–435. https://doi.org/10.1080/10803548.2018.1550912

Bere, P., Neamtu, C., & Udroiu, R. (2020). Novel Method for the Manufacture of Complex CFRP Parts Using FDM-based Molds. *Polymers, 12*(10), 2220. https://doi.org/10.3390/polym12102220

Bourgois, J. G., Boone, J., Callewaert, M., Tipton, M. J., & Tallir, I. B. (2013). Biomechanical and Physiological Demands of Kitesurfing and Epidemiology of Injury Among Kitesurfers. *Sports Medicine, 44*(1), 55–66. https://doi.org/10.1007/s40279-013-0103-4

Byrne, D. W., & Salzberg, C. A. (1996). Major risk factors for pressure ulcers in the spinal cord disabled: a literature review. *Spinal Cord, 34*(5), 255–263. https://doi.org/10.1038/sc.1996.46

Chen, Y. L. (2021). Changes in external ischial tuberosity width at varying trunk–thigh angles between sexes using two measurement methods. *Scientific Reports, 11(*1). https://doi.org/10.1038/s41598-021-99232-w

Choi, S., & Ashdown, S. P. (2010). 3D body scan analysis of dimensional change in lower body measurements for active body positions. *Textile Research Journal, 81*(1), 81–93. https://doi.org/10.1177/0040517510377822

de Looze, M. P., Kuijt-Evers, L. F. M., & van Dieën, J. (2003). Sitting comfort and discomfort and the relationships with objective measures. *Ergonomics, 46*(10), 985–997. https://doi.org/10.1080/0014013031000121977

de Luigi, A. J., & Cooper, R. A. (2014). Adaptive Sports Technology and Biomechanics: Prosthetics. *PM&R, 6,* S40–S57. https://doi.org/10.1016/j.pmrj.2014.06.011

Diaz, R., Miller, E. K., Kraus, E., & Fredericson, M. (2019). Impact of Adaptive Sports Participation on Quality of Life. *Sports Medicine and Arthroscopy Review, 27*(2), 73–82. https://doi.org/10.1097/

jsa.0000000000000242

Disability skiing: The rise of accessible ski resorts. (2012). ENAT - European Network for Accessible Tourism. Retrieved 7 October 2021, from https://www.accessibletourism.org/?i=enat.en.news.1364

Do you really need kitesurfing lessons? | IKO. (2018). IKO. Retrieved 5 October 2021, from https://www.ikointl.com/blog/do-you-really-need-kitesurfing-lessons

Dyneema Carbon. (n.d.). @dsm. Retrieved 28 February 2022, from https://www.thedyneemaproject.com/en_GB/the-fabrics/dyneema-carbon.html

Edsberg, L. E., Black, J. M., Goldberg, M., McNichol, L., Moore, L., & Sieggreen, M. (2016). Revised National Pressure Ulcer Advisory Panel Pressure Injury Staging System. *Journal of Wound, Ostomy & Continence Nursing, 43(*6), 585–597. https://doi.org/10.1097/won.0000000000000281

Flexform. (2020, February 21). *EVA POLYURETHANE FOAM.* Retrieved 12 January 2022, from https://www.flexform.it/en/outdoor/materials/polyurethane/eva-polyurethane-foam#gref

Foam Factory. (n.d.). D*ifference Between Open Cell And Closed Cell Foam*. Foambymail.Com. Retrieved 12 January 2022, from https://www.foambymail.com/difference-between-open-cell-and-closed-cell-foam.html

Fossati, F. (2009). *Aero-hydrodynamics and the Performance of Sailing Yachts.* Adlard Coles Nautical.

Goswami, A., Ganguli, S., & Chatterjee, B. (1986). Ergonomic analysis of wheelchair designs. *Clinical Biomechanics, 1*(3), 135–139. https://doi.org/10.1016/0268-0033(86)90003-3

Gutierrez, E., Alm, M., Hultling, C., & Saraste, H. (2003). Measuring seating pressure, area, and asymmetry in persons with spinal cord injury. *European Spine Journal, 13(*4). https://doi.org/10.1007/s00586-003-0635-7

Harms, M. (1990). Effect of Wheelchair Design on Posture and Comfort of Users. *Physiotherapy, 76*(5), 266–271. https://doi.org/10.1016/s0031-9406(10)62219-5

Hastings, J. D., Fanucchi, E. R., & Burns, S. P. (2003). Wheelchair configuration and postural alignment in persons with spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 84(*4), 528–534. https://doi.org/10.1053/apmr.2003.50036

Henderson, J. L., OTR, M. D., Price, S. H., Brandstater, M. E., & Mandac, B. R. (1994). Efficacy of Three Measures to Relieve Pressure in Seated Persons With Spinal Cord Injury. *Archives of Physical Medicine and Rehabilitation, 1994 (75)*(5), 535–539. https://doi.org/10.1016/S0003-9993(21)01615-4

IKO. (2017). *Kitesurfing for People with Disabilities*. Retrieved 5 October 2021, from https://www.ikointl.com/blog/kitesurfing-people-disabilities

IKO. (2019). *The Essential Guide on How to Get Started and Learn Kitesurfing*. Retrieved 5 October 2021, from https://www.ikointl.com/blog/essential-guide-how-get-started-and-learn-kitesurfing

International Sailing Federation. (2012). *ISAF Kiteboarding Format Trials.*

Invernizzi, M., de Sire, A., & Fusco, N. (2021). Rethinking the clinical management of volumetric muscle loss in patients with spinal cord injury: Synergy among nutritional supplementation, pharmacotherapy, and rehabilitation. *Current Opinion in Pharmacology, 57,* 132–139. https://doi.org/10.1016/j.coph.2021.02.003

ISO. (2017, October). *Basic human body measurements for technological design - Part 1: Body measurement definitions and landmarks* (ISO 7250–1:2017,IDT). Koninklijk Nederlands Normalisatie-instituut.

Jason Mills LLC. (2021, April 30). *Nylon vs Polyester: Resistance to Water, Fire, Sun (UV) and Mildew - Jason Mills LLC*. Retrieved 5 January 2022, from https://www.jasonmills.com/blog/nylon-vs-polyester/

Juriga, B. J., Yang, Y. S., & de Luigi, A. J. (2017). Adaptive Alpine Skiing and Para-snowboarding. *Adaptive Sports Medicine*, 251–299. https://doi.org/10.1007/978-3-319-56568-2_23

Kenedi, R. M., Cowden, J. M., & Scales, J. T. (1976). *Bed Sore Biomechanics.* Macmillan Publishers.

Kitesurfing Handbook. (n.d.). *History of kitesurfing.* Retrieved 12 October 2021, from https://kitesurfing-handbook.peterskiteboarding.com/history-of-kitesurfing

Kitesurfist. (2018, October 14). *How fast do kitesurfers go?* Retrieved 12 October 2021, from https://www.kitesurfist.com/how-fast-do-kitesurfers-go/

Kochem, H. G., & Zimmer, D. (2004). Flexible seat concept for improved occupant protection. *ATZ worldwide, 106(*7–8), 11–14. https://doi.org/10.1007/bf03225300

Lajunen, K., Rapp, W., Ahtiainen, J. P., Lindinger, S. J., & Linnamo, V. (2020). Effect of Sitting Posture on Sit-Skiing Economy in Non-disabled Athletes. *Frontiers in Sports and Active Living, 2*. https://doi.org/10.3389/fspor.2020.00044

Langelier, E., Martel, S., Millot, A., Lessard, J. L., Smeesters, C., & Rancourt, D. (2013). A sit-ski design aimed at controlling centre of mass and inertia. J*ournal of Sports Sciences, 31*(10), 1064–1073. https://doi.org/10.1080/02640414.2012.762598

Laskowski, E. R. (1991). Snow Skiing for the Physically Disabled. *Mayo Clinic Proceedings, 66*(2), 160–172. https://doi.org/10.1016/s0025-6196(12)60488-1

Mayo Clinic. (2020, February 29). *Bedsores (pressure ulcers).* Retrieved 20 October 2021, from https://www.mayoclinic.org/diseases-conditions/bed-sores/symptoms-causes/syc-20355893

Mendes, P. V. B., Gradim, L. C. C., Silva, N. S., Allegretti, A. L. C., Carrijo, D. C. D. M., & Cruz, D. M. C. D. (2018). Pressure distribution analysis in three wheelchairs cushions of subjects with spinal cord injury. *Disability and Rehabilitation: Assistive Technology, 14*(6), 555–560. https://doi.org/10.1080/17483107.2018.1463399

Metissagesbags. (2021, May 19). Polyester 600D : *What really hides behind this generic designation. Bags Development and Manufacturing* | Metissagesbags.Com. Retrieved 5 January 2022, from https://www.metissagesbags.com/metissages-blog/polyester-600d-what-really-hides-behind-this-generic-designation/2018/11

Oborne, D., & Clarke, M. (1975). *Questionnaire surveys of passenger comfort. Applied Ergonomics, 6(*2), 97–103. https://doi.org/10.1016/0003-6870(75)90302-6

Oh, H., Johnson, W., & Syrop, I. P. (2019). Winter Adaptive Sports Participation, Injuries, and Equipment. *Sports Medicine and Arthroscopy Review, 27*(2), 56–59. https://doi.org/10.1097/jsa.0000000000000236

Oxford Learners' Dictionaries. (n.d.). *Oxford Learner's Dictionaries*. Oxfordlearnersdictionaries.Com. Retrieved 21 October 2021, from https://www.oxfordlearnersdictionaries.com/

Park, U. J., & Jang, S. H. (2011). The Influence of Backrest Inclination on Buttock Pressure. *Annals of Rehabilitation Medicine, 35*(6), 897. https://doi.org/10.5535/arm.2011.35.6.897

Pinto Da Silva, F. (2011). Design and milling manufacture of polyurethane custom contoured cushions for wheelchair users. *Australasian Medical Journal, 4(*9), 500–506. https://doi.org/10.4066/amj.2011.963

Polymer Technologies Inc. (2021, March 24). *Open vs. Closed Cell Foam: Understanding Permeability*. The Official Blog of Polymer Technologies, Inc. Retrieved 12 January 2022, from https://blog.polytechinc.com/open-vs-closed-cell-foam-article/

Reenalda, J., Jannink, M., Nederhand, M., & IJzerman, M. (2009). Clinical Use of Interface Pressure to Predict Pressure Ulcer Development: A Systematic Review. *Assistive Technology, 21*(2), 76–85. https://doi.org/10.1080/10400430903050437

Richards, L. G. (1980). *On the psychology of passenger comfort*. Human Factors in Transport Research, 2, 15–23.

Richtlijnendatabase. (2018). *Goed (leren) zitten bij dwarslaesie revalidatie*. richtlijnendatabase.nl. Retrieved 20 October 2021, from https://richtlijnendatabase.nl/richtlijn/dwarslaesierevalidatie/goed_leren_zitten_bij_dwarslaesie_revalidatie.html

Ruibag Factory. (n.d.). *What's the difference between 600D polyester, 500D Nylon, Cordura?* RUIBAG. Retrieved 5 January 2022, from https://www.ruibagfactory.com/600d-polyester/

Shepherd Center. (n.d.). *Spinal Cord Injury Types & Treatment* | Shepherd Center. Retrieved 5 October 2021, from https://www.shepherd.org/patient-programs/spinal-cord-injury/about

SilverBobbin. (2021, August 22). *What Is The Strongest and Durable Fabric Material?* Retrieved 22 December 2021, from https://silverbobbin.com/strongest-fabric/

Snowsports Industries America. (2016). *Report on Global Ski & Snowboard Participation*. Retrieved 7 October 2021, from https://snowsports.org/report-on-global-ski-snowboard-participation-released/

Spinal Cord, Inc. (2020). *T9 - T12 Vertebrae Thoracic Spinal Cord Injury* | SpinalCord.com. Retrieved 5 October 2021, from https://www.spinalcord.com/t9-t12-vertebrae-thoracic-spinal-cord-injury

Stephenson, I. (2015, September 22). *Women Who Kite: The 10% of Kiteboarding*. The Kiteboarder Magazine. Retrieved 5 October 2021, from https://www.thekiteboarder.com/2014/04/women-who-kite-the-10-of-kiteboarding/

Stephenson, I. (2020, September 18). *F-One Works with Thierry Schmitter to Develop Sit-Kiteboards*. The Kiteboarder Magazine. Retrieved 5 October 2021, from https://www.thekiteboarder.com/2020/09/f-one-works-with-thierry-schmitter-to-develop-sit-kiteboards/

Surfertoday. (2021, April 20). *How to ride upwind in kiteboarding*. Surfertoday.Com. Retrieved 14 October 2021, from https://www.surfertoday.com/kiteboarding/how-to-ride-upwind-in-kiteboarding

Trewartha, M., & Stiller, K. (2011). Comparison of the pressure redistribution qualities of two air-filled wheelchair cushions for people with spinal cord injuries. *Australian Occupational Therapy Journal, 58*(4), 287–292. https://doi.org/10.1111/j.1440-1630.2011.00932.x

Valent, L., Nachtegaal, J., Faber, W., Smit, C., Kaandorp, E., Pratt-Sutherland, S., Houdijk, H., Adriaansen, J., Groot De, S., & Post, M. W. M. (2019). Experienced sitting-related problems and association with personal, lesion and wheelchair characteristics in persons with long-standing paraplegia and tetraplegia. *Spinal Cord, 57*(7), 603–613. https://doi.org/10.1038/s41393-019-0272-6

van Boeijen, A., Daalhuizen, J., van der Schoor, R., Zijlstra, J., van Boeijen, A., & van der Schoor, R. (2014). *Delft Design Guide*. Macmillan Publishers.

Verbunt, M., & Bartneck, C. (2009). Sensing Senses: Tactile Feedback for the Prevention of Decubitus Ulcers. *Applied Psychophysiology and Biofeedback, 35*(3), 243–250. https://doi.org/10.1007/s10484-009-9124-z

Williams, C. (2021, June 24). *Hard-working Boa® fit system, built for life*. HSI. Retrieved 14 December 2021, from https://www.hsimagazine.com/press-release/hard-working-boa-fit-system-built-for-life/

WoundSource. (2016). *What is a Decubitus Ulcer?* Woundsource.Com. Retrieved 20 October 2021, from https://www.woundsource.com/blog/what-decubitus-ulcer

WU, S. K., & WILLIAMS, T. (2001). Factors influencing sport participation among athletes with spinal cord injury. M*edicine and Science in Sports and Exercise,* 177–182. https://doi.org/10.1097/00005768-200102000-00001

Zhang, L., Helander, M. G., & Drury, C. G. (1996). Identifying Factors of Comfort and Discomfort in Sitting. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 38*(3), 377–389. https://doi.org/10.1518/001872096778701962

Zijlstra, J., & Daalhuizen, J. (2020). *Delft Design Guide (revised Edition)*. Macmillan Publishers.

APPENDIX

I. PROJECT BRIEF

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: Callens
initials: M.Z.C   given name: Marinke
student number: 4556747
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): (X) 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: Anton Jellema   dept. / section: AED
** mentor: Gonny Hoekstra   dept. / section: AED
2nd mentor: Willem Hooft
organisation: Willem Hooft Foundation
city: country: The Netherlands

comments (optional): Chair and mentor from same dept./section. A. Jellema has experience in Sports Eng. and Medical Design, also connected to UPPS fieldlab. For the 'EurErg' ergonomics track, I need one committee member to be a registered ergonomist, which is G. P. M. Hoekstra.

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.

Design of a seat for sit-kite with optimal ergonomic fit, for use in surfschools — 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: 27 - 09 - 2021   end date: 11 - 03 - 2022

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, ...).

Sit-kiteboarding is a sport derived from the better-known sport kitesurfing. It is meant for people with a physical disability. To perform the sport, muscles in the legs are not needed, which makes the sport suitable for people paralysed in the legs (eg. due to spinal cord injury) or missing one or both legs. However, at least a part of the upper thighs is needed to clamp the athlete into the seat. Also, full arm function and core stability are needed for controlling the kite and board. People from the following paralympic classifications could be part of the target group: spinal cord injuries (ISMWSF) and orthopaedic conditions/amputees (ISOD).

The difference to kiteboarding is that the athlete is seated on the board. This is currently done by mounting an aluminium frame with a carbon seat on an adapted board. At the moment, there is no company making tailor-made seats, so most people would buy the existing sit-ski ones. The current seat (used from sit-ski) comes in 7 different sizes with a price of around 1600 EUR. This still excludes the price of the frame and board.

The sport is currently performed all over the world by a small number of people. Mostly with experience in watersports before their spinal cord injury. In the Netherlands there are around 4 people performing the sport, while Willem Hooft Foundation already has 20 interested people on their list. Currently, there is only one school worldwide focussed on sit-kite lessons, this school is already fully booked for the next two years. This creates a lack of accessibility to lessons and familiarity with the sport. Learning the sport from experienced instructors is crucial for safe handling of the kite. On top of that are the starting costs for the beginner high, because the material has to be purchased by the athlete itself before even trying it out. Offering lessons and reducing these initial costs creates an opportunity for making the sport more accessible to try it out and improve in it. These lessons will be different for a sit-kite student and will most likely be a private lesson instead of a group lesson of 2 to 4 people. The person will also need more attention, eg. helping him/her in and out of the seat, pushing to the water and additional safety guidelines/rescue.

The project has been set up in cooperation with Willem Hooft Foundation (willemhooftfoundation.com). This is a Dutch foundation that promotes seated watersports for people with physical disabilities. Their focus lies on sit-kitesurfing (see fig. 1), but they also offer sit-wakeboard days (see fig. 2). They have a goal to make sit-kite easier accessible and safer. One way to approach this is to make sit-kitesurfing accessible in existing kitesurf schools with suited equipment and instructions. The project will focus on developing an adaptable seat for sit-kiteboarding in surfschools.

Also the fieldlab UPPS (Ultra Personalized Products and Services) is involved in this project. They support companies/organisations with the design process and production of personalized products, using various techniques such as parametric shape modelling and 3D scanning. Their experience and knowledge will be used for creating a well-fitting product for multiple users.

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APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair ______________________ 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 ______________________

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.

As it is important to have a seat fitting to the athlete's body type, a surfschool should purchase all 7 sizes next to the board and frame. This is a big cost for schools and is one of the reasons it is not done yet. Also, there is often not a lot of storage room in the surfschool to store those additional seats. Next to that, it requires effort to change the seat to the board. An adjustable seat could solve this, but more analysis needs to be done in order to further define the problem and will be part of the project.

Since the seat will be re-designed for surfschools, the project will tackle the design of a seat for beginners, rather than for advanced sit-kiters. This target group will demand additional requirements, under which even more feeling safe and being safe in use. For this project, there will be looked at adult users only but can later be extended to children. As the athlete requires additional help compared to standard kite lessons, it is important to include the instructor as a user as well. He/she will also play a role in setting up the gear and adjusting the seat. The way the lessons will be given is important to understand the whole context of how the product will be used, but designing the lessons will not be the focus of the project. However, the design can include suggestions for this.

Another aspect is that the current seat is designed for sit-ski, the strength and stiffness of the chosen material will have other requirements than for sit-kitesurfing and the material should therefore be reexamined. The seat is currently made out of a carbon composite, but other materials are possible.

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 of a seat for sit-kite with optimal ergonomic fit, for use in surfschools, while minimizing the number of seats needed.

There are multiple parameters influencing the fit, researching which dimensions will have a large (or negligible) influence on the fit and comfort of the seat will be crucial for the design. It is known that the hip breadth and tight width will play an important role in the fit. These dimensions are already available, however the thigh width will have large differences between people with and without muscle strength in the legs and has to be taken into account. This research will be done by collecting anthropometric data of the target group, supported by the activities of the UPPS fieldlab. In order to further define the current problem of the lack of accessibility to sit-kite, more research is required. This is expected to be done through desktop and user research of both the schools as the (potential) students and sit-kiters. In this research, it will also be important to tackle other aspects, such as the feeling of safety, discomfort and performance. But also how the course will be set up. When designing the seat, research of materials and safety have to be looked at as well. This can be done by finite element analysis (FEA).

The project will reflect in clear anthropometric guidelines for designing for sit-kiteboarding and a proof-of-concept of the seat. The concept will be used for evaluation of the system, to be sure it is suitable enough to continue. This concept can be validated in the lab, but preferably in such a stage (working prototype) that it can be used in the sea for testing.

introduction (continued): space for images

image / figure 1: Current set-up of the carbon seat, mounted on an aluminum frame

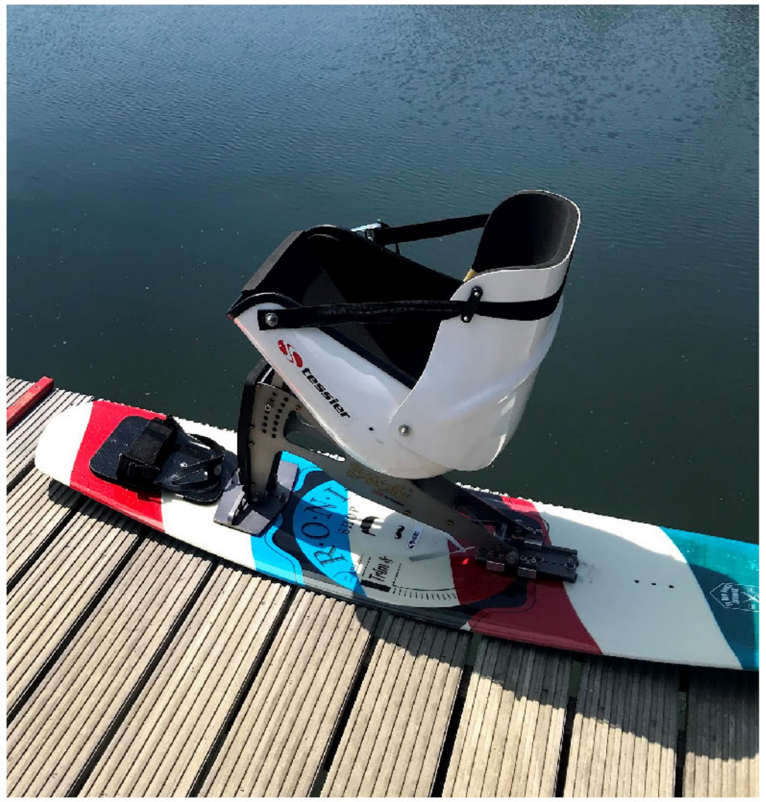


image / figure 2: Seat of the brand Tessier, mounted on a wake-board

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.

As a child, I have grown up at the Belgian seaside where I learnt kitesurfing, surfing and worked as a coast lifeguard. Watersports have been a big part of my life, and therefore sparks my interest to combine this with Industrial Design Engineering. During my master, I did a 6-month internship at a French kitesurfing company (Manera/F-One) where I learnt more about designing for watersports.
Apart from that, I have always had an interest in designing for Global Health and Medisign. This also reflected in the projects done during my Bachelor Thesis (building kit for children with muscular dystrophy) and Master projects (Schistoscope for rural Africa, Syringe Extension Device for Kenya and an Inclusive Coffee Experience for nursing homes). Designing for an adaptive sport seemed like a perfect fit to me.

I still have ambitions to learn more about ergonomics (anthropometrics and comfort) as this is an important factor for sports. During my internship, I feel like I lacked knowledge about this. More specifically I would like to learn how to better perform user research and research about discomfort, as well as methods to collect the right anthropometric data (eg. 3D-scanning). Next to that, I would like to become more experienced in designing for sports, eg. which factors you have to be aware of and how the test performance and comfortability. Although I did the elective Designing for Composites, I can still learn a lot about composites and will most likely be a big part of the project as well.

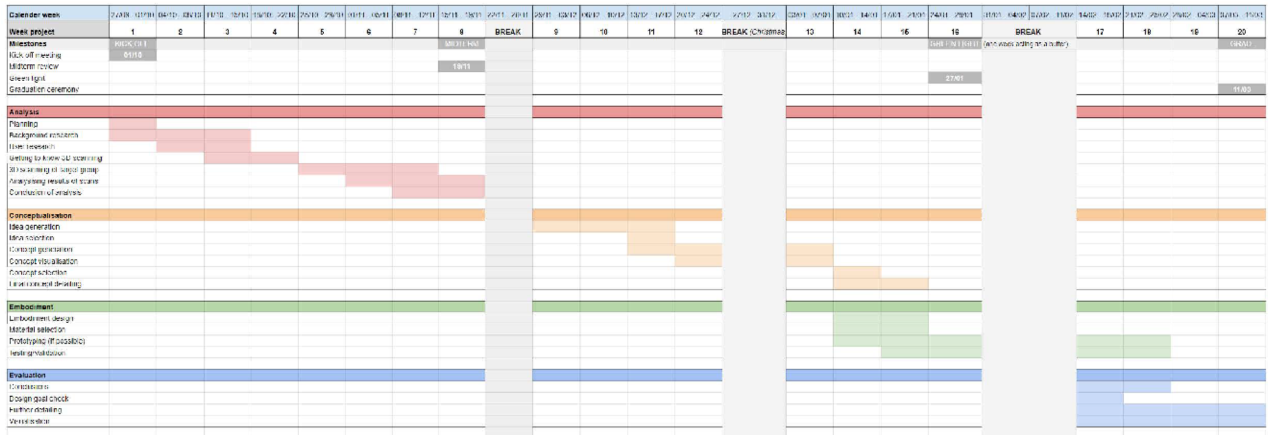
FINAL COMMENTS

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

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 27 - 9 - 2021   11 - 3 - 2022 end date



The graduation project is based on the double diamond design process. Similarly, the project plan is divided into four actionable design steps—Analysis, Conceptualization, Embodiment, and Evaluation.

I will work on the project, full-time for 20 weeks, 8 hours a day. After the midterm, I planned a break of one week. Another break will be during the holiday season, one week will be sufficient. Currently, I have planned two additional week sof a break after the green light. One week will be for holidays, the other week will act as a buffer (eg. sick, unexpected problems, …).

Initials & Name M.Z.C Callens Student number 4556747

Title of Project Design of a seat for sit-kite with optimal ergonomic fit, for use in surfschools

II. Interview questions and insights

A. QUESTIONS

Experienced sit-kiters

GENERAL
- Tell me about how you learnt kitesurfing.
- Level SCI?
- There are not many schools offering sit-kite lessons. Why do you think that is?
- What steps do you undertake if you want to go kitesurfing?

BEGINNERS VS EXPERIENCED
- Comparing your ideal seat to one for beginners: what will be the difference?
- You are an experienced kitesurfer. Can you describe the difference with beginners (independence, technique, ...)?

EQUIPMENT
- What is your full equipment?
- Which size of seat do you have?
- Did you customise anything, and why?
- If you are in trouble while kiting (eg. continuous kiteloop), how do you bring yourself into safety?

SEAT
- How important is the fit of the seat?
- Where should it be tight/more spacious?
- Does it have an influence on safety, (dis)comfort or something else?
- When you would buy a new seat, which aspects would you mostly look at?
- What do you like about your seat?
- What can still be improved about the current seat?
- Discomfort; padding?

Existing schools
- Function; experience with sit-kite (years); country

GENERAL
- Why did you start with offering sitkite lessons?
- What is your experience with sitkite (years, +/- amount of students)?
- Is there a high demand in your school for adapted kitesurfing? How many students per year?
- Who are the participants in your sitkite course?
- Age
- Gender
- Prior experience with kitesurfing?
- Which disability? If SCI, which level?
- You are one of the only ones offering sitkite lessons. Why do you think there are no more schools on the list?

COURSES
- Can you walk me through a sitkite lesson?
- Show step per step the customer journey; ask questions about the step
- Ask where in the process they offer help and where it can go wrong
- Differences with standard lessons

TECHNICAL EQUIPMENT
- Which seats, frame and board do you use?
- Pictures of material and storage
- Ease of storage?
- Any pain points (storage, assembly time, costs, ...)
- Did you do any adaptions to the equipment? What and why?

SEAT
- What do you like about the current seat and why?
- (safety, comfort, performance, ...)
- What are the issues using the seat?
- How many seats do you have?
- What is the most used seat in size?
- What is least used?
- Can you tell me about the importance of the fit of the seat? And why?

PROJECT
- What do you think of an adaptable seat, this way reducing the number of seats needed and effort needed to change to the board?
- Which dimension of the student's body would you consider as most important?

B. INTERVIEWS

INTERVIEW MARKUS P.

Markus: I started 15 years ago with kitesurfing. I love it whenever I go for a weekend or holiday. When I started there was nothing, nobody even knew what you need

Marinke: Did you learn if it's someone else or all by yourself

Markus: All by myself. I mean, I went to different kinds of schools to ask them if they can bring me some advice or support. because I have to learn kite before my accident I had a skydive accident 20 years ago and so I had to learn like kite surfing as well. I just asked some schools a couple of times. It just took like five years to learn.

Woody Coockie built the first boards. So then, at least concerning the boards this was a big step to be able to buy this board or to do sports.

I had a very good friend who always stay with me. Because of course I couldn't go up with yourself. So I always needed the boat to bring me back. I find a school who was willing to take me with them on the boat and then of course that makes it a lot easier than

Marinke:
So what's the kind of equipment that you tried out yourself?

Markus:

I just bought different board sizes I ended up using door board. The boards from Coockie were too soft.

But I tried out a lot of different board sizes and board shapes and so on. And then the other thing is I also tried out somewhere you know, my reaction was like a wave.

I couldn't use the regular wave boards. And , I started to build my own boards a little bit later. I've just got together with some friends or I contacted some board builders I met on the telephone. They started to build some products for me.
Nowadays it works quite well. Okay.

Okay, that's that's actually that's pretty much one of my first frames. It was just aluminum. I wanted to be able to adjust it in terms of height and angle.

Marinke:

And why would you want to be able to depth it?

Markus: Because I didn't know what's best for me. Just to try out different sit positions.
But as you can imagine, it wasn't super stable. At the end, I had to make it a little bit more stable. That's why I welded these joints.

Marinke: The board is really thin!

Markus: The board is shaped is thin. But it has a carbon fiber and fiberglas, makes it super stiff. So it doesn't bend. Then it's always a question of floating. , we don't want to float it too much. But it still has to flow partly. Because when I for example, crash or whatever I can get out of the seat.

Marinke: What about an impact vest?

Markus: , when I'm sitting in the water, it of course helps me to stay upright. It's just much easier. And then as you can see here I am wearing a harness, for example. Most of the other guys. They have the harness attached to the seat. , they have the backrest.

Marinke: Why do you prefer this setup?

Marinke: Because when I started, I have it also the other way. And once I crashed and my kite started to invert, I couldn't really use the safety that they built back then. It would not open up because too much pressure.

, so that wasn't really nice situation back then. Because the quick release back then, is not the safety release that you have now. It was really scary, so I tried something else. And that's why I started then to use a regular harness.

I was able to do so as have a low SCI. I have most of my lower body muscles. I can still use them. So that makes me able to just use a harness. But it's more demanding. I have so much pressure here on the side of the ribs. Now when I'm getting older, I think about using the other system with a hard backrest.

[Markus talks about the frames he made]
Marinke: Do you prefer to have it a bit lower like this?

Makus: I actually nowadays I prefer to see a little bit higher. But for beginners, it's better to be like, lower and more compact. Because the lower you sit, the easier it is to have the balance. But then later on when you are more experienced, you can use the lower. Because when you want to go upwind or to edge, it is easier when you sit a little bit higher. That's why then I started to build the other one. It was so difficult to find someone to build these for a reasonable price. , because I can't order 250 pieces. But I was super happy for them. Just I ordered 10 pieces of each. To be honest, I think I sold most of them.

[Markus shows pictures of setup]

Since I travel a lot. I don't like to travel with too much equipment.. I have to be able to carry it somewhere by myself. Alsom I use just one type of screws on the all the equipment. It's the same screws that I attach the frame to the board that I attach the seat to the frame. I don't have to carry too many screws and spare parts, and so that makes it a lot easier when I lose something. It goes in the overhead compartment on the airplane.

This whole setup as been seen here. It's about three kilogram. So which makes it easy to carry it. I put it in the overhead compartment the airplane, and it is then protected. Because when I have to pull it in the kite bag, I am never sure if it arrives good.

Marinke: What about your seat, is it also from Tessier?

Markus: No it is from a German company, but it is almost the same. As you can see I created a lot of holes in it for the water. If there is too much water you can't do anything with the board. That is why there are the holes on the side. The bottom is almost open. The water can flow through it. Because otherwise if it's closed there is too much water.

Marinke: Did you also try other seats like the bucket yourself? So you had one with the high backrest. But did you also try like other brands or something?

Markus:
Yes. I mean, I try. I don't know if you know Nikki, from Spain, I mean, he's actually from Austria, but he's living in Tenerife. He uses the one made for waterskiing. I tried this one as well.
Using a harness there's no space for the backrest. On the other side the harness gives me some lower body stability, so it's kind of like a backrest. But ofcourse more demanding.
I've tried all these things out but I like the system that Willem and Thierry a lot. The downside is that if something happens you can not get out of the board.

[Marinke explaining direction of context, about adaptable seat and the many sizes needed.]

Markus: , of course that's that's definitely an issue. I mean for example, the school on the Garda lake, they have three or four different seat sizes. I think with three or four sizes you can like cover 80% of the potential customers.
We also we were thinking a lot of like building an adjustable seat, where you can go wider and more narrow. The problem is with the backrest. But probably if you can develop something that you can like go smaller or lighter togheter with the backrest it works. I could really imagine that it's possible to build something that you can make more narrow. For example with rails, when you attach the seat and then you can just slide it open and wider. But , that's an issue with the equipment in general. And that it's quite expensive.
Especially if you are a beginner and you just want to try it out. It's a big step to buy all of the gear.
The question is the rates you can make them pay. . So it's tricky. You just need, like a foundation or something to support. Otherwise it doesn't go. I mean, financially. Business wise you know, that's the biggest issue for schools, I think.
The school in Garda, they got some support from the government. So the government paid for all the equipment. They made it possible to buy two or three sets of equipment and all the stuff.

But I think there's a lot of foundation and it shouldn't be that difficult to find somebody to support this project. Because at the end, it's a cool project. And I think there's a lot of people who are open to support it.

Marinke: If you were thinking about adaptable seats, then the hip width is very important, but maybe some other dimensions? Because the backrest, maybe that has to be adaptable as well. Or do you think that can be a bit more loose?

Markus: I mean, the problem is the backrest has to fit to the seat. First of all, if it doesn't fit, you can't move it. So it's just like, not possible anymore. And then of course, it's another thing is the height of the backrest. I don't think for a school, you to have different types. Because if you have like a medium, this this will fit for 80 percent of the class. But then, of course, when you buy your own gear, you can personalise.

Marinke: Definitely. Can you maybe describe the difference between beginners and yourself because you're an experienced kiter.

Markus: I go to the water with my wheelchair, someone brings my board and I start there. I need like 20cm of water. Someone also passes my kite when I am ready. When I go back to the beach, I can go upwind to my wheelchair. Depending on the wind direction, I can land the kite on the beach or ride to the beach and someone takes over the kite. A beginners can not go upwind so they will need a boat, or go deeper in the water.

Marinke: I was thinking about what you said earlier about the pressure on your ribs. Have you tried using a sliding hook?

Markus: Yes I tried, but the problem is that the bar is too far away with a sliding hook, especially when fully depowered. Now I used a soft hook, like a ball. It goes together with the direction of the kite.

Marinke: How does your safety work?

Markus: The same as othter kitesurfers as I use a harness. I only have one strap around my legs with buckle, which is super easy to open.

Marinke: Did you remove or added any padding after buying the ski seat?

Markus: Yes I added padding. I actually used a yoga mat because it is stable and soft. I only used a little bit on the back and then at the bottom. But the thing is, I always use a wetsuit, even in Bonaire but then I just cut off the legs and above my waist. On another seat I have a honeycomb foam, which is good as the water can go through it. Otherwise the holes I made do not work anymore.

Interview Marc (kitesurf instructor)

- Mallorca Watersports: surfing, windsurfing, wing, kitesurf and catamaran
- Marc (owner of watersports centre) has over 30 years experience with teaching watersports, kitesurfer himself
- He started teaching Access Kite this summer, on a request of Pep who had a kite accident resulting in a SCI
- Material is from the student: same set-up as Willem and Thierry
- They need 2 instructors, while standard kitesurf lessons they just need one for a group or private lessons
- It was hard to get the material, wait for long time
- Student paid 6000 in total
- A school could get 50% off on the board, which leaves them 3000-4000 euros for a setup (only one seat)
- Still expensive; he thinks it should come with a foundation or sponsors
- When he would offer sit-kite, he wants to be able to ask the same price for a private lesson as for standard kitesurf; there should be no difference
- Changes made on set-up
- Harness on the seat, not around body
- Added feet straps → students needed help in closing the feet straps
- Straps around knees and waist (for hook)
- Student needs help
- To close feet straps
- To get in chair in the water (student and board go separately in the water; push against board in the water or from boat
- Buoyancy/turning on back
- Depends on the level of SCI, as instructor it is easy as you use upper body for turning
- For student it was harder, on the first day he fell on his side and he had trouble getting back; as an instructor we had to jump frequently fast in the water
- He uses impact vest but it does not offer enough floatability; they suggested to use a bigger life jacket, but the student did not want to as he wanted to use the equipment he is going to use in the end
- Marc suggest to add foam to the setup, they thought of the same for the SUP paddle as they tend to sink after a while as well
- They want to teach the student until a level he can go kite by himself; this means he still needs help to go in the water, but he does not need instructors or a boat anymore
- Marc would like to see the board changed, as it sinks now and can be scary for beginners. He thinks about a floating board, for example a SUP where the setup is strapped onto, this way they can teach kitecontrol and after that they can use the F-One board; because with the big floating board they can only go downwind
- He compares the lesson with how wing foil is teached now; first without a foil and a big board; then behind boat with foil but without wing; in the end with both together
- Modularity of seat: should be adaptable around hips; also instructors need to fit in them
- Working principle of safety seat
- First detach hook, then belt around knees, under chest and finally the feet → all custom made
- So first release kite, 2 quick-releqses and 2 belts
- Seat is not 100% safe
- Safety jacket is very uncomfortable
- Kitesurf is not a sport for everyone, quite complex. Same will go for sit-kite
- He did not do a bodydrag with Pep, as he already knew how to fly a kite. However he thinks it is important for non-experienced students to get to know the kitecontrol
- Could be possible by using a bodyboard or a rescue platform → lying on the board, the instructor can join
- Do not attach kite to students but maybe on the board
- Students are able to kite at least with the same wind speed as standard kitesurfers; think to add around 10kg to the persons weight for the material

Interview David S. - experienced sitkite instructor

Marinke: Do you have your own equipment?

David Strano : Yes, we have two sets, that means two sets composed of two boards and two frames. We have seven seats with different sizes. Not seven different sizes, we have five sizes 1 2 3 4 and 5. We have 2x 1 and 2x 1. One and two are most used, that is why we have it double. We also want to buy seat number 3 double as we had two students this summer with that size so they could not go together. So we had to switch over time. So we need another seat.

Marinke : My project will be about the seat itself. And looking how to make it adaptable. So that you wouldn't need seven seats for one person, but you can have one seat that adapts to the student.

David Strano : Awesome. Yes, of course, it will be a great idea. I don't know how it will be made, if there's any possibility to make it real. It's not bad, actually. Because now we have to switch. That's why we are buying another two frames. So we don't have to put away the seat. Put another seat. So we have the seat with the frame already fixed. So we just have to switch the seats and frame together on the board. So it's also a problem of time. The ones we have now are from Tessier, very expensive actually. The frame but also the seats. One seat is about 1000 euro and the frame 2000.

Marinke : That's a lot. Do you get any financial support?

David Strano : Yes, some of it comes from the sponsor, but the most comes from the local authority. And that's good. Otherwise it's very expensive and also the price of the courses you know. We want to offer the lesson at same price as the regular students. But we take twice the time to make the course because we need more teachers, and of course, more petrol. We need twice that much of time for students. So we integrate the lack of cost with the money that comes from the authority. It is the only way to go further because otherwise we have to close the sit kite project. Because we don't want to ask twice that much to our students. They have to pay the same. Yeah, that's our mission.

Marinke : And then maybe, about the seat, because if it's adaptable, what would you think are the most important dimensions?

David Strano : You have to imagine they have the wetsuit on. So you have to calculate the wetsuit too. They have to be very fixed in the seat. So the seat must fit perfectly. Because there's, there's the matter of the water too. If they if the seat gets wet, and the wetsuit too. So it has to fit. I mean, the size of the seat must be more or less the size of the of the of the wheelchair. I don't know the measures right now. I have to have to look at the seats. Yeah. But if you look at the internet's seats of this year, the different sizes.

Marinke : And do you ever use big sizes like five?

David Strano : No, we have never used them. We reached the fourth size, not more. Because people with paraplegic. They're very thin. And even big people they don't reach the fifth size. You have to imagine they are sports man. You don't see big or fat people doing kite surfing. I mean, it would be possible but it's very unusual.

Marinke : Right now, you can adjust the backwards with the strap, right? Do you ever change them?

David Strano : Sometimes we put the backrest away. It depends on what kind of disability they have. You know, if they have a lot of abdominals, when they have a very low injury they don't need the backseat. They just have the seat without the back.

Marinke : Would it be useful to have the option to remove the backrest?

David Strano : Yes. that's necessary, actually. Because sometimes this is not unusual.

Marinke : Do you have different sizes of backrest, like higher ones?

David Strano : Yes, there'll be two sizes. Small one and the high one.

Marinke : And that's necessary to have both of them?

David Strano : Yes, it's necessary. Yes, I guess. It's not like someone who can use a small one cannot use a high one. Sometimes they don't, they don't use backseats. But if you have a very high injury you need the backseat. If it's too high it's not impossible but it's quite impossible that you can get independently on the water. Because you need a little bit of function of course if you don't have abdominals you don't have the control of the hips and you have to control the hips. Even if you are a paraplegic with a high injury and you lack of abdominals, it would be quite impossible to have independency in the water and that's a problem.
Marinke : What about when they fall on their side?

David Strano : That is a critical situation, if they are a beginner and they fall with head towards the kite that's the critical situation. So there's a technique to get out of this situation, so you have to get used to this technique to get out. So they have to turn with the hip function and with the specific techniques to get out of this situation. Beginners can't do this on his own and they need our help. So we jump in the water if they have any problems and we bring them in the right position. Expert riders like Willem Hooft or Thierry Schmitter don't have this kind of problem. If they are in this situation they know how to get out of it. For a beginner it's a very critical situation and it could be a dangerous without help from the instructor. So that's why we follow them with the small boat. We have a big boat and we have small boats. If they have a problem, if they fall, we jump in the water and give them assistance. You need three instructors and one guy who is an expert in motorboat.

Marinke : Have you tried any adaptions on the equipment?

David Strano : Not really because I prefer to don't have all the things on it, you know. We tried with some things like sausages on the head. But I prefer to don't have all the things on it. It's it could be dangerous. I prefer to have one instructor more to help instead of all those other things.

Marinke : Any thoughts about the current seat?

David Strano : The seats are okay actually. Maybe the price is a little bit too high. It's more an issue of time that you lose from changing one seat. It's an issue of time and money because now we ordered two frames of 4000 euro just to to save time. So we have four sets ready to go. If we need another seat we just pull off the frame with the seat and take the other sizes with the frame on, it's very fast.

Marinke : How do you pull the students in the boat?

David Strano : We have a crane.

Marinke : One more questions about the safety system. If the kite is looping, is there a quick way to get out of the seats?

David Strano : They have the harness integrated in the seat. To get out of the seat, you have to open the harness and that's not so easy if you're in a critical situation. The first safety system is to let go of the bar. And then afterwards, if you are still in a critical situation you use the quick release of the kite so the kite does not pull anymore. And then you are safe, and then you can get out of the board. There is one Swiss kiter, Dave, he made a sort of quick release to get out of the seat. He used the seatbelt of airplanes. You open it like Click Clack. I guess you have to be careful when you're riding. Because you could touch it and it could open.

Email with Luc F. - material expert at organisation ski-trips etc

- De maten 37-42 cm breedte worden het meest gebruikt.
- De andere maten (28-37 en 42-46 cm breed) worden ook regelmatig gebruikt doordat we een grote variëteit van gebruikers hebben (we hebben een reis voor volwassenen, jongeren maar ook speciaal voor kinderen).
- In een mono/Dualski is een lage rugleuning-hoogte meest gebruikt.
- Zeker gebeurt het wel dat een zitkuip niet optimaal past; we maken het dan passend met behulp van opvulmateriaal/kussens.
- Een ideaal zitkuipje is zo flexibel dat het heel goed passend is, en zo stevig dat het goed steun en bescherming geeft. De voering van het kuipje moet zacht zijn, maar ook goed tegendruk geven zodat een goede comfort bereikt wordt, met minimale risico's op drukplekken. Er dienen banden aan te zitten om de zitskier goed stabiel in de zitkuip te bevestigen. De rugleuning moet voldoende hoog zijn om de benodigde steun te geven, maar (meestal) ook weer niet te hoog omdat anders de bewegingsruimte erdoor beperkt wordt.
- Een zitkuip kan altijd beter, maar doordat wij een ruime keus hebben in typen zitkuipen vinden we vrijwel altijd een bevredigende oplossing.
- Zeker zijn er soms klachten van discomfort. We moedigen zitskiers aan dit kort na het optreden ervan te melden zodat we het op kunnen lossen (met opvulmateriaal/kussens of een andere maar of type zitkuip) voor dat de klachten chronisch worde

Interview Andreas sit-kite instructor in Greece

- He started foundation to promote sit-kitesurfing in a safe way, 3 months ago
- He teached 25 students already; mostly in surfclub Keros (Keros for All)
- they had board and frame but not seat
- You have to adjust lesson plan everytime - depends on physical and mental condition of the student
- They always teach in deep water (with boat) so less likely to have injuries on legs
- Priority is safety; both for student as instructor
- Always teaching private lessons
- Goal: open the sport to everybody
- Also thinking about/doing product development
- Frame: it is good, but not for tall people as their knees will be too close to their bodies; trying to make the frame adjustable in height
- Board: he wants a wider board than the one from F-One
- Students always have a buoyancy aid with them
- Main problem for school: resources (instructors + boat driver + petrol)
- A standard course takes 15min to change clothes and go into sea, while a sit-kite lesson take 30-45min
- They also teach people with no abs or back muscles: balancing is hard; you have to grab each students in an another way
- Currently he has no material, but wants to buy all seat sizes
- He also includes overweight people in his design: his goal is not to teach kitesurfers but to let them have an experience of it
- One student was overweight, but when she wanted to become good in kitesurfing, she lost weight
- You have to be careful with the backrest; he advises not to go to high; medium low is good
- Too high; hard when there is a nose dive
- Too low: is hard to handle for people with no or less abs/back muscles

III. Interview insights

Experienced sit-kiter
W.H. = Willem H.
M.P. = Markus P.
N.L. = Nicolas L.

Sit-skier
L.F. = Luc F.

Instructor
M.W. = Mallorca Watersports
A.A. = Andreas A.
D.S. = David S.

BEGINNERS

EXTRA HELP
- M.W.: Need help with getting board on in the water
- M.W.: Need help when fallen at side -> not add things to setup for safety
- M.W.: Trouble turning to back when fallen; impact vest is not enough

MATERIAL
- M.P.: Difference beginner:
  - Not upwind
  - Need boat/transport
- M.P.: Seat for beginners
  - Backrest not nec. adaptable

OTHER

SAFETY
- M.W.: Seat is not 100% safe

COMFORT
- L.F.: If seats does not fit (in ski) they fill it with cushioning or other materials (person falls inbetween sizes)
- W.H.: Bubble between legs on seat; might be good for one-leg amputees

WEATHER
- M.W.: Sit-kite is possible starting at (at least) same wind speed

SCHOOLS

MATERIAL
- M.P.: Main issue when learning to kite = material
- M.P.: School Italy only uses 3-4 sizes, covers 80% of customers

DIFFERENCES
- A.A.: Starting up takes 30 to 45min, instead of 15min
- A.A.: Always teaching in private lessons

COSTS
- M.P.: Issue schools: too expensive Help from government is needed
- D.S.: Double price as normal course
  - 3 to 4 instructors
  - more petrol
  - more time
- M.W.: Investment should be in coorporation with foundations/sponsors

BACKREST

PREFERENCES
- M.P.: Backrest is less demanding for back than harness/soft
- M.P.: Sit-kite with harness due to safety reasons
- D.S.: Backrest should be removeable (depending on length and level of injury)

PERFORMANCE
- W.H.: Backrest needed for edging (performance)

HEIGHT
- L.F.: In mono/dualski is a low backrest the most used
- L.F.: Backrest should be high enough to give enough support, but not too high so that it restricts freedom of movement

TECHNICAL

FOAM/PADDING
- L.F.: Cushioning should be soft, but give enough back pressure for good comfort with minimal risks on decubitus
- M.P.: Not float too much; but still a little for safety
- M.P.: Padding: Little on back + bottom Always wetsuit Yoga mat as foam

EXPERIENCE
- M.P.: Adapted hook (soft hook) -> sliding hook too far away (10-15cm) when fully depowered
- D.S.: Satisfied with seats
  - expensive
  - losing time when changing to frame

REQUIREMENTS
- N.L.: Seat should be: Simple Affordable Adaptable Safe

WATER EVACUATION
- M.P.: Holes in seat for water evacuation (bottom, sides and back)

SIZES
- L.F.: Most used sizes in ski: 37 - 42cm seat width
- D.S.: Most used sizes: 1+2 Also 3 4 has been used, bigger not

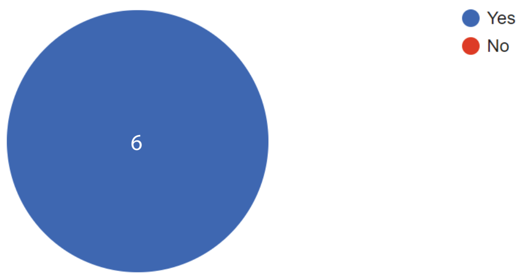
STRAPS
- M.P.: Straps around legs needed for jumps
- W.H.: Straps: 1x feet 2x seat 1x back Harness

STIFFNESS
- W.H.: Seat has to be stiff (edging)
- L.F.: Optimal ski seat should be flexible so it fits well, but stiff enough that give enough support and protection

IV. Questionnaire schools

Q1. Have you heard of sit-kiting before?

6 responses



If yes, where?

6 responses

On instagram

Sur le net, discusion entre examinateur IKO,...

At our school years ago

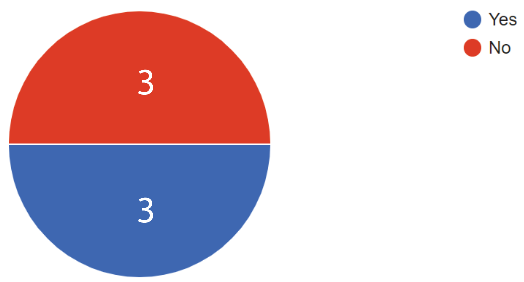
Willem Hooft

Willem hooft

At our spot there is someone kiting with a seat.

Q2. Do you ever get requests about kitesurf lessons from/for people with a handicap?

6 responses



If yes, how often?

3 responses

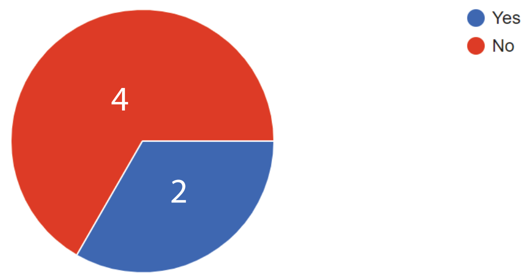
Très très peu dans le passé car nous avions proposé du Catakite

ones in a while

Just once

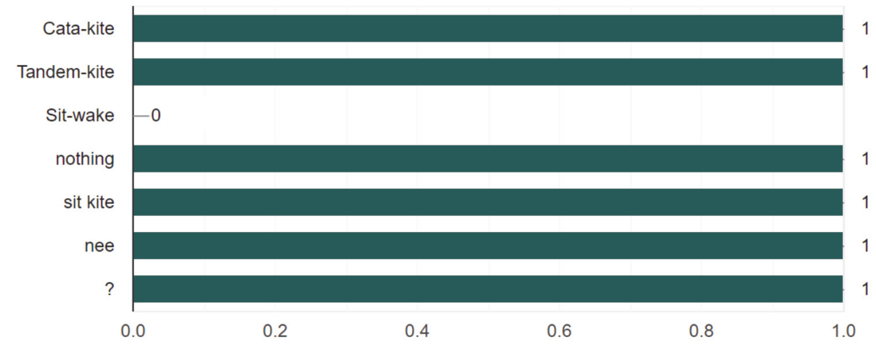
Q3. Have you ever thought about including sit-kite in your offered courses?

6 responses



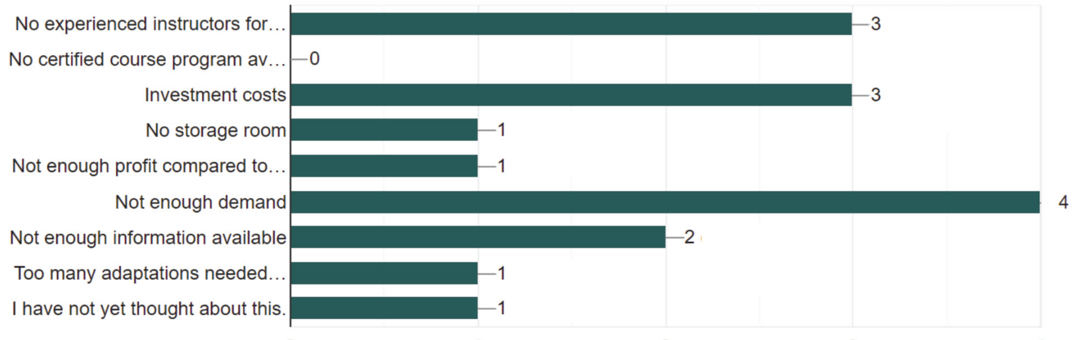
Q4. Have you offered or participated in any of the following adaptive kitesurf (or similar) experiences?

6 responses



Q5. What holds you back in offering sit-kite in your school?

6 responses



Q6. Would you be open to include sit-kite in your course program? Explain why (not).

5 responses

No i'm sorry. We are to busy with teaching and we have no experienced instructors

Oui et non? Oui car je trouve vraiment intéressant de donner l'accessibilité au sport à tous. Et Non, car cela demande beaucoup de logistique, de temps à mettre en place, d'investissement, de difficulté d'intégrer ce cours adapté au cours classique. Hélas, pour être honnête, c'est une uniquement une question de rentabilité!

Je reste disponible pour tout

Ja

Op dit moment niet, maar mocht er een goede voorlichting hierover komen wellicht wel! Het is nu als een ver buiten me bed show

At the moment we work from busses. We are a mobile kitesurfschool. It could be something to try but we would really need to have an instructor be fully trained for this and this will be difficult to do.

V. Product Analysis: parts

Frame

- Brand: Wolturnus
- Anodized high-grade aluminium (7030)
- 1.8kg
- Has been tested for 3 years in all kinds of waves and salty waters, found to be indestructible (TheKiteboarder, 2020)

Footplate

- Fixed in position
- Close with straps; keeps feet to place

Seat

- Brand: Tessier
- Waterproof foam at sides and seat base (gelcoat?) - Memory shape cushion

Seat backrest

- Backrest of 35 or 42cm
- Waterproof foam (gelcoat?)
- Adjustable using buckle

- Backrest is removable
- Two types: open and closed

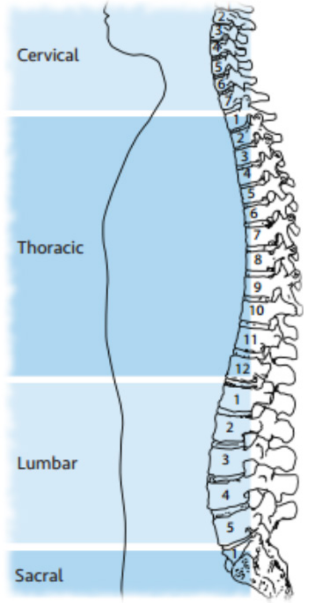
Straps

- Feet 1x
- Seat 2x
- Back 1x
- Harness

Spreaderbar

- Attached to seat
- Brand: Mystic

VI. SCI



Level	Affected
Cervical (neck injuries)	Head and neck region above the shoulders Quadriplegia
C-4	Breath assistance
C-5	Shoulder and biceps control; no control wrist or hand
C-6	Wrist control; no hand control
C-7	Straighten arms; problems with hand and fingers
Thoracic	Upper chest, mid-back and abdominal muscles. Arm and hand function is usually normal
T-1	Hands and fingers
T-2 to T-5	Chest muscles
T-6 to T-8	Chest and abdominal muscles
T-9 to T-12	Abdominal muscles
Lumbar	Hips and legs. Individuals may need a wheelchair or walk with braces

VII: Tessier size guide

tessier
LA TECHNOLOGIE DU SKI ASSIS

Articulated seats for Tessier sit-skis

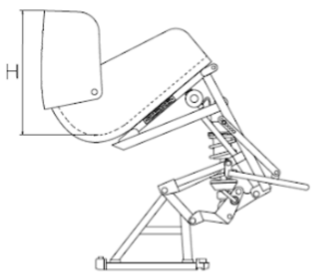
Seat size	Maximum hip width	Backrest width
Children	28 cm / 11,2 in	27 cm / 10,6 in
1	33 cm / 13 in	29 cm / 11,4 in
1 Wide backrest		34 cm / 13,4 in
2	35 cm / 13,8 in	31 cm / 12,2 in
2 Wide backrest		37 cm / 14,6 in
3	37 cm / 14,6 in	32 cm / 12,6 in
3 Wide backrest		34 cm / 13,4 in
4	39 cm / 15,4 in	33 cm / 13 in
4 Wide backrest		34 cm / 13,4 in
5	41 cm / 16,2 in	34 cm / 13,4 in
5 Wide backrest		35 cm / 13,8 in
6	45 cm / 17,7 in	39 cm / 15,4 in
Articulated bucket seat	41 cm / 16,2 in	35 cm / 13,8 in

- Size 1 to 5are available with 2 widths of backrest.
- Today, sizes Children and 6 have only one width of backrest.

Customised seats are possible on request (special cut, special foam, special chest strap…)

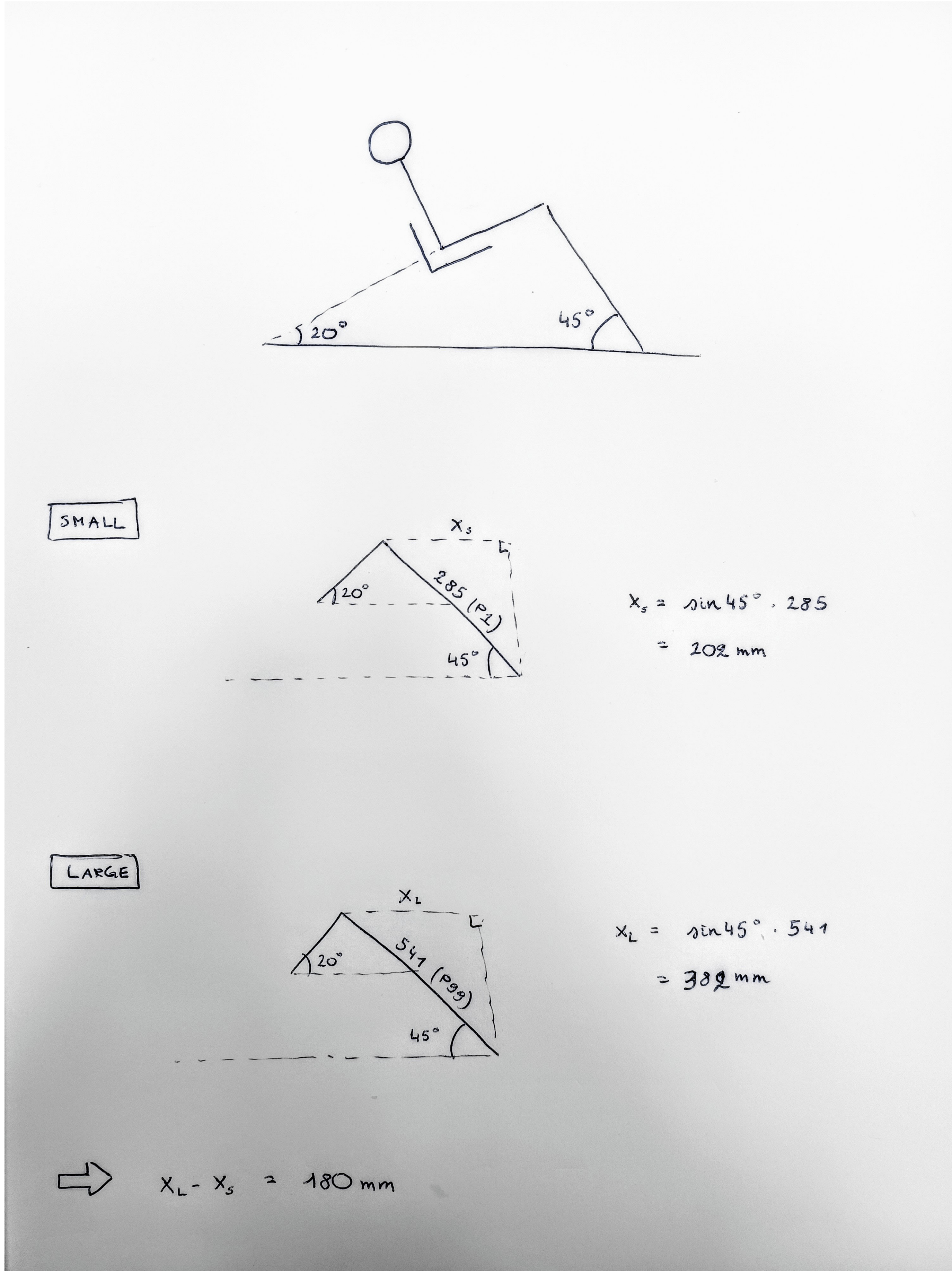
Height of the backrest (H):

- ✓ Standard: 42 cm
- ✓ Low: 35 cm
- ✓ RMC : 37 cm
- ✓ Children seat: 33 cm
- ✓ Special height on request



Seats are white gel coated.
On demand they can be black gel coated or in carbon (extra cost, longer delivery time). All seats have the same construction: fiberglass and carbon reinforcements, only the last layer changes.

VIII: Calculation sitting angles



IX: Pilot measurements

Procedure/Method
A pilot has been performed prior to the tests together with Willem Hooft and Laura Ashmann from the UPPS fieldlab. This was done to check the method and points of improvement.

A. FOAM CUSHION

A cushion with a thickness of 3.4mm is used on the measuring chair (see image below) to avoid decubitus. This has an influence on the measurement of the back width. The back width has to be measured at seating height 35cm and 42cm. Therefore it is important to look at the compression of the foam cushion..

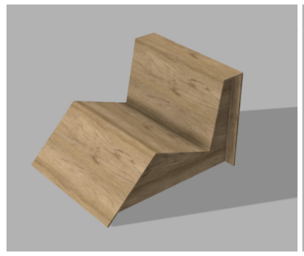
A test is performed to find out this compression. Three people with a weight ranging from 60 to 90kg are measured in sitting height with and without a cushion. The difference between these sitting heights was three times 2.4mm. As most sitkiters will be within this weight range, there can be assumed that the difference in sitting height will be 2.4cm for all participants. Therefore the heights of the backrest are measured on the chair at 37.4cm (without cushion 35cm) and 44.4cm (without cushion 42cm).

Also the influence of the foam on the thigh clearance has been checked. It could be concluded that the thigh clearance does not differ whether the subject is seated on a hard surface or on the used foam. As the measurements were the same, with and without. It should be noted none of three participants had SCI, and that result could differ with less leg muscles.

The same foam cushion will be used for all measurements for reliability.

B. SETUP 3D SCAN

Chair for beanbag
As the chair during the pilot was not stable and secure enough for using it with the test persons, a new chair has been designed (see figure below) while respecting the right seating angle.



Although the seat has the right seating angle, the beanbag and the positioning of the polystyrene balls still play a part in how the person is positioned. For this reason will a goniometer still be important to check the sitting position.

The new set-up allows for easier transition from wheelchair to seat and better distribution of the polystyrene balls in the beanbag.

Markers for alignment
Alignment of the two scans (body and beanbag) is not exact enough using the auto-alignment option in the Artec software. For this reason, stickers are placed on the beanbag which shows in both scans (see figure FIXME). This allows for easier manual alignment, as the stickers can be used as reference or alignment points.

Insights
- Make first the vacuum bag hard, this make it easier for the person to enter the setup
- Manual measurements should be taken at least 2 times, if difference is large (10mm+), a 3rd or 4th measurement should be taken
- Big difference on how hard you press caliper on skin
- For hips: take measurements tight on the bones + softly on widest point
- Take into account cushioning on "meetstoel": target group can not sit on hard surface for decubitus
- Big difference between measurements 3D-scan hip compared to manual measurements
- Use velcro to have legs together, closer to real life situation (where legs are strapped together) + according to NEN-ISO guidelines, it is necessary to have knees together
- Tested difference dark grey vs light grey legging: big difference (the lighter better)
- Ask person at beginning how they would like to be helped
- Ask person at beginning to point out when sitting in beanbag takes too long (pressure points)
- Put little stickers on hip bone: easier to measure distance on 3D-scan
- Footplate at "meetstoel" needs to be removed for easier transfer to the chair. However, this has to be added again to measure conform to the ISO guideline
- The construction should be more stable
- Velcro straps should be connected under the knee to avoid the flesh on the thighs is compressed

X: Research plan measurements 3D

Procedure (week 45 - 46)
Available: researchers (Laura, Marinke)

Preparation:

- A group of 10-15 is asked to participate in the measurements. These are people from the network of Willem Hooft Foundation, with an interest in sit-kite or sit-wake.
- The following things are ready for use:
- 3D-scanner + charger
- Measuring tape
- Goniometer
- Caliper (big + small)
- Vacuum cushion
- Printed consent forms
- Printed manual measurement forms
- Cushion for “meetstoel”
- Velcro-straps (to hold legs together)
- Small round stickers (to indicate end points hip width + pelvis width)
- Tight clothes legging (no dark colour)
- Dressing/welcome room: with bench and bin

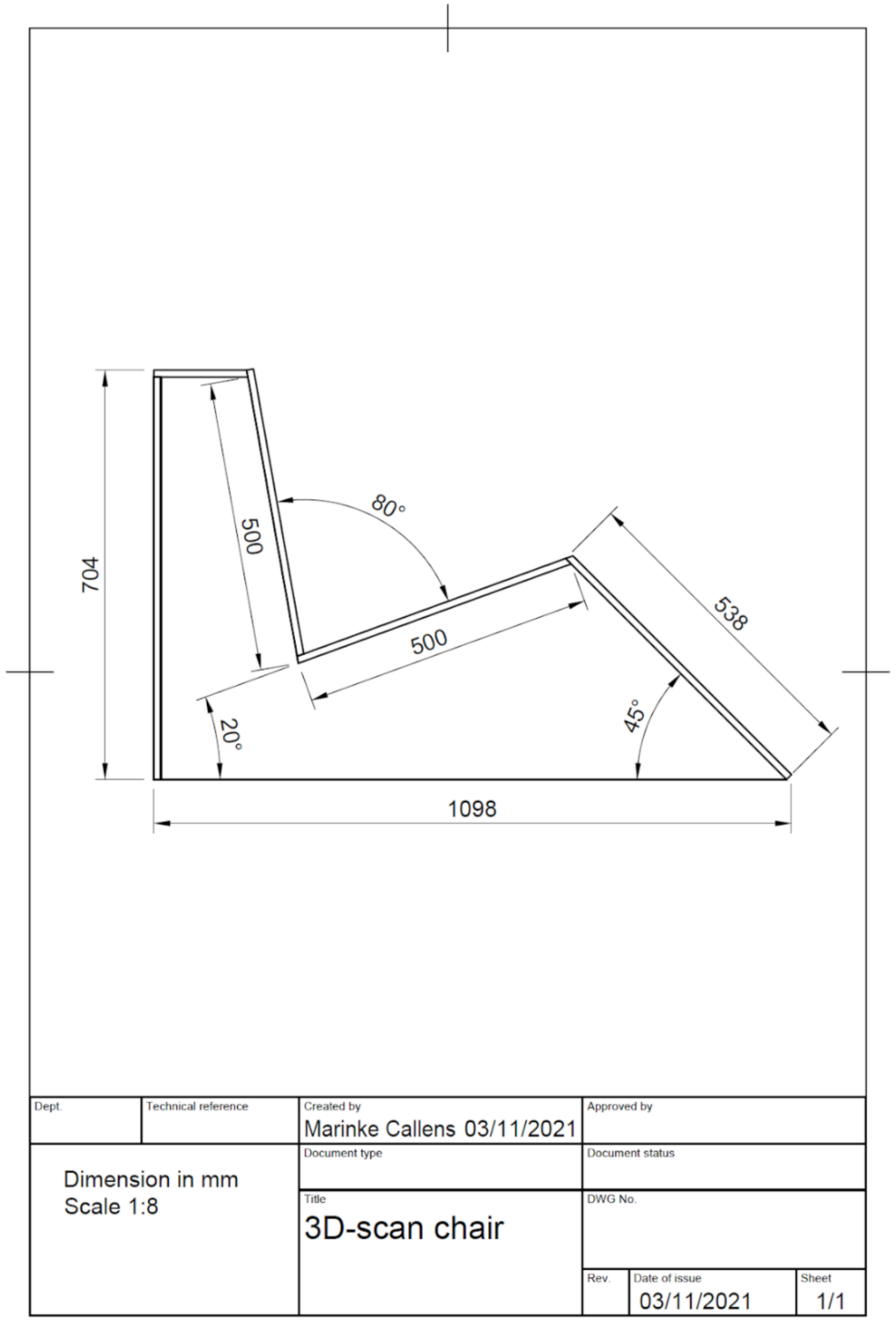
Measurements day:

1. Wait for test subject downstairs, welcome test subject, give information
2. The subject will be asked to fill in the Informed Consent Form
3. Ask subject to put on tight clothing (they can bring this themselves or use the one from the fieldlab)
4. Add stickers on end points of pelvis width and hip width
5. Essential body dimensions will be taken by hand on “meetstoel” and filled in the manual measurement form.
6. Repeat the body measurements at least two times, if difference is big (>10mm) repeat the measurement for a 3rd or 4th time
7. Attach vacuum cleaner to beanbag, turn on until it is hard
8. Test subject will be asked to sit in the bean bag (in their thigh clothing)
9. Turn of vacuum cleaner and let air flow into beanbag until it is soft again
10. Check if the sitting angle is correct with goniometer
11. Turn the vacuum cleaner on
12. Start the first 3D-scan after 30-45 seconds (minimise time in beanbag to avoid pressure sore)
13. When the cushion is hard and 3D-scan is done, the subject gets out of beanbag (if needed help from bystander, ask how)
14. Second 3D-scan will be taken from seat
15. Turn off vacuum cleaner
16. Thank subject

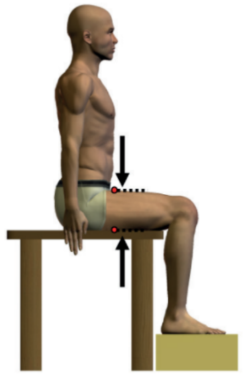
Manual measurement form

Participant #...	Measure 1	Measure 2	Measure 3	Measure 4	Average
Hip width (on bone)					
Hip width (at widest)					
Thigh width (at 420mm seat depth)					
Thigh height (max)					
Back width (at 350mm) - breathing in					
Back width (at 420mm) - breathing in					
Pelvis width					
Popliteal height					
Buttock-popliteal length					
Gender:					
Level SCI / Physical ability:					
Age:					

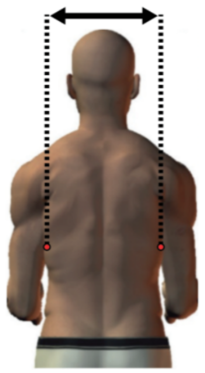
Technical drawing chair 3D-scan
The seat depth is set to 500mm. which is around P50 of the Dutch adults on DINED. However, P5 corresponds to 457mm and P95 with 550mm. To keep the seat simple, stable and safe there has been decided to use foam cushioning underneath the bottom legs, or behind the back, depending if the person’s BPL is shorter or longer than 500mm.



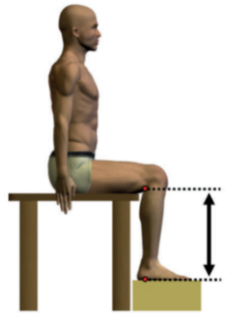
XI: Method of manual measurements

Measurement needed	Instrument needed	Instructions
Hip breadth sitting 	Large sliding calliper	• Sits fully erect • Feet supported (femora are horizontal and parallel to each other) • Knees together (same as in kitesurfing) • Measurement is taken without pressing into the flesh of the hips
Thigh clearance (at seat depth 42cm) 	Anthropometer	• Sits erect • Knees bent at right angles • Feet flat on the floor

Dimensions needed + ISO 7250 instructions

Measurement needed	Instrument needed	Instructions
Back width (at 35cm and 42cm) 	Large sliding calliper	• Sits fully erect • Shoulders relaxed • Measure while breathing out

Thigh width (at seat depth 42cm) 	Large sliding calliper	• Sits fully erect • Feet supported (femora are horizontal and parallel to each other) • Knees together • Measurement is taken without pressing into the flesh of the thighs
Pelvis width 	Large sliding calliper	• Sits fully erect • Feet supported (femora are horizontal and parallel to each other) • Knees together • Measurement is taken without pressing into the flesh of the pelvis

Popliteal height 	Measuring chair	• Thigh and lower leg are at right angles
Buttock-popliteal length 	Measuring chair	• Sits erect • Feet supported extending as far as possible into the hollow of the knee.

Dimensions needed without ISO 7250 instructions

XII. Questionnaire answers discomfort

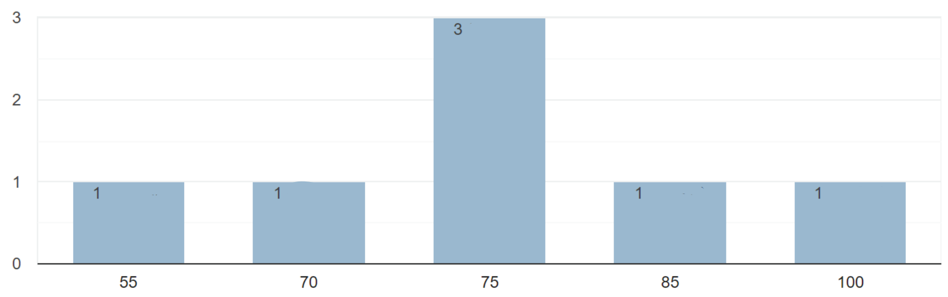
1. What is your age?

7 responses

- 21
- 47
- 36
- 49
- 62
- 59
- 34

2. What is your weight (in kg)?

7 responses



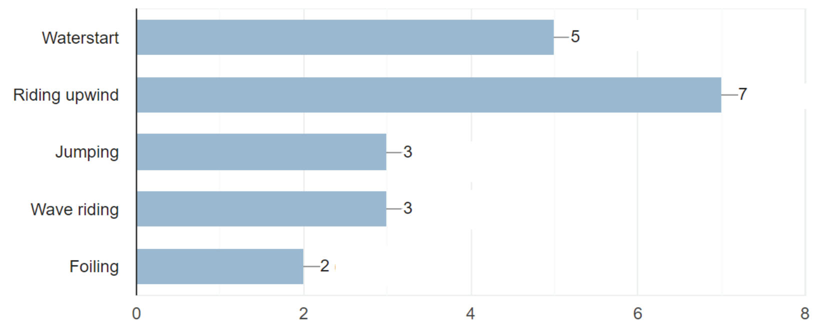
3. How many years are you sit-kitesurfing?

7 responses

- 5 with sit kite + 7 without
- 18
- 12days
- 14
- few months
- 12
- 8 YEARS KITE - 2 MONTHS SITKITE

4. Which skills are you capable of doing? (You can tick multiple boxes)

7 responses



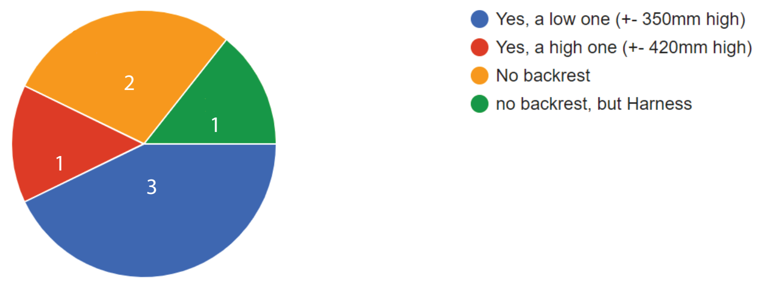
5. If you have a spinal cord injury, what is your level of SCI?

7 responses

- L1
- D12
- L1 comnplete
- TH12-L1
- L1-L2
- no
- T10

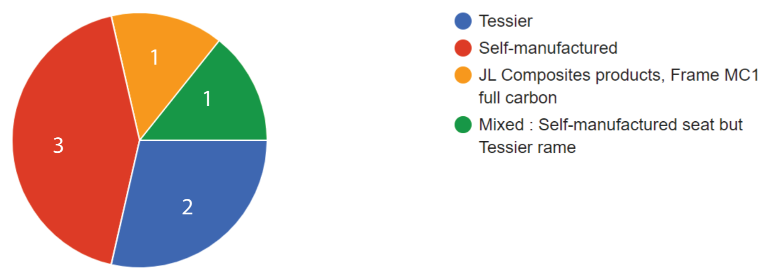
6. Are you using a seat with a backrest?

7 responses



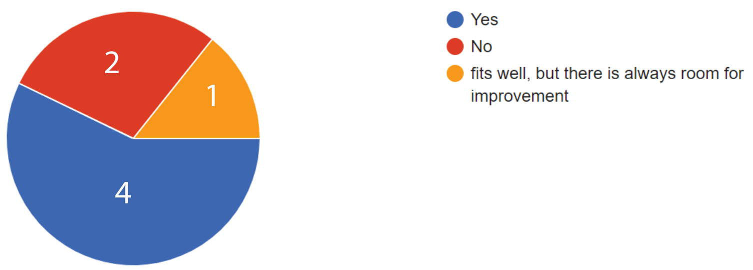
7. Which brand of kite seat are you using?

7 responses



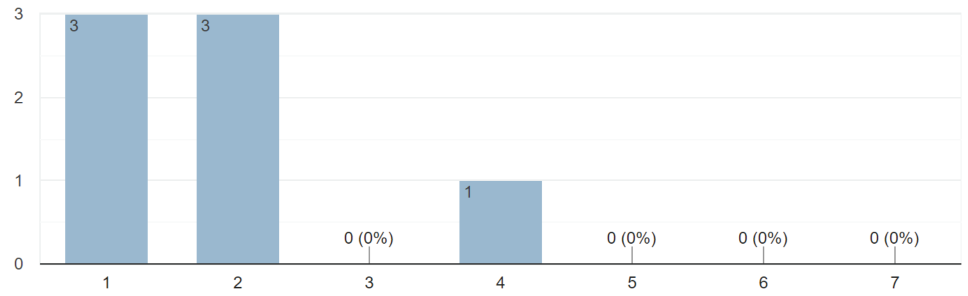
8. Does your seat fit perfectly to your body?

7 responses



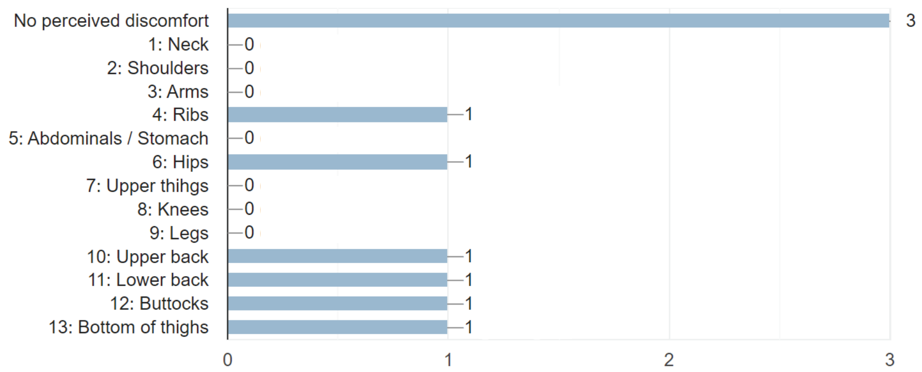
1A. While being seated in the kite seat for the first 5 minutes, which level of discomfort do you perceive?

7 responses



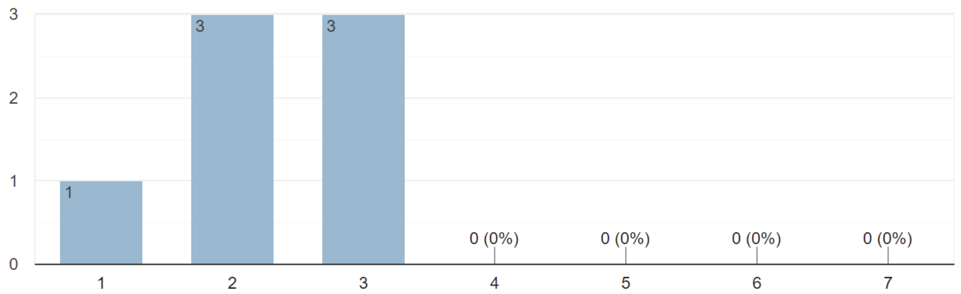
1B. Looking at the images below, can you point out where your perceive discomfort (first 5')?

7 responses



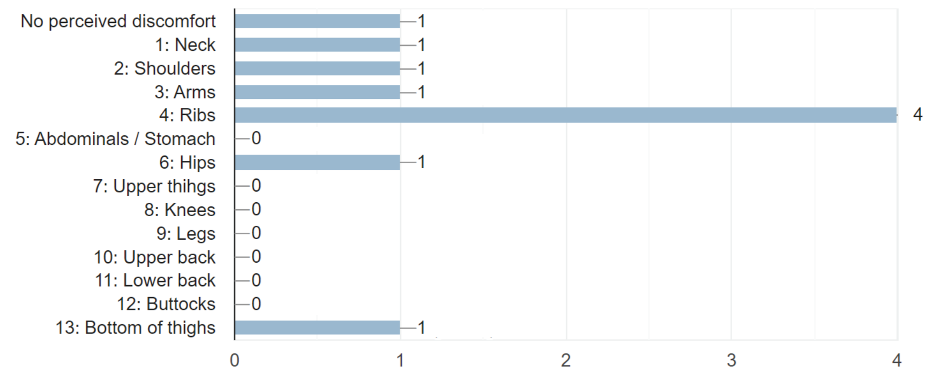
2A. While kitesurfing, which level of discomfort do you perceive?

7 responses



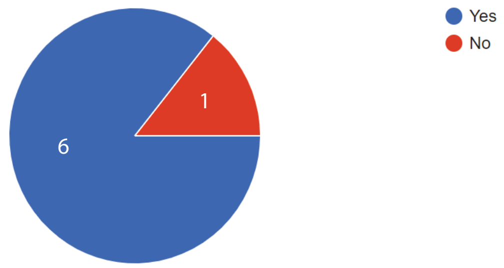
2B. Looking at the images below, can you point out where your perceive discomfort (while kitesurfing)?

7 responses



2C. While kitesurfing, do you feel there is sufficient postural support?

7 responses



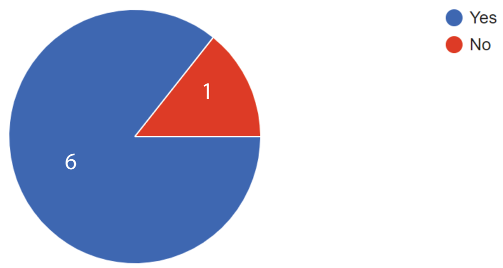
2D. If no, please describe where?

1 response

LUMBAR- THORACIC

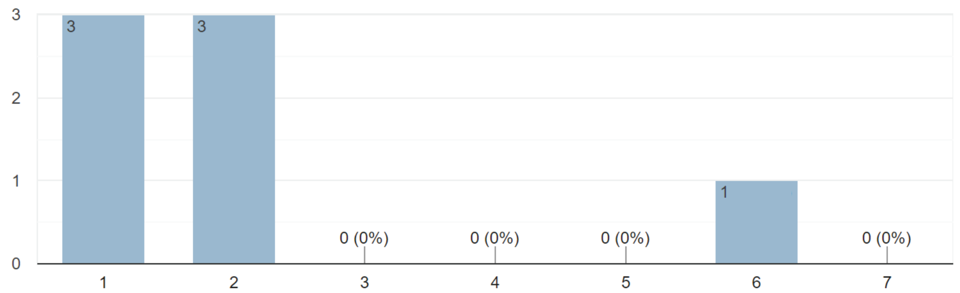
2E. While kitesurfing, are your thighs in contact with the bottom surface of the seat?

7 responses



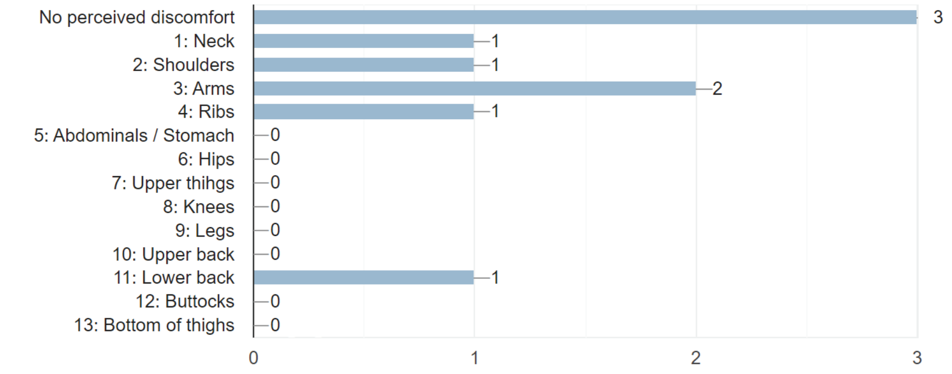
3A. In the first 30 minutes after kitesurfing, which level of discomfort do you perceive?

7 responses



3B. Looking at the images below, can you point out where your perceive discomfort (up to 30' after kite-session)?

7 responses



4. In case you tried other kite seats before, which one felt most comfortable to you? Explain why.

4 responses

my current seat because the old one was too large for me

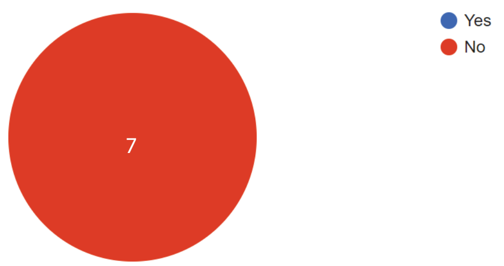
The MC1frame by JL Composites because it's full suspended and the shock absorber protect the spinal. Feet are not in contact with the board , so no shocks and no dolphin effect, i ride generally 1,5 to 2 hours without stop.

Seats or frames? - I knew the different seats from my skiing acivities, so I had my favourite model. Then I tried different frames, which I built myself, had them built.

My own seat was the most comfortable one. The other where very far to adjusted.

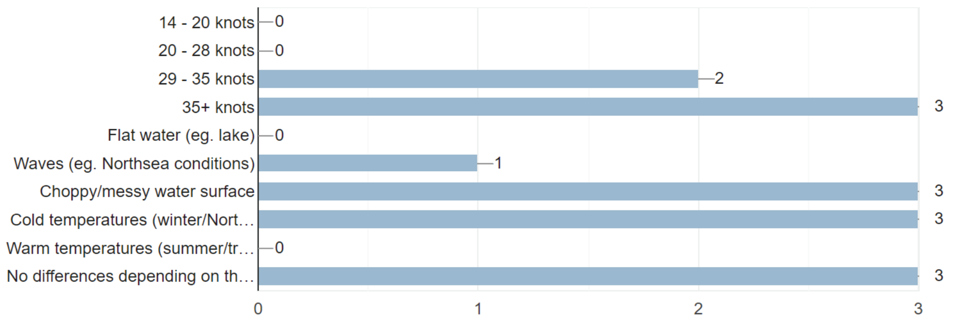
5. Have you perceived any pressure sores/decubitus due to sit-kitesurfing?

7 responses



6. In which conditions is the feeling of discomfort the strongest? (You can tick multiple boxes.)

7 responses



7. Is there a difference in discomfort depending on the clothing your are wearing (eg. size of wetsuit, shorts, life vest, ...). Please explain why.

7 responses

Yes all my equipment is fitted for my body

depend the wetsuit thickness

no. my seat perfectly fits a 4mm neoprene. less than that (2mm) is too lose, more than (6mm) that doesnt fit. Seat, cushion, and your ass needs to fit perfectly

no really - but I prefer, wearing no / s thin wetsuit because I have the feeling, that I can move better / with less effort

No

the thicker and tighter the wetsuit the warmer it is

NO

8. What could improve your feeling of comfort?

7 responses

I have to use a short wetsuit for protection with the seat

Working always on security about eject the spreader bar and the body of the frame

the seat must be the extension of your body. You only achieve this by having a strong and tight connection and a cushion that really grip with neoprene.
I use a cushion that is tailor made to the shape of my body.

By the way: The tessier swaik bucket is to low. It doesnt support the whole hip as it is as high as the trochanter. And the cushion is really bad.
To find out if the seat is tight enough swim with it and if your as is moving in the seat you need to make it tighter

In generel the accessibility of the entire infrastructure (beach access, changing rooms, restaurant, shower...)

YES. The wetsuit always adds a bit of thickness that I didn't take into account when creating the seat

not to freeze

XIII. DATA MEASUREMENTS

Averages per participant	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**Pilot**	**Min**	**Max**	**Difference min and max**
Hip width (on bone)	33.4	34.1	37.4	35.2	**38.3**	**31.1**	36.1	32.8	34.7	35.1	31.1	38.3	7.2
Hip width (at widest)	35.0	38.1	40.7	39.4	**44.9**	**34.3**	41.5	38.3	38.4	37.3	34.3	44.9	10.6
Hip width according to scan	35.1	40.8	41.5	42.7	44.4	34.1	42.6	38.7	40.3		34.1	44.4	10.3
According to DINED international (manual)	P50	P72	P86	P80	P97	P44	P89	P74	P74	P67			
According to DINED adults (manual)	P5	P27	P61	P43	P96	P3	P71	P33	P34	P19			
Thigh width (at 420mm seat depth)	29.4	30.9	34.3	**35.7**	35.3	26.2	27.9	27.9	28.7	**25.6**	25.6	35.7	10.1
Thigh width according to scan	29.1	33.1	32.2	33.5	36.4	25.4	30.0	30.6	31.6		25.4	36.4	11.0
Back width (at 350mm) - breathing out	27.3	27.4	33.6	**35.4**	33.6	28.5	29.4	**26.8**	32.9	30.3	26.8	35.4	8.6
Back width (at 420mm) - breathing out	29.3	**28.7**	34.5	**37.6**	33.5	28.9	31.6	29.9	34.3	32.2	28.7	37.6	8.9
Pelvis width	**25.1**	29.0	34.4	34.0	**35.6**	26.3	27.3	29.8	30.8	31.2	25.1	35.6	10.5
Pelvis width according to scan	25.3			37.1		26.7	30.0	31.2	32.7		25.3	37.1	11.8
Thigh height (max)	**8.7**	11.5	12.7	11.2	**13.5**	9.3	11.6	8.8	9.5		8.7	13.5	4.8
Thigh height according to scan	8.5	13	13.1	13.3	14.2	9.8	12.6	10.1	9		8.5	14.2	
Shoulder height			**54.9**	61.6	57.9	58.1	56.5	56.5	**64.6**		54.9	64.6	9.7
Shoulder blade height			45.3	48.1	**51.6**	45.4	**38.9**	48.1	47.9		38.9	51.6	12.8
Pelvis height			**22.1**	18.3	20.3	19.8	20.6	**17.7**	20.5		17.7	22.1	4.3
Popliteal height	46.2	**35.0**	45.8	42.3	41.1	42.5	41.6	41.6	**49.5**		35.0	49.5	14.5
According to DINED international (manual)	P81	P13	P79	P57	P49	P59	P52	P52	P93				
Buttock-popliteal length	52.0	49.9	52.6	48.8	53.0	**48.8**	50.3	49.6	**57.4**		48.8	57.4	8.6
According to DINED Dutch adults	P70	P42	P77	P28	P81	P28	P47	P36	P98				
Distance hipbone to back (scan)	17.4	19.5	19.9	17.9	15.6	12.8	18.9	16.9	18.6				

#1

Gender:	MALE
Level SCI / Physical ability:	T12 + T9
Age:	18

#2

Gender:	FEMALE
Level SCI / Physical ability:	L3-L4
Age:	56

#3

Gender:	M
Level SCI / Physical ability:	T12 incompleet
Age:	32

#4

Gender:	M
Level SCI / Physical ability:	Geen laesie, verminderde communicatie tussen hersenen en benen
Age:	57

#5

Gender:	M
Level SCI / Physical ability:	Geen laesie, verminderde communicatie tussen hersenen en benen
Age:	57

#6

Gender:	F
Level SCI / Physical ability:	Pinnen in rug, kan lopen maar aangetast zenuwstelsel; niet volledige spierkracht in benen (linkerbeen meer kracht dan rechts)
Age:	41

#7

Gender:	F
Level SCI / Physical ability:	Amputatie beide benen; kracht in bovenbenen; boven L3 geen beweging
Age:	25

#8

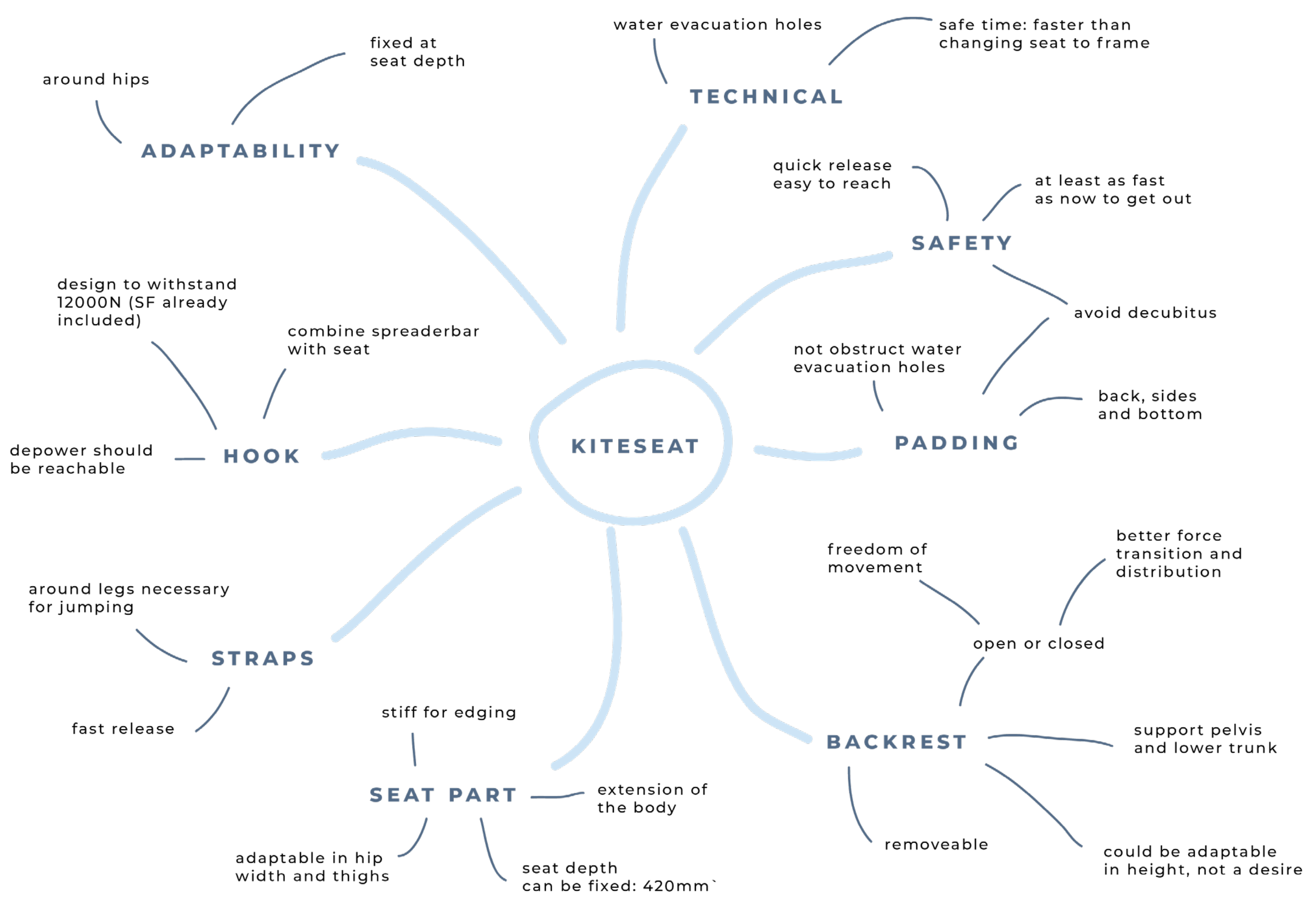
Gender:	F
Level SCI / Physical ability:	vanaf bekken geen functie
Age:	50

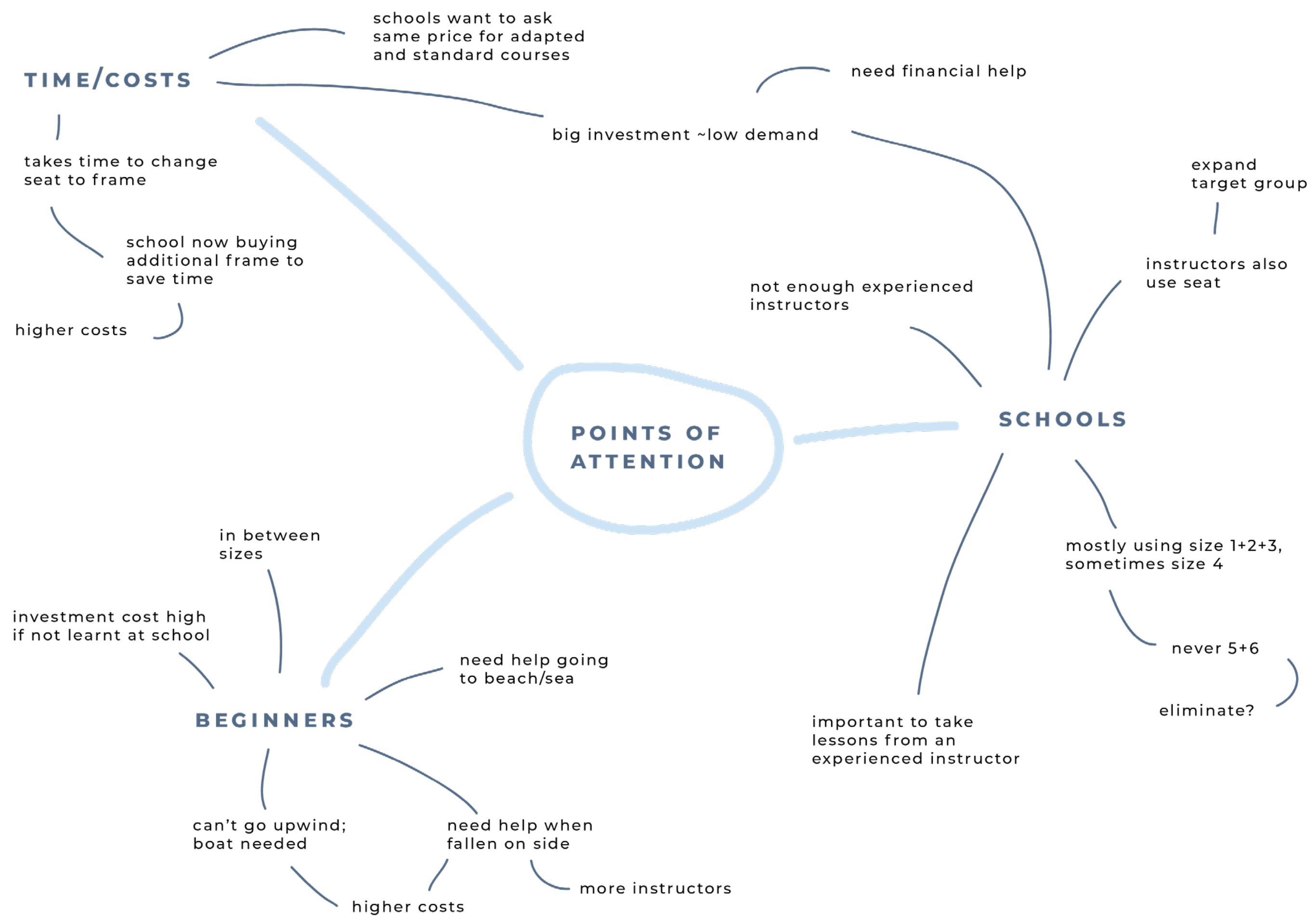
#9

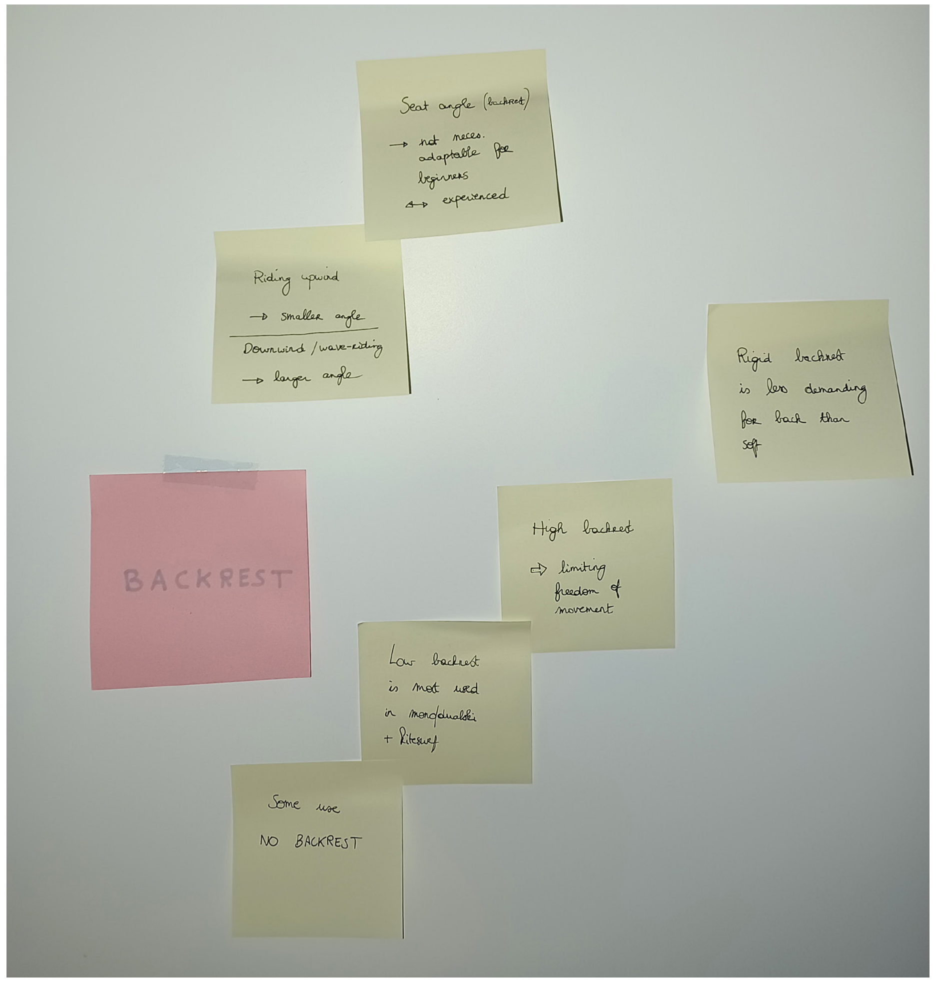
Gender:	M
Level SCI / Physical ability:	T6-T7
Age:	36

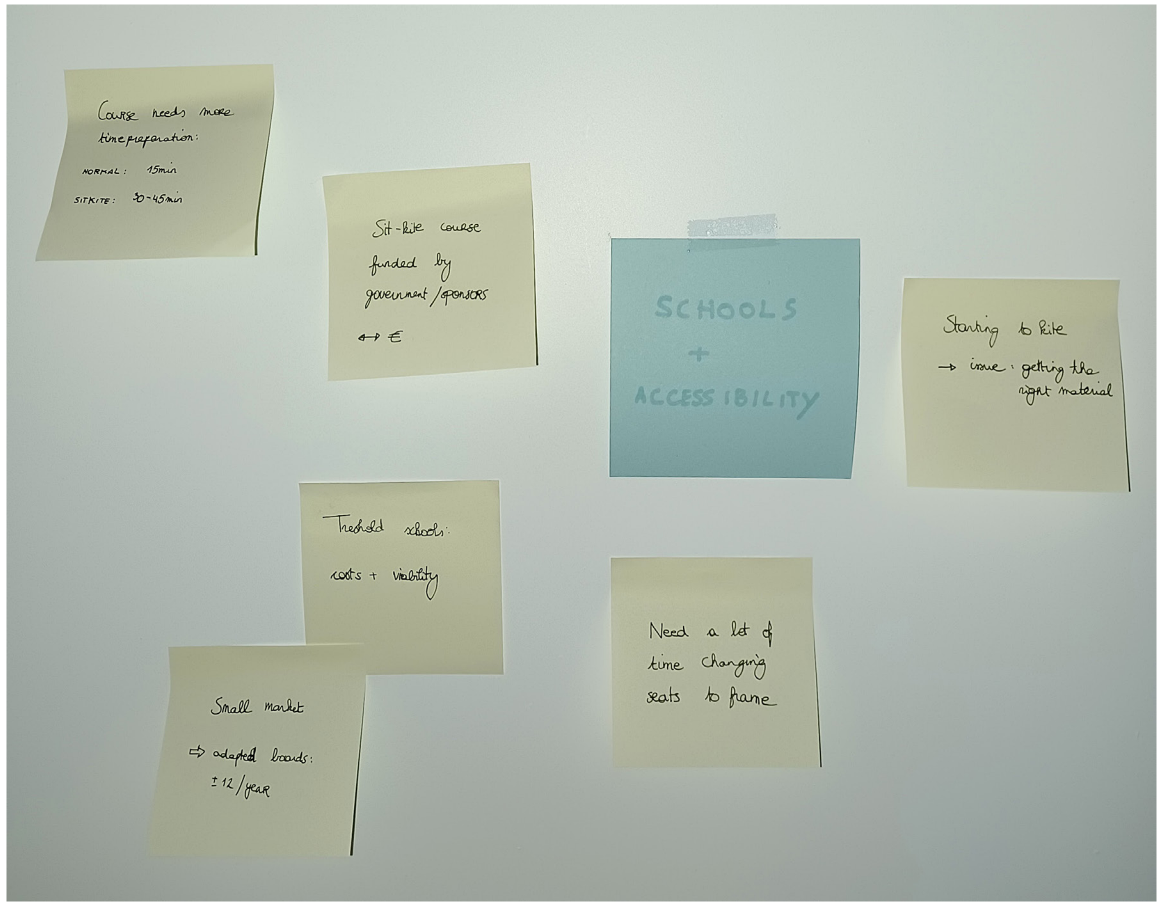
IXX. Method for making connections and clustering

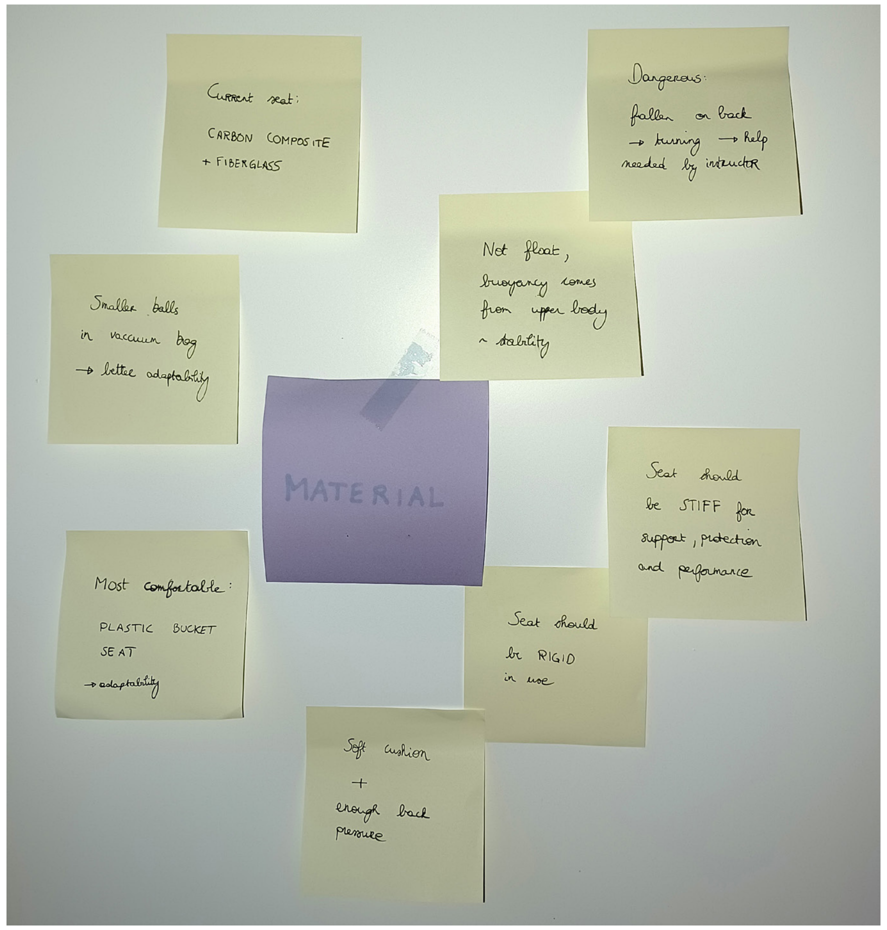
INSIGHTS INFLUENCING DESIGN REQUIREMENTS

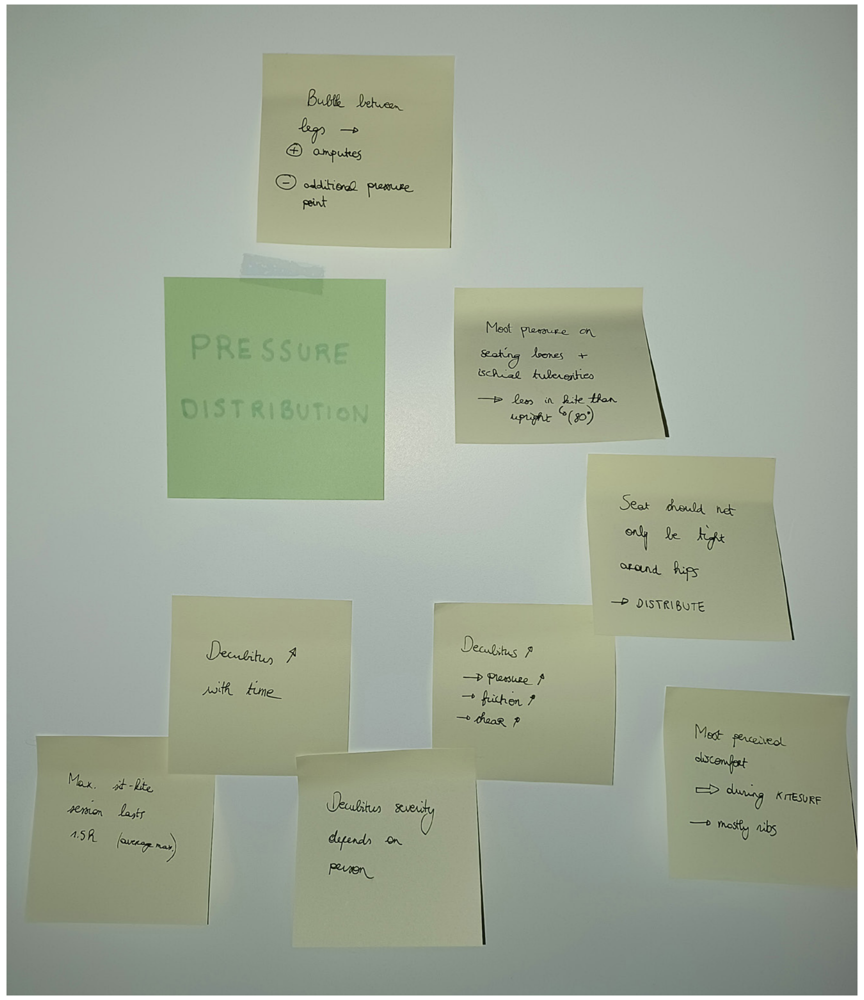


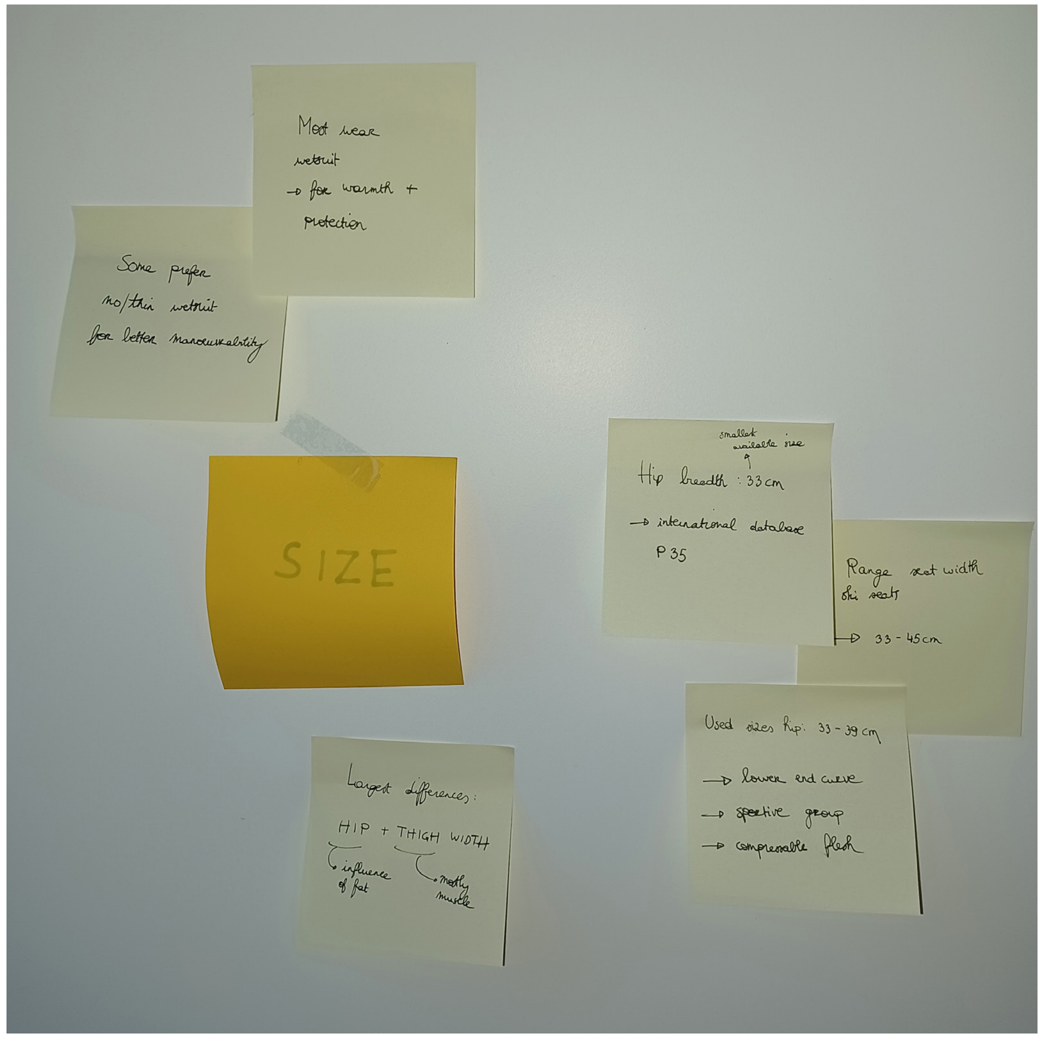


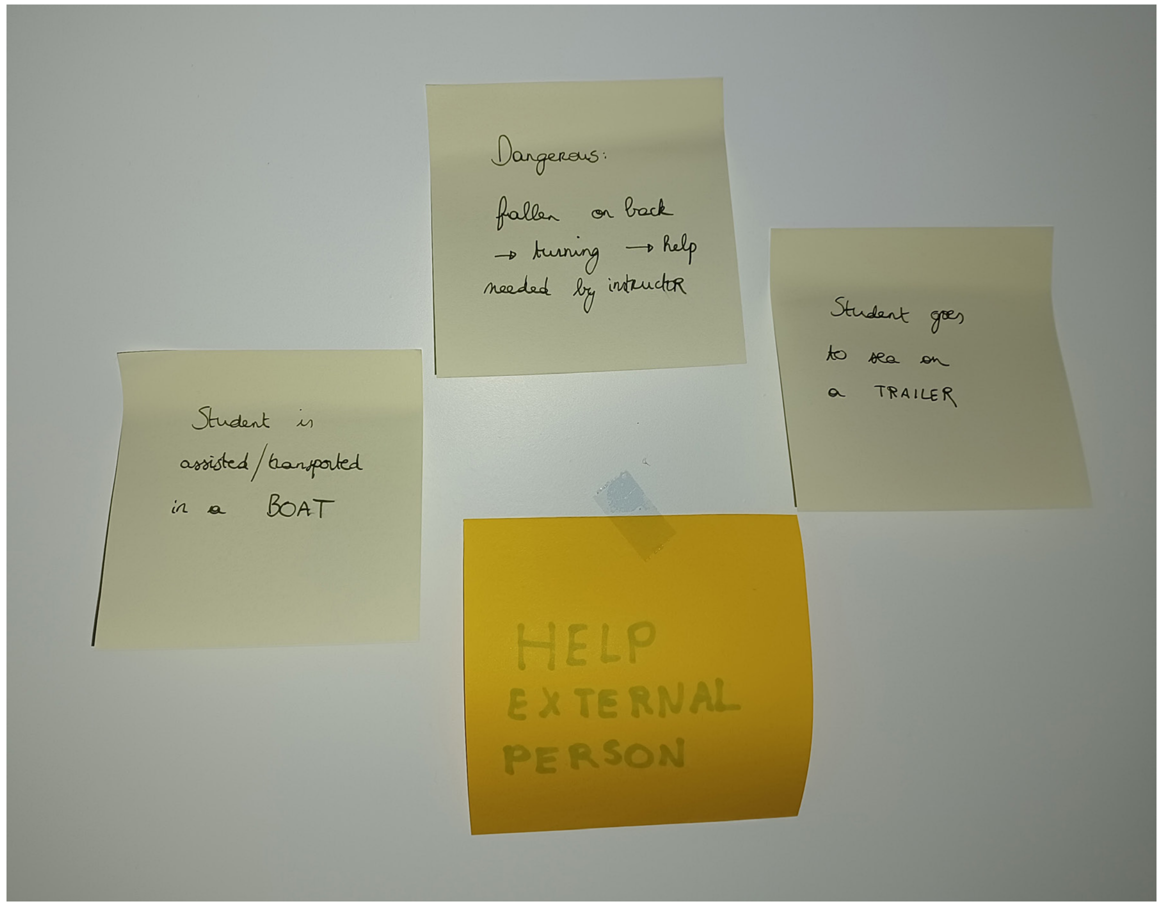

BACKREST
Seat angle (backrest)
→ not neces. adaptable for beginners
↔ experienced
Riding upwind
→ smaller angle
Downwind / wave-riding
→ larger angle
Rigid backrest is less demanding for back than soft
High backrest
⇨ limiting freedom of movement
Low backrest is most used in mono/dualski + kitesurf
Some use
NO BACKREST

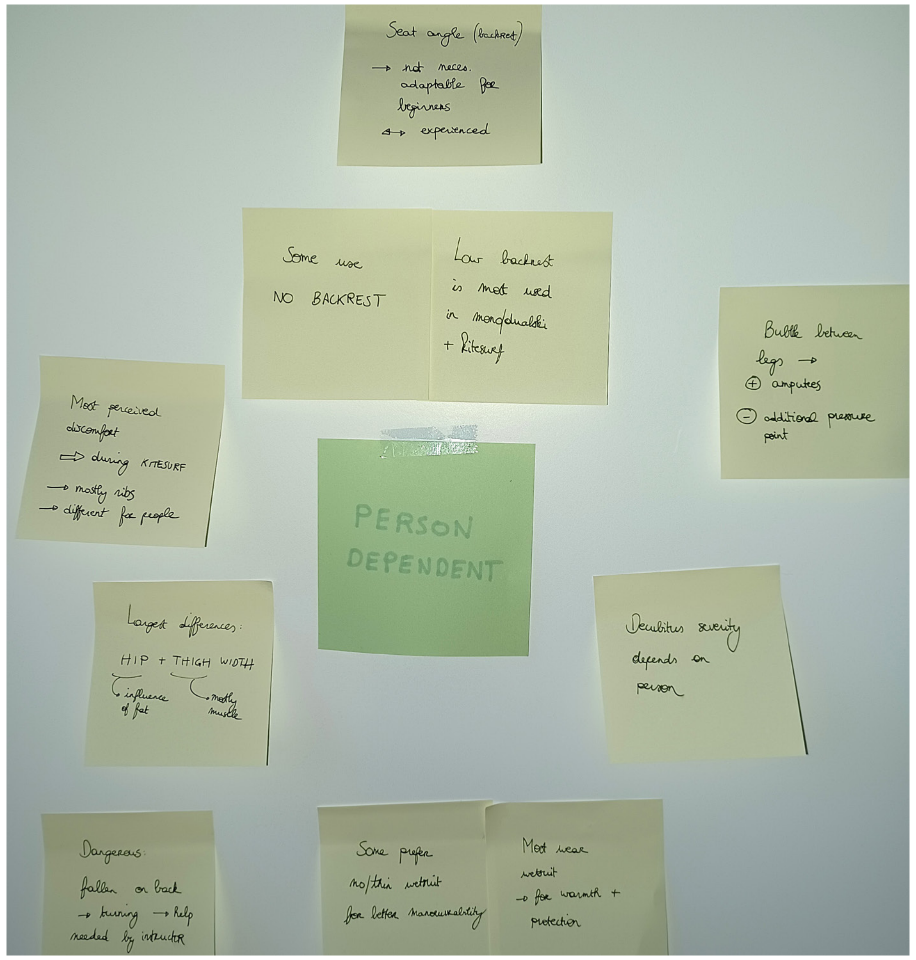

Course needs more time preparation:
NORMAL: 15min
SITKITE: 30-45min
Sit-kite course funded by government / sponsors
↔ €
SCHOOLS
+
ACCESSIBILITY
Starting to kite
→ issue: getting the right material
Threshold schools:
costs + viability
Small market
⇨ adapted boards:
± 12 / year
Need a lot of time changing seats to frame

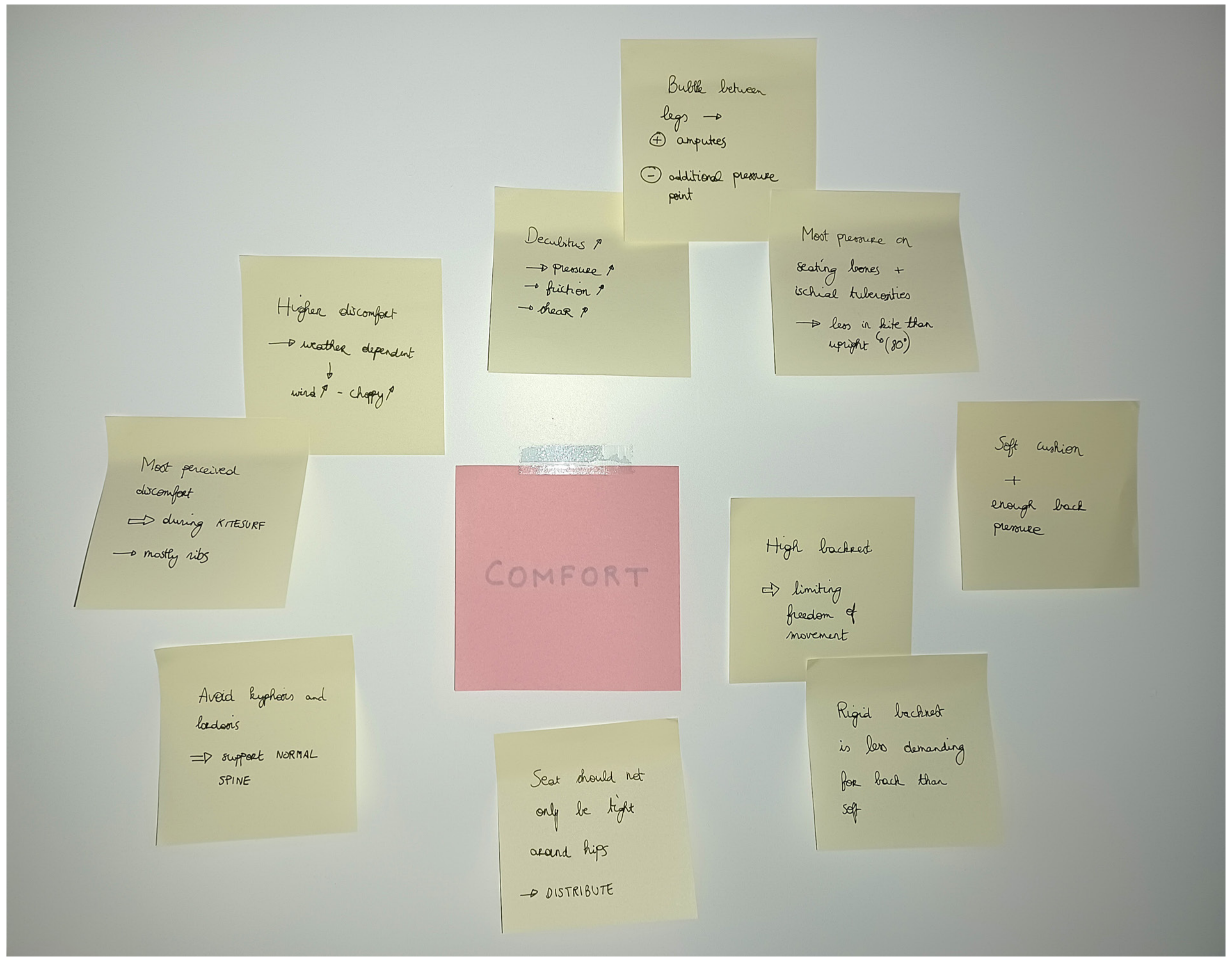

Current seat:
CARBON COMPOSITE
+ FIBERGLASS
Dangerous:
fallen on back
→ turning → help needed by instructor
Not float,
buoyancy comes from upper body
~ stability
Smaller balls in vacuum bag
→ better adaptability
MATERIAL
Seat should be STIFF for support, protection and performance
Most comfortable:
PLASTIC BUCKET SEAT
→ adaptability
Seat should be RIGID in use
Soft cushion
+
enough back pressure


Bubble between legs →
⊕ amputees
⊖ additional pressure point
PRESSURE DISTRIBUTION
Most pressure on seating bones + ischial tuberosities
→ less in kite than upright (80°)
Seat should not only be tight around hips
→ DISTRIBUTE
Decubitus ↗
with time
Decubitus ↗
→ pressure ↗
→ friction ↗
→ shear ↗
Max. sit-kite session lasts 1.5h (average max.)
Decubitus severity depends on person
Most perceived discomfort
⇨ during KITESURF
→ mostly ribs

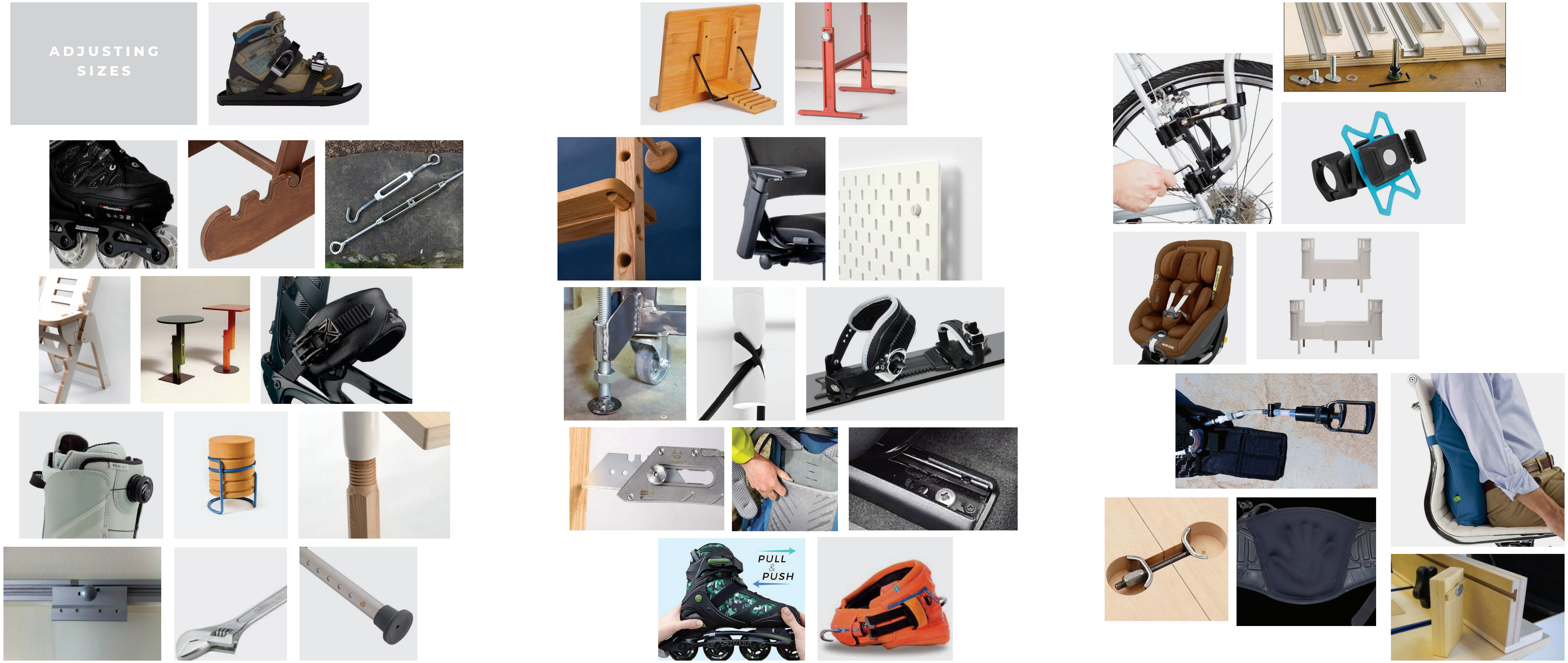

SIZE
Most wear wetsuit → for warmth + protection
Some prefer no/thin wetsuit for better manoeuvrability
Hip breadth: 33 cm
→ international database P35
Range seat width
33 - 45 cm
Used sizes hip: 33 - 39 cm
Largest differences:
HIP + THIGH WIDTH


Dangerous:
fallen on back
→ turning → help needed by instructor
Student goes to sea on a TRAILER
Student is assisted/transported in a BOAT
HELP EXTERNAL PERSON


Seat angle (backrest)
Some use NO BACKREST
Low backrest is most used
Bulk between legs
PERSON DEPENDENT
Decubitus severity depends on person
Largest differences:
HIP + THIGH WIDTH

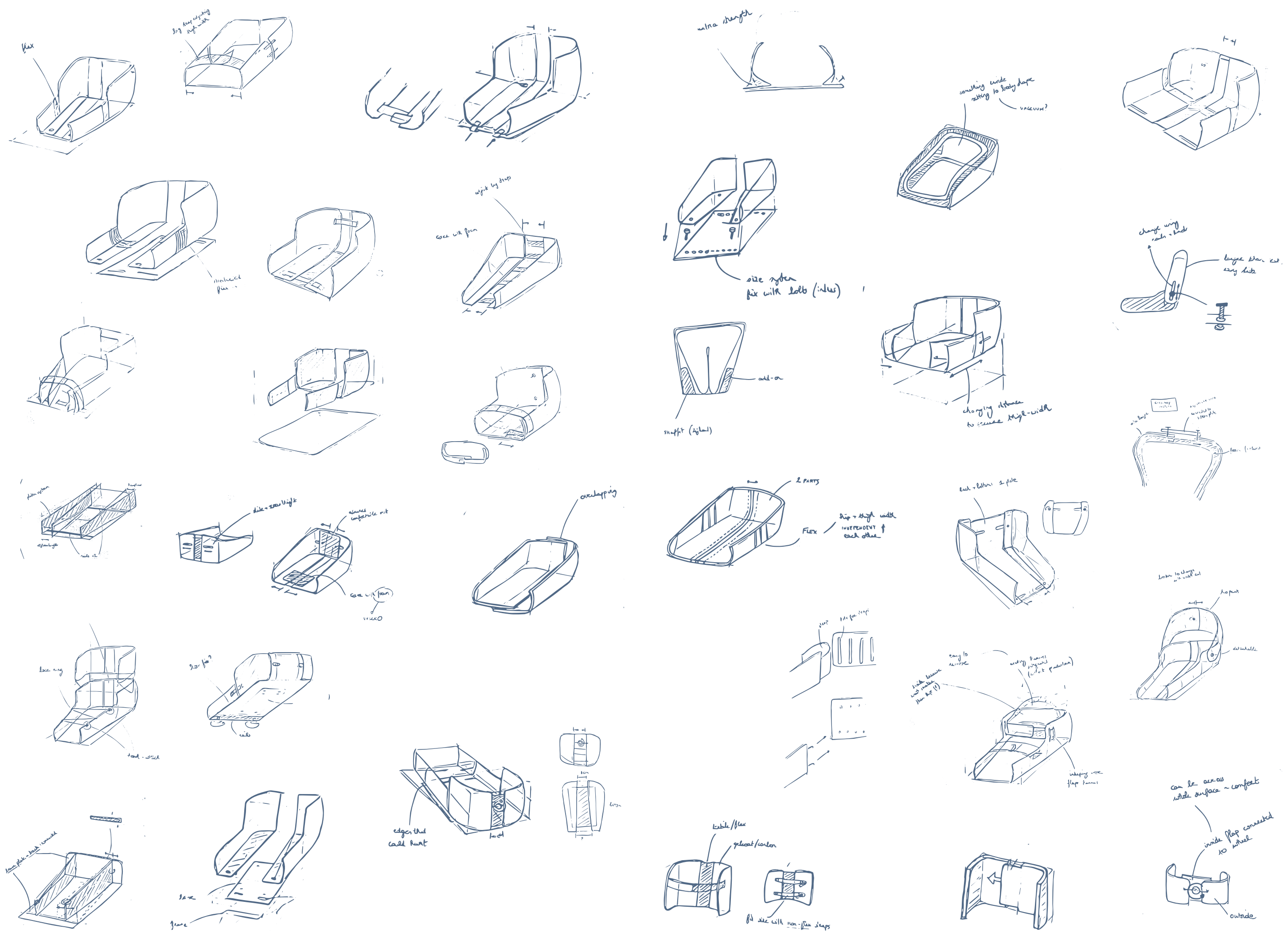

COMFORT
Higher discomfort
→ weather dependent
Most pressure on seating bones + ischial tuberosities
Soft cushion + enough back pressure
High backrest
→ limiting freedom of movement
Rigid backrest is less demanding for back than soft
Seat should not only be tight around hips
→ DISTRIBUTE
Avoid kyphosis and lordosis
→ support NORMAL SPINE

XX. Moodboard ideation



XXI. Design sprints

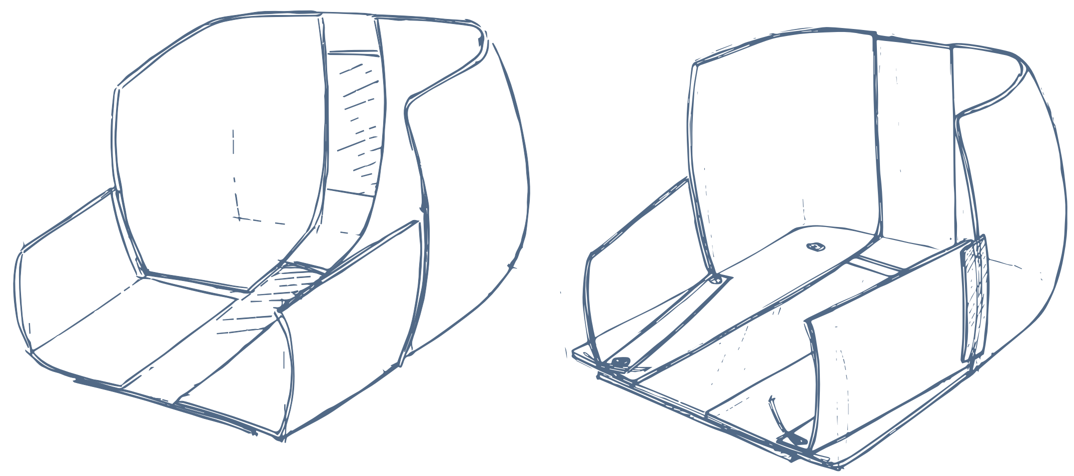
A. Design sprint A

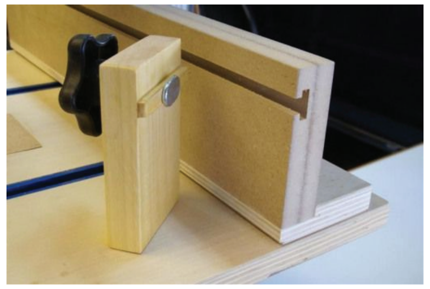


B. Design sprint B

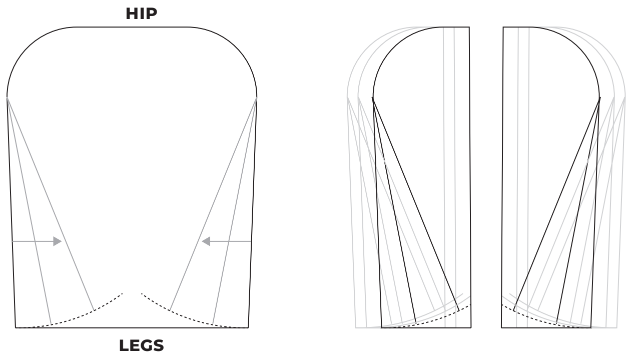
IDEA DIRECTION 1

Four parts and rails



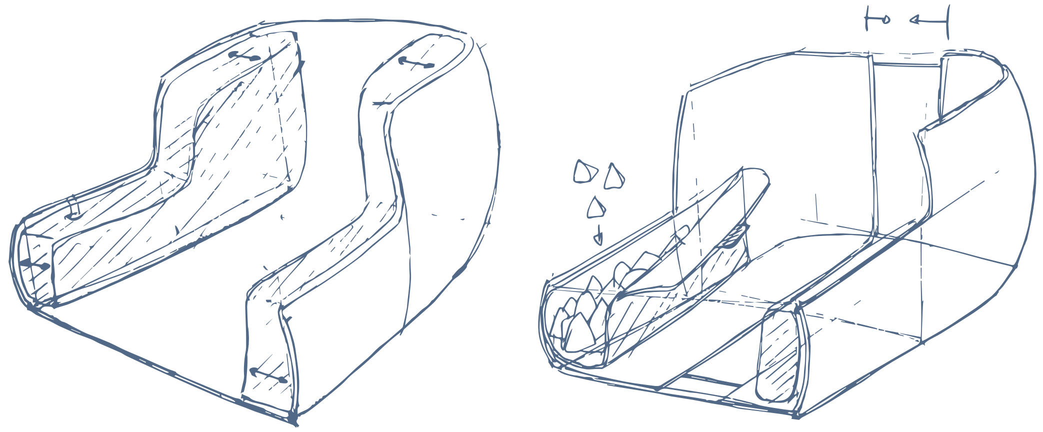


Problem encountered
Rails at the end of the seat (leg side) can not be in a straight line when using a pivot point. Together with a changing hip width, this means rails on different positions which makes it complex. Further exploration has been performed using cardboard to get a better image (see figure FIXME).



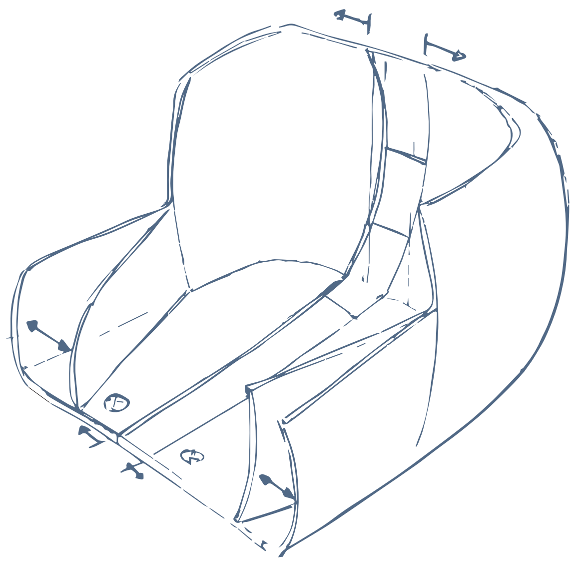
IDEA DIRECTION 2

Outercase + inflatable/vacuum/filling

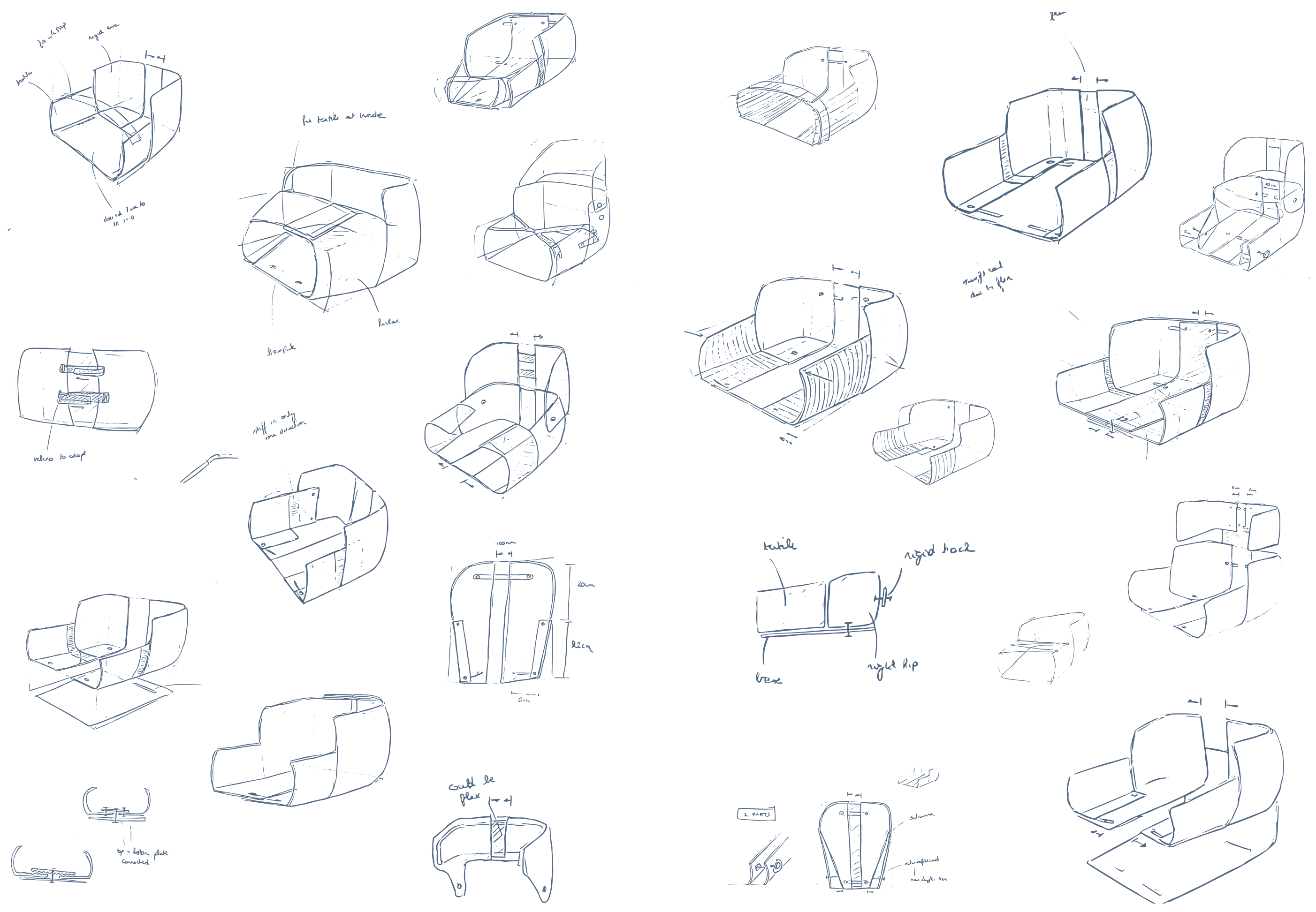


IDEA DIRECTION 3

Two parts + changing sides



C. DESIGN SPRINT C



D. DESIGN SPRINT D