





DESIGNING A KITESURFING HARNESS THAT DECREASES DISCOMFORT WHILE INCREASING PERFORMANCE

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ABSTRACT

The objective of this thesis is to enhance existing harness designs, with a focus on reducing discomfort and enhancing overall performance.

The contextual analysis, literature review, and desktop research yielded crucial insights and identified areas of improvement. Supplementary interviews were conducted with the user group. Initially, anthropometric data was sourced from existing databases like DINED; however, it lacked specificity to kitesurfing and the stances taken during kitesurfing, and some measurements relevant to the design of a kitesurf harness were missing, such as the torso length. To address this, an analysis of individual scans was done, followed by 3D scans of persons in kitesurfing stances.

It was found that the main factors leading to discomfort are the movement of the harness on the body, the pressure on the ribs, and the lack of pressure distribution. The main design goals stated are improved pressure distribution within the variation of movements and body types.

The findings of this thesis offer valuable insights into the potential for enhancing kitesurfing harnesses in terms of comfort, safety, and overall performance. By taking into account both the engineering and ergonomic aspects, this research contributes to the ongoing evolution of kitesurfing equipment, catering to the diverse needs and preferences of kitesurfers.

The final design is a modular kitesurf harness increasing the repairability, maintainability and upgradeability. The project includes anthropometric design guidelines for a kitesurf harness and multiple prototypes to test the concept. Resulting in a set of recommendations and designs that the Mystic team can take into consideration in the future steps towards developing the ultimate harness.

ACKNOWLEDGMENTS

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Bowien van der Linden Katwijk, 2023



Glossary

Anterior Located on the frontside of the body

CS Current solution

FoM Freedom of Movement FBD Free Body Diagram

HKJ Design method "Hoe kan je" - "How can you"

LSP Lowest Shoulder Point

Posterior Located on the backside of the body

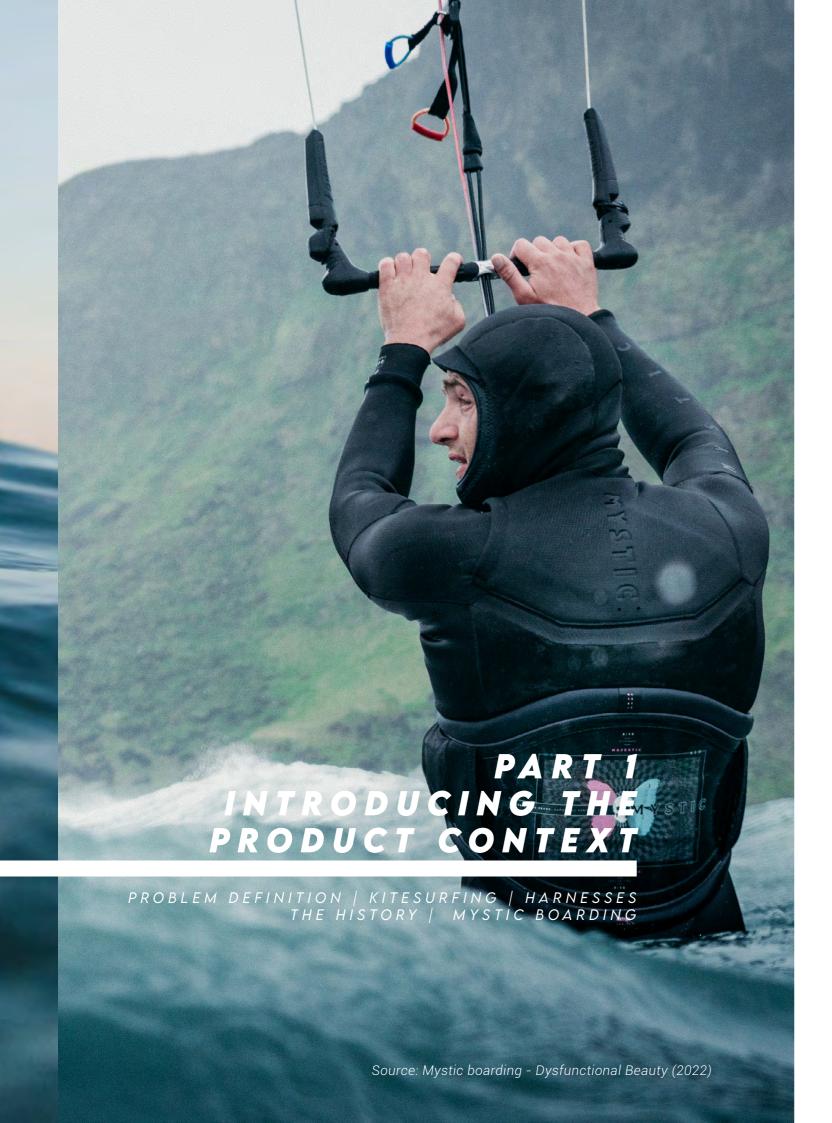
PP Polypropylene
RoM Range of Motion
RQ Research Question
RbD Research by Design

UALo Design method Unique, Advantages, Limitations, and overcoming limitations

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1.1 INTRODUCTION

Kitesurfing became a mainstream sport in 1999. At that time, kites were raw, powerful, and quite dangerous. Kiters started flying higher and further than ever before and needed the gear to match their wild ambitions. This was the start of Mystic, a well-known kitesurf accessories brand from the Netherlands. Since they began producing kitesurfing gear in 2002 (Mystic, 2022), they have become a well known brand in the industry, winning the award for best kitesurfing accessories brand since 2012 (IKSURFmag, 2022).

The developments in materials, weight, stiffness, and attachment methods have led to incremental changes, introducing easier, more comfortable, and safer riding experiences. However, pain in the lumbar area and back problems are still quite common for kitesurfers (kitesurfist, 2022). Kiting causes heavy strain on the back as the kite tugs on the harness, putting pressure on the torso. The abdominal muscles try to keep the pelvis and spine stable while being tugged, making the harness an important aspect of kitesurfing.

The introduction of the hardshell harness in 2015 marked a milestone in the evolution of kitesurfing accessories (Global kite spots, 2019). Compared to its predecessor, the softshell harness, the hardshell harness includes advantages like improved load distribution and prevention of squeezing the user. However, the hardshell harness lacks certain aspects like flexibility and lumbar support.

The evolving demands of a new generation of kitesurfers have created the need for improved equipment. This generation seeks to go higher, faster, and tackle larger waves, especially "Big Air" kitesurfing is growing in popularity. Athletes are pushing the sport by jumping over 30 meters high in soaring winds of 40+ knots, as shown in Figure 01 (Redbull - the editors, 2022). Regardless of the discipline, users are looking for a harness that offers absolute comfort, reliability, enhanced performance, and unrestricted mobility. This has resulted in a growing demand for the ultimate kitesurfing harness.

PROBLEM DEFINITION

The changing user demands and discomfort caused by the use of a kitesurf harness raises the guestion:

"What is the next step for the kitesurfing harness. How can we integrate more support into the harness, leading to more comfort, trust and freedom of movement?"

The design should enhance the support while allowing for unconstrained movements. The kitesurfing-scene has embraced the hardshell harness, but it has lost some of the forgiveness of the softshell. Do we need a solution combining hard and soft materials to achieve the wanted characteristics? This conflict in requirements shows great potential to be solved by designing a smart solution. Especially in combination with the availability and affordability of new high-tech materials and manufacturing methods.

THE SCOPE

The needs of the user are complex, especially when enduring large forces on the body. There is limited well-substantiated analysis of these needs during kitesurfing, which is the focus of this research. The currently available harnesses have been designed using measurements and 3D molding, gaining insights into the shape of the abdominal segment of the torso.

This project aims to provide insights into the different postures of the body and the forces exerted on the body during these postures. These insights will be used to develop a concept for a kitesurfing harness with improved qualities. The report set-up can be found in Figure 02.



Figure 01: Big wave & big air kitesurfing



Figure 02: The report setup

1.2 KITESURFING

Kitesurfing can be seen as a system that can be split into four main components. Each component has its own function and forces working on it.

- A. The kite: Kite, lines and controlbar
- B. The kitesurfer: User, harness and waterwear
- C. The board: Board and bindings
- D. The environment: Body of water and weather conditions

KITE

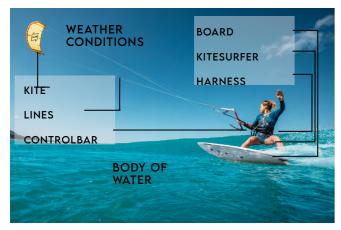


Figure 03: The components of kitesurfing (North, 2021)

The kite is the power source of kitesurfing. The size and the design of the kite influence the properties of the kite - the power, speed, sensitivity, depowering, balance, drift and safety. Therefore, having an influence on the forces that come onto the user. In less wind a bigger kite is needed, but a bigger kite is slower and less reactive. Slower kites are easier to ride, especially for beginners.

The aspect ratio of the kite influences the speed, and consequently the reaction speed of the kite. The angle of attack of the kite affects the power that can be generated by the kite, and how easily you can depower the kite. Also describing the balance of the kite, an unbalanced kite would tend to fall forward or backwards, resulting in falling out of the sky. The structural components, the anchoring points and struts influence the power the kite can handle. Kites with fewer and/or thinner struts tend to be more flexible and lighter but are less stable.

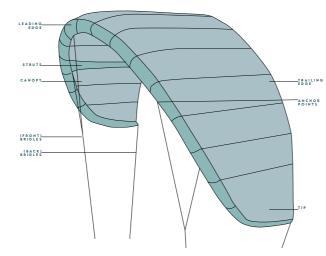
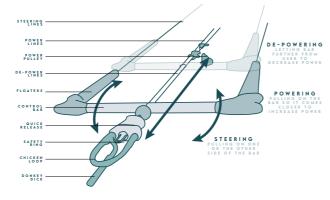


Figure 04: The components of a kite



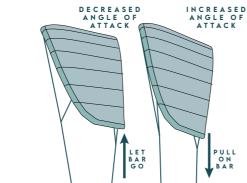


Figure 05: The components and function of the controlbar

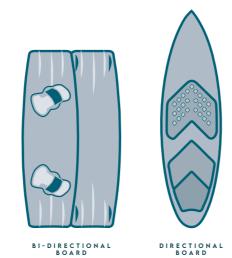


Figure 06: The two types of kitesurf boards. A bi-directional twintip and a directional surfloard

LINES & CONTROLBAR

The lines connect the user and the kite, the harness is connected to the powerlines and the bar is connected to the steering lines. The controlbar is used by the kitesurfer to operate the kite. Most force is directed through the power lines, which goes through the control bar to the hook of the harness, where it is attached with a chickenloop and donkey dick. The steering lines are attached to the sides of the control bar and by pulling left or right the kite steers the kite. When pulling on the bar the angle of attack of the kite is increased and more speed and power can be felt by the kitesurfer, the kite is de-powered when the kitesurfer pushes the controlbar away. The most sold lines range from 18 to 28 meters. The usual line thickness is around 1.5 mm with a breaking strength of 400-600KG.

BOARD

There are 2 different types of boards. Most common is the twintip, this board is bi-directional with a square shape. It is used to learn how to kite and for freeride, freestyle and big air. The directional is a surfboard used for wave riding and freeriding. The biggest impact on the forces is the surface of the board, the volume and the drag of the board caused by the design, weight, fins and use of a leash. The size of a twintip is described in cm's and the size of a directional is described in volume (liters).

THE KITESURFER

The kitesurfer, also named the rider, kiter, kiteboarder, user or system operator. The kitesurfer is the controller of the system and forming the connection between the kite and the board the kitesurfer is a part of the mechanical system.

THE HARNESS

The most important feature of the harness is facilitating the connection between the kitesurfer and the kite. More details on the harnesses functions can be found in chapter Appendix F on page 104.

WATERWEAR

Depending on the water temperatures a kitesurfer rides with a wetsuit or other waterwear like an impact vest, lycra, shirt or bathingsuit. The thickness, style and material of the wetsuit differs Available are full body suits or semi-body suits called "shorty's" with thicknesses ranging between 1mm to 6mm. Some kitesurfers wear lycras over their wetsuit to show membership of a club or participation in an event. Depending on the waterwear and harness used it may cause lateral shifting between the kitesurfer, the waterwear and the harness.

1.3 THE ORIGINS OF KITESURFING

In 1977, the first description of kitesurfing can be found in the patent of Gijsbertus Adrianus Panhuis, which states, "a water sport using a floating board of a surfboard type where a pilot standing up on it is pulled by a wind-catching device of a parachute type tied to his harness on a trapeze-type belt." The first inflatable kite design was patented in 1984 by the Legaignoux brothers, and this design served as the basis for many kites produced thereafter (D. Legaignoux, 1987). Years later, in 1995, windsurfers began experimenting with windsurfing boards and foil kites, and it was around this time that the "Wipika" kite was designed and sold. A design on which kites today are still based featuring inflatable tubes and a simple bridle system for easier waterlaunching as can be found in Figure 07.

By the end of the 2000s, kitesurfing had become a well-known extreme sport, with distribution and teaching taking place through shops and schools worldwide. The first competitions were held during this time and windsurf brands like Naish and Neilpryde started entering the market. Initially, kitesurfing was done on surfboards called directionals. From 2001 onwards, twin-tips became more popular. Especially for flat water kitesurfers, due to their bi-directional abilities, similar to a snowboard.

In 2005, Bruno Legaignoux developed the first Bow-kite, which featured a patented design. This design was adopted by a large group of other brands as it provided a de-powering system, making it much safer to use, especially for beginners. This system also reduced the forces on the user's torso. From that moment on, the trend in kite designs has been focused on creating safer, faster, lighter, stable, and trustworthy kites (International Kitesurf Organization, 2019).



Figure 07: A Legaignoux brother with one of the first inflatable kites

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1.4 THE HISTORY OF THE HARNESS

The journey of the kitesurfing harness can be traced back to the history of windsurfing. In 1974, Pat Love and Ken Kleid of Windsurfing Hawaii developed the first windsurfing harness, which was a vest-like nylon jacket with an attached hook. A year later, when windsurfing worldchampion Robby Naish had problems with his chest being squeezed painfully by the harness, a spreaderbar was developed. Till this day this system is still used, spreading the load and prevents squeezing of the user (Cai, 2018).

To address similar issues, Ian Boyd started wearing his harness upside down, with the hook inverted. This inspired the R&D designers from Dakine to develop a seat harness. Being one of the leading brands in windsurfing, Dakine recognized the potential of kitesurfing and launched the world's first production kite waist harness, which is still part of their product line today. The kitesurf harnesses were heavily inspired by the windsurf harness at the time, which can be found in Figure 08. This product line included leashes, harness loops, and board bags. Other brands, such as Mystic in 2002 with the Darkkitesurfer harness, followed suit.

These first harnesses came with spreaderbars, thick padding, a hook knife, and a back-handle. The spreaderbar prevents the user from being squeezed due to the pull from the kite, but compared to windsurfing these forces are from a more upward direction, resulting in the spreaderbar digging into the ribs of the kitesurfers. Therefore soon the designs of the kitesurf harnesses included a thicker spreaderbar padding.

The next major innovation occurred in materials. The introduction of thermoformed EVA foam covered with marine grade vinyl became standard for use in harnesses. The brand Ride engine was the first to introduce a hardshell harness, first only custom models. Sending a molding kit to the user which would be used to form the hardshell carbon outer layer. In 2015, they introduced the first production hardshell harness. As can be seen in Figure 08 (Chevalier, 2014).



WINDSURF HARNESS COLLECTION SHOWN IN AMERICAN WINDSURFER MAGAZINE IN 1999



2002 TO 2005
THE FIRST KITESURF HARNESSES COMING TO MARKET



2015
THE FIRST COMMERCIALLY AVAILABLE PRODUCTION HARDSHELL HARNESS
RIDE ENGINE'S HEX-CORE



2023
THE CURRENT TOP-OF-THE-LINE HARDSHELL
HARNESSES OF 4 MAJOR BRANDS
RIDE ENGINE, ION, PROLIMIT AND MYSTIC

Figure 08: A short history of the kitesurf harness, showing it's predecesor, the windsurf harness; the first kitesurf harnesses, the first hardshell harness and the latest harnesses. (American windsurfer, 1999) (Mystic, 2023) Dakine, 2023)(Ride Engine, 2015)(Ride Engine, 2023)(ION Apex, 2023)(Prolimit, 2023) (Mystic, 2023)

1.5 THE CLIENT 1.5.1 MYSTIC BOARDING

Mystic boarding is a kitesurf accessories brands. It started in 2002, when the founder of Maui Magic (windsurfing) and Magic Marine (sailing) tasked a team to brand a new product line of kitesurfing accessories called 'Mystic'. With the growing popularity of kitesurfing Mystic became a new brand in the M-brands.

From the moment the task force created Mystic, it has worked on creating an individualistic and young image, which it's still known for to this day. It has always been different from other brands, especially their designs and marketing have been ahead of their time. They have become a trusted manufacturer of harnesses and are most known for their hardshell harnesses.

In 2019 the company was acquired by the North technology group, becoming a part of North Actionsports Group (NAG). Now including North kiteboarding, North foiling, North sails windsurfing, North supping and Mystic. Mystics brand portfolio has grown into different markets going from only kitesurfing to windsurfing, wakeboarding, supping, wingfoiling and surfing, as can be found in Figure 10

1.5.2 PRODUCT PORTFOLIO

In Appendix B on page 99 the history of the harness portfolio of Mystic Boarding can be found. Showing their first ever harness, the Darkrider to their latest, the Stealth 2023. What can be found is that in their 20 year existence they have launched a new harness concept every three to four years. After the introduction of the Stealth in 2020 it could be assumed they are looking for the next concept to launch.

NORTH ACTIONSPORTS GROUP



Figure 09: North Actionsports Group (NAG)



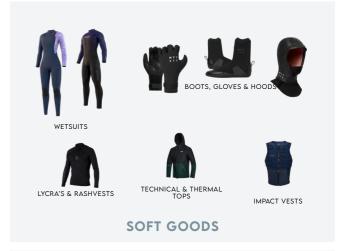




Figure 10: Mystic's product portfolio

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2.0 CONTEXT ANALYSIS

The objective of this chapter is to enhance the understanding of the context of kitesurfing, resulting in a guideline for the design phase. After the context analysis the problem definition will be re-defined a research plan was created. Four research area's are described, each with their own sub-research questions and approach.

RESEARCH QUESTIONS

- 2.1 Product analysis
- 1. What components does a kitesurf harness consist of?
- 2. Which existing harness designs/solutions can be found on the market and similar markets?
- 3. Are these found solutions considered desirable?

Method: Desk research & physical testing

- 2.2 Physical demands of kitesurfing Physical demands of kitesurfing
 - 4. What knowledge of the ergonomics and physics of kitesurfing is available?
- 5. What existing analysis of unfamiliar forces coming onto the lumbar area is available?

Method: Literature review

- 2.3 The user group
- 6. Who is the user group?
- 7. What discomforts concerning the harness are perceived by kitesurfers?
- 8. What are the needs and preferences of the user group?

Method: User interviews & creating personas

- 2.4 The physics of kitesurfing
- 9. What are the components of kitesurfing?
- 10. What are the forces acting upon the harness and user during kitesurfing?

Method: Desk research & literature review

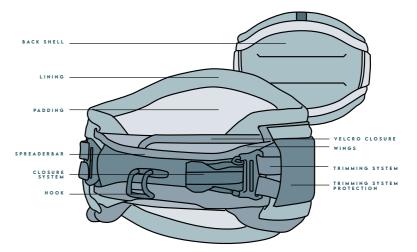


Figure 11: Kitesurf harness components



Figure 12: Mystic's current hardshell harness range: The Stealth 2020, the Stealth 2023, the Majestic and Majestic X

2.1 PRODUCT ANALYSIS

This chapter discusses the product, the kitesurf harness, aiming to answer RQ 1/2/3 by analyzing the current solutions found on the market including Mystic's harnesses and that of it's competitors.

2.1.1 THE HARNESS

The harness plays a vital role in kitesurfing, being the connection between the user and the kite. While encompassing other critical functions like safety and force management. Current harnesses are composed of two modular parts: The harness and the spreaderbar. These parts consist of:

The spreaderbar

The spreaderbar - The rigid bar which includes the hook and closure system. Its main function is to distribute the pulling forces from the kite evenly across the kitesurfer's body, decreasing the compression on the kitesurfer's torso.

The closure system - The system used to lock the harness around the torso of the user. The main function is to provide a secure fit, ensuring the harness stays in place during kitesurfing maneuvers. It typically includes a buckle, lever or a quick-release mechanism.

The trimming system - System used to trim the harness to the perfect size

The hook - Connection between the kite and the user, different riding styles include different systems. Available options are a hook, ring or rope.

The wings - semi-rigid straps attached to the spreaderbar that are tucked into the sides of the harness to keep the spreaderbar in place

The harness

The backplate - The structural element of the kitesurf harness. It's main function is to maintain the shape of the harness. It also provides support to the kitesurfers back as it distributes the load evenly over the back.

The lining - The surface material of the inside of the harness. Thus directly interacting with the surface of the user. It's function is to keep the harness in place without causing discomfort through friction.

The padding - The padding on the inside of the harness. It is designed with materials and features that prioritize comfort, support and protection.

2.1.2 THE MYSTIC HARNESS

The Mystic hardshell harness collection currently consists of three main models: The Stealth, Majestic, and Majestic X. Which can be found in Figure 12. The Stealth is the showpiece of the Mystic collection. A carbon hardshell harness with a low-profile harness and non water-absorbent lining (EVA). The other harnesses are the Majestic and the Majestic X, a composite and stiffer carbon version both with fabric lining. The non-water absorbing padding leads to a lighter harness on the water, and more grip on the body due to higher friction coefficient.

Mystic spreaderbars are sold separately from the harnesses. Giving the kitesurfer the chance to customize their setup between riding styles, sizes and the ability to replace only one of the two when needed. These spreaderbars are connected to the harness via strong closely woven straps, the webbing. These straps can be tightened according the size of the kitesurfer. A disadvantage of webbing is the flexibility, leaving some movement between the harness and the spreaderbar. The mystic spreaderbars all feature the same closure system, a leaver clip that enables the kitesurfer to create a tight fit.

The current harness designs are made available not only in different colors but also with different prints on the backplate. This gives the brand the opportunity to create collaborations with other brands like Dirty Habits, competitions like King of the Air, artists and special teamkitesurfer editions like Bruna, Jalou or Ozzy as can be seen in Figure 12.

2.1.3 THE HARNESS MARKET

In examining the broader harness market, a comprehensive overview of harnesses, including those from Mystic Boarding, has been provided in Appendix F on page 104. Followed by a description of some of the most popular harnesses and overviews of currently available solutions of each component of the harness.

Insights from this analysis showed a continual evolution of the harness. Brands constantly trying to meet the developing needs of kitesurfers. Many brands aim to solve similar problems as stated in the problem statement of this report These solutions, though needing improvement, could serve as inspiration to the concept development in this report. For example: a hybrid harness - the combination between a hardshell and softshell; a rigid connection between the harness and spreaderbar; a modular design.

2.2 PHYSICAL DEMANDS OF KITESURFING

This chapter explored the physical demands of kitesurfing and its corresponding ergonomic considerations through desk research & literature review. The interaction of forces, equipment design, bodily discomfort, and potential injuries highlights the challenging essence of kitesurfing. Existing research emphasizing the potential of design effectively emerging as factor used to align ergonomic principles, enhancing performance and reducing safety hazards.

2.2.1 PHYSICAL DEMANDS DURING KITESURFING

During kitesurfing considerable stress is placed on the musculoskeletal and physiological systems, caused by the high pulling forces on the torso. Walls and Gale (2001) showed that the amount of pulling force to the harness when windsurfing, called the harness line force, was around 4,9N per kg bodyweight. Leeflang and Van Noort (2017) researched this pulling force during kitesurfing and showed that the forces on the harness reached over 300 N. The amount of force on the user by the kite is affected by the wind speed (gusts), the sea-state, angle to the wind and the kite being powered or de-powered, this leads to a constant fluctuation of forces on the harness.

In this constant change of conditions, the lower back and thigh muscles are constantly keeping the body stable and are often perceived as being highly stressed compensating for these forces. Abdominal muscles, knees, and feet are also common sites of pain or discomfort (Bourgois et al., 2013). Riding with high speeds over choppy water can result in whole body vibrations, the exposure to which causes bio-mechanical stress. Which over time can cause spinal degeneration. The knee flexion significantly reduces the amount of vibration reaching the trunk, consequently reducing impact on the spine. But the non-symmetrical stance taken in kitesurfing in combination of the tilting motion of the feet can cause bending motions on the spine, leading to increased compression on the spine (Tarabini & Valsecchi, 2016).

The body position during kitesurfing changes depending on factors such as wind speed, upwind projection and when preparing for take-off. This influences the biomechanics and will determine how well the person can handle and utilize the force from the kite for doing tricks or moving at a certain speed (Lundgren & Brorsson, n.d.)

2.2.2 COMFORT & DISCOMFORT

Comfort can be described as "a pleasant state or relaxed feeling of a human being in reaction to it's environment" in contrast discomfort is seen as "an unpleasant state of the human body in reaction to its physical environment". Hence the main criteria used in the evaluation of a product is discomfort as negative, and comfort, as positive criterion (Paschoarelli, 2003).

The term comfort is often used in relation to marketing of products (Vink and Hallbeck, 2012). But comfort is not measurable, therefore in scientific research and literature the term (perceived) discomfort is leading. According to Helander and Zhang (1997) analyses of variance demonstrated that subjects can evaluate comfort and discomfort simultaneously without bias. They do argue a dis -continuity on the scale between discomfort and comfort. While the model of De Looze et al. (2003) reflects that the two different states each have their own scale. This model, presented in Figure 13, suggests that discomfort is influenced by mostly physical factors while comfort is influenced by physio-social factors, physical aesthetics, the expectations and emotions of the user.

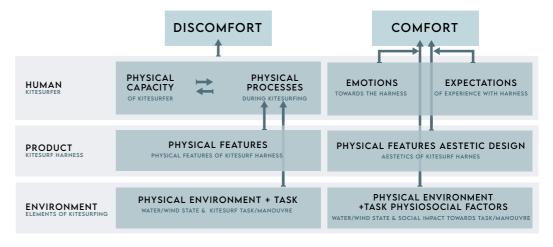


Figure 13: De Looze et al.'s (2003) Comfort model modified to include the factors related to the comfort of a kitesurf harness.

2.2.3 PERCEIVED DISCOMFORT DURING KITESURFING

Research has shown that postural discomfort perceived linearly increases when the holding time and holding force increases (Kee et al, 2010). Thus we can assume that the discomfort during kitesurfing should increase with longer session and higher wind speeds or a combination thereof. Galinsky et al. (2000), examined the effects of supplementary rest breaks on musculoskeletal discomfort. Finding that discomfort was significantly lower under a supplementary than a conventional rest break schedule. We could conclude that taking breaks between sessions has a positive effect on the perceived discomfort throughout the session and in future situations as research shows that musculoskeletal stress effects the body over time. Heightened musculoskeletal discomfort has shown to lead to an increased chance of back, neck and shoulder complaints years later according to Hamberg van Reenen (2008).

Lundgren et al. (2012) conducted interviews with 17 kitesurfers about their harness. The most mentioned discomfort concerning a harness was the sliding upward towards the chest, resulting in pressure and discomfort on the ribs. This was mentioned by 53% of the participants. Other important characteristics of a kitesurfing harness mentioned were the support to the lumbar area(47%) and that it should fit properly, not being to big or too small(41%). Most interviewees (14 out of 17) reported high activation of the abdominal muscles during kitesurfing. Tiredness and muscle soreness after the session was most noticeable during or after a large amount of jumps. The lower back was not often experienced as having high musculoskeletal stress, though some had back problems from other sporting activities and experienced worsening of their back problems after kitesurfing.

A questionnaire with 208 kitesurfers also by Lundgren et al. (2012) showed pain and discomfort were experienced in the knees (38%), lower back (38%), shoulders (29%), feet/ankles (26%), and elbows (23%). No statistically significant relations were found between other region and any performance variable. The causes of discomfort were reported to be crashes, pressure from the harness, a hard pull from the kite, long sessions or colliding with equipment. In comparison to the previous research from Lundgren et al. it shows that when not specifically asking about the discomfort of the harness also crashes and colliding with equipment are mentioned by the participants. Still the other three causes for discomfort are related to the harness.

Discomfort in extreme amounts can result in pain. Research on the PDT(Pressure discomfort threshold) and the PPT (Pain pressure threshold), shows that different values can be found in different regions of the body, due to the proximate or direct location of nerves, blood veins and soft (muscular) tissue (Smulders et al., 2023b). The exposure of prolonged muscular stress or flexed postures can decrease the PDT and PTT. The research by Petersson and Abbott (2020) demonstrated that exposure to prolonged static sitting in a fully flexed lumbar posture decreases pressure pain threshold of inter-spinous lumbar spine structures. Additionally, Binderup et al. (2010b) showed that the PPT of the trapezius muscle, located on the back, also decreased when measuring directly after and 24 hours after exercise. This research did show that the area with a lower threshold in the first test also showed the lowest threshold after the 24 hours.

Products with pressure points can result in discomfort, pain and even pressure sores. This is extensively researched for wheelchair and prosthetics users. Having evenly distributed pressure points makes use of the products more comfortable, can improve positioning and results in decreased chance of sores. In this industry pressure mapping and 3D scanning are used to create custom designs. (Da Silva et al., 2011b)

Different types of stress result in different effects on the body. Research has shown that the shear stress on the body-support interfaces is a critical parameter in the forming of pressure sores on the body and is just as important as the reduction of normal forces in the prevention of such sores and thus discomfort. (Zhang et al., 1994). This same research showed that sores in prosthetic wearers mainly occur near the rim of sockets, possibly because upward shear forces increase the compression stresses on the tissue near these rims.

2.2.4 INJURIES DUE TO ACCIDENTS

Kitesurfing can be considered an extreme sport, and with extreme sports come accidents. According to Bourgois et al. (2013) most accidents during kitesurfing were attributed to the inability to detach the kite from the harness. Recent studies report uncontrolled actions and jumps with inadequate landings as the main causes of injuries.

The injuries are affected by certain internal factors (Gender; Age; Experience; Physical fitness) and external factors (Elements of kitesurfing; Environmental circumstances; Wind force; Wave height). In contrast Lundgren et al. (2007) state that equipment and environmental factors have shown to have the largest impact on the safety during the sport. Also, for ergonomic issues, the equipment has to be well designed for the athlete to enable maximum performance and to reduce injury risk (Cottam et al., 2002) (Reilly & Lees, 2009).

Lundgren, Brorsson, & Osvalder (2011b) researched injuries related to kitesurfing, they reported about 251 injuries. Most being the knee(24%) and ankles(17%) but also reports can be found in the trunk (16%) and shoulders (10%). This research also showed that respondents who were able to perform advanced tricks experienced fewer injuries compared to those who could not.

Lundgren et al. (2012) researched the use of waist and seat harnesses, 85% of the questionnaire respondents used waist harness and these participants were able to perform advanced tricks to a wider extent than those who used a seat harness ((1)=10.8, p<0.01)

2.2.5 CONCLUSION

This chapter set out to analyze existing research concerning kitesurfing and ergonomic analyses of forces on the lumbar area. This research showed that kitesurfing involves substantial stress on the body due to the kite's pulling forces. Fluctuating forces, influenced by wind and sea conditions, engage muscles for stability. Discomfort is commonly felt in the abdomen, knees, and feet.

Accidents are often attributed to equipment failures, emphasizing the need for proper gear design to reduce injury risks. The dynamic nature of kitesurfing exposes the lumbar area to unfamiliar forces, potentially causing discomfort. Effective equipment design and lumbar support are crucial for minimizing this discomfort. Prolonged stress and flexed postures can lower pressure discomfort thresholds. Shear stress at body-support interfaces can lead to pressure sores, highlighting the need for ergonomic solutions.

To conclude, the analysis of kitesurfing's ergonomics and physics highlights its demanding nature on the body. Fluctuating forces, dynamic conditions, and unfamiliar pressures on the lumbar area contribute to discomfort and potential injury risks. Proper equipment design is essential for both performance enhancement and safety improvement, as highlighted by existing research.

2.2.6 REQUIREMENTS

Safety: The equipment has a significant impact on the safety of the sport. The harness should be well designed to reduce injury risk and enable maximum performance.

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2.3 THE USER GROUP

Who is the user group? Describing the demographic of kitesurfing could be described as difficult, due to the diversity between kitesurfers. Persons from all classes, ages and physique are found on the water. In this chapter the target group is described, user interviews are conducted with kitesurfers and a sales employee from a kitesurf store was questioned about his clients.

2.3.1 THE TARGET GROUP

Worldwide there are said to be more than a million kitesurfers, the global market for kitesurfing gear being estimated at 909 billion dollars (Fact.MR, 2022). The following factors describe kitesurfers:

AGE Though kitesurfing attracts many young persons, the majority of the user groups is assumed age 25 - 50 due to the high entry into watersport when windsurfing was very popular (Seabreeze, 2015).

Persons aged 16 - 65 years, all adult sizes

GEO Kitesurfing is considered a high-cost sport. Resulting in a predominant practice in first-world countries. For instance, Europe accounts for 33% of the total sales of kitesurfing gear. (Fact.MR, 2022).

International with target on the European, American and Oceania Market

GENDER Kitesurfing is practices by both genders but predominantly by males.

Males and females

PHYSIQUE Regarded as an extreme sport, kitesurfing requires sufficient strength and physique to control the kite, handle unexpected falls, and manage the power exerted on their bodies.

Persons physically capable of kitesurfing

RIDING Kitesurfing includes many different disciplines STYLE like; free-riding, freestyle, wave-riding and big air.

All disciplines; possibility for modular items for certain discipline

LEVEL The demographic consists of beginners, intermediates and advanced kitesurfers. The time on the water is an indicator for the level and the commitment of the kitesurfer.

All level kitesurfers (frequent & infrequent kitesurfers)

2.3.2 PERSONA'S USER GROUP

A set of persona's has been created, which can be found in Appendix D. These fictional representations of specific user archetypes embody the characteristics and goals of real users, covering a wide spectrum of potential kitesurfers of a Mystic harness. A step in the design process, helping understand the needs, preferences, and behaviors of the target group.

2.3.3 USER INTERVIEWS

To further enhance the understanding of the user experience, interviews were conducted with a range of 12 participants. The interviews included individuals from beginners to very advanced kitesurfers (no professional kitesurfers). The questions asked during the interviews and the corresponding answers can be found in Appendix C. The demographic can be found in Figure 14.

During the interviews, participants were asked to draw and describe any pain or discomfort they experienced during their kitesurfing sessions. These schematic drawings, along with their descriptions, can be found in Appendix E, a summary of the findings can be found in Figure 15.

HARDSHELL 50% AGE RANGE 19 - 51 YEARS AVERAGE AGE 34 YEARS SEAT SOFTSHELL 33%

Figure 14: Demographic of the participant group

RESULTS FROM INTERVIEWS:

58 % of participants mentioned a factor of discomfort being the pressure on their ribs. Two factors that attributed to this discomfort were mentioned:

- 1. The harness moving up on the torso and therefore pressing on the ribs.
- 2. The tightening of the harness obstructing their breathing. One even called the harness a "corset".

The interviewees were asked about the most important characteristics of a harness, and they answered that comfort, padding, and stability were the most important factors. This indicates that comfort and fit are crucial in choosing a harness. Interestingly, none of the participants considered sustainability or weight to be among the most important characteristics.

Participants reported that beginners often experience problems with the harness moving out of place, which could be attributed to the kite being at it's highest point more often and ill-fitting harnesses during lessons or in the first months of kiting. Many participants mentioned using a seat harness when they first started kitesurfing.

Even when purchased from a kite shop, participants reported issues with harness sizing and comfort, being disappointed from having the wrong size or discomfort during riding. Those with previous back issues were particularly concerned about the support of their back during kitesurfing.

Participants who find a comfortable harness from a certain brand were happy sticking to this certain brand/line when they were considering a new kitesurf harness.

Participant 6 and 12 had switched from the Mystic Majestic to the Stealth. Participant 12 kept his Majestic as is was much more comfortable than the newer Stealth. He especially has pain due to chaffing and even bruising on the sides of his ribs. This occurred when he was in Brazil kiting without a wetsuit on a daily basis. Likewise, Participant 6 switched to the Stealth and wondered if the rigidity during sessions in warm places like Brazil might cause discomfort in the future.

Unexpectedly none of the participants mentioned sustainability being a factor they thought of during purchase.

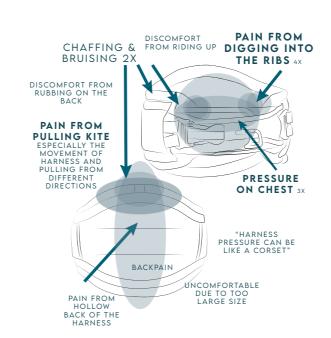


Figure 15: Summary of indication of area's of discomfort and pain by participants on schematic drawing of harness

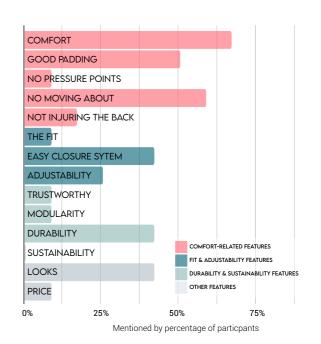


Figure 16: The most mentioned characteristics of importance to a kitesurf harness according to the interviewed user group

2.3.4 INTERVIEW SALES EMPLOYEE

Kitemana is the largest kitesurf-webshop in Europe and their warehouse is located in the Netherlands. Their collection includes the most current harnesses from a few large brands. These can be found in their showroom and on their website. Their range includes 72 different harnesses, a summary of their collection can be found in Figure 17. An interview was conducted with one of their experienced sales employees. The sales employee is also a semi-professional kitesurfer himself and has a lot of experience testing the different brands. He rides a Stealth harness and was riding a majestic X in the past.

According to the sales employee, the most comfortable Mystic harness is the Majestic X. However, the Stealth harness is harder, offering a more direct feel to the kite and being lighter, making it perfect for traveling. While it may be slightly less comfortable, the direct feel and lightweight design are preferred by some.

ION harnesses feature replaceable Velcro padding in the middle of the backplate with two different thickness options. However, some people dislike the closure system, which can be challenging to open with cold or wet hands. ION also offers a tall version of their harness. To help users navigate sizing, they have created a shop stand with measuring equipment. However, the sales employee advises against using it, as most people know their size and body type. Instead, they can try on multiple sizes in the store if kitesurfers are unsure about their size.

Regarding harnesses of the brand Promlimit, the sales employee has some concerns. The backplate shape with a dent feels illogical, and the closure system isn't strong enough to withstand the forces experienced in strong winds, causing some users to replace the clip multiple times due to bending. Finally, the harness of Manera is unique in appearance and features due it's hybrid qualities, making many people hesitant to try it. The Kitemana sales employee has never tried it and prefers to stick with their Mystic harnesses.

PRODUCT RANGE

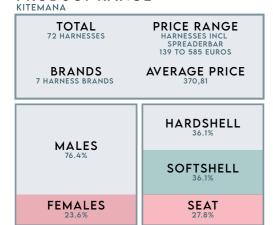


Figure 17: The demographic of the harnesses offered at Kitemana, the largest kitesurf webshop in Europe. (April 2023)

2.3.5 CONCLUSION

This chapter aims to find out whom the target group included and what their needs and preferences are. The user interviews revealed insights into their needs, showing that comfort, padding, and stability are the most important features when choosing harnesses according to kitesurfers. Discomfort, particularly pressure on the ribs, was a common issue. Beginners often struggled with harness movement. Brand loyalty was evident, highlighting the potential for market differentiation based on user trust. The findings suggest the need for better sizing guidance.

Concluding, the kitesurfing user group is diverse, spanning various ages, physical abilities, diverse locations, and levels. It includes both males and females, although it's predominantly maledominated. Physical fitness is crucial for kitesurfing, which encompasses multiple disciplines and experience levels. This diversity underscores the need for modular and adaptable harness designs to cater to different user types, preferences and skill levels.

2.3.6 REQUIREMENTS

Consider the needs of professional and amateur kitesurfers: Although the harness is a performance product, it should not exclude amateur or aspiring kitesurfers who want to improve their skills. It is important to design the harness to be user-friendly and adaptable for a wide range of skill levels for both frequent and infrequent kitesurfers.

Focus on performance in all disciplines: Since the harness is designed to be at the top of the range, it should prioritize performance and versatility. This means it should be able to handle a wide range of disciplines, riding styles and levels, catering to a diverse demographic of kitesurfers.

User needs: According to the interviewees comfort, padding, and the staying in place are the most important factors for users when choosing a harness. Hence, the design of the harness should prioritize these factors.

Ease of use: The systems of the harness should be easy to use for all users - thus not needing extreme force or skills to adjust or close the system.

Modular designs: Since kitesurfers have different riding styles, creating a modular harness should be considered. That can adapt to the different disciplines. This can include interchangeable parts or add-ons that allow users to customize the harness to their specific needs.

2.4 THE PHYSICS OF KITESURFING

During kitesurfing the kitesurfer is pulled across a body of water by the power of a kite. Despite the kitesurfer continuously grasping the bar the majority of the continual force of the kite are located on the lumbar region, where the harness connects the kite and the user. This requires participants to tolerate and counteract these pull-based forces. The continual or repeated counteraction of these types of pulling forces causes muscular strain on portions of the human body and may therefore prevent or limit participation in this activity.

This chapters aims to discuss the physics of kitesurfing, summarizing the forces and moments on the components of the system, which can be split into four main components: the kite, the kitesurfer, the board and the environment. The main forces can be summarized and grouped into three categories: The Hydrodynamic lift from the bottom of the board (normal force); The drag on the board; Gravitational force (the weight); The aerodynomic lift (pulling force of kite); The used formulas, calculation, and images can be found in Appendix H. The description of these forces, can help develop equipment that could decrease discomfort caused by mechanical stress.

2.4.1 ENVIRONMENTAL FACTORS

The wind is the main source of energy during kitesurfing, the majority of kitesurfers will ride in winds ranging from 12 - 40 knots (3-8 Beaufort). Kitesurfers must deal with changing conditions including wind gusts. Figure 18 shows the axis used to describe the situation. Kitesurfing can be practiced on different types of open water like oceans, lakes and rivers. In these waters the current must be considered. For example: If the current is 2 knots in the same direction of the wind the kitesurfer has less pressure in the kite and has more difficulty riding upwind.

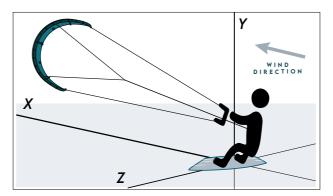


Figure 18: The X, Y and Z axis used in this chapter. The wind direction following the X-axis

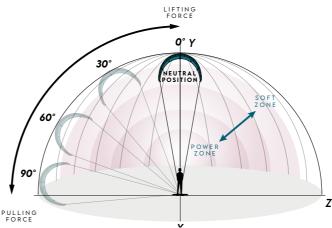


Figure 19: Explanation of the neutral (minimal force), soft (gentle pulling force) and power zone (maximum power)

2.4.2 THE KITE

The kite operates within a wind window consisting of a neutral zone, a soft zone, and a power zone, as indicated in Figure 19. The zone indicates the power and speed the kite can generate, in some situations the kitesurfer shall move the kite between zones to create more speed.

The sailing directions in relation to the wind are indicated in Figure 20. The red zone indicates the area where the user cannot ride, due to it's upwind projection. The force in the kite depends on the direction taken by the user, for instance, going extremely downwind may decrease the power in the kite due to less wind pushing the kite.

Kitesurfing is a constant interaction between the direction of the wind, position of the kite, current direction, speed of the kitesurfer, the drag of the board and the drift angle as can be seen in Figure 21. These factors contribute to the sailing direction of the kitesurfer.

The resistance force of the water has some effect on the sailing direction of the kitesurfer, it results in drift. The difference between the board direction and the sailing direction is called the drift angle.

There are four major forces working on the kite:

Fpull, power = Pulling force exercised via the harness (N)

Fpull, steer = Pulling force exercised via the bar (N)

Fgkite = Gravitational force of kite (N)

Fresistance = Air resistance of kite (N)

The pulling force is distributed on the kite through the 4 main lines: The two powerlines and two steering lines. As the majority of the forces are on the powerlines the equation of equilibrium can be simplified by estimating the Fpull, steer as 0.

The gravitational force of the kite is influenced by the weight of the material, design and size of the kite. Being of small influence on the flying of the kite with the exception of light winds, in which the lifting force is smaller than the gravitational force of the kite. The air resistance of the kite can be split in two forces in the horizontal and diagonal direction as can also be seen in Figure 22.

Fresistance, x = Flift = Resistance of the air resulting in lift Fresistance, y = Fdrag = Resistance of kite resulting in drag

The lift created by the kite can be explained using the Bernoulli's principle. The shape of the kite creates a low pressure and a high pressure on the top and bottom of the kite, resulting in lift due to the pressure difference on the two sides of the kite.

Bernoulli's effect:

Fb = Bernoulli force (N)

Cb = the Bernoulli coëfficiënt = $2 * \pi * \alpha$

 α = angle of attack (degrees)

A = The surface area of the screen/canopy (m2)

p = Air density (kg/m3)

v = wind velocity (m/s)

As mentioned before the kitesurfer influences the angle of attack by pulling or releasing the bar. When pulling the back the angle increases and more air particles hit the canopy, changing the balance between the drag and lift, especially the lift increasing.

According to the first law of Newton the forces working on the kite shall result in 0 when there the kite is moving at a constant speed and direction. This equilibrium can be described as:

ΣFx :

Fdrag,kite - Fpull,power,x - Fpull,steer,x = 0

Fdrag,kite = Fpull,power,x

ΣFy:

Fpull,power,y + Fpull,steer,y - Flift - Fg = 0

Fpull,power,y = Flift + Fg

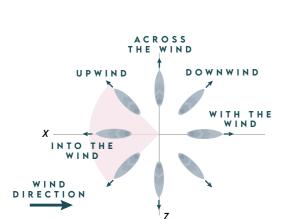


Figure 20: The sailing direction compared to the wind direction during kitesurfina

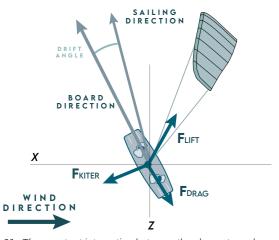


Figure 21: The constant interaction between the elements and components resulting in a certain sailing direction

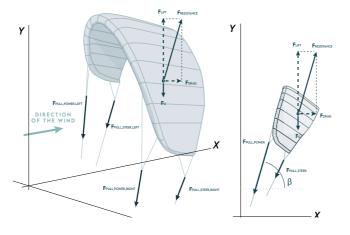
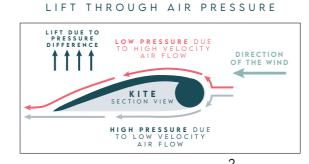


Figure 22: Freebody diagram of a kite, the kite is depicted in the neutral position and is in equilibrium.

BERNOULLI'S PRINCIPLE



 $F_b = C_b * A * P * \frac{V^2}{2}$

Figure 23: Explaination of Bernoulli's principle

2.4.3 THE KITESURFER

For this analysis the kitesurfer, harness and board are seen as one system. The force of the kite, the normal force from the water and gravitational forces are working on this system.

The normal force is a function of the speed of the kiter, the surface area of the board, the buoyancy force of the board, the gravitational force of the kitesurfer and the angle of the board.

The buoyancy force of the board is the volume of the board expressed in liters. Resulting in a force that is directed upwards and influences the resistance force of the water and therefore also the normal force. A directional board has more volume resulting in more buoyancy force than a bi-directional board and is therefore easier to ride in little wind.

The gravitational force on the kitesurfer depends on the weight of the kitesurfer and accessories like wetsuit and harnesses. In a neutral stance without a harness the center of gravity is positioned a few cm's below the belly button at about 56% of the body's height measured from the soles of the feet (Davidovits, 2019). The center of gravity shifts as a person's posture moves and bends. During a kitesurfing session the gravitational force itself doesn't change but the center of the force shifts as the kitesurfer changes posture, an example can be found in Figure 25.

To explore the location of the center of gravity tests and calculations were done, of which the results can be found in Appendix H. A test-setup was made using a loadcell attached to a harness, analyzing the effect of a participant hanging in different angles.

The hypothesis was that in a straight posture AC is longer than AB (Figure 26), but they are quite similar. Some limitations of the test could be that the angles in photo-analysis are an estimation and not a measurement and that the participant might not have a perfectly straight posture during the test. The results consist of 5 images with the angles alpha and beta added in a photo-analysis software. These were analyzed using the equilibrium equations. Resulting in a ratio between AB and AC.

The ratio has a mean of 0.8909 and a standard deviation of 0.0014 showing a low dispersion between the data, giving a high confidence that the used equations are correct, and the dispersion is caused by the limitations of the research. On average AB is 4,7 percent larger than AC, thus the hypothesis is correct.

 $\Sigma Fx:$ Fkite,power, x + Fkite,steer,x-Fn,x = 0 $Fkite,power * cos (\beta) = FN * cos(\alpha)$ $\Sigma Fy:$ Fkite,power, y + Fkite,steer,y-Fn,y-FG = 0 $Fkite,power * sin(\beta) + Fn * sin(\alpha) = FG$ $\Sigma M@A:$ $AB* cos(\alpha) * Fg - AC * sin(\alpha+\beta-90) / Fkite,power= 0$

 $\begin{array}{ll} F_{kite,steer} & \text{The pulling force coming through the bar (N)} \\ F_{kite,power} & \text{The pulling force through the harness (N)} \\ F_g & \text{The gravitational force on the kitesurfer (N)} \\ F_n & \text{The Normal force on the board (N)} \\ F_{drag} & \text{The drag force (N)} \\ angle ~\beta & \text{The angle of the Normal force (degrees)} \\ angle ~\alpha & \text{The angle of the Pulling force (degrees)} \\ angle ~\gamma & \text{The angle between the direction of the kite and the board (degrees)} \\ \end{array}$

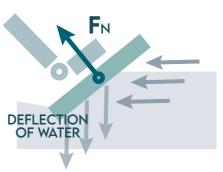


Figure 24: Water deflection and normal force on the board

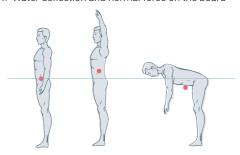


Figure 25: The displacement of this center of gravity during different postures (Egoyan & Moistsrapishvili, 2013)

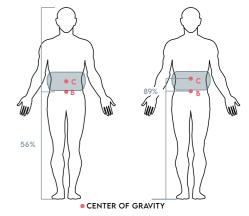


Figure 26: Location of center of gravity (Davidovits, 2019)

To calculate this equilibrium in context of the kitesurfer, a set of assumptions and simplifications are made:

The kitesurfer, harness and board are seen as one component.

We assume the kitesurfer is going at a constant speed and direction.

During riding the kitesurfer is exercising barely any force on the bar, Fkite, steer, left and Fkite, steer, right are close to 0.

Due to the active stance during kitesurfing we can assume that the center of gravity of the kitesurfer shifts. In this equation we assume the distance between B and C is negligible, resulting in AB =AC

The maximum pulling force described in these equations describes the minimum forces the harness should be able to endure. Using these equations this can be calculated. By creating equations with anthropometric data of the 99th percentile in DINED (DINED CAESAR male 99th percentile: Stature: 2015 mm; Body mass: 120.8 kg), this maximum force is explored. This resulted in a max pulling force from the kite of 1057 N.

Assumptions and simplifications:

Most force comes onto the harness when the kitesurfer goes from standstill to riding, due to the expected acceleration.

The heavier the kitesurfer is the higher this force is as more weight needs to be accelerated.

The center of gravity is at 56% of the total body height (Davidovits, 2019). Thus the hook of the harness is at 56% / 89,1% = 49.9% of the total body height.

The kitesurfer is standing in a straight position as in the previous tests.

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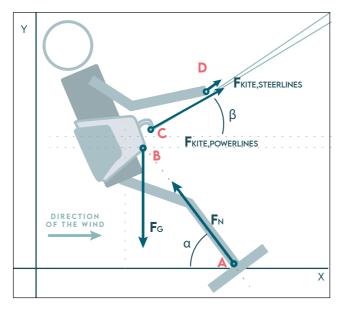


Figure 27: Freebody diagram of the kitesurfer in equilibrium (sideview & tonview)

2.4.4 THE HARNESS

The forces acting onto the harness originate from the kite and are directed to the harness through the lines attached to the hook of the harness. Figure 27 shows the theory behind different kinds of harness designs and how it influences the distribution of forces within a harness. A larger backplate with a spreaderbar lead to the least compression on the side of the body.

The simplification of the equilibrium with the assumptions that the user is wearing the harness without using the kite: Fpull,x + Fpull,y = 0 and thus Ffrictionx = 0 as this is a result of the Pulling force of the kite. Results in:

thus: ΣFx : $\Sigma Fn,x$ - Ffric,x + Fkite = 0 ΣFz : $\Sigma Fn,z$ = 0 ΣFx : $\Sigma Fn,x$ - Ffric,x + Fkite = 0 ΣFy : Fkite,y - Ffric,y - Fg = 0

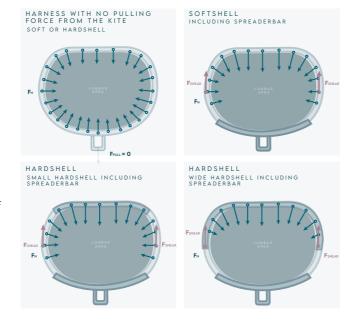


Figure 28: Freebody diagrams of different harness designs. Here the difference in force distribution can be found between soft/hardshell, using a spreaderbar and the influence of the size of the backplate.

 F_{kite} The pulling force from the kite (N)

 $^{\mathsf{F}_{\mathsf{g}}}$ The gravitational force (N)

Ffric

The friction force between the kitesurfer and the $\boldsymbol{F}_{\boldsymbol{n}}$ harness (N)

The normal force resulting of the pressure from the tight fit on the body (N)

Through the fit of the harness a pressure force is distributed around the lumbar area of the kitesurfer. The tighter the harness is made with the closure and trimming system the more pressure is exerted on the lumbar area. During riding this pressure could decrease as materials get wet and when static friction forces show some moments of dynamics friction, untightning the trimming system. When riding the balance between the normal force shift within the harness. This distribution is dependent on the design of the harness as can be found in Figure 31.

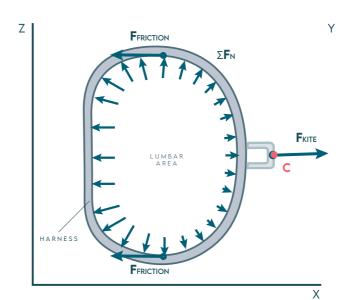


Figure 29: Freebody diagram of a kitesurf harness in equilibrium topview; section view including pulling force of the kite Fkite.

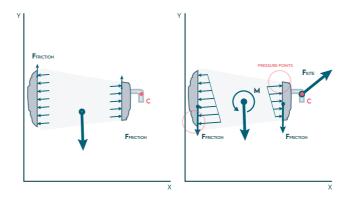


Figure 30: Freebody diagram of a kitesurf harness in equilibrium. sideview; section view comparing no pulling force on the left with pulling force on the right

2.4.5 THE SKIN (& WETSUIT)

One of the most important functions of the harness is the force distribution over the body. This pressure is described per unit area [N/m2] and is determined by several factors; the force, the contact area, and the characteristics of the interface (lining/padding). The characteristics of the interface are determined by the material [Young's modulus] and the shape of the surface. These variables can be chosen in the design process and ultimately have effect on the stiffness and deformation of the pad, which has effect on how the forces are transmitted onto the body.

Figure 31 shows the expected pressure distribution in a few different situations where force is distributed via a rigid or flexible material. These illustrations show the effect of edge geometry in blue, the deformation of skin on the sides of the geometry that is pressed on the area leading to stresses. The skin undergoes deformation due to the internal forces caused by the friction on the surface area.

What can be concluded is that rigid materials should be avoided on the edge of the products and a better distribution of forces in the middle of a surface. Also it should be avoided that the forces are directed onto the product close to the edges as this could lead to an uneven distribution of forces.

The wetsuit can be seen as an extra layer of skin where shear, tensile and compression stress can be found, just like in the surface skin. This extra layer can effect the perceived discomfort of the user, a different friction coefficient and less wear and tear on the human skin resulting in less - or more discomfort due to friction between the skin and the wetsuit.

Not only the amount of stress on the skin influences the deformation but also the amount of time a stress in conducted skin is of influence (Pavšelj, 2010). Therefore, after a certain amount of time this will result in permanent plastic deformation. It could be assumed that the longer the harness is used the more chance on deformation and thus discomfort.

The shear forces on the wetsuit and skin can have an effect on the discomfort of the harness - due to these forces.

According to Blair et al. (2020) Skeletal tissue changes with age which includes diminished muscle mass, decreased epidermal thickness and reduced skin elasticity. Consequently older users could experience higher discomfort and have different needs and wishes when choosing a harness than younger users.

Moisture conditions can increase the vulnerability of the skin to injury, the friction coëfficiënt of human skin increases when it is moist. It especially increases between skin and textiles under wet conditions, making skin more susceptible to damage from friction so it is important to keep both surfaced clean and dry (Rotaru et al., 2013). Kitesurfing is practiced in wet conditions, thus the skin must be protected from skin injuries by avoiding dirt getting between the torso surface and the harness.

Friction is the force resisting the relative motion of two elements sliding against each other. In the situation of the harness this friction can be found in a few locations. Between the harness and the wetsuit and the skin of the kitesurfer. During static friction (stiction) their is no movement. A certain amount of friction is needed to let it become dynamic friction.

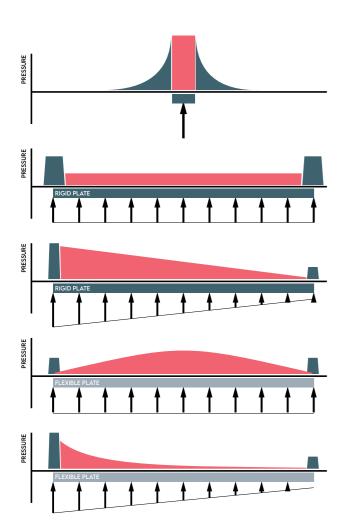


Figure 31: The expected pressure distribution on the surface of the torso in five different situations.. The pink areas show the pressure onto the torso surface and the blue area's show the show the pressure as result from the deformation of the skin. (Van Abbema, 2011)

2.4.5 CONCLUSION

This chapter aims to describe the components and forces found during kitesurfing. In conclusion, there are various forces and factors involved during kitesurfing. It is not possible to predict these exact forces. It depends on the environment of the kitesurfer, the state of the body of water and the weather conditions, which change constantly. when anlysing the forces during kitesurfing the kite's steering and power forces, the normal force, gravitational force, and the interaction between the kitesurfer and the harness should be taken into account. Simplifications can be made, such as neglecting the forces exerted by the kitesurfer on the bar. With these simplifications an equilibrium can be calculated.

The kitesurfers weight and weight distribution during kitesurfing have a large influence on the riding, thus the posture and center of gravity play a role in the equilibrium too. The maximum force a harness should be able to cope with are calculated and are used to create requirements of the design.

Friction forces, normal forces, and pressure distribution between the kitesurfer and the harness are important considerations. The behavior of the skin and wetsuit, including shear, tensile, and compression stress, can impact the force distribution and reduce comfort during kitesurfing. Understanding and considering these forces and factors are crucial in designing kitesurfing equipment that ensures safety, comfort, and optimal performance for kitesurfers.

2.4.6 REQUIREMENTS

High pulling forces of kitesurfing: The harness needs to be designed to withstand the high pulling forces of over 1000N during kitesurfing.

Unpredictability of kitesurfing: The biomechanics of the body position during kitesurfing change depending on many factors, such as wind speed, upwind projection, The design of the harness should consider these factors to ensure that the user can handle and utilize the force from the kite for tricks or speed.

The force-direction: The harness should withstand forces from all directions within the wind window of the kite

Edge-geometry: The edge-geometry of the design should be designed in a way that the pressure is distributes evenly.



3.0 ERGONOMICS

The aim of this chapter is to develop a deeper understanding of the ergonomics related to the design of a kitesurfing harness. To achieve this, a set of five sub-chapters including 9 research questions has been formulated. In order to solve the defined problem with a performance-enhancing harness with decreased discomfort, it is crucial to first comprehend the meaning and origin of discomfort followed by an understanding of the structure and requirements of the human body in relation to discomfort.

RESEARCH QUESTIONS

3.1 DISCOMFORT

1. What is the relation between discomfort and ergonomics?

Method: Desk research and literature review

3.2 THE HUMAN BODY

2. What is the anatomy and function of the human body where the harness is worn?

Method: Desk research and literature review

3.3 THE DESIGN OF A SIZING SYSTEM

- 3. What are the relevant dimensions of the user group? And what are the relations between the dimensions? (1D and 2D Anthropometry)
- 4. What is the shape of the lumbar area of the user group? (3D Anthropometry)

Method: Measuring participants & analyzing Dined data

3.4 ANALYSIS OF CURRENT HARNESS SIZING

5. What are the relations between dimensions within certain harness sizes?

Method: Analyzing Dined data

3.5 KITESURFING MOTIONS & POSTURES

- 6. What postures(static) and motions(dynamic) are taken during kitesurfing?
- 7. What are the most relevant motions for the design of a kitesurfing harness?
- 8. How does the body move? What shape and angles does the body take during kitesurfing and maximum bending and rotation?
- 9. Where and how does the current harness design move on the body?

Method: Desk research & 3D scanning & photographs

3.6 GENDER SPECIFIC CONSIDERATIONS

10. What considerations should be made when designing a kitesurf harness for both genders?

Method: Analyzing data Dined and results previous sub-chapters

3.1 DISCOMFORT

Ergonomics is one of the dominant factors for understanding how to optimize human performance. Its primary objective is to optimize and prevent the breakdown of physical, physiological, and psychological performance leading to discomfort. The aim of this chapter is to understand what discomfort is.

3.1.1 WHAT IS DISCOMFORT

The interviews concluded that users consider high comfort and the correct fit as the most important qualities of a harness. However, what does comfort actually mean? Comfort can be described in three ways:

Discomfort – a physical disturbance is causing discomfort

No discomfort – the user is not aware of discomfort or comfort

Comfort – a high experience of comfort (more than expected)

The objective of the design should not be to create comfort, rather to eliminate discomfort. When unfamiliar forces are exerted on the kitesurfers torso, they should feel connected to their kite without experiencing any discomfort.

3.1.3 PHYSICAL DISCOMFORT

To develop an effective design solution decreasing the discomfort the factors leading to discomfort must be understood.

Key-factors contributing to physical discomfort include the presence of pressure points, chafing and bruising on the skin, muscle fatigue, limitations in range of motion, the impact of breathing constraints and strain on the back and spine.

These discomforts emerge particularly around the ribs, lower back and hips. Prolonged kitesurfing sessions can magnify any discomfort initially experienced. Kitesurfers may start to notice discomfort more acutely as time goes on, making it essential for harnesses to provide enduring comfort throughout extended sessions.

3.1.3 COGNITIVE ERGONOMICS & DISCOMFORT

During kitesurfing, the kitesurfer must navigate through constantly changing conditions while facing external forces pulling at the torso. The athlete needs to be physically and mentally prepared to handle the unpredictability of these situations. Several physical factors influence the perceived level of (dis)comfort, but there is evidence that the experience of pain is also influenced by cognitive factors (Chavadi & McConnell, 2019). These cognitive factors include the anticipation of pain, anxiety and attention, suggestion and placebos, evaluation of the meaning of pain-inducing situations, cultural background, hypnosis, early experiences, and prior conditioning. These theories can also be applied to kitesurfing. For instance, a professional athlete's ability to perform despite pain, anxiety about re-injury leading to heightened pain perception, or previous experiences of pain that may result in the pain being disregarded.

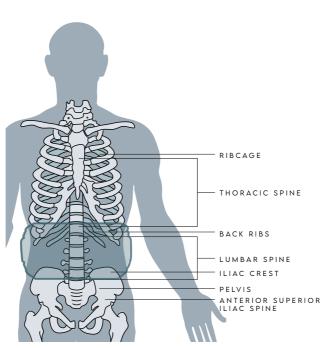


Figure 32: The location of the harness on the torso

3.2 THE HUMAN BODY

This chapter aims to describe the anatomy and function of the human torso, as this is the part of the human body which is influenced by the harness and the forces of the kite. The insights gained from the conducted desk and literature research should be leading when designing the features of a kitesurf harness with decreased discomfort and increased performance.

3.2.1 THE TORSO

The positioning of the harness depends on the shape of the backplate and the shape of the user. A male with a muscular triangle shape leads to a lower position, while a feminine shape with wider hips causes the harness to easily ride up to a higher position.

The harness typically covers an area from just under the ribs (T10-12) to just above the pelvis (L5-S1). This region is also known as the torso, which refers to the central part of the human body between the neck and the pelvis. It contains most major organs, including the heart, lungs, liver, stomach, and intestines, as well as the spine and ribs. In terms of anatomy, the torso is divided into several regions, including the thorax (chest), abdomen, and pelvis. The spine runs vertically through the torso, providing support and protection for the spinal cord, while the ribcage protects the thoracic organs, playing a crucial role in supporting vital functions

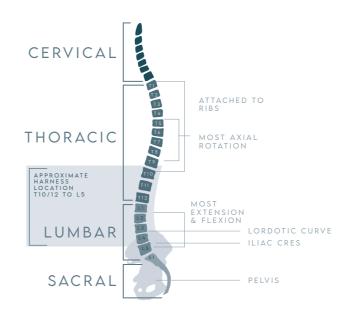


Figure 33: The human spine and it's functions



Figure 34: Description of Flexion, Extension, Lateral flexion and Axial rotation

3.2.2 THE SKELETON THE SPINE

The main function of the spine is to provide stability to the torso and protect the spinal cord, which runs through it. The spine consists of 33 vertebrae categorized into four parts: the Cervical, Thoracic, Lumbar, and Sacral regions. The spine allows for various movements, including flexion, extension, axial rotation, and lateral flexion, often occurring in combinations. Each part of the spine can facilitate bending and rotation at certain angles, which is referred to as the Range of Motion (ROM). K. Raits and J. Šavlovskis have created a database of the ROM of the spine by analysis and compiling multiple research projects that contain data on the range of motion of different parts of the spine. This database provides the mean and standard deviation of ROM for each part and direction of the spine. The mean values are depicted in Figure 35.

These movements are the result of pulling and pushing forces exerted by the muscles surrounding the spine, resulting in compressive, tensile, shear force bending, and torsional moments. These forces generate compression between the spinal vertebrae, and the amount of pressure varies with each vertebra and movement. A specific force (N) is required per degree of bending or rotation, the pressure between each vertebrae can be found in Figure 35 (Bayoglu et al., 2019) In most situations the pressure increases, except during the extension of the thoracic and lumbar disks.

The lumbar spine consists of five spinal cords starting from the pelvis to the bottom of the ribs. Its function is to control leg sensation and movement. The lumbar spine is primarily responsible for flexion and extension, with the lowest two lumbar vertebrae contributing significantly to these movements. From a side view, the healthy lumbar spine exhibits a lordotic curve (lordosis). In the maximum flexion posture, the lumbar spine appears to have no curve.

The middle section of the spine, known as the thoracic spine, begins at the base of the neck and ends at the bottom of the ribs. It comprises 12 vertebrae. Compared to the lumbar spine, the thoracic spine has limited flexion and extension capabilities but exhibits a higher degree of axial rotation. The vertebrae in the thoracic spine differ from the others as they provide attachment points for the ribs, except for the vertebrae located at the bottom of the ribcage (T11 - T12). Within the thoracic region, T5 to T8 demonstrate the greatest rotational ability.

34

THE PELVIS

The male's pelvis is higher and narrower than the female's pelvis, making it the only bone that differs between genders. At the pelvis the spinal cord begins. The pelvis helps maintain the balance of the torso, as found in Figure 36.

The pelvis is composed of two wings, known as the ilium wings. The upper border of these wings is referred to as the iliac crest. The highest point of this crest corresponds to the level of the fourth lumbar vertebral body (L4). The portion of the iliac crest that can be felt from the abdominal area is called the Anterior Superior Iliac Spine. The harness often rests on the iliac crest, making it the lowest part of the harness in many cases.

THE RIBS (& LUNGS)

The ribs play a crucial role in protecting the lungs while also facilitating the constant inflation and deflation of the lungs. This expansion and contraction of the chest is particularly facilitated by the front of the ribs, which move. The back, being attached to the thoracic spine, remain in position. Considering this movement, pressure on the ribs should be avoided as it could cause discomfort. As the backside of the ribs experience minimal movement this surface area can be used. For example designers of chairs for individuals with limited torso support utilize the back of the ribs as an anchor point. This ensures that the person does not slide out of position (Dolf, 2022).

3.2.3 ABDOMINAL MUSCLES

The torso count numerous muscles, playing a vital role in facilitating movement and providing stability. The muscle development or underdevelopment influence the body shape, affecting the ideal design of a kitesurfing harness. Here, we delve into a selection of these muscle groups:

The muscles running along the length of the spine control extension, bending, rotation, and maintain an upright body posture. It is crucial for these muscles to function properly to prevent back pain. These muscles can be felt on the sides of the spine, locations where the harness may exert pressure. Also a pair of muscles originating from the wings of the pelvis and extending to the lower posterior border of the 12th rib also play a role in these movements. Contraction of one of these muscles causes lateral flexion, while contraction of both muscles leads to extension of the lumbar spine.

The Rectus Abdominis, commonly known as the six-pack, are long paired muscles that span the length of the abdomen. These muscles act as trunk flexors, expiratory muscles, and provide protection of the abdominal contents. During kitesurfing they are actively engaged, stabilizing the torso.

The obliques are located on the sides of the Rectus Abdominis and are responsible for lateral flexion and rotation of the upper body. When contracted, they generate intra-abdominal pressure, enhancing spinal stability (Lumbosacral Biomechanics, n.d.).

The pectoralis major, the bulk of the chest area, primarily functions in arm movements. Although this may not seem directly relevant to harness design, the shape of this muscle influences the overall shape of the upper body. When welldeveloped, associated with an athletic triangular build, it can prevent the harness from digging into the chest area.

Between the two shoulder blades, triangular-shaped muscles known as the trapezius muscles can be found. These muscles primarily function in the movement and stability of the shoulder blades, facilitating motions where the scapulae move while the spine remains stable, and vice versa.

	Lumbar	Thoracic	Cervical
Flexion	Increased pressure Max angle 65°	Decrease in mid T-discs Max angle 26°	Slight increase in pressure Max angle 64°
Extension	Decreased pressure Max angle 31°	Slight increase in upper to mid T-discs Max angle 22°	Pressure stable throughout motion Max angle 63°
Lateral flexion	Increased pressure Max angle 30°	Slight increase in upper to mid T-discs Max angle 30°	Increased pressure Max angle 49°
Axial rotation	Slight increased pressure Max angle 15.3°	Slight increase Max angle 47°	High increase in pressure Max angle 85°

Figure 35: Pressure (Twente spine model) and max. angles in lumbar, thoracic and cervical spine (K. Raits and J. Šavlovskis, 2021)

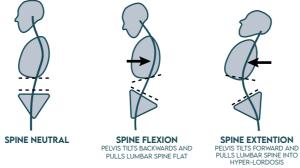


Figure 36: Pelvic rotation creating a balanced posture

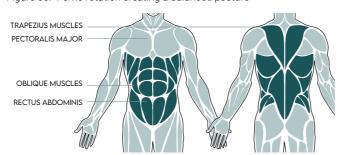


Figure 37: The muscles on surface of torso

3.2.4 THE SKIN

The human skin is a complex organ that serves as the interface between the body and the environment. It consists of different layers, each with its own functions. The main functions of the skin include insulation, protection from the environment, and the sense of touch, which is distributed throughout the body. The sense of touch originates from the bottom layer of the skin, and various receptors are responsible for detecting sensations such as heat, cold, pain, pressure, and

The density of receptors in a specific area can influence the sensitivity to touch, as depicted in Figure 38. This illustration shows the distribution of receptors, highlighting that areas like the hands and face are more sensitive to touch, while the back is less receptive compared to the belly.

In the field of biomechanics, the deformation of the skin is an important factor to consider when analyzing the interaction between the body and external objects or forces. The skin can undergo deformation in response to compression, tension, and shear forces. The properties of the skin, including its elasticity and mechanical behavior, vary throughout the body. The Young's modulus is a measure of the skin's mechanical behavior. Figure 38 shows an elasticity curve often seen in skin here the modulus of elasticity typically amounts to 5KPa in region A.

These stresses can consist of 3 components the shear stress, tensile stress, and compression stress. The behavior or reaction of the skin is influenced by the bone structure beneath the surface. Understanding the skin's deformation in relation to biomechanics can aid researchers and designers in developing improved solutions to enhance comfort, reduce the risk of injury, and optimize performance. Aging influences the mechanical properties of the skin. The skin's extensibility changes, but the Young's modulus, which represents the relationship between tensile and compressive stress, remains unchanged (Gallagher et al., 2012).

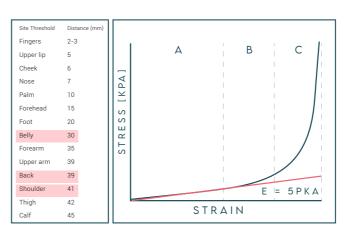


Figure 38: Receptor distance & Stress and strain of skin

3.2.5 CONCLUSION

This chapter aims to understand the anatomy and functions of the human body where the harness sits, the torso. Doing so to optimize the human performance and prevent physical, physiological, and psychological issues. Analyzing the movements of the torso and spine provides insights into designing the localized flexibilities of the kitesurfing harness. The spine is capable of various movements such as flexion, extension, axial rotation, and lateral flexion, often occurring in combination. Each section of the spine allows for a certain degree of bending and rotation, known as the Range of Motion (ROM).

The harness rests on the top of the pelvis, where the iliac crest is located at the height of L4. The lumbar spine extends from the pelvis to the waistline, while the thoracic spine begins at the bottom of the neck and ends at the bottom of the ribs. The lumbar spine plays a significant role in flexion and extension, with the lowest two lumbar vertebrae contributing the most to these movements. In comparison, the thoracic spine exhibits higher axial rotation but limited extension and flexion capabilities. The vertebrae in the thoracic spine serve as attachment points for the ribs, except for T11 - T12. T5 to T8 offer the greatest rotational ability in the thoracic region. Concluding, when designing the harness it should be considered that the top half of the harness should allow axial rotation and flexion and extension on the bottom half of the harness.

When designing a kitesurf harness the distribution of forces over a larger portion of the spine reduces discomfort, as more vertebrae are involved in the pulling and pushing actions. The location of the force also impacts comfort, with lower positions on the spine requiring less muscle contraction.

During the design process, it is crucial to consider that the torso not only moves but also constantly expands and contracts during breathing. This results in chest expansion followed by contraction, with the front of the ribs in constant motion while the back of the ribs remain fixed due to their attachment to the thoracic spine.

The human skin is a complex organ with multiple functions, including insulation, protection, and the sense of touch. Strain and deformation of the skin distribute the effects of external forces. The location and direction of the force applied to the skin affect the amount of deformation that can occur.

3.3 THE DESIGN OF A SIZING SYSTEM

Anthropometry is described as the measuring of humans, describing the human physical variations in body size and shape. The aim of this chapter is to describe the relevant dimensions of the target group, the relations between the dimensions and the 3D shapes of the relevant body parts. These 3 methods to describe the body can be described as 1D, 2D and 3D anthropometry. These descriptions of the available anthropometric data will help the design process of the sizing, shape and adjustability leading to a design with an optimal fit of the majority of the target group.

3.3.1 USED DATASETS

This report makes use of the Dined CAESAR Project (Age 18 - 65), available in the online Dined tool. The available dimensions are limited. Therefore use was made of the datasets of the individual participants of the Italian and Dutch CAESAR research. This created a larger set of dimensions available for the research and created a better representation of the target group. As the Dutch have one of the largest and the Italian one of the smallest stature lengths in Europe (Rodriguez-Martinez et al., 2020). However, the limitation of using data from only two populations is acknowledged. The used dimensions can be found in Appendix I.

3.3.2 1D ANTHROPOMETRICS

1D anthropometrics describes the use of single measurements for designing a product. The relevant measurements for designing a kitesurfing waist harness can be found in Figure 39. Measurement 2, 4, 5 and 9 can be found in the online Dined tool. The other measurements could be derived from the individual datasets of the participants.

WAIST CIRCUMFERENCE

The harness sits around the waist, making the waist circumference the guiding measurement when choosing a harness. Figure 40 shows the normal distribution based on the Dutch and Italian database. It can be concluded that the waist circumference in the student database is the smallest, followed by the Italian measurements.

TORSO LENGTH

Torso length cannot be found in the Dined database. However, by using the database of the individual measurements from Dined, the vertical distance between the hips and shoulders can be calculated to find the torso length. This is done using the found measurements of the hip height, waist height, acromion height and stature of the CAESAR databases. The used measurements can be found in Figure 39. Figure 41 is made using the calculated mean and standard deviation of the databases.

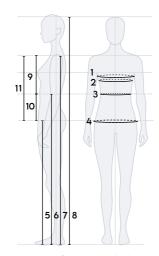


Figure 39: Measurements of human body that are of relevance to the design of a kitesurfing harness. (1) Chest circ.: Chest circumference measured just above the nipples and under the armpits; (2) Under Bust circ.: Chest circumference measured under the bust; (3) Waist circ.: Waist circumference measured around the narrowest part of the torso; (4) Hip circ.: Measured around the widest part of the hips; (5) Hip Circ. Max Height: Vertical distance standing surface to hips; (6) Waist Circ. Height: Vertical distance standing surface to LSP; (8) Stature: Vertical distance standing surface to LSP; (8) Stature: Vertical distance standing surface to the top of the head; (9) Waist to LSP. Vertical distance waist and LSP; (10) Hip to Waist: Vertical distance hips to waist; (11) torso length: Vertical distance from hips to LSP

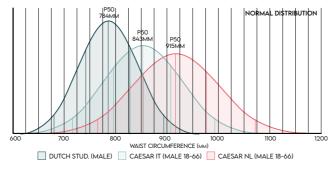


Figure 40: Normal distribution of waist circumference data from Dined (mm)

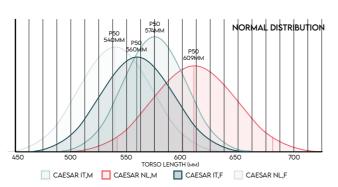


Figure 41: Torso length data from Dined & Normal distribution of Torso length (mm)

3.3.3 2D ANTHROPOMETRICS

2D anthropometrics describes the relation between two relevant measurements. This correlation between two body dimensions gives useful insights for the design dimensions.

WAIST & CHEST CIRCUMFERENCE

The ellipses in Figure 42 and Figure 43 show the relation between the waist and chest circumference. The slimmer ellipse shows a higher correlation between the two dimensions in females. The green line through the graph shows the situations where the two dimensions are even. It can be found that the waist circumference is very rarely equal or less than the chest circumference. The relation between the two dimensions can be described by a function displayed with a red line in the figure. This shows the difference between the two dimensions gets smaller as the they get larger, especially in females. Assuming kitesurfers have a reasonably fit build and that athletically built persons would have a larger chest circumference and smaller waist circumference. It could be assumed that the user group would fall around this left edge.

HIP & WAIST CIRCUMFERENCE

The ellipses in Figure 44 and Figure 45 show the relation between the waist and hip circumference of males and females. Here also a higher correlation between the two dimensions can be found in females. The graph shows that in males the waist and hip circumference becomes similar in cases on the larger percentiles. Assuming this could be due to men with a larger waist circumference having a "belly". The red line through the graph shows the direction of the ellipse. Here can be seen that the difference between the waist and chest circumference gets smaller as the dimensions get larger, especially in females.

TORSO LENGTH & WAIST CIRCUMFERENCE

This data can be used to design the backplate size for the different sizes of the harness. A scatter plot found in Figure 46 was made compiling the data from the Dutch and Italian database. Here the male and female data points are compared. The red (male) and blue (female) line and ellipse show the correlation and relation between the data points. The graph shows a higher correlation between the male participants compared to the female participants and a very similar trendline between the males and females, with a slightly steeper line for the males.

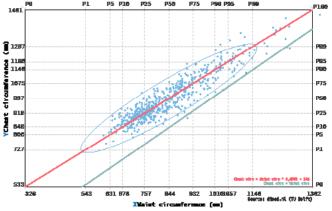


Figure 42: Ellipse displaying waist & chest circumference; Males, CAESAR(NL); 18-66y; Correlation coefficient: 0.892;

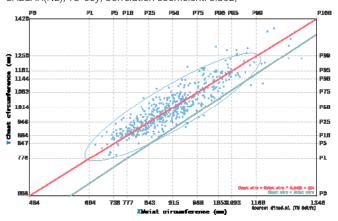


Figure 43: Ellipse displaying Waist & Chest circumference; Females, CAESAR(NL); 18-66y; Correlation coefficient: 0.924

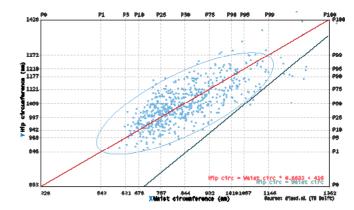


Figure 44: Ellipse displaying Waist & Hip circumference; Males; CAESAR(NL); 18-66y; Correlation coefficient: 0.806

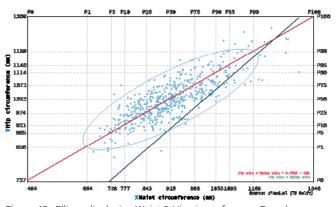


Figure 45: Ellipse displaying Waist & Hip circumference; Females; CAESAR(NL); 18-66y; Correlation coefficient: 0.757

3.3.4 3D ANTHROPOMETRICS

3D anthropometrics are utilized to design products catering to the diversity of body shapes. Dined has introduced 3D mannequins, these can be employed to create 3D models of individuals with various predetermined measurements. Figure 47 showcases examples of Dined mannequins with P5, P50, and P95 chest, waist, and hip circumference. Similar mannequins have been created to resemble the Mystic size chart as can be found in Appendix J on page 117.

While these mannequins serve as useful design tools, it is important to note that they are representative models and not actual individuals, as the concept of an "average" person does not exist. To study and analyze actual bodies the individual scans made for the CAESAR database have been used. In the same figure scans of real persons with the same waist circumference of the Dined models are displayed. When comparing these to the Dined mannequins, they bear notable dissimilarities, showing the diversity of bodies the harness must be designed for.

In Figure 48 the features that define the torso shape are described. These features between the scans of one size set are compared, which can be found in Appendix figure 40 on page 117. The outcome may differ when describing the similarities and differences within a different size.

All scans shows an inward curve of the lumbar spine (lordosis) followed by an outward curve over the thoracic spine, an inward curve between the chest and hips with the smallest circumference always being just above the belly button (the waist) and all scans from the sample show an inward curve under the chest meaning the chest circumference is always larger than the under bust circumference

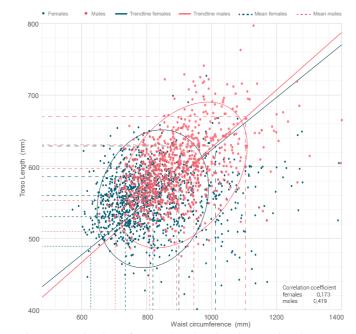


Figure 46: Waist circumference plotted against the torso length

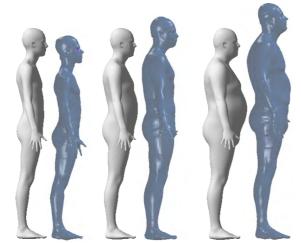


Figure 47: 3D Dined mannequin (white) and 3D scans from CAESAR database (blue) waist, hip and chest circumference P5, P50 and P95

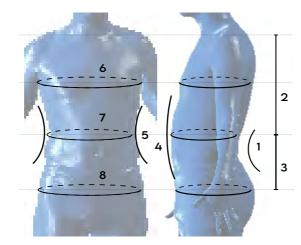


Figure 48: Characteristics that define the torso shape. (1) Lordosis: The curvature in the lower spine; (2 + 3) Torso height: Vertical distance between the hip and LSP; (3) Waist height: Vertical measurement between the hip and waist; (4) Belly shape: Shape of front of the torso; (5) shape of waist: Shape of the waistline. Shows the difference between the hip, waist and chest circumference; (6) Chest cross-section: Horizontal section view of the chest; (7) waist cross-section: Horizontal section view of the waist; (8) hips cross-section: Horizontal section view of the hips.

CROSS-SECTION TORSO

Additionally the database of 3D scans was used to describe the shape of the torso. Figure 49 illustrates which cross sections were used.

The images were created by overlapping the crosssections of the waist by joining point o. By choosing this point at a fixed distance from the posterior surface of the waistline the focus lies on the shape of the posterior contour of the waist. This focus was chosen as this is the location where most forces act onto the body during kitesurfing.

16 lines were drawn to divide all the cross sections, which also originate in point o. The cross-sections used in each figure consist of randomly chosen samples from the CAESAR IT & NL database who, according to their measured waist circumference, would wear the same size. The two largest and two smallest datapoints on each line were excluded from the dataset as these are counted as outliers.

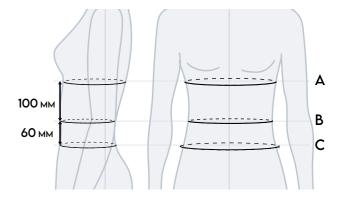


Figure 49: Diagram showing the location and description of the cross-sections used. A 100mm above the waist; B the waist, measured around the narrowest part of the torso, which lies just between the iliocristale and the lower rib; C 60 mm under the waist.

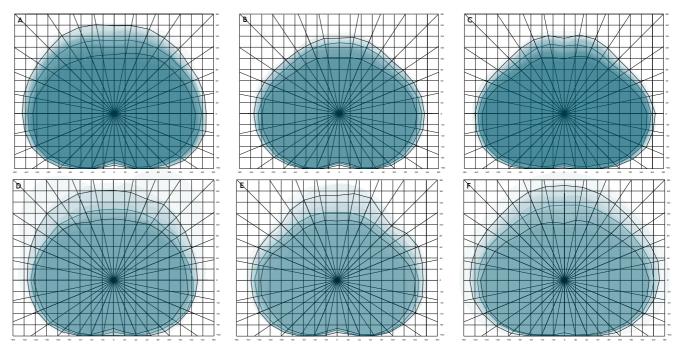


Figure 50: Cross section of the torso. Males harness size M. Males: 100 mm above waist (A); waist (B); 60 mm under waist(C). Females: 100 mm above waist (D); waist (E); 60 mm under waist (F)

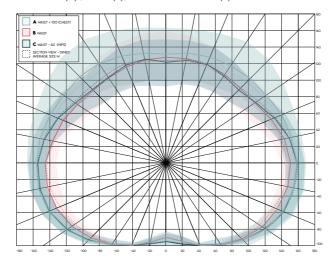


Figure 51: Minimum, Maximum and Median dimensions of the waist cross-section (B) compared to (A) and (C) - CAESAR NL & IT males (mm)

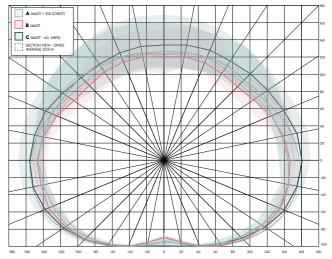


Figure 52: Minimum, Maximum and Median dimensions of the waist cross-section (B) compared to (A) and (C) - CAESAR NL & IT females (mm)

When describing the differences and similarities of the cross-sections. It can be determined that the posterior shape is similar between the different sizes. All participants from the sample have a inward curve in the spinal area, the larger the size the larger the curve. These larger sizes have a larger waist width but the waist depth can be described as significantly larger in the higher sizes. A body characteristic that could also be described as a "belly". What can be concluded from this comparison is that the location of the backplate, the contour of the posterior waistline, is very similar between the different sizes. The most prominent difference is the width of this posterior contour.

Not only the section view of the waist on the smallest part is important for the design of a kitesurf harness but also how the shape evolves from the lower abdominal area to the chest area. Cross-sections of 60 mm under the waist, the waist and 100 mm above the waist are made and compared in Figure 52.

Displaying a square-like shape towards the chest area and a wider cross-section on the towards the hips, especially on the posterior side of the torso. The inward curvature in the spinal area is equal around the waist and up towards the chest but is smaller towards lumbar spine.

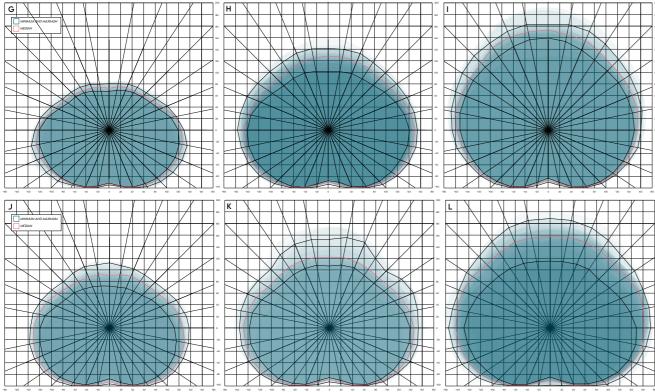


Figure 53: Minimum, Maximum and Median dimensions of the waist cross-section of male sizes XS, M and L. Male cross-sections: XS(G), M(H) and L(I); Female cross-sections: XS(J), M(K) and L(M) - CAESAR NL & IT (mm)

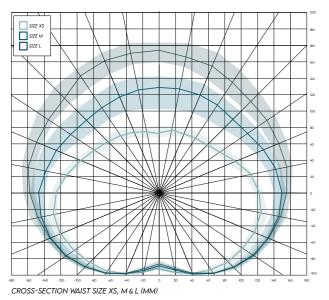


Figure 54: Minimum, Maximum and Median dimensions of the waist cross-section (B) comparing size XS, M & L - CAESAR NL & IT males

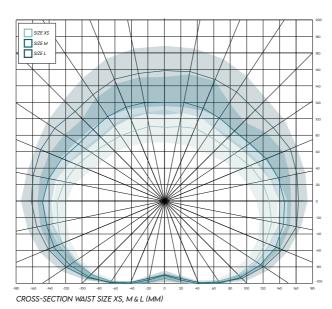


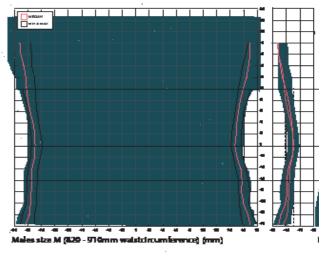
Figure 55: Minimum, Maximum and Median dimensions of the waist cross-section (B) comparing size XS, M & L - CAESAR NL & IT females (mm)

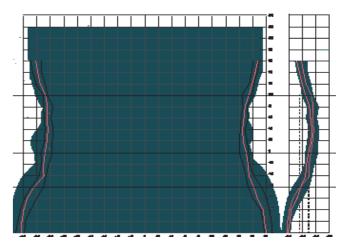
TORSO OUTLINE

The analysis also included examining the outline of the torso. This was done by utilizing a database of 3D scans of individuals who would wear a size M harness, and of females wearing size XS. The back-view outline revealed the average curvature of the sides of the torso, while the side-view outline provided insights into the waistline and lordosis. The females showed to have a shorter torso, and due to the chosen size, a male M which corresponds to a female L, many of the female scans from the research have a less "athletic" body shape. The analysis from the start of this sub-chapter showed that a smaller difference between the waist and hip and waist and chest circumference could be found in females with a larger waist circumference which corresponds to outcome of this research. Therefore an analysis of female's wearing size XS is also included.

The frontview: The waistline of the males showed to be less wide than the hips and chest area in every scan in the sample, the amount averages from section B to A at about 25,8 mm and from point B to C averages at about 15,6 mm. In comparison to the females where the median showed a difference of 3 mm between section A and B in the size M females and 20 mm in size XS females. The difference between the hips and the waist was found to be larger in females, with a difference between section B and C being 28.0 mm with size M wearing females and 44 mm with size XS wearing females. The outline of the females wearing size M had more irregularities which could be due to more soft tissue and the cutting of pants and a bra in the skin.

The sideview: The side-view outlines are shown in Figure 57, Figure 58 and Figure 59. The side-outline shows the lordosis is located between the cross-section B and C with differing sizes and depths. In Figure 60 the outline from the side aligned at the lordosis of males and females can be found. This shows that the median angle upwards is around 11 degrees and a median downward angle of around 19 degrees. The males have a smaller angle below the lordosis with the median being only 13 degrees. Besides the shorter torso's, the larger angle and the breasts of the females the side-view of males and females could be considered similar.





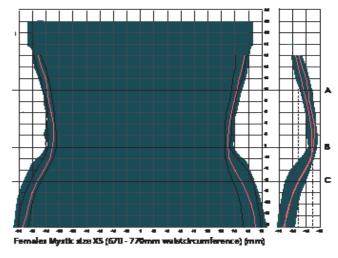


Figure 56: Outline of torso -frontview - Sample CAESAR NL & IT - males size M, females size M and females size XS

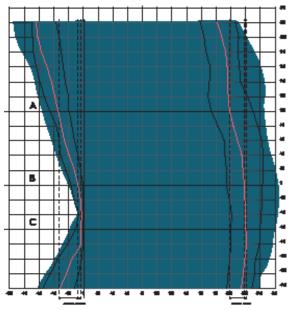


Figure 57: Vertical section view of the torso; sample CAESAR NL & IT; males (male size M; waist circumference 820 - 910 mm)

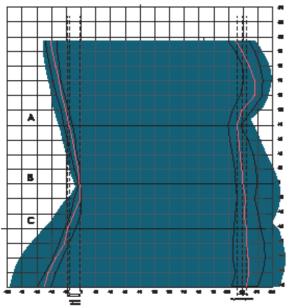


Figure 58: Vertical section view of the torso; sample CAESAR NL & IT; female (male size M; waist circumference 820 - 910 mm)

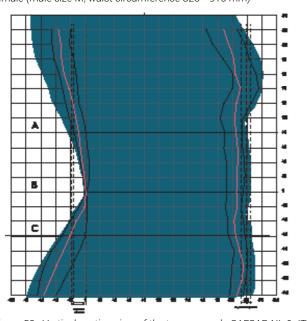


Figure 59: Vertical section view of the torso; sample CAESAR NL & IT; female (male size XS; waist circumference 670 - 770 mm)

3.3.5 CONCLUSION

Anthropometrics play a crucial role in the design process of a kitesurfing waist harness. The aim of this chapter was to describe the anthropometric data of the target group in 1D, 2D and 3D. By measuring the target group and analyzing the datasets human physical variations in body size and shape an optimal fit that accommodates the majority of the target group can be designed. The use of anthropometric data from the Dined CAESAR Project, along with individual datasets from the Italian and Dutch CAESAR research, provided a comprehensive set of dimensions for the study. While the limitation of using data from only two populations is acknowledged.

In the realm of 3D anthropometrics, Dined's 3D mannequins served as useful design tools to create models with predetermined measurements. However, it's important to recognize that these models represent average dimensions and do not capture the true diversity of body shapes. Actual body scans from the CAESAR database were utilized to study and analyze real individuals, revealing the variations and resemblances within specific waist circumference sizes.

Insights were gained into the posterior shape and contour of the body, by studying the variation in depth and angles found. The difference between the shape of males and females is illustrated and the difference of the torso shape between the sizes. Interestingly the shape of the posterior side of the torso showed great similarities between the sizes while most difference can be found in the shape of the anterior side of the torso. Insights which can be used in the design of the harness.

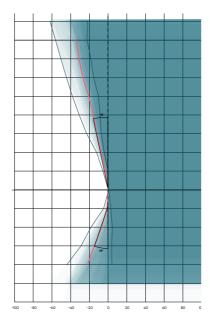


Figure 60: Males and females wearing harness size M (820 - 910 mm) vertical cross-sections aligned at the lordosis

3.4 HARNESS SIZING

The previous chapter presents anthropometric data with which an analysis of the current sizing of Mystic boarding can be made. The previous and current harness size-chart can be found in Appendix J on page 117. It should be noted that the female size XS corresponds to male XXS and so on. This is done due to the reduction in production costs when using the same backplates for males and females. This chapter aims to find out the relation between the torso height and the wasit circumference within certain available sizes.

3.4.1 ANALYSIS

Figure 61 shows the percentiles of the population compared to the current sizing chart, displaying which amount of the population is represented by the sizing. It also displays that 75% of the female population is covered by the current sizing. The other 21% would have to wear male sizes and 5% would not fit any sizing according to the data. Compared to males sizes 98% of males fall within the sizing range. When analyzing Figure 61, where the relation between the waist and torso can be found in comparison to the sizing, this same conclusion can be made.

According to research, the correlation between an individual's stature and waist circumference is considerably weak. Therefore, it is not a reliable predictor for determining the appropriate harness size. This could also suggest that an individual's confection harness size may not be an accurate indicator of the required backplate size.

If we assume the torso length (Hip to LSP) is an indicator for the needed harness backplate height. then the relation between the waist circumference and the torso length gives insight into how to scale the harness backplate over the size range of the harnesses. The torso length is analyzed and the relationship to the waist harness is described using data sheets. This relationship is used to create a size-suggestion of the backplate per harness size. This suggestion is compared to the current backplate size in Figure 63. In this analysis, a comparison is made between the needs of males and females, which have been shown to be different. The results indicate that the difference in needed backplate height between the M size and other sizes is smaller than in the current backplates produced by Mystic. Additionally, the larger sizes of men require a larger backplate height, while the smaller sizes require a smaller backplate height compared to females. (This model is created assuming that the size range is designed from size M and from there out scaled to the other sizes, thus assuming the M has the most accurate backplate height)

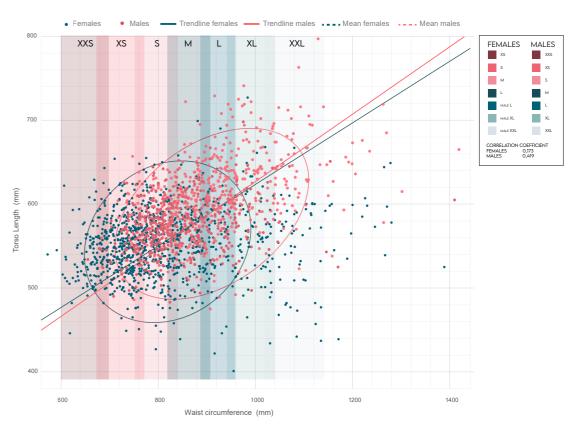


Figure 61: Two ellipses showing the relation between the Torso length and the waist circumference in males(red) and females(blue)

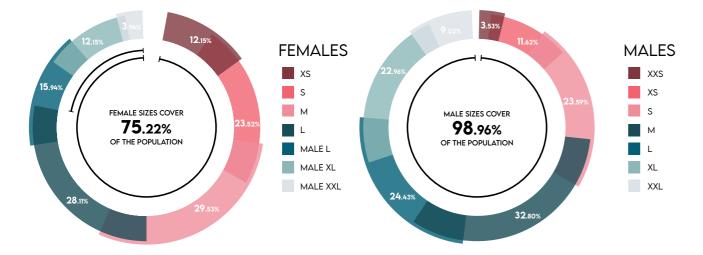


Figure 62: Mystic sizing compared to the waist circumference of the female and male target-group according to CAESAR NL & IT

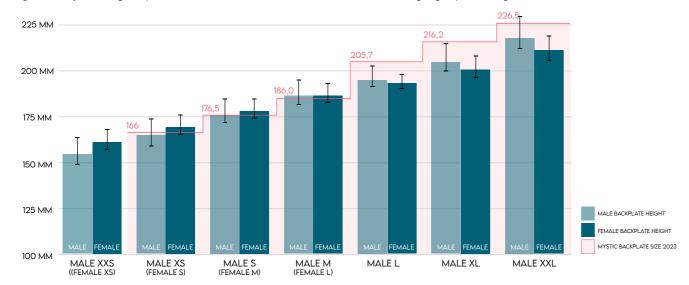


Figure 63: The backplate height of current (2023) Mystic harnesses (red) compared to the estimation of the needed backplate height in relation to the waist-circumference and thus harness-size in males and females (blue bars). Calculated with the torso height and waist-circumference of the CAESAR-NL and CAESAR-IT participant group.

3.4.2 RECOMMENDATIONS

In conclusion, the analysis of anthropometric data reveals that the current sizing of Mystic boarding harnesses can be improved. The comparison of percentiles and sizing charts shows that the current sizing covers 75% of the female population, as 21% needing to wear male sizes. However, using waist circumference or conventional clothing size as indicators for harness size is unreliable.

Instead, this study suggests using torso length (Hip to LSP) as an indicator for the required backplate height. By analyzing the relationship between waist circumference and torso length, the needed backplate height can be determined. This is analysed using the ellipses showing the relation between the torso length and waist circumference, as found in Figure 61. These results are compared to the backplate height of the current Mystic harness range (2023) in Figure 63. It is assumed that the harness is designed for a size M and this design is scaled to fit the remaining sizes.

It can be found that the difference between size M and other sizes of currently produced backplate heights is larger than the difference needs to be according to the graph. Additionally, larger sizes for men require a larger backplate height, while smaller sizes require a smaller backplate height compared to females.

3.4.3 CONCLUSION

To improve the harness fit and accommodate the needs of both genders, it is recommended that Mystic implements the suggested design adjustments based on the data shown in Figure 63. Especially when designing the size sets of a kitesurf harness. This approach will enhance the overall comfort of the entirety of available sizes. Concluding, a smaller difference in backplate height between sizes is recommended.

3.5 KITESURFING MOTIONS AND POSTURE

This chapter aims to firstly analyze which postures and motions are adopted and most relevant during kitesurfing. Secondly to find out which shape the body takes during these relevant postures and movements.

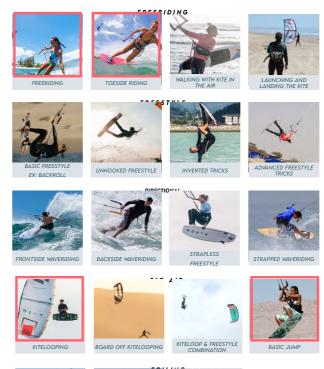
3.5.1 OVERVIEW OF MOTIONS

There are hundreds of kitesurfing "moves", an overview of these moves can be found below (Rossmeier, n.d.). This wide array of moves were analyzed based on how common it is, how much time is spent doing it, the extremity of the rotation or bending, the amount of forces coming onto the user and the angle of the kite during the move. Three manoeuvres were chosen to analyze via a video annotation tool, designed for sport analysis. This can be found in Appendix K on page 118. To create more insights into the shape and angles of the body during these common moves two of these moves were studied through 3D scanning in the 3.5.2.

HEELSIDE RIDING

The most common stance during kitesurfing is heelside riding: The feet in the straps and the heels pointed towards the wind. The front-leg is stretched and the back-leg angled to push the board against the water. Within this stance the kitesurfer can ride up-, perpendicular or down-winded. The kitesurfer can ride with one or two hands on the bar. This body position changes throughout the session due to wind, speed, direction (upwind / downwind), fatigue, etc. The photo analysis shows that with normal heelside riding the pulling angle is 70 to 110 degrees. Preferably in 90 degrees, in which the forces are likely to be evenly divided over the entire backplate of the harness.

The motion analysis shows that in some cases the kitesurfers upper body is leaned forward. In this situation the kitesurfers shoulder, especially the back shoulder, are extended towards the bar sometimes resulting is a slouched-looking stance. Hereby static shear forces and eventually also dynamic shear forces can be found, resulting in the upward pulling of the harness. An observational analysis by L.Lundgren & S. Brorsson showed that the most common body position of the observed kitesurfers was a position leaning back towards the water surface with an angle averaging 38,5° (SD≤7,5°) of the lower extremities towards a horizontal plane and the upper body ca 66° (SD≤6,9°) towards the horizontal plane while going upwind.











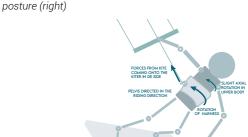


Figure 65: Illustration of heelside riding correct (left) and incorrect

Figure 64: Moves performed by kitesurfers

Figure 66: Illustration of stance during toeside riding

TOESIDE RIDING

During toeside riding the toes are directed towards the wind, thus the lower extremities are directed away from the kite while the upper extremities are directed towards the kite. Resulting in a twisted stance. The legs are bend and the pelvis is directed in the riding direction, the upper body has a slight axial rotation. Kitesurfers should keep their core tightened and straight while direct their upper body towards where they want to go.

Some kitesurfers show some lateral flexion during toeside riding but this should be avoided. The angle of the torso is influenced by the holding of the bar - it can be held with one or two hands. As toeside riding proves more difficult to ride upwind, kiters often hold out their hand to guide them upwind. During heelside riding the angles of the kite are ranging between 70 to 110 degrees, the images show that the same angles are used during toeside riding. What can be found in the images is that the harness is often displaced as the hook has shifted more towards the kite. This is due to the forces that are not perpendicular on the harness. These forces lead to shear forces between the kitesurfer and the harness.

JUMPING

When performing a jump, the kitesurfer has a decent speed and just before "popping" of the water carve upwind slightly. At this moment the kitesurfer pulls the bar for more power, pulling the kiter up into the air. During a "normal" jump the kite stays above the kite, resulting in an upward force pulling on the harness. This causes an uncomfortable position and pressure on the chest during and after the jump.

How the kitesurfer hangs under the kite varies, depending on where the kiter holds their legs during the jump: forwards or backwards. Shown in Figure 67. The back is in an straight angle. The kitesurfer often pulls the legs in keeping the board closer to the body. No axial rotation of lateral flexion can be found in a regular jump.

An observational analysis by L.Lundgren & S. Brorsson showed while preparing for take-off for jumps the angles were ca 20° (lower extremities to horizontal plane) respective 70° (upper body to horizontal plane). Meaning the hip flexion (angle between upper and lower body) was decreased for all subjects while preparing take-off.

KITELOOPING

The kiteloop is an advanced trick. During this jump the kitesurfer pulls on one side of the bar mid-air, this steers the kite to make a full circle motion. Creating momentum and high speeds, the kitesurfer is pulled across the air often landing tens of meters from where they launched. The highest kiteloops go up to 35 meters and has become an official discipline in kitesurfing. Where professionals do variations like backrolls, boogieloops, boardoffs, etc.

The stance for this move is similar to a simple jump, the difference is the higher altitude and speeds resulting in a different direction. The kite is pulling in a horizontal direction, the kitesurfer is pulled across the air and this creates a more horizontal stance, with the legs and board behind the kitesurfer.

During the performance of a jump there are two moments when high forces come onto the user:

The Take-off: Before making such a high jump the kitesurfer is at high speeds and carves into the wind to get the most height. During this moment high forces come onto the user. An example of this is when Mystic had a production error in the spreaderbar most had failed during the take-off of a high jump.

The Loop: When making a loop with the kite, the kite accelerates creating extreme forces. These horizontal forces are pulling the kiter forward.

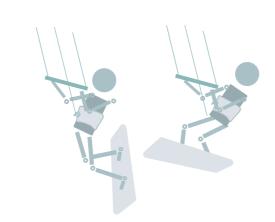


Figure 67: Illustration of a basic jump

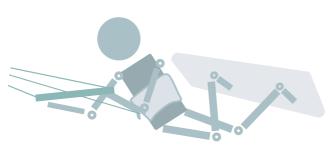


Figure 68: Illustration of a kiteloop

3.5.2 EXPLORING THE SHAPE OF THE LUMBAR AREA THROUGH 3D SCANNING

This sub-chapter aims to answer what shape and angles does the body take during kitesurfing and maximum bending and rotation? 3D scans were made of a small set of participants to examine the postures taken during kitesurfing. This was used to analyze the shape of the lumbar area in different (kitesurfing) stances. This examination creates insights into the needed shapes and flexibilities in the harness design. Images were made of the participants during maximum bending and rotation postures as reference.

RESEARCH AIM

These scans can be justified by the fact that there is much research, measurements and data available describing the body in the neutral stance. But limited research is available where the body is measured during stances other than a neutral stance. As this research shall not be used for actual sizing but only for insights concerning needed shapes and angles of the harness, only a small sample of the population shall be used.

RQ: What shape and angles does the participants lumbar area take during heelside riding and toeside riding compared to the neutral stance?

PARTICIPANTS

A sample size of 5 participants was used, of which 3 males and 2 females. All participants can kitesurf and were thus able to correctly take a kitesurfing stance. The aim was to find a group of participants with different body types and sizes, recruited via convenience sampling. The participant group doesn't represent the age or geographical demographic of the target group. The potential implications could be that the body shape and flexibility changes through age and thus the measurements of the younger demographic doesn't represent the older demographic accordingly. This overview can be found in Appendix M on page 120.

The participants have consented to being scanned, photographed and filmed throughout the research. They were aware of the activities during the research beforehand what the data was used for.

TOOLS & EQUIPMENT

3D scanning tools and observation were utilized in the study. To create a suitable scanning environment, various attributes were employed to simulate kitesurfing, including a Kitesurf twintip, controlbar, and waist belt. The kiteboard, controlbar, and waist belt were used to create a natural kitesurfing stance for the participants. The controlbar was suspended from the ceiling, while the waist belt represented a kitesurfing harness that covered only a small portion of the torso.

The clothing of the participant influenced the outcome of the 3D scan. Men were asked to wear no shirt and their jeans/pants as low as possible. The woman were asked to wear a soft bra or bikini with pants as low as possible. The items that are worn shouldn't be black or have prints as that could distort the details of the scan.

The 3D scans were performed with a LIDAR scanner. This software would produce object file (.OBJ) which can be processed and analyzed in CAD software solidworks.

RESEARCH ENVIRONMENT

The study was conducted in a laboratory setting. Specifically a photo studio with ample lighting and a white backdrop to minimize distractions and provide sufficient room for participant movement. To simulate the experience of kitesurfing, participants stood on a kitesurfing board placed on a yoga mat for support, allowing them to lean into the "kite" as they would in actual kitesurfing. They held a specially modified kitesurfing bar that hung from the ceiling.

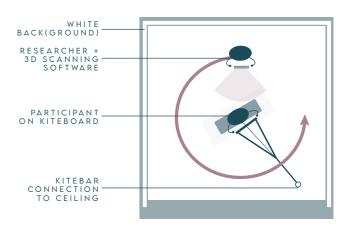


Figure 69: Illustration of the research situation

RESEARCH PROCEDURE & DATA PROCESSING

The procedure of the research can be found in Appendix M on page 120. This procedure was made using the insights from the pilot session.

The participants dimensions were measured for two reasons: (1) Finding out the percentiles of the participant compared to the data in Dined and (2) check the 3D scan on its accuracy concerning the measurements.

Hip circumference | Waist circumference | Chest circumference | Height | weight (kg)

The data output from the 3D scanning is object files (.OBJ) These were imported and processed in Solidworks, developed into solid torso's. These torsos were used to analyze the angles and shapes the human body takes in the different postures.

RESULTS

The description of the results can be found in Appendix M and the solidworks drawings of the 3D models of the scans can be found in Appendix O on page 121.

These 3D models are used to create sections views as can be found in Figure 72, which were not only used to analyze the angles of the body, but also the shape of the participants. For example these section views showed that the males have a more square shape around the chest area and the woman were more square around the hips. The females had a smaller rounder waist while the men's waists were also smaller than the hips and chest but with less difference and a more oval shape.

DISCUSSION & CONCLUSION

The flexion and extension positions showed the results that were expected, as research has showed that the lumbar spine was capable of higher angles during flexion and extension than the thoracic. The 3D models showed that the largest curvature occurred just under the waist.

Figure 70 shows that this maximum curvature around the waist should be difficult to perform when wearing a harness. Is it preferable by the kitesurfer to give the back more support or would the kiter need more freedom of movement in this direction?

The scans showed that the thoracic vertebrae stays considerably straight except in the top vertebra during the maximum flexion. This means that the harness only has to accommodate very little bending for the thoracic spine.

As expected no lateral flexion could be found during the heelside and toeside riding as it is not done often during kitesurfing, most commonly only short moments during freestyle with moves like board grabs. The possible lateral flexion varied between participants ranging from 17 to 32 degrees from the waist up. Showing a large difference between participants. The 3D models can be used to decide on a appropriate size and flexibility for the side of the harness, to accommodate at least a board grab.

As with the extension and flexion, the axial rotation found in the research also confirms the research in chapter Appendix M on page 120 as most of the axial rotation could be found around height of the thoracic spine. The axial rotation and the toeside riding models were very alike for most participants. Showing that the toeside riding is a posture which mostly consists of an axial rotation.

During the scans the user seems to be hanging less than during usual kitesurfing, this angle would depend on their personal preference and their trust in the kitesurfing simulation hanging from the ceiling. As the board was not in an angle which it is usually on the water the angle might be a more in a real kitesurfing situation. It was surprising to see barely any axial rotation in this stance as most of the angle is already taken by the position of the legs by stretching the front leg and bending the back leg.

The shape of the body was more oval than expected but this could be due to the sample used. All participants were fairly young with a maximum size of L. In a different demographic this shape could change. Might there be a correlation between the shape and the size of the user? This would mean the quality of the fit of the harness could be improved by making the smaller harnesses more oval and the larger sizes rounder.

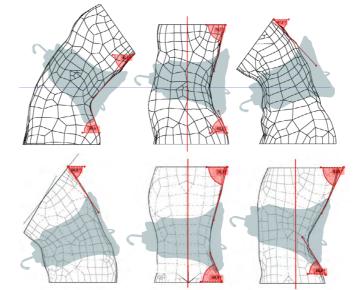


Figure / I: Maximum extension, neutral stance and maximum flexion of a female participant (top) and male participant (bottom)

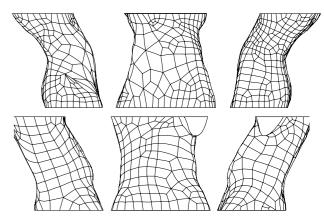


Figure 72: Heelside riding female (top) and male (bottom) participants

3.5.3 ANALYSIS OF THE INTERACTION BETWEEN THE HARNESS AND THE KITESURFER

The larger the surface area between the kitesurfer and the harness, the better the pressure distribution, the less pressure points and the less discomfort is experienced by the kitesurfer. Thus, studying the interaction between the kitesurfer and the harness is of the essence. There are two reasons for the decrease of this surface area: The harness moving out of place, and the body bending or rotating changing the shape of the body.

RESEARCH AIM

The goal of this research is to create a deeper understanding of how and when the harness and body move according to each other. This research is focused on motion analysis. It aims to explore the movement of the kitesurfing harness in different postures taken during kitesurfing, this deeper knowledge shall help design a kitesurfing harness with the correct shape and flexibility throughout the different postures during riding. It is based on the hypothesis that the harness moves out of place during these stances.

RQ: How does the harness displace during heelside and toeside riding?

RESEARCH ENVIRONMENT & EQUIPMENT & PROCEDURE

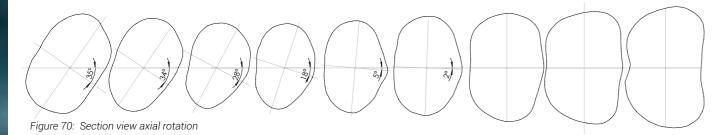
A participant group of three persons was found, representing one male and two females.

To create a suitable scanning environment, various attributes were employed to simulate kitesurfing, including a kitesurf twintip, controlbar, harness(Mystic). These were used create a natural kitesurfing stance for the participants. The controlbar was suspended from the ceiling.

Stickers were stuck on the skin and the harness to measure the displacement - for this the participant was asked to be bare-skinned.

During the test a camera was used to record the findings. These results consist of images of the participants in a neutral, heelside riding and toeside riding stance. The participants have consented with being scanned, photographed and filmed through, they are aware of what they must do in the research beforehand and are aware for what the data shall be used.

The research is done in environment where a kitesurfing simulation is made. To create the kitesurfing simulation the participants are with their feet in the straps of a kitesurfing board (with a wooden board or yogamat under the board so the participant can lean into the "kite". The participants hold a kitesurfing bar that has been modified so that it can hang from the ceiling.



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RESULTS

Images from the entire research can be found in Appendix Q on page 129. Figure 73 shows images from the findings from all three participants, these findings are labeled A to F and shall be mentioned as such in the analysis.

The hypothesis of this research is based on the user research, the images found in Figure 74 resemble the movement mentioned in the user research. Here examples can be found of professional kitesurfers making moves where the harness moves out of place or has less surface area in contact with the user. These images are number 1 to 6. Image 1 to 3, show heelside riding. The kitesurfers are in a flexion position, with the bottom and top rim are not touching the kitesurfers torso. Images 4 to 6 show toeside riding, here an axial displacement can be found and especially in the 4th image the effects of a hardshell harness displacing can be seen.

Participant A: During heelside riding the harness was staying in position. During toeside riding the "kite" was pulling the harness to the left. On the chest area could be seen that there was a slight displacement of the harness. On the back the harness wasn't touching the body on the left bottom side (A) and digging into the skin on right side of the body.

Participant B: During heelside riding the harness was staying in position, on the frontside of the harness the chest area was totally disconnected from the harness(C). The toeside stance showed a high displacement of the harness on the front and back of the participant(D)

Participant C: During heelside riding the harness was staying in position, the backplate of the harness was pushing the skin on the back up and the harness position was high on this participants back.

The toeside stance showed a displacement of the harness on the front and back of the participant(E), it also showed a high displacement of the skin (F). This resulted in discomfort with the participant. The participant had to tug hard to place the harness back into position.

DISCUSSION & CONCLUSION

All the participants harnesses showed some sort of displacement during the research. Thus the hypothesis that the harness does move proved to be correct. The researched showed a difference between the softshell and the hardshell harness. The softshell harness showed significantly more displacement during the toeside stance, which resulted in discomfort in the participants due to shear force on the surface of the skin.

The hardshell harness showed less displacement due to its stiffness. As the shape of the torso changed going into the stance the harnesses surface area touching the body decreased, creating a reduced dispersion of the forces. These pressure points could be found on the hardness lining on the top, and the point were the harness was not touching at the bottom lining in the direction where the harness is pulling.

These insights could lead to the assumption that a hardshell harness is more likely to create discomfort due to pressure points and a softshell harness is more likely to create discomfort due to shear forces.

Most of the shear stress felt by the participants during the test was in the top and bottom of the lining of the harness. This being an area of higher discomfort on the bare skin especially.

The spreaderbar being a significant distance from the body in the test with participant B. Creating a situation where the spreaderbar can easily rotate if the kite takes a higher position - having a high chance on discomfort. due to high pressure, shear forces on the chest area and a disturbance of the breathing.

We can conclude the hypothesis is correct as the harness showed displacement during the heelside and toeside stances. Proving there is a need for a harness that accommodates these postures. And that this harness has an increased surface area during these stances compared to the current situation. The twisting of the body during toeside riding especially showed an increase in potential pressure points on the edges of the harness and the flexion position during heelside riding showed potential pressure points in the mid-section of the harness.









Figure 73: Images of research done to analyze the movement of the harness on the body





Figure 74: Images of Harnesses moving on the body of professional kitesurfers,: Airton Cozzolino, James Carew, Gabriel Beneton, Fransesco Cappuzzzo and Alex Middler. Images: Global Kitesurfing Association by Svetlana Romantsov and Lukas K Stiller.

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3.6 GENDER-SPECIFIC CONSIDERATIONS

The previous chapters have shown a notable difference between the torso of males and females. When designing a kitesurf harness for both males and females, it is essential to consider gender-specific considerations to ensure a comfortable and secure fit for both genders. Anatomical differences between genders, such as waist-to-hip ratios, torso lengths, waist measurements, hip measurements, and chest measurements, should be taken into account.

3.6.1 ANALYSIS

Chapter 3.3 The design of a sizing system showed the relation between the waist-to-hip ratios and waist-to-chest ratios. The waist-to-hip ratio showed a lower correlation in females while the difference between the hip and waist was found to be smaller in males. Concerning the chest circumference a larger correlation can be found in males and females, especially in females where the correlation was found to be 0.924. The outlines of the torso which were studied showed this same difference between males and females. Showing a high difference in the hip width in females compared to men.

Chapter 3.4 Harness sizing showed the relation between the harness size and the torso length - a relation which can be used to design the backplate height over the range of sizes. This also showed that there are gender could be used to predict the needed backplate height.

Also the difference between the shape of the torso during different postures between the genders was discussed in chapter 3.5.2 Exploring the shape of the lumbar area through 3D scanning. This showed higher flexibility in the females, and a distinct difference in males and females especially in the shape of the cross section of the hips and the chest. The hips being much larger and square-shaped in females and the chest being much larger and square shaped in the males. Which corresponds with the earlier done analysis of the CAESAR scans.

3.6.2 CONCLUSION

Summarizing, gender-specific considerations based on anthropometric data are crucial when designing a kitesurf harness. The research highlights the need for accurately measuring and understanding body size and shape variations to ensure an optimal fit and accommodate the diversity of the target group. The findings suggest improvements in harness sizing, taking into account the relationship between waist circumference and torso length and highlights the major differences in the shape of the two genders specifically the larger difference in the hip width compared to the waist width in females. By recognizing and addressing gender-specific considerations, the harness can provide equal support, freedom of movement, and confidence to all kitesurfers, enhancing their overall experience on the water. It can be concluded that some adjustments are needed then designing a harness for both genders, this could be solved by incorporating more components that can be adjusted or customized by the user.

3.7 ERGONOMICS CONCLUSION

The aim of this chapter was to develop a deeper understanding of the ergonomics related to the kitesurf harness. This was done by answering a set of 10 research questions. The results of this done research leads to deeper understanding of the possibilities but also highlights the limitations of the human torso. This overall conclusion but also implications for the design requirements are discussed below.

3.7.1 CONCLUSIONS

A strong relationship between discomfort and ergonomics in the design of kitesurfing harnesses can be found. Physical discomfort factors, including pressure points, chafing, muscle fatigue, limitations in range of motion, and strain on the back and spine, are discussed.

The spine's capabilities, including flexion, extension, axial rotation, and lateral flexion, are critical for harness design. Lumbar and thoracic spine play distinct roles in kitesurfing.

The constant expansion and contraction of the chest, driven by the movement of the ribs during breathing, emphasize the importance of designing harnesses that do not hinder these natural motions.

The current sizing chart, which relies primarily on waist circumference and conventional clothing size, has limitations in accurately accommodating the diverse body shapes within the kitesurfing community. To address this issue, this study suggests using torso length (Hip to LSP) as a more reliable indicator for the required backplate height. By analyzing the relationship between waist circumference and torso length, size recommendations for the backplate can be derived. When compared to the current backplate height, the results indicate that the difference in backplate height between different sizes should be smaller than in the current production.

Significant variations in body posture between neutral, heelside, and toeside riding positions are discovered. Harness displacement, especially during toeside riding, can cause discomfort and safety concerns for kitesurfers. The difference between softshell and hardshell harnesses in displacement and pressure points highlights the importance of harness design.

Anthropometric differences between males and females, such as waist-to-hip ratios, torso lengths, and chest measurements, were shown to significantly impact harness fit and comfort. These findings highlight the need for harnesses that can be adjusted or customized to accommodate these variations effectively.

In conclusion, this chapter suggests that harness design should not be a one-size-fits-all approach. Instead, it should consider the diverse range of body shapes, postures, and gender-specific differences within the kitesurfing community.

3.7.2 REQUIREMENTS

Reduction of dis-comfort: As kitesurfers spend long hours on the water, it's essential to create a comfortable harness that can reduce the pressure on the body, the design should focus on eliminating discomfort and not creating comfort.

Distribution of forces: The high pulling forces of the kite are directed onto the body through the harness, which place considerable stress on the musculoskeletal and physiological systems of the user. Improved force distribution should reduce discomfort as the forces are administered onto more vertebrae.

Height of forces: If forces as distributed on the lower vertebrae this requires less muscle contractions in the torso leading to less decreased fatigue and thus less chance on discomfort.

Mobility of the spine: The design should consider the ROM of the spine: The lumbar spine (especially L4 & L5) is responsible for most of the flexion and extension. The thoracic spine is responsible for most axial rotation compared to the lumbar spine. The vertebrae of the Thoracic spine provide attachment for the ribs, except for T11-T12. T5-T8 show the greatest rotation ability.

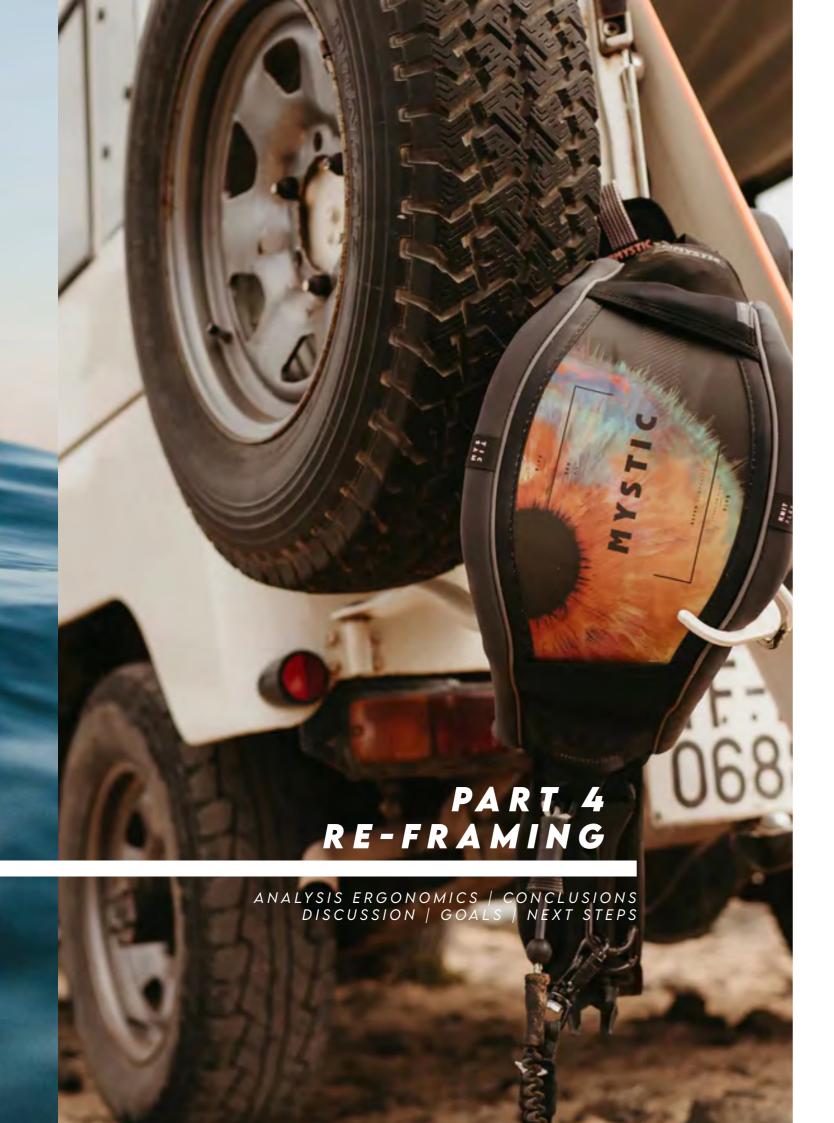
Breathing: Though a tight fit is desirable the harness should allow the user to comfortably breath throughout the session.

Perfect fit: The design of the harness should support the lumbar area and fit properly, not being too big or too small, to reduce discomfort and ensure maximum performance. The sliding out of place is a common discomfort reported by users, as it results in pressure and discomfort on the ribs.

Shear stress in harness: Most of the shear stress in found on the edges of the harness, through the shape and design of the padding this should be decreased to decrease the discomfort.

Size exclusivity: As kitesurfers come in different shapes and sizes, the harnesses should be inclusive and cater to different body types. The sizing range of the harness should cover a majority of the target group.

(Fe)males: Though kitesurfing is practices more by men the harness design should be adaptable to men and woman. The difference in body shapes and dimensions should be taken into account when doing so. (Modularity and adjustability to female shape).



4.0 RE-FRAMING

This chapter presents the analysis of the research, aiming at generating insights. This analysis is led by a discussion on the used research questions in chapter 2 - context and chapter 3 - Ergonomics. Followed by a re-framing of the problem statement accompanied by the set of requirements of the product derived from these chapters, a summary of the target group and a set of four market opportunities found during the previous chapters.

CONTEXT

- 1. What components does a kitesurf harness consist of?
- 2. Which existing harness designs/solutions can be found on the market and similar markets?
- 3. Are these found solutions considered desirable?
- 4. What knowledge of the ergonomics and physics of kitesurfing is available?
- 5. What existing analysis of unfamiliar forces coming onto the lumbar area is available?
- 6. Who is the user group?
- 7. What discomforts concerning the harness are perceived by kitesurfers?
- 8. What are the needs and preferences of the user group?
- 9. What are the components of kitesurfing?
- 10. What are the forces acting upon the harness and user during kitesurfing?

ERGONOMICS

- 1. What is the relation between discomfort and ergonomics?
- 2. What is the anatomy and function of the human body where the harness is worn?
- 3. What are the relevant dimensions of the user group? And what are the relations between the dimensions? (1D and 2D Anthropometry)
- 4. What is the shape of the lumbar of the user group? (3D Anthropometry)
- 5. What are the relations between dimensions within certain harness sizes?
- 6. What postures(static) and motions(dynamic) are taken during kitesurfing?
- 7. What are the most relevant motions for the design of a kitesurfing harness?
- 8. How does the body move? What shape and angles does the body take during kitesurfing and maximum bending and rotation?
- 9. Where and how does the current harness design move on the body?
- 10. What considerations should be made when designing a kitesurf harness for both genders?

4.1 PROBLEM REDEFINITION

The original problem statement read:

"What is the next step for the kitesurfing harness. How can we integrate more comfort, support, trust and freedom of movement into the harness?"

The discussion of the previous chapters has led to a redefined design question, leading the ideation and conceptualization phase:

"How can we decrease the experienced discomfort by creating a better fitting harness for the wide variation of body types of the target group?"

This new problem definition was reached through the conclusion that most discomfort is caused by the harness not fitting optimally. This is due to the extremely wide variation in body types and preferences. If a solution is found that would cater to this wide variation it would create a solution towards decreasing the discomfort felt by users.

4.2 DISCUSSION

The results from the RQs which the previous chapters set out to answer summarized and discussed below.

The user group, the kitesurfer, mentions perceived discomfort due to digging into the ribs of the spreaderbar, chaffing and bruising due to shear forces, the harness moving out of place due to wrong sizing and the backplate having the wrong shape leading to unwanted pressure points. When asked about important characteristics of a harness, comfort, padding, and stability were mentioned as most important factors.

Many brands have set out to overcome these discomforts, designing different solutions trying to solve these factors. Some contributing to a decreased discomfort but often designs prove to have been unsuccessful due to over complications, deterioration due to salt, sand and sun or have barely have no positive or negative effect on the comfort of the user. Making certain design aspects more of a marketing attribute.

In the analysis of the tensile forces during kitesurfing it was found that its components should be able to resist pulling forces of as 1000N. Also the components and the user should be able to resist the variation of these forces that constantly change as they are dependent on the environment like the

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body of water and weather conditions.

An anthropometric analysis includes the measurement of the target group, describing the physical similarities and variations in body sizes and shapes. Navigating towards an optimized fit of the harness throughout all sizes.

The designed sizing should represent the majority of the targeted population. Data from the Dutch and Italian CAESAR databases were used to obtain a representative results. The waist circumference is the most important sizing factor of the harness and should be the basis of the sizing of the harness. The relations between the chest, waist, and hip circumference represent the taper of the torso. The shape of this taper influences the movement of the harness on the torso. Wider hips might result in more riding up and a triangular muscular male shape might result is a better positioning of the harness. The waist circumference is very rarely larger than the chest circumference, this is only found in a few single cases in participants with large waist circumferences. When analyzing the relation between the hip and waist circumference it can be found that these measurements are very similar to each other especially in males with a larger waist circumference.

The torso height represents the possibilities of the backplate height of the harness. The relation between the torso length and the waist circumference determines the needed backplate height per size set. Among males, there is a higher correlation between these two dimensions, yet the trend line for males and females is very similar. Additionally, the larger sizes of men require a larger backplate height, while the smaller sizes require a smaller backplate height compared to females.

A combination of photo analysis, 3D scans of kitesurfers and ROM of the spine showed where the rotation and bending of the body can be found. Showing how the shape of the body is suspected to change during the session, which should be used to design a harness with local flexibilities and rigidness.

The research showed the movement of the harness on the body of kitesurfers, and found that there is a large difference between the hardshell and softshell harness. The softshell showed significantly more displacement. The hardshell showed less displacement but pressure points were found. Creating a decreased dispersion of the forces as the area touching the body has become less. These pressure points could be found on the lining on the top of the harness. Most of the shear stress felt by the participants during the test was in the top and bottom of the lining of the harness. These are the areas of higher discomfort, especially on the bare skin

After analyzing the ergonomics and context of the harness we can conclude that there are four main factors contributing to discomfort which can be found in Figure 75.

A kitesurf harness design shouldn't move out of position, even with unexpected stormy conditions or forces resulting from winds higher than 8 Beaufort. The design must also decrease the ability of the spreaderbar to rotate into the ribs. The harness should give the kitesurfer the sense of control. It's an instrument to master the circumstances and helps steer the kite within difficult situations without losing control.

THE MOVEMENT OF THE HARNESS ON THE BODY

DUE TO HIGH VERTICAL FORCES

PRESSURE ON THE RIBS

DUE TO HIGH VERTICAL FORCES LEADING TO THE "DIGGING" INTO THE RIBS AND HINDERD BREATHING

PRESSURE POINTS

DUE TO THE WIDE VARATION OF BODY TYPES THE SIZING, SHAPE AND FLEXIBILITY OF THE HARNESS LEAD TO PRESSURE POINTS ON THE TORSO

UNDESIRED FORCES DURING BENDED OR ROTATED STANCES

FORCES FROM VARIOUS POSITIONS AND DIRECTIONS COME ONTO THE BODY DURING EXTREME STANCES

Figure 75: Areas of discomfort found during the analysis- of the kitesurf harness

4.3 REQUIREMENTS

Based on the project brief, renewed problem statement and the results from the previous chapters a set of requirements are described. The Chapter from which the requirement originates is mentioned. The most important requirements are highlighted.

THE TARGET GROUP

Consider the needs of professional and amateur kitesurfers: Although the harness is a performance product, it should not exclude amateur or aspiring kitesurfers who want to improve their skills. It is important to design the harness to be user-friendly and adaptable for a wide range of skill levels for both frequent and infrequent kitesurfers. (Chapter 2.3 The user group)

Consider different kitesurfing-disciplines: Since the harness is designed to be at the top of the range, it should prioritize performance and versatility. This means it should be able to handle a wide range of disciplines, riding styles and levels, catering to a diverse demographic of kitesurfers. (Chapter 2.3 The user group)

Size exclusivity: As kitesurfers come in different shapes and sizes, the harnesses should be inclusive and cater to different body types. The sizing range of the harness should cover a majority of the target group. (Chapter 3.3 The design of a sizing system)

(Fe)males: Though kitesurfing is practices more by men the harness design should be adaptable to men and woman. The difference in body shapes and dimensions should be taken into account when doing so (Modularity and adjustability to female shape). (Chapter 3.6 Gender-specific considerations)

COMFORT OF THE HARNESS

Reduction of dis-comfort: As kitesurfers spend long hours on the water, it's essential to create a comfortable harness that can reduce the pressure on the body, the design should focus on eliminating discomfort and not creating comfort. (Chapter 3.1 Discomfort)

Perfect fit for wide-variation of target group: A harness with the correct fit leads to a reduction of discomfort due to the harness staying in place and a reduction of pressure points. (Chapter 3.3 The design of a sizing system)

Positioning of harness: Kitesurfers experience problems with harness movement during kitesurfing. The harness design should decrease the harness displacement during use without increasing the tightness that leads to discomfort. (Chapter 2.3 The user group)

Positioning of spreaderbar: Kitesurfers experience problems with the spreaderbar rotating during riding. Resulting in pressure on the ribs from the harness riding up. At the moment the webbings are the solution in connecting the spreaderbar and the harness and this discomfort is due to it's flexibilities. (Chapter 2.3 The user group)

Shear stress in harness: Most of the shear stress in found on the edges of the harness, through the shape and design of the padding this should be decreased to decrease the discomfort. (Chapter 3.2.4 The skin)

Breathing: Though a tight fit is desirable the harness should allow the user to comfortably breath throughout the session. (Chapter 3.2.1 The torso)

(FORCES ON) THE USER

User needs: According to the interviewees comfort, padding, and the staying in place are the most important factors for users when choosing a harness. Hence, the design of the harness should prioritize these factors. (Chapter 2.3 The user group)

Ease of use: The systems of the harness should be easy to use for all users - thus not needing extreme force or skills to adjust or close the system. (Chapter 2.3 The user group)

Distribution of forces: The high pulling forces of the kite are directed onto the body through the harness, which place considerable stress on the musculoskeletal and physiological systems of the user. Improved force distribution should reduce discomfort as the forces are administered onto more vertebrae. (Chapter 3.2 The human body)

Mobility of the spine: The design should take into consideration that the lumbar spine is responsible for most of the flexion and extension, of which its lowest two lumbar vertebrae allow for most. The thoracic spine, being responsible for most axial rotation, but little extension and flexion capabilities compared to the lumbar spine. The vertebrae of the Thoracic spine provide attachment for the ribs, except for T11 - T12. T5 to T8 have the greatest rotation ability of the thoracic region. (Chapter 3.5 Kitesurfing motions and posture)

FORCES OF KITESURFING

High pulling forces of kitesurfing: The harness needs to be designed to withstand the high pulling forces of over 1000N during kitesurfing (2.2 Physical demands of kitesurfing)

Unpredictability of kitesurfing: The biomechanics of the body position during kitesurfing change depending on many factors, such as wind speed, upwind projection, and take-off preparation. The design of the harness should consider these factors to ensure the user can handle and utilize the force from the kite for tricks or speed. (Chapter 2.2 Physical demands of kitesurfing)

The force-direction: The harness should withstand forces from all directions within the wind window of the kite. (Chapter 2.4 The physics of kitesurfing)

Safety: The equipment has a significant impact on the safety of the sport. The harness should be well designed to reduce injury risk and enable maximum performance. (Chapter 2.2 Physical demands of kitesurfing)

THE HARNESS DESIGN

Design for durability and longevity: Kitesurfing is an expensive high performance sport, and the equipment needs to last for a long time. The harness should be designed to withstand the wear and tear of regular use. Using high-quality materials and construction methods will not only increase customer satisfaction but will also build on the positive reputation for the brand. The harness also needs to withstand the extreme circumstances of it's use in salt water, the harmful UV radiation from the sun and the presence of sand. (Appendix aA, The project brief)

Modular designs: Since kitesurfers have different riding styles, creating a modular harness should be considered. That can adapt to the different disciplines. This can include interchangeable parts or add-ons that allow users to customize the harness to their specific needs. (2.3 The user group)

Simplicity: The current Mystic harness is lightweight and has a simple design. These appealing factors should be transferred into the new harness design. (2.1 Product analysis)

Waterwear: The waterwear and harness used can cause lateral shifting between the kitesurfer, waterwear, and the harness, which should be minimized in harness design. The design should ensure that the harness remains comfortable with or without a wetsuit. (2.4 The physics of kitesurfing)

BRAND IDENTITY AND RESPONSIBILITY

Highlight the brand identity: The harness design should be consistent with the strong brand identity of Mystic. The design should reflect the brand's image, values, and culture. (Chapter 1.5 The client)

Sustainability: As the world, and Mystic, becomes more environmentally conscious more sustainable and eco-friendly designs should be considered. Creating more circular products can include material choice, modular replacements, repairability and recycle-ablity. (Appendix aA, The project brief)

4.4 THE USER GROUP

Mystic boardings brand identity is closely related to whom is riding their gear. Their aspirational customer/kitesurfer could be described with phrases like:

Kitesurfers with wild ambitions; Adventure seeking; Flying higher and further than ever before; Dawn patrolling and sundown chasing; Inspiring and pushing the boundaries of their sport

In contrast the harness should be designed not only for the kitesurfers with wild ambitions but for all the kitesurfers. All disciplines. All skills.

All skill level kitesurfers: The harness design should be adaptable to a wide range of skill levels, include amateur to professional kitesurfers. Both frequent and infrequent kitesurfers

All disciplines & riding styles: The harness should handle a wide range of disciplines and riding styles

All sizes & shapes kitesurfers: Kitesurfers come in all different shapes and sizes, the harness should be inclusive to cater to different body types within the sizing range of Mystic

Users looking for a performance product: Kitesurfers looking for a performance product

16 to 65 years / All kitesurfers able to wear adult sizing

Males and Females: All males and females practicing kitesurfing

4.5 MARKET OPPORTUNITIES

During the analysis of the context and the ergonomics of the kitesurfing harness a set of four market opportunities were found. These were used as "wishes" and inspiration in the design phase:

HYBRID HARNESS

Create local flexibilities by combining the features of a "softshell" and "hardshell" harness.

RIGIDITY IN CONNECTION BETWEEN HARNESS AND SPREADERBAR

Decrease the discomfort by decreasing the digging into the ribs of the spreaderbar. This has been tried by certain brands but has not been adopted by the user group.

SUSTAINABILITY

Create a circular product with replaceable components increasing the repairability. Does not only contribute to the responsibility of the company but also to the longevity and thus desirability of the product.

ADJUSTABILITY

Increasing the adaptability of the harness to the body and preference of the user. Which should lead to decreased discomfort and increased performance.



5.0 IDEATION & CONCEPT DEVELOPMENT

In the previous chapters the aim was to identify and analyze the problem, in this chapter the pursuit of a diverse range of ideas and ultimately the development and choice of a suitable concept is described. The entire process is split in 3 stages: The problem finding stage from the previous chapters, Design sprinting and concept finding. Each consisting of a Diverging, Reverging and Converging stage. This process is visualized in Figure 76.

Use is made of different creative problem solving techniques, including research by design (RbD). RbD is based on practice, experimentation and visualization to achieve new cognitions through form and space - the use of drawings and models. This type of design thinking, called research by design, can create added value in the design and research phase by creating rich insights when developing complex solutions and answering design questions. It is based on a reflective process where there is a continual weaving between problem and solution in an iterative movement between inquiry and proposal (Thomsen and Tamke, 2009).

5.1 DESIGN SPRINTING DESIGN SPRINT 1

Before starting with a the ideation two methods to stimulate this process have been used, a crossindustry solution collage and 'HKJ's'.

During the design process inspiration is taken from other industries like snowboarding, hiking, climbing. A cross industry inspiration board can be found in Appendix R on page 131.

'HKJs' is a method that simplifies a more complex issue by brainstorming in sub-questions. During the creation of the HKJ's purging techniques were used creating quality through quantity.

The complex issue: "How can we decrease the experienced discomfort by creating a better fitting harness to fit the wide variation of body types of the target group?" This question was split in 4 subquestions based on the four major factors leading to discomfort. How to decrease the movement of the harness?; How to decrease the pressure on the ribs?; How to decrease the pressure points?; How to distribute the undesired forces on the torso during rotation or bended stances? From these questions, new questions emerged which lead to a map of HKJ's shown in Appendix S on page 132.

TEST THEORY & REQUIREMENTS DESIGN (RE)DESIGN

EVALUATE

CONCEPT DEVELOPMENT

Figure 76: How 'Research by Design' is used to test the made hypothesis about the concepts

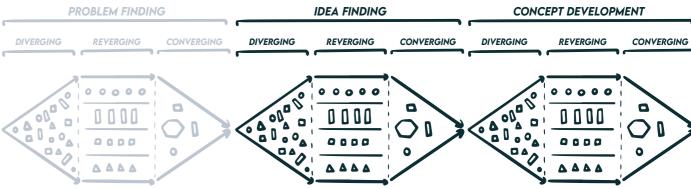


Figure 77: Creative diamond 2.0 (Heijne & Van Der Meer, 2019). Spliting the design process in thee stages: problem finding, idea finding and concept development.

DESIGN SPRINT 2

Using spontaneous clustering, the post-its from the HKJ's were clustered into 8 groups, found in the figure below. Another brainstorm session was conducted expanding the solutions and ideas in the clusters, creating new insights and inspirations. The entire clusters can be found in "Appendix S" on page 132.



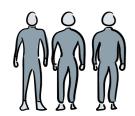
CROSSBREEDING

Design by mating or hybridizing two different varieties (hardshell and softshell)



LIBERATION

Freedom of movement

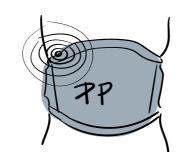


ONE SIZE FITS NONE

Adjustable or adaptable design to the wide variation of bodies

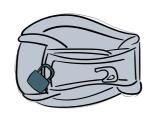


MODULARITY



PERFORMING UNDER PRESSURE

Decrease pressure points



I'M GOING NOWHERE

Harness stays in place



IT'S NOT ME

Optimize the environment



STORY TELLING

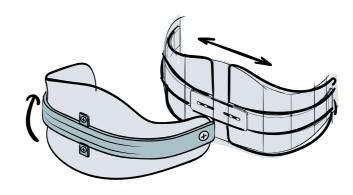
The products and brands story

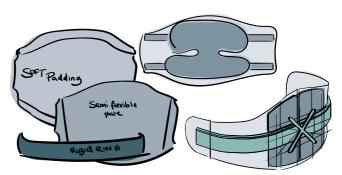
Figure 78: Design sprint 2 - Titles and description of the clusters made of the HKJ results using creative problem solving techniques

DESIGN SPRINT 3

The most promising, interesting or suitable ideas/solutions from design sprint 2 are collected and recategorized into four idea directions of which the descriptions can be found below. The design directions and all the solutions included can be found in Appendix S on page 132.

Going into the concept development phase, these four design directions will serve as the foundation upon which the harness concepts are built.



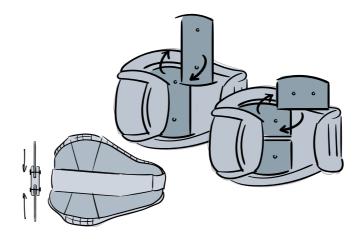


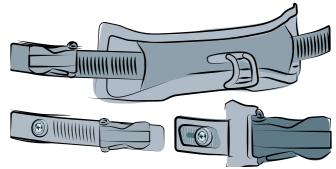
IDEA DIRECTION 1 MOVEMENT OF COMPONENTS

This design direction introduces a shell which consists of multiple components. The aim of having different parts is to enable the harness to adapt to the variation of bodies and postures. This dynamic approach holds the potential to enhance comfort and ergonomics, catering to a broader spectrum of kitesurfers.

IDEA DIRECTION 3 RIGID & FLEXIBLE COMPONENTS TO CREATE LOCAL FLEXIBILITIES

This design direction is a more nuanced approach, integrating rigid and flexible components. These concepts introduce local flexibilities with the objective to reduce pressure points and enhance freedom of movement.





IDEA DIRECTION 2 REPLACEABLE COMPONENTS

This design direction focuses on adaptability. The designs includes replaceable parts that allow the user to adjust to their preference and body. Giving the users the flexibility to customize the harness according to their preferences and body characteristics.

IDEA DIRECTION 4 THE CONNECTION BETWEEN THE HARNESS AND THE SPREADERBAR

This design direction includes solutions that create a connection between the harness and the spreaderbar. These solutions includes trimming and closure systems, aiming to give users the control to fine-tune the fit of the harness.

5.2 CONCEPT DEVELOPMENT

The aim of this chapter is to evaluate the ideas found in the previous chapter and use these to develop a set of concepts. These concepts are described, and hypotheses are formulated for each concept based on the working or unique factors of the concept. With these hypotheses, the unique characteristics of each concept can be evaluated through practice, experimentation, and visualization. Creating sketches, models, and prototypes and reflecting on the outcomes of these partial solutions generates insights on which concepts must be further developed or discarded.

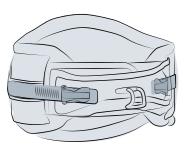
In the design process, the concept is divided into two distinct components: the harness and the spreader bar. A variety of ideas and concepts have been developed for each component, with the intention of combining them to create a comprehensive concept.

5.2.1 CONCEPT FINDING

In the previous phase four design directions have been developed. The aim of this phase is to generate concepts from the ideation phase. This is done using the SCAMPER method. By substituting, combining, adapting, modifying, put to other use, eliminating and reversing the solutions from all the design directions were developed into spreaderbar and harness concepts. This resulted in four spreaderbar concepts found in Figure 79 and eight harness concepts found in Figure 80.

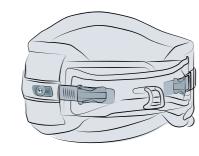
5.2.2 CONCEPT GALLERY

By creating overview and structure, insights and perspective are implemented into the design process. This is done in the form of an "Idea gallery". Here the generated concepts are revisited and used to inspire each other and compared to each other. The concept gallery can be found in Figure 79 and Figure 80 and a detailed description of each concept can be found in Appendix T on page 139.



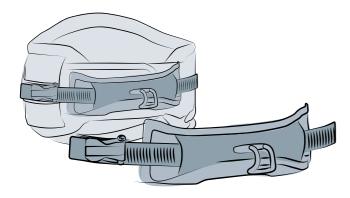
SPREADERBER CONCEPT 1

Coated webbing goes around the entire harness



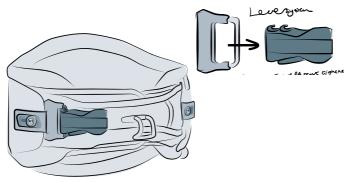
SPREADERBER CONCEPT 3

Ratcheting strap attached to the hardshell



SPREADERBER CONCEPT 2

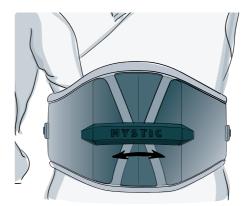
Ratcheting strap that goes through the spreaderbar.



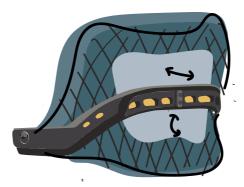
SPREADERBER CONCEPT 4

Semi-permanent trimming (screws) including lever for last moment tightening.





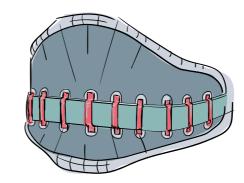
CONCEPT 1: HARNESS ADAPTABLE TO TORSO WIDTH



CONCEPT 3: TIGHTENED MATERIAL STRETCHED OVER FRAMEWORK



CONCEPT 5: CUTOUT BACKPLATE

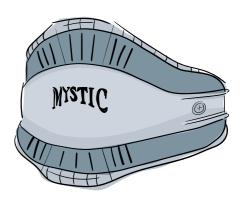


CONCEPT 7: SIMPLE MODULAR DESIGN

Figure 80: Concept gallery of harness concepts



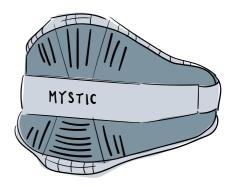
CONCEPT 2: HARNESS ADAPTABLE TO LORDOSIS ANGLE



CONCEPT 4: MODULAR SEMI-SHELL BACKPLATES



CONCEPT 6: HARNESS ADAPTABLE IN TORSO WIDTH THROUGH MODULAR PARTS



CONCEPT 8: FLEX / SEMI / RIGID MODULAR DESIGN

65

64

5.2.3 CONVERGING

The aim of this step is to choose a final concept that can be further developed and presented to Mystic Boarding as a design direction for the further development of the kitesurf harness.

To analyze and compare the concepts the UALo method and weighted objectives were used followed by a reflection and final choice. With UALo, the concepts are described according to their unique qualities, advantages, limitation and methods to overcome these limitations. This creates valuable insights into the potential of the concepts. The UALo's and weighted objectives can be found in Appendix T.

Using this analysis the choice was made for harness concept 8 and spreaderbar concept 4, the coming paragraphs specify this choice.

CLIENT FEEDBACK

A brainstorming session was conducted with the company's mentor to evaluate the proposed harness designs and their prototypes, and a clear preference of the modular harness concept 8 for the harness design was expressed..

THE HARNESS DESIGN

Following an assessment of the proposed harness concepts it becomes clear that concept 8 stands out due to its unique combination of hardshell and softshell features, adaptability, and stiffness. This design eliminates the concerns of the design becoming more complex than the current solutions.

The modular features of the harness addresses the complexity of designing a harness for the large variation of body types and preferences, and this feature makes it possible to tailor the harness to the users unique needs to enhance user comfort and performance.

Due to the design consisting of a combination of flexible and rigid components, the rigid backbar and semi flexible shell, the concept can easily accommodate different user postures and provide adequate support during different kitesurfing movements, ensures that the harness remains comfortable and supportive throughout the session. Consisting of different parts the design allows for different flexibility characteristics in the different shells to improve comfort during movement.

The design is a unique combination between hardshell and softshell features. The backbar providing the needed stiffness and the semi-shell the needed comfort and freedom of movement. The inclusion of a rigid outer ring provides essential stiffness to the harness, distributing the forces generated by the kite, ensuring that compressive forces do not impact the kitesurfer's body by providing a balance between flexibility and support.

Overall, Concept 8 provides a versatile and comfortable solution providing kitesurfers with more freedom to adapt the harness to their personal needs and preferences, meeting the needs of a diverse range of users.

THE SPREADERBAR DESIGN

After an evaluation of the four proposed spreaderbar concepts, it has become evident that Concept 4 stands out as the most advantageous choice. This conclusion is reached based on several critical factors.

The concept distinguishes itself through its cleanliness and the utilization of the Mystic lever mechanism, a well-established, proven system. The design complies to the principles of simplicity and elegance, as it avoids the need for excessive webbing and extraneous parts. The uncluttered appearance aligns with the desire for a sleek and minimalist aesthetic for a kitesurfing harness.

Besides the concepts unique advantages it is important to acknowledge the limitations, such as limited on-the-fly trimming options and the reliance on side screws, these limitations can be effectively addressed by making some minor changes to the lever system. By introducing a larger lever system and using extra screws, the trimming and safety issues can be minimized.

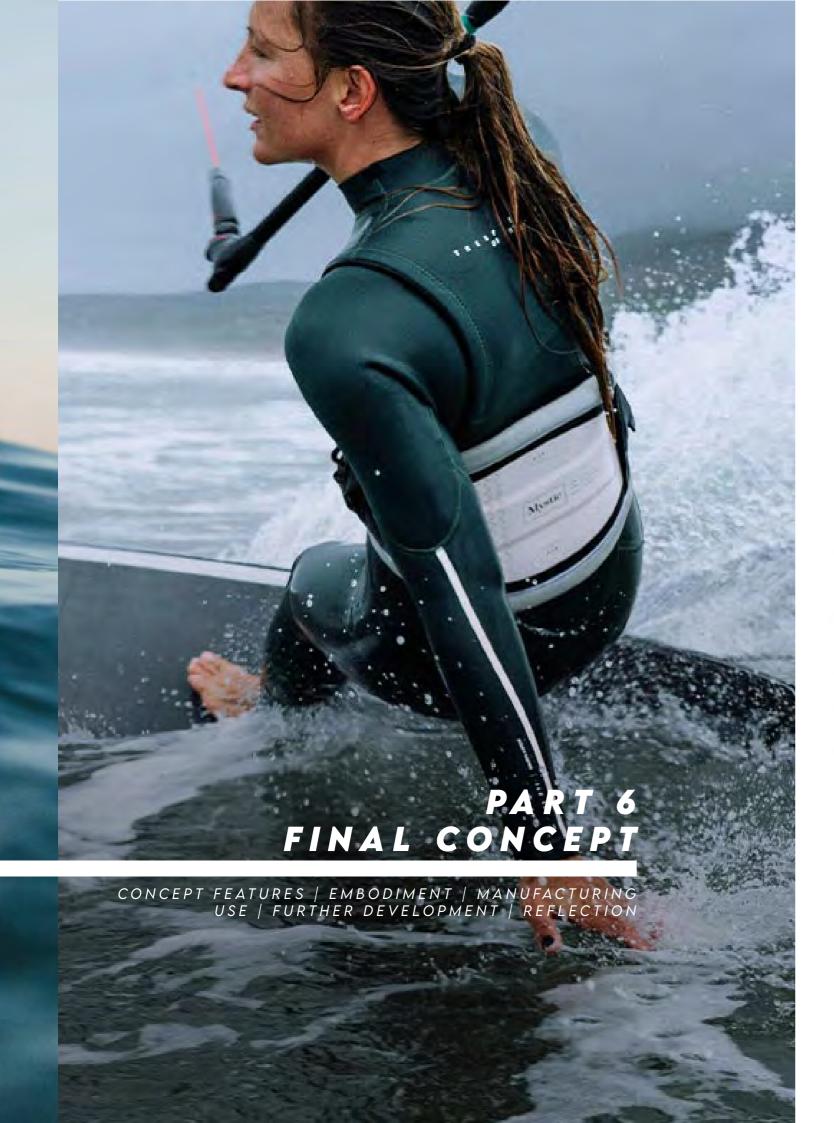
Furthermore the harness is a very personal item, minimizing the issue of the reduced on-the-go ability of trimming as the fit of the user doesn't change session-by-session. Therefore the system creates a consistent experience through different sessions in comparison to webbing.

CONCLUSION

In conclusion, a combination of harness concept 8 and spreaderbar concept 4 will offer a unique blend of features that cater to the diverse needs of kitesurfers. This combination embodies a design philosophy that prioritizes user comfort, safety, simplicity, personalization, aligning with the modern kitesurfing harness market's demands. While there are concerns about the impact of moving parts, these can be addressed through careful design considerations and material choices. Therefore, this combination is recommended as the preferred choice for further development and implementation in the kitesurf harness design.

		C1		C2		C3		C4		C5		C6		C7		C8		CS	
Adjustability fit to the body of the user	9	8	72	7	63	7	63	9	81	6	54	7	63	6	54	8	72	5	45
Local flexibilities / Freedom of movement	9	5	45	7	63	8	72	6	54	5	45	5	45	6	54	7	63	5	45
Complexity / simplicity (incl affordability / weight)	7	5	35	6	42	4	28	5	35	7	49	8	56	7	49	7	49	8	56
Modularity / Sustainability / Repairability	6	6	36	8	48	3	18	8	48	4	24	7	42	8	48	7	42	5	30
Durability / reliability / Resistance to salt & sand	6	7	42	5	30	3	18	6	36	7	42	7	42	3	18	8	48	8	48
Design / Brand image / Innovation	5	6	30	6	30	8	40	6	30	7	35	6	30	5	25	7	35	6	30
Total			260		276		239		284		249		278		248		309		254
		C1		C2		C3		C4										cs	
Durability / reliability / Resistance to salt & sand	10	6	60	6	60	6	60	8	80									8	80
Trimming abilities (on and off water)	8	7	56	7	56	7	56	5	40									8	64
Cleanliness of design	8	5	40	6	48	7	56	9	72									4	32
Easy of use	6	6	36	6	36	7	42	7	42									6	36
Rigidity between harness and spreaderbar	6	7	42	7	42	5	30	8	48									4	0
Total			027		0/.0		04.6		000										010

Figure 81: Weighted objectives



6.0 FINAL CONCEPT

The next steps involve establishing the technical details and functionalities of the chosen concept. This involves the creation of drawings of the key features, a CAD model, 1:2 prototypes and final 1:1 prototypes. This chapter showcases an overview of the final design: the key-features, embodiment and manufacturing. The conclusions of the design process can be found in the next chapter.



Figure 82: Overview of components of the concept design

6.1 KEY FEATURES

The modular harness concept consists of three components: a bar, a shell and the spreaderbar. This shell consists of a semi-flexible shell and the padding, connected to the bar through screws which can be found on the inside of the harness under the padding. This chapter describes the key-components and the key performance features of the concept.

6.1.1 KEY COMPONENTS OF THE BACKPLATE

THE BAR (1) The bar acts as the skeleton of the harness and determines the stiffness of the harness. The bar wraps around the shell of the harness and the stiffness is determined by the shape and composite materials used.

The function of this stiffness is to disperse the forces of the kite over the entire back and keep the shape of the harness to decrease the rotation of the harness over the body of the kiter. This bar functions as the "hardshell" of the harness.

Similarly as in the current range of Mystic, the Majestic, Majestic X or Stealth series, where a different backplate materials are used, like glassfiber or carbon composites. Leading to different price ranges and characteristics. This modular design could give the user the opportunity to tune the harness to their preferences, size, shape and price-range.

THE SEMI-SHELL (2) The semi-shell is a semi-flexible backplate with local flexibilities designed through material, thickness, outline and shapes.

During kitesurfing freedom of movement is key. It has become so important that the harness backplates have become systematically smaller in the past years. This decreases the amount of surface area and vertebrae the forces of the kite are directed onto. The semi-shell has the surface and flex needed to create an optimal dispersion of forces onto the torso for increased comfort. While still having optimal freedom of movement allowing the kitesurfer to perform at maximum capacity.

PADDING (3) The design makes use of closed cell foam. This padding doesn't absorb water, and thus stays light during use. The texture padding of the harness has 3 different functions:

The aesthetics: the padding can be designed to to look aesthetically pleasing and in line with the brand's identity.

The shape of the padding: The padding is produced flat and due to the texture, the padding folds into the shell without creasing.

Local grip textures: The texture on the padding can be designed to create extra grip on the body where needed. This design aims to allow for axial rotation in top of harness (thoracic spine) while gripping onto the bottom (lordosic spine).

6.1.2 KEY COMPONENTS OF THE SPREADERBAR

The spreaderbar includes the bar, hook, padding, trimming system, wings and leverage buckle.

THE BAR (4) The function of the bar is to give the spreaderbar it's stiffness, decreasing the compression of the harness on the sides of the torso. The bar is made of a composite material and all the other spreaderbar components are attached to it with screws and pins.

THE HOOK (5) The part of the bar to which the kite is actually attached. The shape and size of the hook are not redesigned compared to the current systems. As in the current product range 3 systems should be available: The hook, the ring and the slider, to allow the rider to customize his harness to suit his riding style.

THE LEVER BUCKLE (6) The lever buckle is the closing system of the current harness design making use of a leverage effect to close the harness.

This proven concept enables the user to give the harness that last little tightness before use.

THE PADDING (7) As with the shell, the spreaderbar also includes closed-cell foam padding. The function of this padding is to protect the ribs from extreme pressure points. As the kite doesn't pull the kite downwards but only upwards the padding on the top-side of the spreaderbar is most important.

TRIMMING SYSTEM (8)

The trimming system consists of two rigid straps on both sides of the harness. This trimming method is semi-permanent, as it is attached to the harness with screws. This results in a harness that can't be trimmed on-the-go. These screws are located under the padding on the inside of the harness bar.

THE TRIMLOCK (9)

The rigid straps replacing the webbing of the current harnesses. The left strap is attached to the spreaderbar with the lever buckle and the right strap is attached to the spreaderbar with a pin.

THE WINGS (10)

These wings are attached to the back of the spreaderbar and are fed into the sides of the harness to create rigidity between the spreaderbar and harness. In this design these wings are solid.

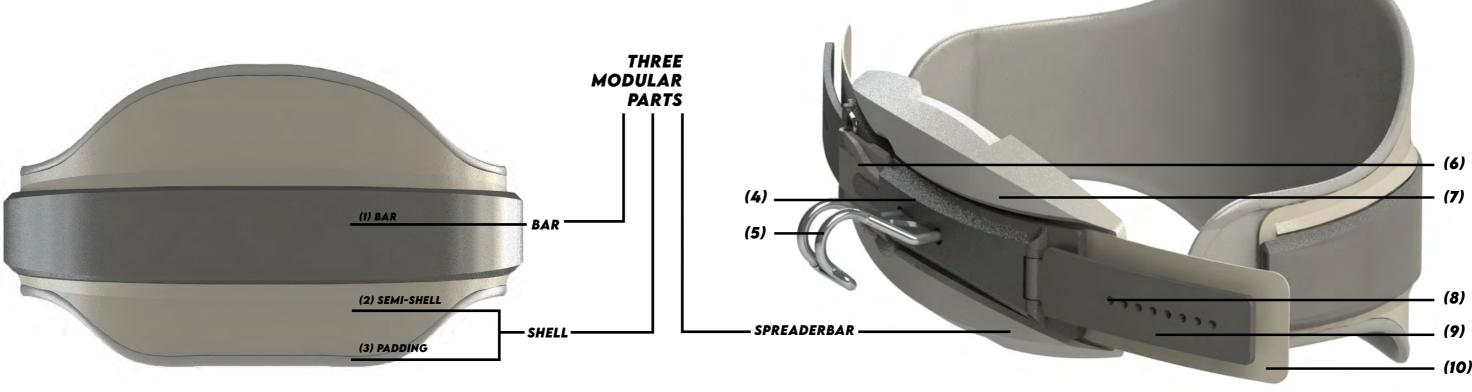


Figure 83: The modular components of the concept

Figure 84: The spreaderbar components

6.1.3 KEY PERFORMANCE FEATURES

MODULARITY

CUSTOMIZE, RE-USE, UPGRADE & MAINTAIN

The harness consists of four modular parts. This modular design allows the user to customize, re-use, upgrade, or maintain the harness. Most importantly the user has the freedom to adjust the harness to their personal needs and preferences, increasing the comfort and performance of the harness.

The waist circumference determines the needed bar-size; the torso height, shape, riding style and preferences determines the needed shell and padding; and the riding style and size would determine the spreaderbar model and size.

The users are given the opportunity to make combinations of the available modular parts to customize a harness that fits their size & shape, preferences and their budget.

The modularity of the harness also aligns with the sustainability goals of the company. By allowing the re-use, upgrading and maintenance the lifespan of the product is increased.

One of the advantages of the current Mystic hardshell harnesses is it's simplicity and light weight, with the exception of the bulky webbings.

This design has eliminated webbing replacing it with an integrated design where the bar falls into the semi-shell. Both these features create a sleek looking harness.

IMPROVED FIT

USE OF ERGONOMIC RESEARCH

In this report an ergonomic analysis of the shape of the torso can be found, using the data from this analysis a shape of the semi-shell and padding is designed.

The aim of this design is to increase the surface contact area between the rider and the harness throughout the session. By increasing this the extreme pressure points and the chance of discomfort are decreased.

This is achieved by designing the outline and shape of the harness. In the next chapter (6.2 Embodiment) the outline shall be further explained. In Figure 86 the frontview of the fit can be found. The lower sides of the harness give the needed freedom of movement. This image also shows that the harness would probably sit higher on a female torso compared to a male torso.



Figure 85: Modular components: The backbar, semi-shell, padding and

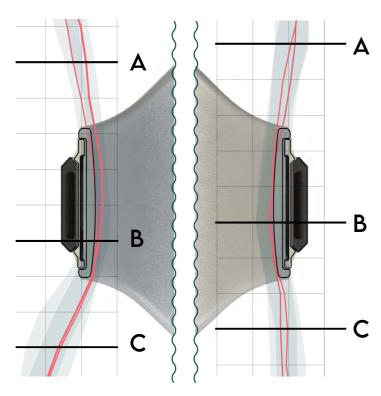


Figure 86: Improved fit of the harness - females size XS (left) and males size M (right)

HYBRID

THE BALANCE BETWEEN STIFFNESS AND FREEDOM OF MOVEMENT

The concept is a combination between the features of a softshell and a hardshell harness.

The directness, fit and dispersion of forces of a hardshell harness with the forgiveness and freedom of movement of a softshell harness.

FREEDOM OF MOVEMENT

LOCAL FLEXIBILITIES

Local flexibilities in the semi-shell of the harness decrease the probability of pressure points during movements.

This shell is made of a composite and with the design of the shape, thicknesses and material local flexibilities are introduced in the system.

A method to create these local flexibilities in this shell is overmolding, using two materials, a semi flexible as base with a high stretching material as overmold. This would create areas where the semi-shell can "move" with the body and allow the needed freedom of movement. Using this technique, the harness maintains the desired clean looking design.

The shape and specific lay-out created can deliver stiffness in one direction and while maintaining flex in the other directions.

LOCAL GRIP

The freedom of movement is not only influenced by the features of the semi-shell of the harness but also by the grip performed on the torso by the padding. With localized grip texture in the padding the concept creates areas which accommodate certain bending and movement. For example: the top half of the harness has less grip texture so the user can easily axially rotate, which takes place in the thoracic spine.

The EVA padding is produced flat and bend when placed in the harness, this results in some vertical patterns being needed in the harness to minimize than chance of creasing of the padding.

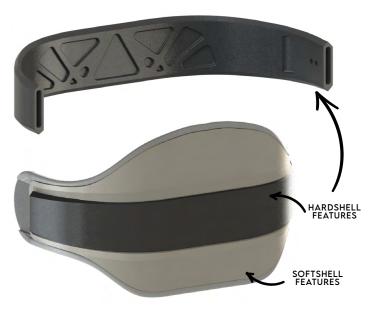


Figure 87: Combination between hardshell and softshell features

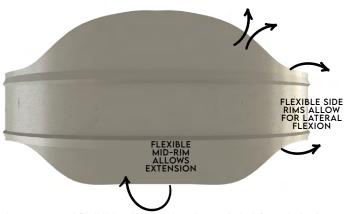


Figure 88: Local flexibilities designed into the semi-shell for optimized freedom of movement

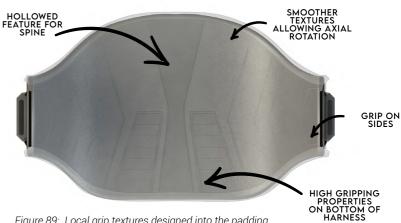


Figure 89: Local grip textures designed into the padding

RIGIDITY BETWEEN HARNESS AND SPREADERBAR

DECREASE THE PRESSURE POINTS ON THE RIBS

By eliminating the flexible webbing from the design the rigidity between the harness and the spreaderbar is increased. This rigid connection is created by the rigid trimming system and the rigid wings on the spreaderbar. This increased stiffness decreases the pressure from the spreaderbar on the ribs. This also leads to a more lean / clean design through the elimination of webbing. The straps are fed into the rigid backbar, creating a unity between the spreaderbar and the harness

A CONSTANT EXPERIENCE

SEMI-PERMANENT TRIMMING METHOD

The trimming system in this harness concept is based on semi-permanent trimming, as the straps on both sides of the spreaderbar are adjusted in length with screws.

This creates a constant experience for the user, as the length of the straps stays the same session-tosession and throughout the session. This creates a harness that is personalized to the user and non-bulky due to the elimination of webbing.

This does limit the possibility for on-the-go trimming, as the only last moment trimming available is the tightness created by the lever buckle.

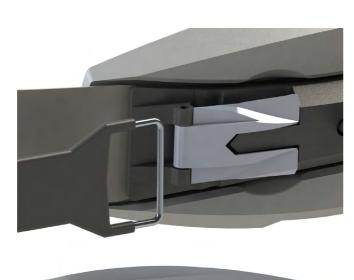
The straps are attached to the harness through screws, each strap with a set of two screws to reduce risk of failure. These screws can be reached through the inside of the harness, so the look of the harness stays clean and the screws don't effect the freedom of movement.

ON-THE-GO TRIMMING

The Lever buckle is a system that is used in the current mystic harnesses. A proven system and loved by the users. The system has been adjusted. Where the system usually only has one tightness possible, by adding an extra hook on the inside of the lever the lever has two tightness levels, as can be seen in Figure 91. Giving the user the last minute ability to choose between two tightnesses.



Figure 90: The rigid straps are fed into the rigid back bar and the wings are tucked between the semi-shell and the padding.



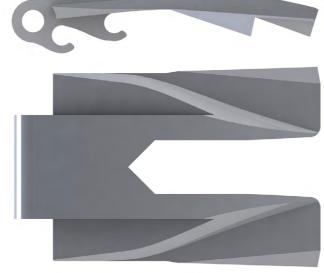


Figure 91: The lever closure system found on the spreaderbar

6.2 EMBODIMENT

The aim of the embodiment of the concept is to describe the design choices made, the problems found, the constructed solutions and the limitations that led to the key features of the concept. In this chapter use is made of partial prototypes of 1:2 and 1:1 to test certain features.

The prototypes and 3D designs made are based on a size M harness.

6.2.1 THE BACK BAR THE SHAPE

The shape of the bar is based on the section views as can be seen in Figure 92. The bar is a bit higher on the back compared to the sides, to make sure there is enough freedom of movement in the lateral direction.

The bar is designed with cut-out in the inside, if designed appropriately it could enhance the stiffness while reducing the weight. These are made on the inside to keep the sleek look of the bar on the outside. These cutouts can be found in Figure 94.

MATERIAL & PRODUCTION

The bar's main function is to give the harness the wanted stiffness, besides this fact the bar should be lightweight and the closure and trimming system should be attachable to the bar.

Wanted characteristics:

- Lightweight
- Durable and resistance to UV, salt and water
- Trimming, closure and semi-shell should be attachable to the bar through screws or integrated in the shape.

To achieve these characteristics a composites is a recommended. These materials can provide an excellent level of rigidity while maintaining a light weight.

An injection molded composite, like polypropylene (PP) is proposed. This is a material already used in the Mystic warrior harness and is known for its lightweight and durable properties while also exhibiting excellent resistance to impact, moisture, and UV radiation.

If more stiffness is needed injection molded High-Density Polyethylene (HDPE) is also suitable. The material is known for its stiffness and strength and is also resistant to water and chemicals, making it suitable for water sports equipment.

If testing concludes that superior stiffness is needed fiberglass- or carbon reinforced composites are recommended. These materials, especially carbon, can provide an superior level of rigidity while maintaining a light weight.

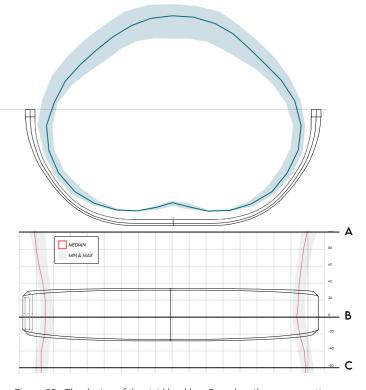


Figure 92: The design of the rigid backbar. Based on the cross-sections of the ergonomics research





Figure 93: Prototypes of back-bar.

6.2.2 THE SEMI-SHELL

The semi-shell is very similar to a current backplate. The difference is the lower stiffness. Thus allowing for a higher freedom of movement and less pressure points. Adjustments are made to the shape, outline and flexibilities.

11 2000

Figure 94: Design of the backbar

THE SHAPE

The shape of the shell compared to the previous harness shall include the curvature derived from the section views analyzed in 3.4 Harness sizing and 3.5 Kitesurfing motions and postures.

Still the design is challenging as the curvature between persons varies heavily. To design the shape the scans of a person standing in a "neutral" stance are compared to the postures taken during kitesurfing where the kitesurfer is extremely flexed. This shape was verified with a prototype seen in Figure 95. This shape is based mainly on the 3D models and after testing it can be recommended that the curvature on the sides of the harness should be followed but the inward curve on the backplate should be designed slightly straighter.

The unity of the rigid ring and semi-shell is an important feature of the design. The semi-shell includes a channel where the bar fits in. Figure 96 shows this channel.



Figure 95: Prototype to validate the shape from the ergonomic research. The prototype consists of 3 3D printed parts.

THE OUTLINE

Secondly the outline of the shape is of importance to the fit. Also based on the current harness design (Stealth 2023), the aim of the redesign is to increase the contact area without decreasing the FoM.

The height of the backplate is redesigned to be higher with a less wide highest part, as the semi-shell is more flexible than the current carbon backplates. And the reduced width also allows for more FoM.

In comparison the height of the outline on the new design is higher in the middle, creating a larger surface area with the body, creating higher comfort in high force situations.

In the future, if Mystic should offer different semi-shells for this modular harness this would give users the opportunity to change the outline according to their body-type, style and preferences. For example a backplate with a reduced surface area for a high freedom of movement for freestyle.



Figure 96: Channel of the semi-shell for the back bar

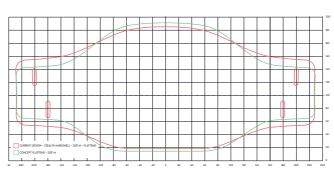


Figure 97: The design of the outline

LOCAL FLEXIBILITIES

Local flexibilities can be achieved by overmolding, a process where two or more components are molded over top of one another (Formlabs, 2023). With this method local flexibilities can be designed while the outside of the design keeps it uniform looks. Limitation of this method could be sustainability issues associated with the difficulty of recycling the two materials used.

The desired properties are described in Figure 98. To test possible structures for the overmolded structure 1:4 prototypes were made seen in Figure 99, testing different cutouts. These shapes were later tested in 1:1 prototypes found in Figure 100. Consisting of an EVA padding, carbon bar and different PP cutouts resembling different semi-shell structures. It can be concluded that the cutouts contributes to a more comfortable Extension and axial rotation. For flexion and lateral flexion it didn't make a notable difference. Also stacking two layers of the shell material was tested (prototype 5) which still gave the needed FoM but with a more supportive feeling.

Concluding, cutouts are a viable way to create more comfort and increased surface area during movements between the user and harness.

Future research is proposed into auxetic patterns in combination with overmolding to create local flexibilies. Auxetic structures have the unique characteristic of being able to expand when stretched and contract when compressed. By utilizing an auxetic structure, the shell can adapt to the wearers' shape on a local level.

MATERIALS

As overmolding is the proposed production method, the component should consist of two materials. The inner material, which resembles the semiflexible parts of the harness and the outer material which resembles the flexible parts of the harness. To achieve these characteristics two materials are proposed:

For the inner material thermoplastic Polyurethane (TPU) is proposed for it's flexible properties. For the outer material a thermoplastic elastomers (TPE) is proposed for it's elasticity, enabling the harness to form to the shape of the user during movement.

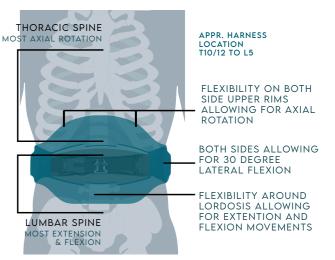


Figure 98: The theory behind the wanted local flexibilities in the harness

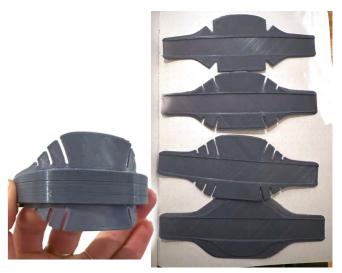


Figure 99: 1:4 prototypes testing the structure in the semi-shell



Figure 100: 1:1 Prototype to verify the shapes of the shell

6.2.3 THE PADDING

The semi-shell has padding attached to it and it is designed such that the edge geometry creates as little pressure points as possible. The pattern on the padding can influence the grip on the body (skin / clothing / wetsuit). As mentioned before different parts of the spine has different functions, the design is proposed according to this research.

MATERIAL & PRODUCTION

EVA polyurethane foam has proven to be an efficient material for the padding of a kitesurf harness in the current design due to it's lightweight on and of the water, design possibilities and grip characteristics. This foam can also withstand higher pressures, is resistant to UV and salt and consists of closed of air cells that lead to the floating of the harness, this makes EVA the best choice for the padding.

The padding is produced flat and therefore needs vertical lines in the pattern to prevent creasing.

6.2.4 THE SPREADERBAR

The spreaderbar design is very similar to the current design. The main redesign lies in the connection between the spreaderbar and the harness. The bar itself and the padding will remain similar to the current design, as will the materials used.

The main aim of this design is creating a system that reduces the pressure on the ribs, decreased the twist between the systems, can be easily trimmed by the user and is safe and reliable to use.

THE TRIMMING SYSTEM

The harness is a very personal item, still users are often forced to carry "excess" material as the trimming is made to fit a wide variety of shapes and sizes within a harness size, for example the bulky webbing. Therefore choice was made for system that can not be trimmed on the water and is personalized to the user beforehand.

The trimming system is split into two straps, these straps are fed into the rigid backbar and attached to the system through two screws as can be seen in Figure 105. These screws are found on the inside of the harness. This creates a constant experience every session. The limitation of this system is that the size can't be changed without a tool and not during the session.

The left strap has a clip attached to it's end, this is used to buckle into the lever system and is thus also part of the closure system. The right strap is also attached to the spreaderbar semi-permanently through a pin. The system can be trimmed on both straps for a symmetric system. The strap design was iterated on. Finally Rigid strap style 3 was chosen due to it's less bulky look and feel, which can be seen in Figure 104.

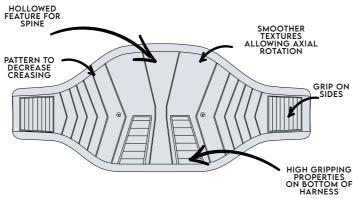


Figure 101: Proposal EVA padding pattern flattened designed to create local grip textures



Figure 102: The spreaderbar design

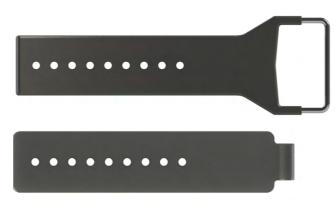


Figure 103: The straps of the trimming system.

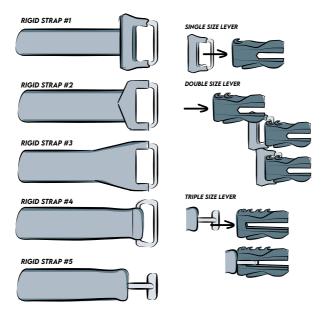


Figure 104: Ideation of trimming and lever system

CLOSURE SYSTEM

The current lever design is re-used with only one change: an extra hook within the lever. This gives the lever buckle not one but two tightnesses it can be set to. This was chosen because the trimming capabilities of the harness are reduced. Also a slightly larger lever handle to create a better tightening capability should be considered.

The function and use of the system can be found in Figure 106. To test this system multiple prototypes were made. Firstly a singular lever hook was prototyped, after testing and discussing with kitesurfers it was concluded that some sort of last moment trimming is needed. This prototype can be found in Figure 107. After prototypes were made with double inner hooks. These prototypes proved a lever with multiple inner hooks is a functional system and can be adapted to the kitesurf harness as can be seen in Figure 108.



Figure 105: The straps are fed into the rigid backbar and fixed by the

PRODUCTION & MATERIALS

The connection and trimming system are partially new to Mystic. The strip of the trimming system should be made from a composite which should be reinforced with fibers or webbing so ensure that the system cannot fail during critical moments.

Examples of materials that can be used are PP, TPU or PVC.

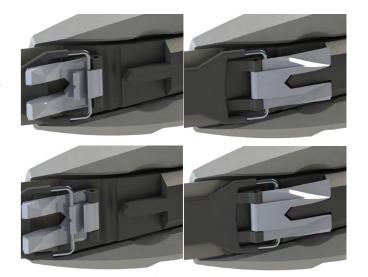


Figure 106: Double hooked lever buckle design



Figure 107: First prototype of the lever system with singular inner hook

6.2.5 FIXTURES

This concept has eliminated most glued and sewed components and replaced them with screws. There are 3 sets of screws found in the design:

Connecting the back-bar, semi-shell and padding Screws used for the trimming system

Connecting the components of the spreaderbar

In the current harness design use is made of screws in the spreaderbar, this proven connection has very similar characteristics to the other systems in this concept, therefore screws will be used in the concept as the preferred connection method. An example can be found in Figure 109. Consisting of small Stainless steel Torq bolts and stainles steel inserts in the composites spreaderbar. The locations of these fixtures are depicted in Figure 110. It is recommended to make use of The Torq heads to minimizes the likelihood of the tool slipping or the screw head deforming during assembly.

The use of screws can lead to problems concerning corrosion and rust due to the high corrosive qualities of salt water. Over time this can cause failure and difficulty in adjustment. Also sand particles can get trapped in between the screw threads or other mechanical parts. This could lead to parts becoming loose or less effective in their intended use. This could lead to maintenance problems and even warranty claims. To overcome these limitations it's essential to use high quality corrosion resistant materials in the screws and the other components.

Additionally some responsibility lies with the user as rinsing with fresh water can help prevent these problems. Regular inspection and maintenance ensures the harness remains in good condition and safe for use.

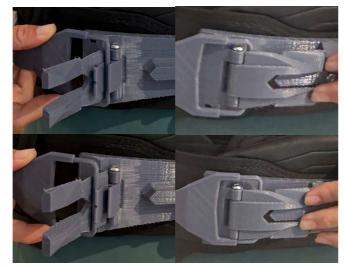


Figure 108: Double hooked lever buckle prototype



Figure 109: Screws used to connect the spreaderbar's components

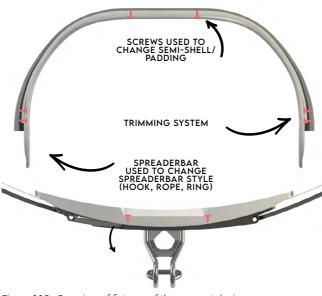


Figure 110: Overview of fixtures of the concept design

6.3 SUMMARY

Summarized, the final concept for the modular kitesurfing harness focuses on creating a versatile and user-friendly design. Offering a range of benefits for kitesurfers:

The harness is designed with modularity in mind, allowing users to customize it according to their specific needs. Whether it's adjusting for size, shape, or budget, this design gives riders the flexibility to create their ideal setup.

Extensive ergonomic research has informed the design, resulting in an improved fit that increases the contact area between the rider and the harness. This in turn reduces pressure points and increases comfort during kitesurfing sessions.

The harness strikes a balance between the stiffness of a hardshell harness and the freedom of movement associated with a softshell harness. This hybrid approach offers both support and flexibility.

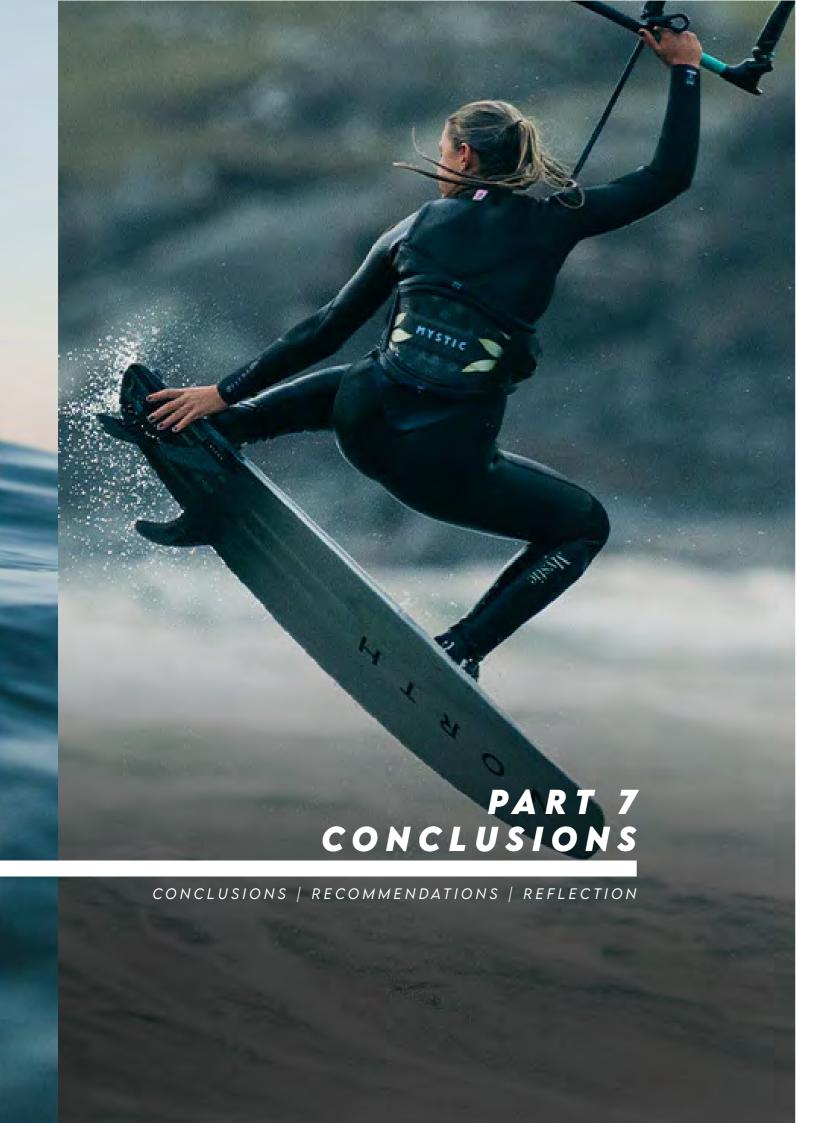
To maximize freedom of movement, local flexibilities are integrated into the semi-shell, and grip textures on the padding are strategically placed to allow for axial rotation and ensure comfort.

The elimination of traditional webbing enhances rigidity between the harness and the spreaderbar, reducing pressure points on the ribs and providing a cleaner look.

The trimming system offers a personalized and constant experience for users, with options for last-minute adjustments using a lever buckle system.

The use of screws for various connections is a key aspect of the design. However, regular maintenance is essential to prevent issues related to corrosion in saltwater environments.

In summary, this modular kitesurfing harness concept offers a user-centric and adaptable solution for riders. It combines customization, comfort, and performance, all while maintaining a sleek and sustainable design.



7.0 CONCLUSIONS

At the end of this project, a final design concept is presented with the potential of revolutionizing the kitesurfing harnesses. The concept aims to enhance the kitesurfing experience. It's modular design allows users to fine-tune their gear, thereby boosting their performance and reducing the discomfort through personalization.

Through a comprehensive analysis of the technical details, functionalities, and embodiment in the previous chapter of this report is concluded by validating the end result, the concept, through it's viability, desirability, and feasibility. Followed by suggestions for future steps and a reflection on the design process.

7.1 VALIDATION 7.1.1 PROTOTYPING

This project includes many prototypes to test singular features of concepts, this way the design process was lead by physical design with multiple iterative steps.

Most prototypes are made using a combination between EVA foam, a semi-flexible PP board and 3D printing. For this a private 3D printer was used, making use of PP. These prototypes are suitable for testing form and function but not for performance testing where water or high forces come into play.

Most prototypes only test one function, 1:1 prototypes to test all the functions of the harness on the water are the next step.

7.1.2 DESIRABILITY

The main question concerning desirability is: Does the user need the product? The product's desirability is enhanced by its ergonomic design, versatility, comfort-focused features, and the ability to offer a personalized experience to kitesurfers.

The design incorporates ergonomic research, resulting in increased surface contact between the rider and the harness, reducing extreme pressure points and discomfort. The harness's hybrid nature combines the advantages of both softshell and hardshell harnesses, offering directness, fit, and force dispersion. Local flexibilities within the semi-shell minimize pressure points during movements, while localized grip textures on the padding enhance user comfort and mobility.

Furthermore a modular design is not only desirable due to the increased comfort and personalization but also because it allows for upgrades, replacements, and cost-efficient maintenance, making it a practical and eco-friendly choice.

To conclude, By addressing common issues in kitesurfing, such as discomfort and pressure points, and by providing customization options, the product should become a sought-after solution that caters to the desires and needs of the kitesurfing community.

7.1.3 FEASIBILITY

To create a feasible harness design, the concept should align with the current capabilities of the company. As Mystic Boarding is one of the market leaders in hardshell harnesses, they have the financial resources, human resources, and technical capabilities to develop, design, prototype, manufacture, market, and distribute a harness innovation

The embodiment of the concept considers shape, outline, local flexibilities, padding, connection, trimming and the spreader bar. Prototypes and 3D designs were crafted to validate the function and the shape of the design using ergonomic research. Material selection is based on durability, resistance to environmental factors, and lightweight properties. Fixtures were designed to minimize corrosion issues, and use practices were emphasized. To mitigate potential risks when introducing this new concept, many of the materials are based on materials familiar to the product department of Mystic.

To manage the risks associated with developing an innovation of the current design, the concept consists of new components, but also familiar components (including some upgrades) that have been proven to work and are loved by the user group: the EVA padding and lever-closure system.

The concept presents a market opportunity within the kitesurfing industry, characterized by several factors. Firstly, kitesurfers are showing an increased demand for personalized equipment, aligning with their style, preference, and body shape. The modular design caters to this demand. Secondly, discomfort is a common issue for kitesurfers, and the design, based on ergonomic research, targets the users who have dealt with this issue.

In summary, Mystic is assumed to have the capabilities to develop and market this concept. The embodiment of the design is a combination of innovation and familiar design solutions in an effort to mitigate risks. Lastly, the level of innovation of the design can be seen as a necessary step for Mystic to stay a market leader and differentiate themselves from the competition.

7.1.4 VIABILITY

The harness concept introduces a versatile approach to kitesurfing gear, enabling users to tailor their harness to individual preferences, body types, and price ranges. Reaching a large target group for the harness design.

By accommodating varying bars, semi-shell flexibilities, and padding textures, it provides a range of options. Making it cost-effective for customers to stay up-to-date with the latest innovations while maintaining their original investment. This gives Mystic an opportunity to build on a long-termproduct-relationship and resales in the form of upgrading.

The kitesurfing industry is characterized by growth, and in this increase in riders, a strong demand for innovation can be found. In this scenario, the modular harness design provides an opportunity for market differentiation and creates a competitive advantage in an intensively competitive market, appealing to kitesurfers seeking freedom of movement and force dispersion.

The incorporation of familiar components, alongside new elements and upgrades, shows a balanced approach to risk mitigation. By building on proven components, you reduce the likelihood of unforeseen challenges in the development process.

The concept, with its versatility, customization options, and strategic approach to building long-term customer relationships, positions Mystic to seize the opportunity for market differentiation, enhance brand loyalty, and meet the demands of the growing kitesurfing industry while mitigating risks effectively.

7.1.4 ANALYSIS OF PROBLEM STATEMENT

"How can we decrease the experienced discomfort by creating a better fitting harness for the wide variation of body types of the target group?"

The problem statement reflects a clear and specific objective. The project's core concept is centered around creating a harness that better fits the wide variation of body types within the target group. Through the consideration of ergonomic research, shape design, and local flexibilities within the semi-shell, the project has made substantial efforts to improve the fit of the harness. Further user testing and feedback will be crucial to validate the design's effectiveness in minimizing discomfort and ensure it caters to the diverse needs of the target group.

The project acknowledges the wide variation of body types, and the design concept specifically addresses this diversity. By allowing users to customize their harness components based on their personal needs, body shape, and preferences, the project offers a solution that accommodates this variation.

In summary, the kitesurfing harness concept aligns with the objectives of improving comfort, safety, and overall performance, though certain aspect have been (partially) proven the success of the concept is dependent on continuous testing and user input to ensure its efficacy for kitesurfers. Especially rigorous testing on the water is essential.

7.2 GENERAL **RECOMMENDATIONS**

Firstly a further prototyping, testing and iteration is recommended on the entire design. Though most main functions have been tested with (low-fi) prototypes. How these components act in high force situations on the water is very relevant to the success of the product.

Further testing and research on cut outs pattern, angle, depth and quantity of the semi-shell is recommended. Also further expertise on overmolding should be gathered as warranty issues where the overmolds might be damaged by high forces should be tested and researched. It is also recommended to prototype with stiffer semi-shell harness material. Potential materials are carbon fiber plates and SR-Pet plates.

If the design consists of an overmolded semi-shell, the elastic overmold could be used as padding, especially if the overmolded material could be EVA or a similar material. This would eliminate one component of the harness and creating an even more coherent look and feel.

The current harness design is gender neutral, but the research done showed a significant difference between males and females. Mystic boarding could create opportunities by creating modular components designed specifically for users with a deviating torso compared to an average male. This could be marketed to women or even children specifically.

By proposing a modular design some sustainability issues found in the current harnesses like repairability and recycle-ability are solved. Future development of the harness should continue to prioritize sustainability by responsible manufacturing practices and material sourcing and by encouraging users to reuse and upgrade their harness components.

It is recommended to research the acceptance of a semi-permanent trimming method by the user group. During the design process most kitesurfers spoken to were very positive, but perhaps kitesurfers are reluctant to take a risk. The best way to keep them open-minded is though testing, the inspiration of team-riders and mouth-to-mouth.

It is recommended to research if one center bar support is more advantageous compared to a skeletal outline support.

Overall, it is recommended to proceed developing this concept. Doing so would offer a product that meets the needs and preferences of kitesurfers while maintaining a commitment to quality, sustainability, and user satisfaction.

7.3 FUTURE STEPS

For the continuation of this project, future steps are suggested. This mainly includes the building of a full 1:1 prototype should be made followed by prototypes which can be used and tested on the water to test the performance of the product.

The image below shows which phases of the design workflow this report contains and should be followed in future steps.

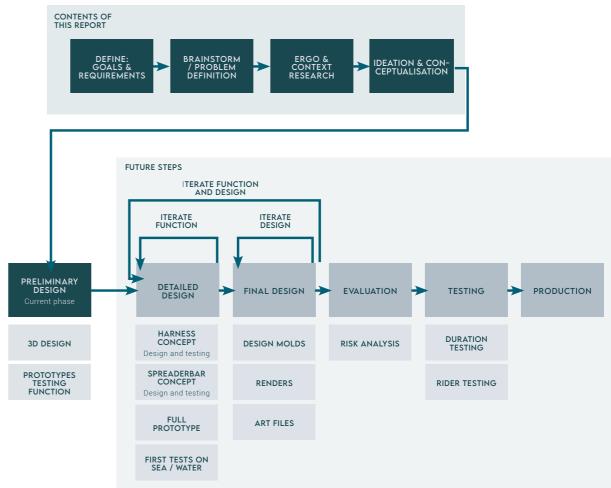


Figure 111: Contents of this report and Future steps

7.4 REFLECTION

As the project concludes, I find myself with a sense of incompleteness. There are still uncharted territories of further development: testing, prototyping and refinement could be explored. However the reality of timelines calls for a point of closure. Nevertheless, I'm proud to say my project has already been picked up by the product department for further development and shall not land on the pile of undeveloped projects.

In the end I am pleased with the result and the collaboration with Mystic, it was great to get to work at the office. Besides creating structure during the last months it also created a deeper understanding of the needs, desires and capabilities of Mystic.

Communication has in some instances been a struggle in past projects, when and how to keep mentors up to date have sometimes proven difficult. In the first weeks I tended to share too little but later found more balance as the project progressed.

Writing the report from the start of the project was a good step to make sure no information got lost, and maintaining a structured thought process.

During the project, planning was one of the main challenges. Due to my busy schedule traveling and training the project took a little longer than the average student and than anticipated. It proved difficult to get back into the project after being away for a couple of weeks. Especially in the first phase of the project this was challenging. In the later stages more structure was found, lessons learnt and it became easier to combine the two.

It was very educational for me to work together on a project with different people, who all have their own vision, experience and input. Ultimately bringing all these different perspectives together in a report is a challenge. Putting the visualization of a harness on paper and then converting it into a prototype is an interesting process. Working together towards an end product is fantastic. I'm very proud that Mystic has taken a positve outlook on the results of the project and is planning to progress the project "the ulitmate harness".

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APPENDIX A PROJECT BRIEF

TUDelft

Personal Project Brief - IDE Master Graduation

Designing a kitesurf harness supporting the ergonomic needs of the user place.

oiect title

end date

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 13 - 12 - 2022

11 - 06 - 2023

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,...).

Kitesurfing became a mainstream sport in 1999. Back then the kites were raw, powerful, and relatively dangerous. At the time kiters started flying higher and further than ever before and needed the gear to match their wild ambitions, This was the start of Mystic, a well known kitesurfing-accessories brand from the Netherlands. Since they produced their first line of kitesurfing gear in 2002(1) they have been at the top of the segment and have won the best kitesurfing accessories brand since 2012(2).

Much has changed since, especially the gear. In particular the developments in the materials, weight, stiffness and attachment method have led to easier, more comfortable and safer riding. Still back problems are quite common for kitesurfers(3). Kiting places a lot of strain on the back as the kite is tugging on the harness putting unfamiliar pressures on the abdominal region. Thus the abdominal muscles are trying to keep the pelvis and spine stable while being tugged at. Making the harness an important aspect of kitesurfing. One of the biggest evolutions has been the hardshell harness, which first came to market in 2015 (4). Though having many advantages compared to its predecessor - the soft shell harness with improved distribution of the load, prevention of user-squeezing and smaller sizing - it is still lacking in certain aspects like flexibility and lumbar support.

There is still a need for better gear, to match the changing user demands of a new generation of kitesurfers. Like the growing popularity of big-air kitesurfing and the introduction of foil-racing at the 2024 Olympic games. Athletes pushing the sport by jumping over 30 meters high in soaring winds of 40+ knots shown in image 1 (5)(6) and reaching speeds of over 50km/h (7) hoping to represent their country in the 2024 Olympics. No matter the discipline the users are looking for a harness with absolutely no discomfort, is 100% trustworthy, with increased performance and doesn't prevent any needed movements. This leads to the need for "the ultimate harness".

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space available for images / figures on next page

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Title of Project Designing a kitesurf harness supporting the ergonomic needs of the user

TUDelft

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introduction (continued): space for images



image / figure 1: Kitesurfer performing a megaloop in the big-air discipline



image / figure 2: Mystic Stealth harness (IKSURFMAG, 2021)

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Fitle of Project	Designing a kitesurf harness supporting the	e ergonomic needs of the user	



Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

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

chair <u>Dr.ir. A.J. Jansen</u>	date <u>13 - 12 -</u>	- 2022	signature	Digitally signed by JamfProtect Client DD2FAC93-E64C-538E-BFD0-ED11A350E14E Date: 2022.12.14
CHECK STUDY PROGRESS To be filled in by the SSC E&SA (Shared Service Co The study progress will be checked for a 2nd time			er approval of the	project brief by the Chair.
Master electives no. of EC accumulated in total: Of which, taking the conditional requirements	EC	OY	'ES all 1 st ye	ar master courses passed
	EC		NO missing 1 ^s	t year master courses are:
name	date		signature	
FORMAL APPROVAL GRADUATION PROJECT To be filled in by the Board of Examiners of IDE TU Next, please assess, (dis)approve and sign this Pro-	Delft. Please check the		am and study the p	parts of the brief marked **
Does the project fit within the (MSc)-programmer the student (telling into account if described).	Marie and the second se	\bigcirc	APPROVED	NOT APPROVED
the student (taking into account, if described, activities done next to the obligatory MSc specourses)?			APPROVED	NOT APPROVED
 Is the level of the project challenging enough the MSc IDE graduating student? Is the project expected to be doable within 100 working days/20 weeks? Does the composition of the supervisory team 	0			
comply with the regulations and fit the assign	ment?			comments
name	date	S	signature	
IDE TU Delft - E&SA Department /// Graduation pr Initials & Name BJM van der Linden	roject brief & study ove		01 v30 number <u>4542231</u>	Page 2 of 7

Title of Project Designing a kitesurf harness supporting the ergonomic needs of the user



Personal Project Brief - IDE Master Graduation

PROBLEM DEFINITION **

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

The changing user demands and discomfort caused by the use of a harness during kitesurfing would raise the question "What is the next step for the kitesurfing harness. How can we integrate more comfort, support, trust and maneuverability into the harness?"

The discomfort that is being experienced requires more support in the harness design but should still allow for unrestrained movement. The kitesurfing-scene seems to have embraced the hardshell harness, but it has lost some of the forgiveness of the softshell. Might we need a solution combining hard and soft materials to achieve the wanted characteristics? This conflict in requirements shows great potential to be solved by designing a smart solution. Especially in combination with the new availability and affordability of new high-tech materials and manufacturing methods.

As this scope is too large for this project of 100 working days. The focus shall be on the research of the ergonomic needs of the user followed by a conceptualization phase with prototyping.

The current harnesses on the market have been designed with measurements, 3D molding and 3D scanning to gain insights in the shape of the abdominal segment of the torso. The available research should be analyzed to find out if sufficient and usable for this design project. (How) should the current shape be redesigned? The biomechanical needs of the user are much more complex and there are very limited well-substantiated analysis of the biomechanical needs while enduring the unfamiliar forces from kitesurfing. Thus being the focus of this research.

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.

		harness that						

This research shall aim to find out what forces come onto the user during kiting, what effects these different forces have on the body (for prolonged time) and deepen the knowledge about the biomechanical needs of the user in the lumbar area. For this a motion, force or biomechanical analysis is needed, this seems to be the first step to designing the ultimate harness. The insights from these static and dynamic analysis shall lead to the generation of conceptual designs/ideas of a kitesurfing harness that will give solution to the conflicting requirements. This research has the aim of delivering a (partial) solution in the form of a concept-design(s) where a combination is made between a soft and hard shell to support the user in the best way possible.

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Personal Project Brief - IDE Master Graduation

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.

I believe the graduation project should be a reflection or an exploration to answer the question "Where do I see myself in a couple of years?" For me personally this question doesn't only reflect on my academic/work related life but also on my sports career. The last two years have been revolving around my life as a professional wingfoiler and reaching my goals as an athlete, winning the world tour and becoming the first ever wingfoiling world champion in 2021.

Being part of the creation and growth of a new sport has been an exciting experience. The watersports industry using and making available new designs, materials and production techniques have helped to bring the different water sports to where they are now. And thus the answer to "Where do I see myself in a couple of years?" would be: I see myself still being part of this industry, maybe not as an athlete but definitely as a product developer, designer or in some other form. This is something I would like to explore. With this project I would like to combine my knowledge and passion for watersports with my knowledge and abilities as a designer, helping to push the sports further by researching and designing. I will explore the ergonomics field, different research methods and work closely together with the main stakeholder, Mystic, to design the ultimate harness.

This project being a company based graduation project is also one of my goals. Throughout my studies I have never done any internships or internal company based projects, and it has really felt like I am missing some real workspace experience. Working together with experienced product developers who have many years of experience seems very insightful.

FINAL COMMENTS

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

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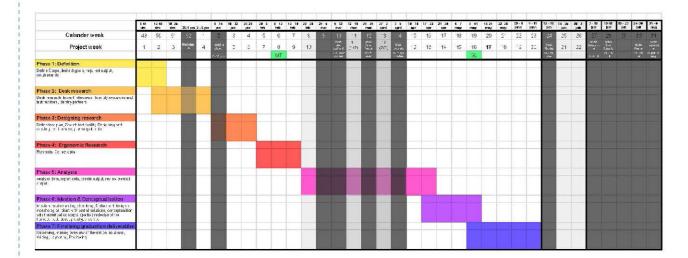
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Personal Project Brief - IDE Master Graduation

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 13 - 12 - 2022 end date



For the year 2022 / 2023 I have a Topsport Den Haag and a TU Delft topsport status. This is due competing on the wingfoiling worldtour.

Planning specific to my travel agenda, the current goal is finish in calender week 23. This is the calendar posted by the Global Wingfoil Association in November 2022, this calender is due to change as only the New Zealand and Leucate event dates are 100% confirmed. Due to changed I have a personal maximum goal of calender week 26. As there are many competitions planned in the summer.

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APPENDIX B HARNESS PORTFOLIO MYSTIC



2002 THE DARKRIDER

The first mystic harness. Heavily based on the design of windsurf harnesses at the time, differentiating itself in style and a few design tweaks like added loops for the leash.



2007 THE WARRIOR

Still sold today as a hybrid harness for kitesurfers and windsurfers



2012 THE DUTCHESS

Mystic's first kite harness for ladies, mostly differentiating in colors and a smaller sizing



2016 LEGEND HARNESS

First non water absorbing softshell harness



2017 MAJESTIC X

First ever hardshell harness, coming available in a carbon and glass fiber



2018 THE GEM

First ever hardshell harness for woman - the replacement of the Dutchess. Including a smaller glass fiber hardshell backplate for a better fit.



2020 STEALTH HARNESS

Stealth harness - first non absorbing hardshell harness



2023 STEALTH HARNESS

Stealth harness - the successor of the first stealth harness with a lower and backplate. Compared to it's predecessor the harness weighs 52 grams less when dry (without bar).

Appendix figure 01: Historic portfolio of Mystic boardings harnesses

APPENDIX C

USER RESEARCH - INTERVIEW QUESTIONS

[-		.1					.1		.1			1
Testsubject		1 2	3	4	5	-	5 7	7	9	9 10	11	1
Age:	2	5 24	45	51	49	29	9 19	9 3	69	59	51	
Gender:	M	Male	Female	Male	Female	Male	Female	Male	Male	Male	Female	Male
Chest circumference:	Student	Student	71 - under boob	99	88 met borsten	104	4 91	1	88		84 / 75	1
Waist circumference:			80			91,5			87		69	:
Hip circumference:			110			97	7 93,1	1	100	0	89	
Height:			168								164	
What is your kitesurfing experience / level	1,5 jaar – Ik ben een beginner maa ik kan wel al een aantal kleine sprongetjes doen.	Ik kite nu 1 jaar, maar ik ben niet heel erg vaak geweest, dus ik ben een beginner. Ik kan waterstarten	Intermediate	Kitesurfing nearly 25 years	Advanced - 20 years of kitesurfing	Kitesurfing for 3 years	Beginner - intermediate - upwind riding	Advanced - kitelooping - long downwinders - 10 years experience	Intermediate	Advanced - was 1st in the		Advanced - 5 years Also an advanced windsurfer
Do you have a sponsor, if yes for what?	No	en stukjes varen.	NO	no	100	NO	NO NO	No	No	netherlands many years ago	Experienced - 7 years	
What is your preferred riding style / manouvres ?	Freeriding	Freeriding	Freeriding	Freeriding	Waveriding on a directional	Freeriding and jumping	Freeriding	Freeriding / Jumping	Freeriding	-	No	Freestyle, wave - backroll -
					_					wave	waveriding	jumping
Other (board)sports	Surfen, Skaten, wakeboarden, snowboarden	Skaten, Snowboarden	Snowboaridng	sup, wavesurf, wingfoil, Mountainbiking	Longboarding - beginner wingfoiler - mountainbiking	Skating	Wakeboarden - Snowboard - Skate	Snowboarding - Wakeboarding	SUP	Wingfoil - sup - snowboarding	SU P	snowboarding - golfsurfen - wingfoiling
Which harness do you use at the moment?	The harness I rent from my	Ik gebruik altijd het harnas van	Mystic GEM jalou hard shell	Prolimit alpha hardshell	Naish Alana + Mystic waveride	Mystic stealth 2020	Mystic diva - softshell S	Seat harness	Mystic Hardshell	Willigion - sup - showboarding	30	Mystic Majestic composite shell
(brand model sit / waist soft/hard shell)	student association: DROP Prolimit FX - soft	mijn vriend of die van vriendinnen die wel een eigen harnas hebben.	myddo o'i myddo nai'd oneil	Very light, at 550 euro's one of the most expensive harnesses						ION pro carbon windsurf - I have attached a rope bar becasue a		use it for waveriding Mystic Stealth - I use it for the twintip - I don't have any ropes as was a windsurfer and I want the
										kitesurf harness doesn't have enough surface area compared to a kitesurfing harness	Seat harness - Dakine	hook to always be in the same place - I have the freeride loop from duotone with itit
Which harnesses have you used/owned in the	I have never bought a harness, I	Nog nooit een gehad	I used a sit harness in the first	Naish Boss	Naish Alana older types	Mystic majestic X	Lesson harness - seat harness	I have had wasit harnesses but	Mystic hardshell			
past?	always lend the prolimit harness. So I've only used that one.		lessons					due to much backpain I have switched to a seat harness - This is also due to my work I am a chel and have been bent over a workbench in the kitchen too	I started with a seat-harness			I used to have everything from NP Then I started kiting and switched to mystic wetsuits and I like to have everything from the same
Miles did and a house it is a	Manual and the state of the sta	Daniel 171	Mahada 21 1171	Lucian day of the first	The bosses of the state of	Lucian dala da	D	much hours in a day	B	Seatharness - mystic	Seatharness - Dakine	brand
Why did you chose this harness?	It was available and cheap	Deze was beschikbaar	My husband bought it for me	I wanted to try a hardshell	The harness is ladies oriented - and we have a naish shop close to our house	I wanted the best hardshell harness	Recommended by shop - good deal	Because of my back	Recommended by the shop	I would rather have a seat harness with the hook at the same hight as a wasit harness		
Do you ever think about buying a (new) harness? Why? Which one?	N/A	Nee ik heb er niet aan gedacht om er een te kopen Ik heb dus een mannen en een vrouwen harnas geprobeerd, deze verschilnde wel van elkaar. Het vrouwen harnas gleed meer omhoog.	kitesurifng a sit harness is better because you hold your kite more	Just bought the prolimit	No I am happy	Now that the Stealth 2023 is out I might want to buy that in the future if it is a better harness	No, maybe if I start kitesurfing more.	Maybe if they make one that doesn't crawl up and pinch my balls so much when the kite is at 12	Yes I would like one with a rope	The ideal harness doesn't exist yet	Becasue I'm now focussed oon waveriding I would like/prefer a	I think I would keep both harnesses, the stealth is not suitable to ride with on holidays in warm kite-destinations. The harness is much to hard to use without a wetsuit for many hours especially if your not used to it
What proportion do you find most important in a	Vet eruit ziet		Looks	Durchilty	Durability	The looks - one of the reasons I	ondersteuning van de rug	Comfort - good for my back - no	Looks - durability - padding - no	The ideal flamess doesn't exist yet	names with rope	especially if your not used to it
What properties do you find most important in a harness design? (FOR EXAMPLE - looks = durability – padding – comfort – no moving about – adjustability – price – attachment method – modularity – sustainability) Why?	Vet et al. Ziel Durable Goede padding – Geen harde delen die uitsteken Simpel mehcanisme – maar wel trustworthy	Makkelijk dichtgaan Niet omhoog glijden	Coorfort attachment padding adjustability	Durability Padding Comfort No moving of harness	Dulabinity Padding Comfort No movign about	like mystic Being able to strap it really tight, I like to pull hard on the webbing before I get onto the water Comfort - I don't want the harness to give me any discomfort and I don't want to get a tired back	Miet mijn rug blesseren Makkelijk aan te doen is en makkelijk lekker strak doen Dat het harnas niet draait is hetr aller belangrijkste	moving about	moving about - modualrity	1 comfort 2 durability 3 no moving about (reason I want		1. Looks - I want it to fit with the wetsuit 2. comfort 3. Attachment method Padding
What characteristics do you like about your harness?	Vind het niet zo'n heel fijn harnas, maar het sluit systeem is wel makkelijk	Het vrouwen harnas had een betere pasvorm Het mannen harnas gleed minder omhoog	It looks nice	Stiffness There is no more pressure from the kite Takes the pressure away from the	it fits well, doesn't move	when riding. I like the looks, I like how light it is	Hij is lekker zacht en dat zit comfortabel bij de rug En hij ziet er leuk uit - mooie kleuren	That it is better for my back and I can kite for many hours comfortably	I like the stiffness	a seat harness)	2. moderate price	The mystic attchment is perfect -
		Offinous		kite			Redicii			No backpain	Comfort and price	comfort - the hook - easyfit
What characteristics don't you like about your harness?	Het harnas is te groot (maat XL) dus het harnas schuift alle kanter op.	Het mannen harnas zat in eerste instantie niet heel erg lekker maar gleed uiteindelijk niet omhoog. Het vrouwenharnas was de pasvorm beter maar deze gleed heel erg omhoog.		Hollow back		The non-absorbing materials on the harness are not as soft as my previous harness. I haven't used the new harness much yet so I don't know if I will feel such a difference on the water. I always have to make the hahrness super tight before my session, not always as comfortable to do.	hij draait (axial) - even if I make the harness very tight - sometimes it's so tight I can barely breath and still it moves Hij draait mn ribben in - pressure on chest Closure system - need to redo the webbing tightness evry single time to get it tight enough - I can't get it tight enoug by myself have to ask men to help me		the harness is not comfortable, the harness is a size L while it should be a size M	Het touwtje slijt telkens of hij breekt zelfs	On my previcous harness I didn't like that that I couldn't change the spreaderba.	The carbon harness is too stiff, in brazil kitesurfing 5 hours per day gave trouble. I had irritation and even bruises on the sides
How would you describe the fit of the harness?	Het harnas is te groot dus ik heb	+	OK	I love the stiffness and the and the	it fits well because it's a	The fit is nice. The back is not so	Goed maar een beetje groot - too	The fit is good - I have the right	The harness is to big	DICCRE ZCIIO	spicaucibai	Creat bruises on the Sides
What qualities make the harness fit well / bad? What characteristics of your harness would you	het niet goed kunnen testen		Loss proceurs on my short	softness but the hollow back doesn't fit me at all. Without it it would be much more comtable The hard plate in the wrong shape	womand's harness and it's small	high so the harness is a bit smaller so I have a lot of freedom moving around.	high as I am a small girl	How it sits between my legs and		Yes because it is a windsurf harness, daar wordt harder aan getrokken	You don't feel the pulling. The presure is equally spread 1. I would really like to ride a waist	majestic is more comfortable. The Stealth is too firm
what characteristics of your harness would you change? / How would you improve your harness?	In plaats van al die losse stukjes foam van het harnas zou ik liever dat de rand helemaal bedekt was in foam.	is bij de taille - zachter aan de	2000 production my chest	In the world shape is uncomfortable. Is it rubbing over my spine maybe the cheaper harness is better for me the prolimit vapor hardshell	The focus is a periodic for the	the softnesss	harness	the bag I am sitting in - more comfort oriented and a more clean look just like a wasit harness	harness with a rope	I did, I applied a rope	harness that doesn't moce up- stays on my waist 2. Don't make me feel like in a corsett (I need to breath) 3. Nice colour - Not always pink or violet for ladies please	Make the stealthbar lighter Work away the webbing
Have you ever felt discomfort during or after a session because of the harness? Where / How / When		Pijn door het omhoog schuiven van het harnas				Yes, if I kitesurf without a harness I get pain on the skin from the harness. I starts to rash and can become quite painfull I have had pain in the ribs especially when I just started kitesurfing and jumping. I kept the kite quite high and the harness would move out of it's place	Yes, in the water: very painfull pressure in the chest When turning its painfull in de side / back of the ribs After the session on the back - top side of the harness.	2		I had discomfort during sessions due to the harness pressing into my ribs	4. moderate price!	Kiting in Brazil - Bruises and sores due to the stealth
Have you ever felt pain during or after a session because of the harness? Where / How / When						Section to place		The state of the s		Pijn? ja ribben pijnlijk en ook rug pi	in	Bruised ribs
Pain due to pressure on ribs	x	x	x	Likent the Medib has it is year.		x	x			x		X
extra		Stiekem wil je gewoon een zitharnas maar het ziet er niet uit		I kept the Nasih boss, it is very soft and you feel everything. The Alpha is better.								It they would make a mix between the majestic and the stealth it would be perfect

Appendix figure 02: Answers participants user group

APPENDIX D USER RESEARCH - PERSONA'S



THE BEGINNER

SOMETIMES SWIMMING MORE THAN KITING

Can often be found walking upwind with their gear, body-dragging to find board and can be recognized by their kite at 11 and 12 o' clock and looking uncomfortable in their harness

Behavior "I just bought what the shop recommended, and it looked good" or "it was a good secondhand deal"

Gear preferences & needs: A harness that is comfortable during their first hours on the water. The harness should move on the body as little as possible.



YOUNGSTERS

NEW GEN

A new generation of kitesurfers. Hanging out with their friend on the beach all-day.

Behavior: Pushing each other on the water and can also be found jumping off of the dunes with their kites. It's all about fun! (Maybe some pro's in the making)

Gear preferences & needs: They want the best gear to push their skills but are often restricted to whatever they get from their parents, whatever they can afford



WEEKEND WARRIORS

ALSO KNOWN AS MID-LIFE-CRISIS KITERS

Instead of an affair, cabriolet or new job they escape from reality by being part of the kitesurfing community.

Behavior. Mid 40's and always has the latest of the latest gear. Some keeping kitesurfing as their forever-hobby and others already selling their gear after a year or two looking for the next best thing.

Gear preferences & needs: The latest models from the best brands including the best harness to get the most out of their time on the water.



THE-NICE-WEATHER-KITER

NOT FOUND ON THE BEACH IN THE WINTER

A person who can be found on the beach only around the summer or holidays destinations.

Behavior. Doesn't own gloves and booties and seems ride overseas more often than at home.

Gear preferences & needs: Spoils themselves every other season on a new kites and boards. Searching for a setup that works all over the world including a harness that is comfortable without a wetsuit.



"LEGENDS"

WILL HAPPILY TELL YOU ABOUT THEIR FIRST KITE WITHOUT DEPOWER OR SAFETY SYSTEMS

Started out windsurfing and switched to kitesurfing in the 0's, having been there for the entire kitesurfing evolution. After all those years they have very respectful skill on the water and often very good wave riding skills. Are now 35 to 60 years old.

Behavior: Has been riding with the same brands since forever, often have deals at the brands or stores they have been coming for years.

Gear preferences & needs: They have many experience using harnesses and this experience to choose a harness, the harness features should be recognizable to this user.



KAMIKAZE KITERS

UNSKILLED KITESURFERS

There are some at every spot, kitesurfer who reverse on the water without looking, jumping without paying attention. Crashing into people. Can sometimes be recognized by their "Frankenstein-kite" with many repairs.

Behavior: Regular customer at the shop and repair-shop. Gear preferences & needs: Gear that handles their clumsiness - durable.



GRÜNDLICHKEIT-KITER

RECOGNIZABLE FROM MILES AWAY

The more careful kitesurfer, always equipped with all the necessary safety equipment like helmet, leash, knife, impact vest, etc

Behavior. Making sure that kitesurfing can be enjoyed safely.

Gear preferences & needs: Gear should be safe-to-use. A harness that has all the needed safety equipment, like safety leash and knife, and will make sure the kitesurfer can safely enjoy their session.



EQUIPMENT-SPECIALIST

KNOW-IT-ALL

Believes in the power of the gear, if you don't have the best gear you won't get better either.

Behavior: His whole life revolves around equipment, very active on forums and loves to tech-talk.

Gear preferences & needs: This kitesurfer needs the best gear to achieve the highest performance. Mix and matches brands and is always on the lookout for the best stuff out there, large quiver.



(SEMI-)PROFESSIONALS

WHO THE WANNA-BE'S WANT TO BE

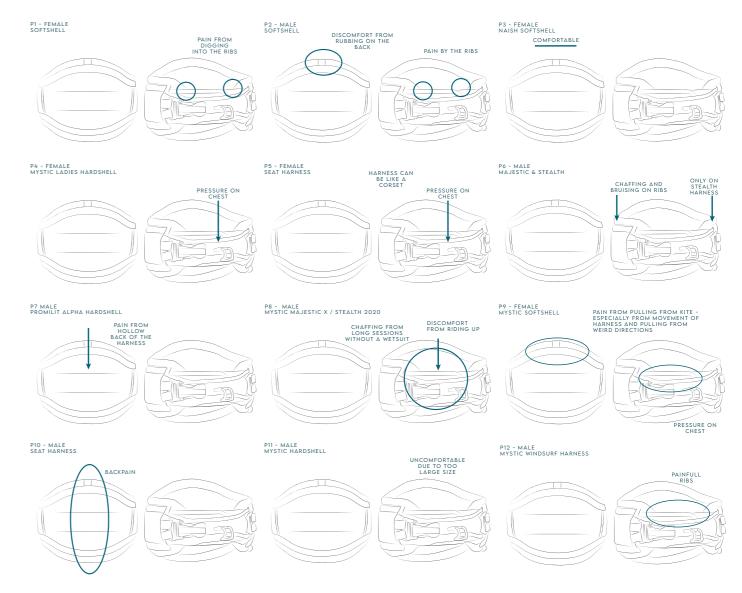
The best kitesurfers our there - dedicating all their (free) time to the sport. The professionals are traveling often and can always be found on the worlds best spots. Some kitesurfers stay with a brand for the benefits/money but are not always happy with the gear.

Behavior. Doing advanced ticks, very active on social media showing off their skills.

Gear preferences: In need of the best of the best gear -Performance goes over comfort. Their sponsor deal restricts them to only riding with that brand. Semi-professionals often have a deal to buy for a heavily discounted price.

APPENDIX E

SCHEMATIC DRAWING PARTICIPANTS USER INTERVIEWS



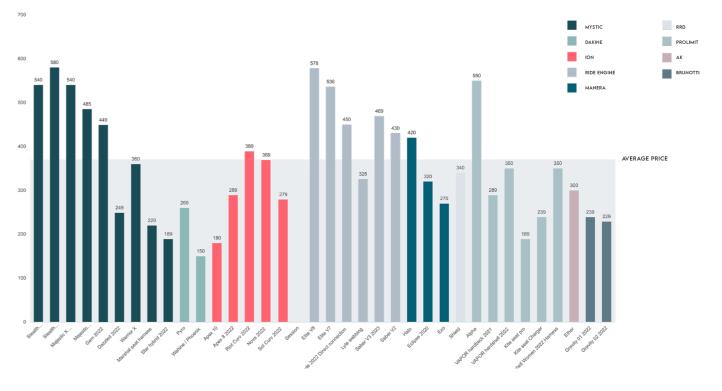
Appendix figure 03: Schematic drawing made by the participants from the user group Answers user interviews

APPENDIX F MARKET ANALYSIS

	Name	Back Support & flexibility	Profile & shape	Lining	Closure	Price Harness *	Price bar *	Total	Image
Mystic	Stealth 2020	Hardshell Stiff plate	Low-profile Symmetrical	Non-absorbant lining	Waist belt strap Webbing Mystic Laverage closure	420	120	540	C007
	Stealth 2023	Hardshell Stiff plate	Low-profile Symmetrical	Non-absorbant lining	Waist belt strap Webbing Mystic Leverage closure	460	120	580	
	Majestic X 2021	Hardshell Carbon Stiff	Low-profile Symmetrical	Soft fabric lining No patterns	Waist belt strap Webbing Mystic Leverage closure	420	120	540	TAYSTIC .
	Majestic 2022	Hardshell Glass fiber Bit more flexible than the Majestic X	Low-profile Symmetrical	Soft fabric lining No patterns	Waist belt strap Webbing Mystic Leverage closure	365	120	485	
	Gem 2022	Females Hardshell Glass fiber Bit more flexible than the Majestic X	Extra Low-profile Symmetrical	Soft fabric lining No patterns	Waist belt strap Webbing Mystic Leverage closure	329	120	449	
	Warrior X	Most luxe Softshell harness from mystic	Higher profile than the other mystci harnesses	Soft fabric lining	Waist belt strap Webbing Mystic Leverage closure	240	120	360	
	Marshal seat	Softshell seat harness		Soft fabric		220	0	220	
	Star hybrid	Softshell hybrid seat harness		Soft fabric		189	0	189	8
Dakine	Pyro	Medium stiffness softshell	medium-high profile	Soft fabric lining	Dual Straps With Quick Clips	260		260	
_	Wahine / Phoenix	Medium stifness Softshell	Low-profile in-curving on bottom	Soft fabric lining	Waist belt strap Webbing Quick clip	150		150	
NO	Apex 10	Medium-stiff Hardshell Flex 13/20	High profile	Soft fabric lining Plastic profiling	Waist belt strap Leverage buckle Webbing	180		180	
_	Apex 8 2022	Medium-stiff Hardshell Flex 13/20	High profile	Soft fabric lining Plastic profiling	Waist belt strap Leverage buckle Webbing	289	0	289	
	Riot Curv 2022	Hardshell	Low profile	Soft fabric lining Small square with profiling Interchangeable Ergo pad	Waist belt strap Leverage buckle Webbing Incl Specter bar	389	0	389	
	Nova 2022	6/ 20 flex	Female harness	EVA lining		279	0	279	
	Sol Curv 2022	medium soft harness Female hardshell	Low profile	Interchangeable ergo pad	Inc Specter bar	369	0	369	
Ocean Rodeo	Session	Medium (BEst for beginners)	Extra wide velco strapping	fabric lining no profile	Snag-Free Buckles	\$		203	
Ride C Engine		Hardshell carbon Stiff	Low-profile	Fabric lining With textured inner lining	Direct Connection / Speed	459	119	578	
	Elite V7	Hardshell carbon Stiff	Low-profile	Fabric lining With textured inner lining	Direct Connection / Speed	406	130	536	₹₹
	Lyte 2022 Direct connection	Hardshell Carbon	Low-profile	Fabric lining With textured inner lining	Direct Connection / Speed	320	130	450	91
	Lyte webbing	Hardshell Carbon	Low-profile	Fabric lining With textured inner lining	Direct Connection / Speed Lock	326		326	,,

Appendix figure 04: Comparison of harnesses on the market

				_					-
	Saber V3 2023	Hardshell carbon	Low-profile			339	130	469	(1)
	Saber V2	Hardshell Composite Medium stiff	Low-profile	Fabric lining With textured inner lining	Direct Connection / Speed Lock	300	130	430	⊚ r → ₹
MANERA	Halo	Hybrid Soft & Hardshell	Low-profile	Soft universal lining		420		420	
	Eclipse 2020	Hard shell	Low -profile	Simple fabric lining no texture		320	0	320	
	Exo	Hardshell Carbon	medium profile very straight, higher back			270		270	
RRD	Shield					340		340	
Prolimit	Alpha	Hardshell carbon inward curve allong spine	low-profile	Simple soft lining with anti- slip texture	leverage closure	550	0	550	TATOLINI.
	VAPOR hardback 2021	Hard back panel		Anti-slip with neoprene lining on the sides		289	0	289	
	VAPOR hardshell 2022	Hardshell carbon	Lower backplate than the alpha	Simple soft lining with anti- slip texture	Leverage closure	350	0	350	PROMI
	Vapor Hardshell Women 2022 Harness	Polypropelyne hardshell		Soft neoprene lining	leverage buckle	350	0	350	
AK	Ether	soft shell				300		300	
Brunotti	Gravity 01 2022	Hybrid harness	Straight	fabric lining - 5 components seperated by stitching	Hook + push + webbing	240	No bar		
					* Most prices are from Kit	emana.cor	<u>n</u>		



Appendix figure 05: Price comparisons harness market

MYSTIC BOARDING | STEALTH 2020 & AND MAJESTIC 2023

The showpiece of the mystic harness collection is the Stealth. There are two versions, the 2020 and the 2023. The harnesses consists of a carbon hardshell in a low-profile. The spreaderbar must be bought separately and is connected to the harness through webbing. What makes the harness special is the use of non-absorbent lining, this makes sure the harness stays light during riding and doesn't stay wet when storing it. Due to the use of this material the harness might feel stiffer and less soft on the rims than the majestic X, which has the usual soft lining. This cushioning has a good grip on the body.

Design changes in the 2023 harness:

- The Velcro strap under the spreaderbar is reduced in height on the 2023 version, thus having more chance of the spreaderbar touching the skin or wetsuit when bing pulled at an angle.
- The 2020 harness has a low-profile symmetrical design, while the 2023 version is slightly asymmetrical with a higher top-backplate. The total backplate area is smaller on the 2023 model.
- The 2020 harness has the non absorbent lining in a chunky cut out design. In the 2023 version this is made less chunky and the design consists of one piece in comparison to 4 pieces.

MYSTIC BOARDING | MAJESTIC X



Appendix figure 06: 2020 Stealth harness (left) & 2023 Stealth harness



Appendix figure 07: & Majestic X with two special editions

Mystic's first hardshell harness, a carbon hardshell (Majestic X) and glass-fiber (Majestic) edition. The later being less expensive and more flexible. The design is quite similar to the stealth 2020 but this harness is lined with fabric materials, thus becoming heavier in the water. This material does let the harness feel more comfortable when comparing the two in the showroom.

The design of the harness is low-profile but not the smallest backplate on the market. This backplate is guite straight and the carbon hardshell is strengthened with a small curve running over the middle. This backplate can be printed in different designs giving the brand the opportunity to launch designs and kitesurfer/brand specials. Like with the king of the air, dirty habits and special teamkitesurfer editions(like Jalou, Bruna and Ozzy).

MYSTIC BOARDING | WARRIOR

In the Mystic range since 2007, first only as a softshell harness and in 2022 launched with a crossover design. The Warrior X. A semi-hardshell with a 6/10 stiffness rating. This harness is marketed for kitesurfing and windsurfing, typical for a crossover harness it has a higher backplate. The backplate consists of horizontal and vertical ribs to provide the right amount of flex. The center ribs being thicker for more support while the sides are thinner for more flexibility during moves. The backplate is more curved than the majestic and stealth range. Giving the harness more comfort in the spinal extension posture. When hanging back using the force of the kite.

The lining of the harness is a neoprene fabric, which absorbs water during riding.

RIDE ENGINE - ELITE

The name says it all, this is Ride Engine's top of the



Appendix figure 08: The warrior (left) and the warrior X (right)

range harness. It is also the most rigid harness in the line. The 2022 harness has replaced the neoprene lining with a rib-stop lining, reducing the weight of the lining. Ride Engine advises to buy a spreaderbar that is as large as possible and a harness which is as tight as possible. The backplate of the elite is tallest and widest, thus having the most surface area of the ride engine range. This stiffness and sizing makes it more difficult to make a grab, etc.

RIDE ENGINE - LYTE

The entire harness is lined with fabric. This seems to me more cushioning than comparable hardshell harnesses which makes it very comfortable. The backplate gives more support on the top and less on the bottom end compared to the elite harness.

RIDE ENGINE - SABER

Ride engines most affordable hardshell harness due to the use of SES (Structural Engineered Shell), a composite. The entire harness is lined with fabric. The harness can be tightened with the ladder lock system which looks like a snowboard boot binding. The absence of webbing gives the harness a clean look. The harness is heavier than the stealth when dry, when wet this difference is very noticeable as it absorbs water.

MANERA HALO

The Halo, the first true combination between soft&hardshell harness on the market, is a real breakthrough in the industry. Not only being the first to create a harness with a hard core and soft outer laver embracing the benefits of both types of harnesses. Usually harnesses are sown and glued together, making it bad for the environment and difficult to replace components when broken. This harness is 100% connected with screws overcoming these problems, as can be seen in Appendix figure 11.

The shell of the harness consists of 3 main parts:

The halo: The harness consists of a hard outer ring. This ring, 'the Halo' is produced from a composite is very rigid. The ring doesn't touch the user, this makes sure the pressure from the kite is not directly loaded onto the user.

The backplate: This backplate is made from a softer composite, it keep gives the inner lining some rigidity but it not connected to it though glue or sowing.

The inner lining: A very simple soft inner lining, it fits around the body snugly and it easy to tighten. Reviews state the harness stays in place well because of the

Having the right size does seem to be an important factor for the harness as reviews state: "If you don't get the fit right then, you will find pressure points on your hips, or if it's too big, it will move on your body."

PROLIMIT PROLIMIT ALPHA

One of the most expensive harness on the market at 550 euro's.

The backplate has a negative curve in the middle of



Appendix figure 09: Two different locking systems Ride Engine offers, webbing (left) and the Unity Ladder-Lock (right)



Appendix figure 10: 2022 Ride engine Elite, Lyte and Saber harnesses from Appendix figure 11: Manera Halo Harness left to right



the harness. Exactly where the spine is. The userinterviews showed that it was very uncomfortable for one of the interviewees, and he only felt it when riding the harness, not in the shop.

- Should the shop have advised to hang into the harness?

The other characteristics of the harness are quite similar to other brands. The lining is neoprene with little anti-slip printing.

ION

Ion is the first major brand to come with a modular padding, the harness comes with two paddings with a different thickness/softness which can be placed in the middle of the inner backplate with velcro. With this design they try to accommodate the different needs of different users.

Ion's 2023 harnesses are available not only in standard sizes but also in tall versions, such as medium-tall and large-tall, to accommodate different lengths. This is already common in the wetsuit industry.

ION APEX, RIOT & RIOT TEAM

The Apex has a higher and asymmetrical backplate compared to the Riot. Both harnesses have a composite backplate and come with a carbon composite spreaderbar. All the harnesses in the ION range are rates for their stiffness from 0 to 20. The Apex is rates 8, the Riot 14 and the Riot team 18, a high performance harness has to be stiffer at the expense of some comfort.

APPENDIX G PRODUCT COMPONENT ANALYSIS

LINING & PADDING

The lining or padding, the material on the inside of the harness, has high influence on the comfort of the harness as it effects the dispersion of forces and the amount of shear resistance found in the harness. The factors influencing the characteristics of the lining are material choice, padding thickness, weight, stitching & pattern and the texture of the lining.

Lining material: The Lining is the outer material of the inside padding, this is often made from neoprene or fabric. Some harnesses only have padding like the EVA foam liner of the Mystic Stealth harnesses.

Padding Material: Under the lining the padding can be found, different type materials are used. The paddings have different flexibilities, softness and weights. Also some absorb no water, like the EVA foam. Some harnesses consist of multi material padding to create softer/harder parts.

Thickness of padding: The thickness of the padding is used to create areas with more and areas with less support to create or relieve certain pressure points and it is also used to achieve a certain shape for the inner backplate.

Stitching & pattern: Different patterns are created by the use of stitching or the variation between padding and no padding.

Texture of lining: Texture is added to the lining of the harness to decrease the movement of the harness, for example a rib-lining or anti-slip textures added for less movement of the harness.

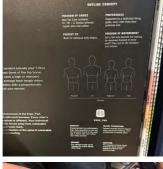




Appendix figure 12: Prolimit Alpha





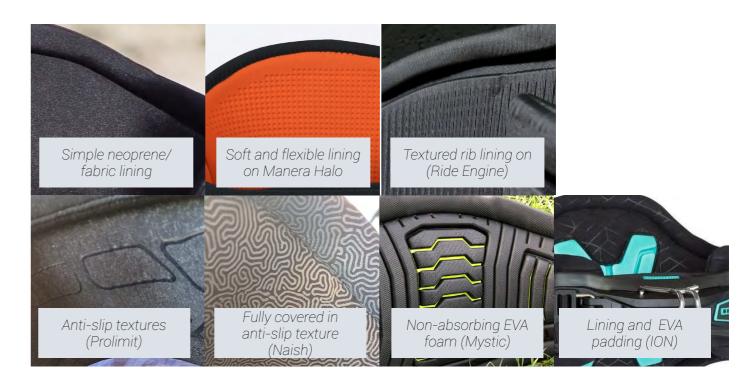








Appendix figure 13: ION Apex, ION Riot, sales stand, interchangeable Velcro padding and closure system



Appendix figure 14: Examples of current lining and padding solutions

TRIMMING AND CONNECTION SYSTEM

The trimming of a harness is how the harness is tightened to the size of the user. This often functions in combination with the closure system. Some closure systems rely on the trimming system to stay closed and other closure systems tighten up the harness after trimming to get an even tighter fit.

WEBBING

The most common trimming system is webbing, it's been around since the first windsurfing harnesses. It's reliable and simple but doesn't offer rigidity between the spreaderbar and the harness, thus permitting unwanted movement within the harness. Webbing is also influenced by the wet/dry cycles of the harness, when it gets wet it stretches. This is why users re-trim the harness after a few minutes of riding, especially is the harness hasn't been used for a while. Another disadvantage of webbing is how it looks. The webbing is often meant to be hidden behind a little piece of elastic fabric on the side of the harness. But some don't bother to do so, thus making the harness look messy as can be seen in Figure 19. Under this fabric the clip with which the webbing is trimmed can also be found.

There are different types of webbing; thickness, flexibility, width and material influence the use of the webbing. Also designs differ by using one or two webbings per side of the harness. Having two webbings gives the spreaderbar more stability.



Appendix figure 15: Messy look of webbings not tucked away properly









Appendix figure 16: Examples of current webbing solutions

RIGID LADDER TRIMMING

Ride-engine is offering their Unity Ladder-Lock system, a rigid trimming option. The rigidity of the Ladder lock makes it easy to always set the harness to exactly the same tightness as the ladder shows the sizing. The system is very clean looking as there is no webbing sticking out to all the sides. The ladder system doesn't disappear into the harness but comes out behind the elastic fabric which lessens the clean look. Use shows the Ladder-Lock is difficult to open and is found more difficult to trim compared to webbing.





Appendix figure 17: Rigid clipping system from Ride Engine | Ride Engine Flite 2022

BAR-LOC CLIPPING TRIMMING & CLOSURE

This is a closure and trimming system in one. A ladder is found on either side of the harness and all the user has to do is click in the spreaderbar on both sides. It was produced by Prolimit but seems to not be very successful as the system isn't being used in their newest harnesses.



Appendix figure 18: Prolimit BAR-LOC system

CLOSURE SYSTEM LEVERAGE BUCKLE CLOSURE SYSTEM

The Leverage buckle is a large clip that closes the harness and also gives a bit of extra tightness to the harness. The user must place the clip at the end of the webbing on the leverage buckle and can then easily close the system. The buckle is attached to one side of the spreaderbar. It is a very popular system at the moment as users love to get that extra bit of tightness and is still easy to use in situations where the hands might be tired or cold.

Testing showed that the amount the harness is tightened and the ease of use is influenced by the size of the lever. The Mystic clip being easier to use than smaller levers like the small Ride Engine lever.



Appendix figure 19: Leverage closure system | Mystic Stealth bar | Ride Engine Elite

PUSH BUTTON CLOSURE SYSTEM

This system requires a button or component to be pushed or squeezed to open up the harness. The system closes by pushing a pen into a hole. This is often very easy especially if the harness trimming system isn't made very tight yet. Opening the system can be very difficult especially when the hands are tired, wet and cold. especially for less powerful kitesurfers like women and children.



Appendix figure 20: Push button closure system | Mystic Stealth bar (left) | Ride Engine Elite (right)

PULLING LABEL CLOSURE SYSTEM

This system requires a button or component to be pushed or squeezed to open up the harness. Just like the push button system this system closes by pushing a pen into a hole. This is often very easy especially if the harness trimming system isn't made very tight yet. Opening the system back up can be very difficult though, when the hands are tired, wet or cold especially.



Appendix figure 21: Pulling label closure system | Prolimit Pure Girl & Prolimit Seat harness

HOOK AND WEBBING

This is the most simple system, the spreaderbar and the harness are connected with a hook and by tightening the webbing this closure stays in place. The advantage of this system is simplicity and light weight.



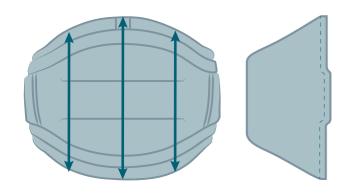
Appendix figure 22: Hook and webbing combination | Ride Engine Elite 2019 (left) | Manera Halo (right)

SHAPE OF THE BACKPLATE

Since the first hardshell came to market many different types of backplates to be found on the market. Three design aspects of the backplate influence the user during kitesurfing.

THE PROFILE OF THE BACKPLATE

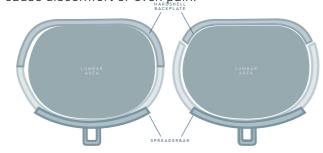
This refers to the shape of the backplate. The larger the backplate is the more support the harness shall give as it is pushing onto more vertebrae than a smaller backplate would. A larger backplate does compromise the freedom of movement of the user. By designing a certain outline a balance between support and freedom of movement is achieved.



Appendix figure 23: Profile backplate (left) structure in backplate (right)

THE LUMBAR LOCK OF THE BACKPLATE

The more the backplate "wraps around" the user the more lumbar lock it provides. Having more lumbar lock shall give the user more of a pushing sensation instead of a pulling sensation in the back as the user is squeezed by the harness less. With more lumbar lock the sizing of the harness is very important, as the harness is less flexible and thus a wrong size can cause discomfort or even pain.



Appendix figure 24: Amount of lumbar lock of back plate

THE FLEXIBILITY AND DESIGN OF THE BACKPLATE

The flexibility of the backplate is influenced by the shape and material of the backplate, as the "texture" given to the backplate gives the plate more rigidity. As a straight plate would result in much torsion being possible. By designing this plate in different thicknesses and designs the flexibility in certain regions can be influenced. Material choice, carbon, glassfiber or composites, also contributes to the rigidity of the backplate.













MYSTIC STEALTH 2020 MYSTIC MAJESTIC & MYSTIC WARRIOR X 2023 MYSTIC STEALTH 2023 MAJESTIC X 2021 OCEAN RODEO SESSION DAKINE PYRO **ION APEX ION RIOT BEXO** PROLIMIT VAPOR MANERA EXO PROLIMIT VAPOR MANERA HALO RIDE ENGINE LYTE RIDE ENGINE ELITE **RRD SHIELD** RIDE ENGINE SABOR

Appendix figure 25: Example of variety in backplate shapes and profiles

SPREADERBAR

The spreaderbar is a crucial part of the harness, dating from the early days of windsurfing. It makes sure the user is not squished by the harness as it introduces the forces from the kite not in the middle of the chest area but on the two sides.

Spreaderbars consist of 4 main components, the hook, the spreader, the attachment method and the padding. In the past spreaderbars were always only made from steel without padding, now more functions are integrated into the spreaderbar and other materials like carbon are being introduced to the market.

There are currently 3 different types of spreaderbars, the choice depends on the riding style of the user.

Most spreaderbars can be mixed and matched between different brands.



STANDARD HOOK KITE & FREESTYLE



CLOSED LOOP FREERIDING



ROPE WAVERIDING

Appendix figure 27: Overview of types of spreaderbars



COMPOSITE SPREADERBARS

METAL SPREADERBARS
WITH FABRIC OR FOAM
LINING

CARBON SPREADERBARS

APPENDIX H PHYSICS OF KITESURFING

 $\alpha := 69.1 : \beta := 31.4 : \textit{Fkite} := 288.12 : g := 9.81 : \textit{m} := 85 : \textit{Fg} := \textit{m} \cdot \textit{g} :$

restart; with(Degrees) #TEST 1

```
\Sigma Fx: Fkite * \frac{cosd(\beta)}{f} = Fn:
                     cosd(\alpha)
\Sigma M@A: AB*cosd(\alpha)*Fg=AC*cosd(\alpha+\beta-90)*Fkite:
     AB = solve(AB * cosd(\alpha) * Fg - AC * cosd(\alpha + \beta - 90) * Fkite = 0, AB);
                                          AB=0.9523623617 AC
restart;
#TEST 2
\alpha := 66.1: \beta := 32.4: \textit{Fkite} := 299.88: g := 9.81: \textit{m} := 85: \textit{Fg} := \textit{m} \cdot \textit{g}:
\Sigma Fx: Fkite * \frac{cosd(\beta)}{cosd(\alpha)} = Fn:
\Sigma M@A: AB*cosd(\alpha)*Fg=AC*cosd(\alpha+\beta-90)*Fkite:
     AB = solve(AB * cosd(\alpha) * Fg - AC * cosd(\alpha + \beta - 90) * Fkite = 0, AB);
                                           AB = 0.8779221417 AC
restart; with(Degrees) #TEST 3
\alpha := 64.8 : \beta := 32.3 : Fkite := 309.68 : g := 9.81 : m := 85 : Fg := m \cdot g :
\Sigma Fx: Fkite * \frac{cosd(\beta)}{f(\beta)} = Fn:
\Sigma M@A: AB*cosd(\alpha)*Fg=AC*cosd(\alpha+\beta-90)*Fkite:
     AB = solve(AB * cosd(\alpha) * Fg - AC * cosd(\alpha + \beta - 90) * Fkite = 0, AB);
                                           AB = 0.8655609603 AC
```

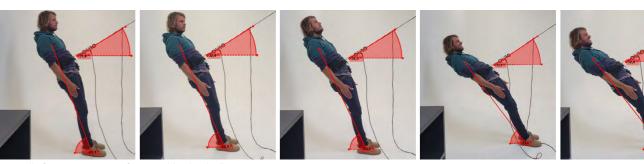
#TEST 4 $\alpha := 54.5 : \beta := 33.1 : Fkite := 437.08 : g := 9.81 : m := 85 : Fg := m \cdot g :$ $\Sigma Fx : Fkite * \frac{\cos d(\beta)}{\cos d(\alpha)} = Fn :$ $\Sigma M@A : AB * \cos d(\alpha) * Fg = AC * \cos d(\alpha + \beta - 90) \cdot Fkite :$ $AB = solve(AB * \cos d(\alpha) * Fg - AC * \cos d(\alpha + \beta - 90) * Fkite = 0, AB);$ (1) AB = 0.9018573467 AC(4)

#TEST 5 restart; with(Degrees) : $\alpha := 51.9 : \beta := 32.8 : Fkite := 442.96 : g := 9.81 : m := 85 : Fg := m \cdot g :$ $\Sigma Fx : Fkite * \frac{\cos d(\beta)}{\cos d(\alpha)} = Fn :$ $\Sigma M@A : AB * \cos d(\alpha) * Fg = AC * AC * \cos d(\alpha + \beta - 90) * Fkite :$ $AB = solve(AB * \cos d(\alpha) * Fg - AC * \cos d(\alpha + \beta - 90) * Fkite :$ $AB = solve(AB * \cos d(\alpha) * Fg - AC * \cos d(\alpha + \beta - 90) * Fkite :$ $AB = solve(AB * \cos d(\alpha) * Fg - AC * \cos d(\alpha + \beta - 90) * Fkite :$ $AB = solve(AB * \cos d(\alpha) * Fg - AC * \cos d(\alpha + \beta - 90) * Fkite = 0, AB);$

AB = 0.8572459497 AC

A = surface area (m2)

Appendix figure 29: Maple sheet



(2)

(3)

Appendix figure 30: Image of a test with a loadcell

Angle α (degree)	Angle β (degree)	Force (kg)	F	orce (N)	result : $AB = x * AC$	
69.1	31,4	29,4	288,12	AB = 1.	093 AC	
66.1	32,4	30,6	299,88	AB = 1.	0549 AC	
64.8	32,3	31,6	309,68	AB = 1.	0380 AC	
54.5	33,1	44,6	437,08	AB = 1.	0655 AC	
51.9	32,8	45,2	442,96	AB = 0.9	983 AC	

Appendix figure 31: Results of test with loadcell

Equilibrium of forces between kitesurfer and kite ΣFx : Fkite,steer * $\cos{(\beta)}$ + Fkite,power * $\cos{(\beta)}$ - FN * $\cos{(\alpha)}$ = 0 ΣFy : Fkite,steer * $\sin{(\beta)}$ + Fkite,power * $\sin{(\beta)}$ + FN * $\sin{(\alpha)}$ - FG = 0 $\Sigma M@A$: AB* $\cos{(\alpha)}$ * Fg - AC * $\sin{(\alpha + \beta - 90)}$ / Fkite,power - AD * $\sin{(\alpha + \beta - 90)}$ / Fkite,steer = 0 $\sin{(\alpha + \beta - 90)}$ / Fkite,power * $\cos{(\beta)}$ - FN * $\cos{(\alpha)}$ = 0 ΣFy : Fkite,power * $\sin{(\beta)}$ + FN * $\sin{(\alpha)}$ - FG = 0	Friction force Ffriction = k * Fn Ffriction = the friction force (N) k = the friction constant - material dependent Fn = The Normal force perpendicular to the plane in which the friction occurs (N) Fn * Us = max static friction Us = static friction coefficient Fn = normal force
Σ M@A: AB* cos(α) * Fg - AC * sin(α + β - 90) / Fkite,power = 0	Pressure from harness on body surface p = F/A or F = p * A p = pressure (N/m2) Fn = Normal force (N)

Appendix figure 28: Overview of spreaderbars

APPENDIX I

ANTHROPOMETRIC DATA CAESAR

CAESAR IT: Mean and standard deviation calculated using the CAESAR - Italy database - Sheet can be used to calculate the measurements according to set percentile or the percentiles according to the measurements.

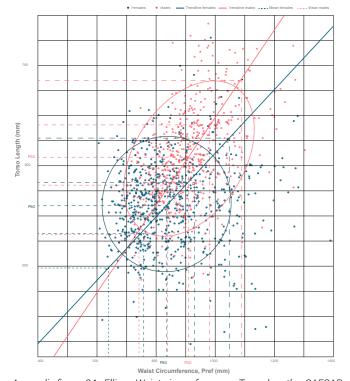
	Acromial Height, Sitting C	hest Circumference (B	ust/Chest Circumfere Ch	hest Girth at Scye (C? H	p Circumference, Ma H	p Circ Max Height (m. S.	tting Height (mm)	Stature (mm)	Waist Circumference, F.W.	laist Height, Preferrer W	eight (kg)	Hip to waist height (cm) V	laist to top of head	Shoulder to top of hear W	aist to shoulder	Torso Length
Standard deviation M&F	32,697	86,354	57,934	90,188	66,600	58,707	42,227	89,889	92,839	53,441	12,598	31,753	54,509	20,596	44,661	37,817
Mean M&F	577,955	925,270	742,539	917,984	978,359	813,234	882,350	1675,300	798,813	992,076	65,329	178,709	683,156	304,383	378,774	557,483
Standard deviation F	26,539	80,270	57,934	60,290	68,763	45,746	30,415	61,878	78,473	49,212	9,031	32,722	36,871	15,593	32,643	35,196
Mean F	560,005	890,049	742,539	854,487	976,593	776,137	854,639	1610,979	751,923	968,861	57,519	192,724	642,119	294,634	347,485	540,209
Standard deviation M	28,736	78,496		70,820	64,536	46,979	34,510	67,354	83,281	47,815	10,951	24,327	37,537	20,530	32,858	32,663
Mean M	594,818	958,358		977,637	980,022	848,170	908,383	1735,726	842,864	1013,886	72,684	165,510	721,803	313,563	408,240	573,750
Percentile M&F	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%
Dimensions M&F	577,9550562	925,2696629	742,5386598	917,9837703	978,35875	813,23375	882,349563	1675,299625	798,8127341	992,0761548	65,329	178,70875	683,15625	304,3825	378,77375	557,4825
Percentile F	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%
Dimensions F	560,0051546	890,0489691	742,5386598	854,4871134	976,5927835	776,1365979	854,6391753	1610,979381	751,9226804	968,8608247	57,51907216	192,7242268	642,1185567	294,6340206	347,4845361	540,2087629
Percentile M	50,00%	50,00%		50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%	50,00%
Dimensions M	594,8184019	958,3583535		977,6368039	980,0218447	848,1699029	908,3825666	1735,726392	842,8644068	1013,886199	72,68398058	165,5097087	721,8033981	313,5631068	408,2402913	573,75
Dimention M&F	534	800	700	900	900	850	563	1700	575	900	578	150	700	300	300	500
Percentile M&F	8,94%	7,34%	23,14%	42,10%	11,97%	73,44%	0,00%	60,83%	0,80%	4,24%	100,00%	18,30%	62,13%	41,57%	3,89%	6,43%
Dimention F	534	800	700	900	900	850	563	1700	575	900	578	150	700	300	300	500
Percentile F	16,36%	13,10%	23,14%	77,48%	13,27%	94,68%	0,00%	92,49%	1,21%	8,09%	100,00%	9,58%	94,18%	63,46%	7,29%	12,66%
Dimention M	534	800		900	900	850	563	1700	575	900	578	150	700	300	300	500
Percentile M	1,72%	2,18%		13,65%	10,75%	51,55%	0,00%	29,79%	0,06%	0,86%	100,00%	26,19%	28,07%	25,44%	0,05%	1,20%

Appendix figure 32: Torso length calculated with CAESAR-IT database

CAESAR NL: Mean and standard deviation calculated using the CAESAR - Dutch database - Sheet can be used to calculate the measurements according to set percentile or the percentiles according to the measurements.

		Chest	Bust/Chest	Chest Girth (Chest					Waist							
	Acromial Height,	Circumference	Circumference			Hip Circ Max Height S	Sitting Height (cm)	Stature (cm)	Circumference,	Waist Height,		Hip to waist	Waist to top of	Shoulder to top	Waist to shoulder	
	Sitting (cm)	(cm)		Scye) (cm)	Maximum (cm)	(cm)			Pref (cm)		Weight (kg)	height (cm)	head (cm)	of head (cm)	(cm)	Torso Length (cm)
Standard deviation M&F	3,878	11,163	9,296	9,488	8,786	6,514	4,875	10,605	12,690	6,332	16,791	3,787	6,469	2,478	5,675	4,950
Mean M&F	60,792	100,541	84,322	97,796	104,256	85,222	91,288	173,972	87,716	104,844	77,864	19,594	69,145	30,496	38,602	58,212
Standard deviation F	3,170	11,874	9,287	8,758	9,481	5,071	3,768	7,604	13,115	5,543	15,541	3,115	3,684	2,169	3,488	4,070
Mean F	59.007	99.817	84.308	94.317	105.871	82.258	88.692	167.987	84.509	103.377	72.933	21.091	64.627	29.674	34.955	56.041
Standard deviation M	3.521	10.157		8,543	7.372	6.235	4,112	9.002	10.918	6.766	16.282	3,730	4.524	2.458	4,469	4,608
Mean M	63,006	101,434		102,117	102,255	88,878	94,509	181,373	91,685	106,650	83,953	17,753	74,720	31,521	43,143	60,913
Percentile M&F	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	5 0,5	0,5
Dimensions M&F	60,79197776	100,5408696	84,3218117	97,79554849	104,2559618	85,22238924	91,28840349	173,971722	87,71616482	104,8437055	77,86424625	19,59380952	69,14548336	30,49648281	38,60184591	58,21230893
Percentile F	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dimensions F	59,00688666	99,81745351	84,30801144	94,31736011	105,871408	82,25816619	88,69153515	167,9872857	84,50931232	103,3771879	72,93271429	21,0905036	64,62697274	29,67435159	34,95455861	56,04092888
Percentile M	0,5	0,5	i	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	5 0,5	0,5
Dimensions M	63,00587189	101,4342756		102,116934	102,2553381	88,87791519	94,50907473	181,3729682	91,68492908	106,6496466	83,95255732	17,75274336	74,71964602	31,52082585	43,14288288	60,91281588
Dimention M&F	102	100	92	90	100	80	90	170	85	100	80	18	70	30	35	55
Percentile M&F	100,00%	48,07%	79,56%	20,56%	31,40%	21,13%	39,58%	35,40%	41,53%	22,21%	55,06%	33,69%	55,25%	42,06%	26,28%	25,82%
Dimention F	102	100	92	90	100	80	90	170	85	100	80	18	70	30	35	55
Percentile F	100.00%	50.61%	79.62%	31.10%	26.79%	32.81%	63.58%	60.44%	51.49%	27.12%	67.54%	16.06%	92.76%	55.97%	50.52%	39.91%
Dimention M	102	100		90	100	80	90	170	85	100	80	18	70	30	35	55
Percentile M	100 00%	44 38%		7 80%	37 98%	7 73%	13.64%	10.32%	27 02%	16 28%	40 41%	52 64%	14.84%	26.81%	3 42%	9.97%

Appendix figure 33: Torso length calculated with CAESAR-NL database



Appendix figure 34:	Ellipse Waist circumference x Torso length - CA	ESAR
NL		

	Females	• Males —	Trendline female	es — Trendlin	e males •••• Me	an females • • •	Mean males
700							
700							
	- = = = =						•
600 (EEE						· · · · · · · · · · · · · · · · · · ·	
loiso Lengin (min)							
500							
400							
400							
	60	10	8	00	1	000	

Appendix figure 35: Ellipse Waist circumference x Torso length - CAESAR-

Measures	Waist circumference (mm)					
Populations	P5	P25	P50	P75	P95	
Dutch adults 20–60, male	760	858	926	994	1092	
Dutch students 17–27, male	679	741	784	827	889	
CAESAR (NL) 18-66, male	739	843	915	987	1091	
Dutch adults 20–60, female	639	761	845	929	1051	
Dutch students 17–27, female	629	683	721	759	813	
CAESAR (NL) 18-66, female	632	757	844	931	1056	
CAESAR (IT) 18–66, male	705,88	786,69	842,86	899,04	979,85	
CAESAR (IT) 18-66, female	622,85	698,99	751,92	804,85	881,00	

116

Measures	Torso Length (veritcal distance) (mm)				
Populations	P5	P25	P50	P75	P95
CAESAR (NL) 18-66, male	533,33	578,04	609,13	640,21	684,93
CAESAR (IT) 18-66, male	520,02	551,72	573,75	595,78	627,48
CAESAR (NL) 18-66, female	493,47	532,96	560,41	587,86	627,35
CAESAR (IT) 18-66, female	482,32	516,47	540,21	563,95	598,10

Appendix figure 36: Waist circumference and torso length of the target group - CAESAR NL & IT

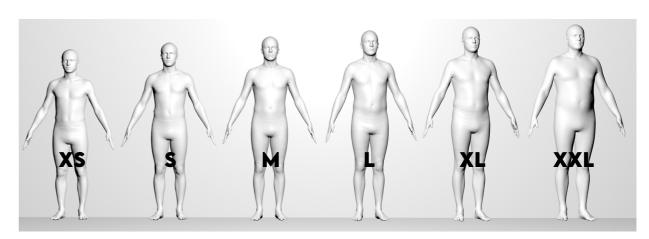
APPENDIX J SIZING MYSTIC - CHARTS AND MANNEQUINS

	EURO	WAIST (cm / inch)	STEALTH BAR	ACE BAR
xxs	36-38	60-70 / 24"-28"	240 m m	240mm
XS	40-42	67-77 / 26"-30"	240 m m	240 m m
S	44-46	75-84 / 29"-33"	240/280mm	240/280mm
M	48-50	82-91 / 33"-35"	280 m m	280 m m
L	50-52	89-96 / 35"-38"	280/320mm	280/320mm
XL	54-56	94-104 / 37"-41"	320 m m	320mm
XXL	56-58	102-114 / 41"-45"	320 m m	320mm

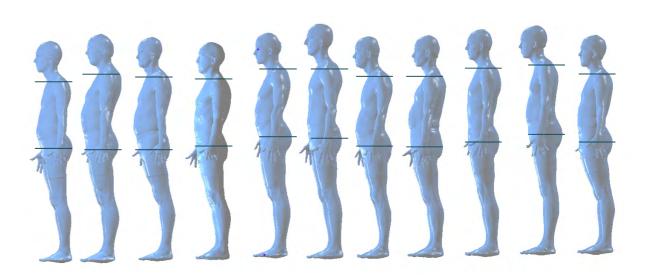
Appendix figure 37: Current Mystic sizing chart males

	EURO	WAIST (cm / inch)	STEALTH BAR	ACE BAR
XS	34-36	60-70 / 24"-28"	240 m m	240 m m
s	36-38	68-76 / 27"-30"	240/280mm	240/280mm
М	38-40	74-84 / 29"-33"	280 m m	280mm
L	40-	82-94 / 32"-37"	280 m m	280 m m

Appendix figure 38: Current Mystic size chart females



Appendix figure 39: Mystic sizing 3D mannequins

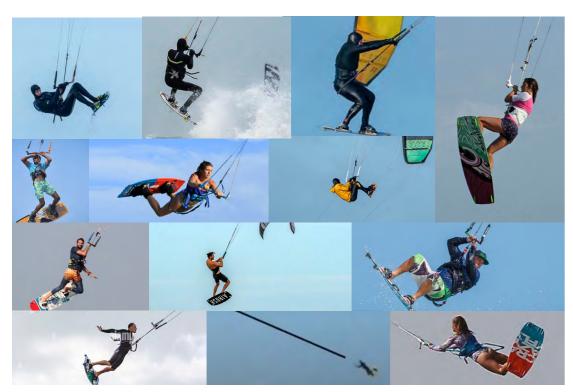


Appendix figure 40: Eleven 3D scans of male participants of the CAESAR-NL Anthropometric research (waist circumference between 810 and 860, the corresponding waistcircumference to male size M)

APPENDIX K SAMPLE OF IMAGES USED FOR PHOTO MOTION-ANALYSIS







APPENDIX L

PROCEDURE AND DEMOGRAPHIC ERGONOMIC RESEARCHES

INSIGHTS FROM THE PILOT SESSION:

Insights were collected concerning the handling of the participant. Due to the time of the year, it was quite uncomfortable for the participants to wear little clothing, with the insights from the pilot an extra heating was placed in the location for the comfort of the participants. Asking the participant beforehand what their favorite forward foot is created a more relaxed and natural stance during the research.

Other insights concerned the 3D scanning software capabilities. The 3D scanning software needed practice - it took some time to learn how fast must be moves during the scan and from which and how many angles should be scanned to create high quality scans. Also the environment played a role; How much light is needed during the scans; which clothing created the best results, as was found of black tight clothing and crazy prints led to distortion in the shapes of the files; and that the bar and lines are confusing to the software, thus avoiding them was essential to a high quality scan.

DEMOGRAPHIC OVERVIEW 3D SCANNING

Participant Age(y) Gender Experience Weight Size Build Nationality Height Hip circ. Waist circ	Chest circ.
Subject A 19 F Intermediate 67 M Highly athletic NL 168 93.1 73	91
CAESAR female 18 - 66 P36.94 P51.06 P7.98 P18.84	P22.66
Subject B 26 M Intermediate 70 M Average NL 181 92.5 81	89.
CAESAR male 18 - 66 P19.31 P46.72 P8.59 P16.32	P11.94
Subject C 29 M Intermediate 89 L Average size large NL 180 97 91.5	104
CAESAR male 18 - 66 P65.54 P42.07 P23.2 P50	P60.16
Subject D 24 F Beginner 60 S Skinny & tall NL 178 90 74	86
CAESAR female 18 - 66 P61.19 P91.31 P4.03 P21.02	P11.88
Subject E 23 M Advanced 70 M Athletic NL/MAR 180 92.5 86	100
CAESAR male 18 - 66 P42.07 P8.59 P36.14	P40.94

DEMOGRAPHIC OVERVIEW - MOVEMENT OF HARNESS

Participant A - Male - Clothing size L - Wetsuit size L - Stealth 2020 size M

Participant B - Female - Clothing size S - Wetsuit size M - Gem softshell size S

Participant C - Female - Clothing size M - Wetsuit size M - Gem softshell size S

APPENDIX M

RESULTS 3D SCAN KITESURFING STANCES

Neutral stance - extension - flexion

Figure 70 shows the side view maximum extension, neutral stance and the maximum flexion of two participants. The image shows that bending from neutral to extension is 20 to 30 degrees. When bending from neutral to a maximum flexion the participants bend 35 to 45 degrees. Most bending comes from the lumbar spine. Just under the waist, the largest curvature in the lumbar spine can be found during extension. While the thoracic stays considerably straight, with an exception during maximum flexion where bending can be found in the top thoracic vertebrae. Figure 70 shows the location of a kitesurfing harness during the different stances.

Lateral flexion

The possible lateral flexion varied between participants, but in all cases the bending in from the waist up was more than the bending from the waist down.

Axial rotation

The axial rotation varies between a possible 8 to 35 degrees between the participants. Comparison between the neutral stance and the axial rotation and the horizontal section views showed that from the hips to the waist the participants spine barely rotated.

Heelside riding

The angle of the back varies between the participants between 18 to 30 degrees. Some scans contain a disruption around the chest area when a small waist harness is used.

The feet are in a wide stance in the straps. The board is directed towards the kiting direction. The feet are in the straps perpendicular to the riding direction. The front leg is straight, and the back leg is slightly bended. The pelvis is slightly directed towards the kiting direction.

It could be observed that most of the rotation comes from below the pelvis as the pelvis is directed slightly towards the direction of the kite. The lower spine is in the same direction as the pelvis, from the waist up there is a very slight axial rotation and no lateral bending.

The direction of the shoulders and chest depends on whether the participant is holding one or both hands

on the bar. When only holding one hand on the bar the shoulders are directed more towards the kiting-direction.

Toeside riding

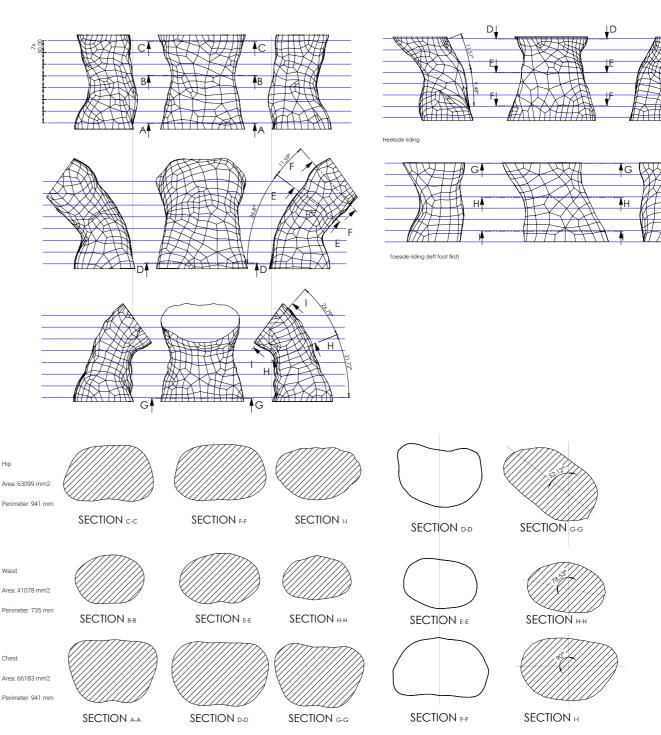
Both feet are in the straps of the board and both knees are bent. The body is in an upright position, no extension of flexion or flexion were observed. The upper body is angled towards the kite and thus the spine is in a high axial rotation, between the participants this ranged from 8 to 24 degrees.

Shape

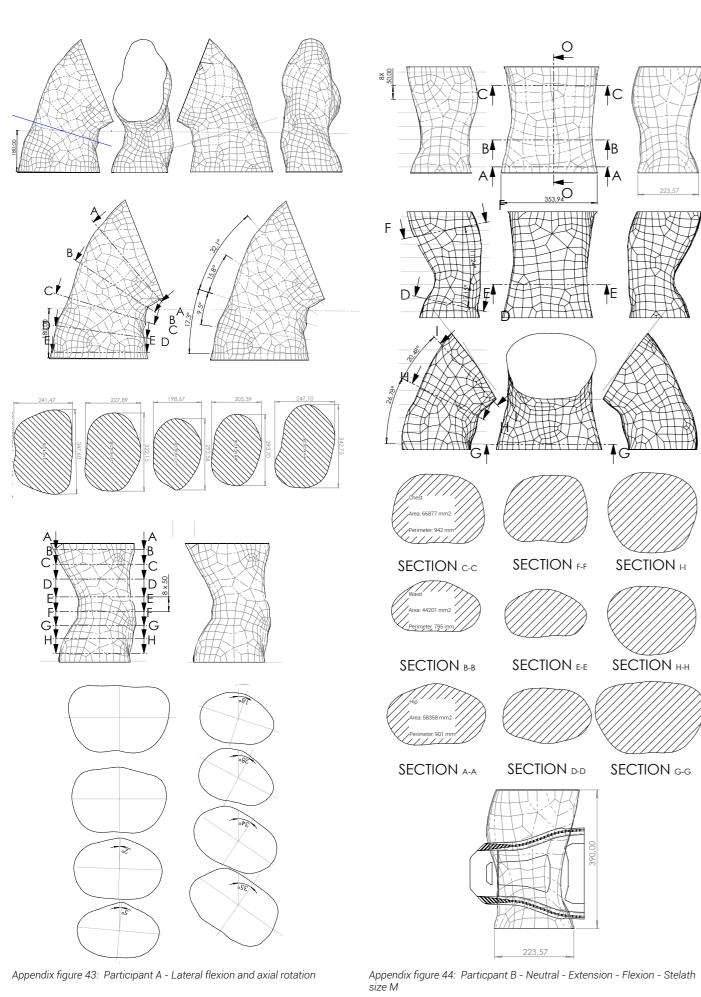
The sections views as the ones that can be seen in Figure 72, were not only used to analyze the angles of the body, but also the shape of the participants. These section views showed that the males have a more square shape around the chest area and the woman were more square around the hips. The females had a smaller rounder waist while the men's waists were also smaller than the hips and chest but with less difference and a more oval shape.

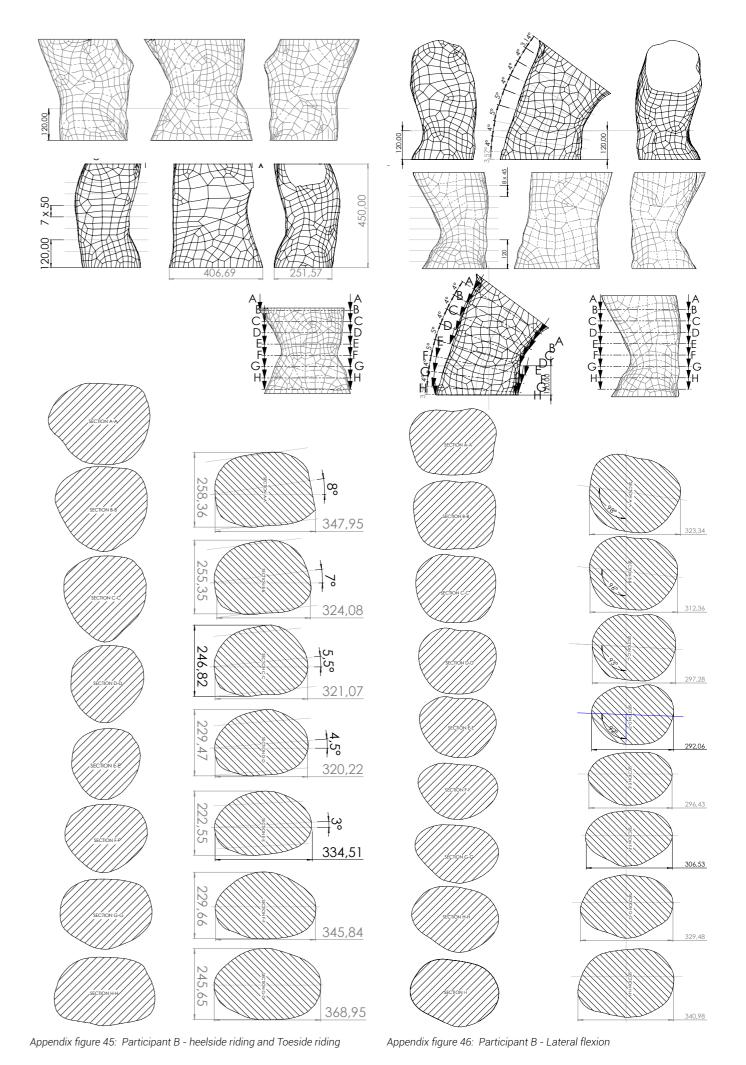
APPENDIX O 3D SCAN KITESURFING STANCES

PARTICIPANT A

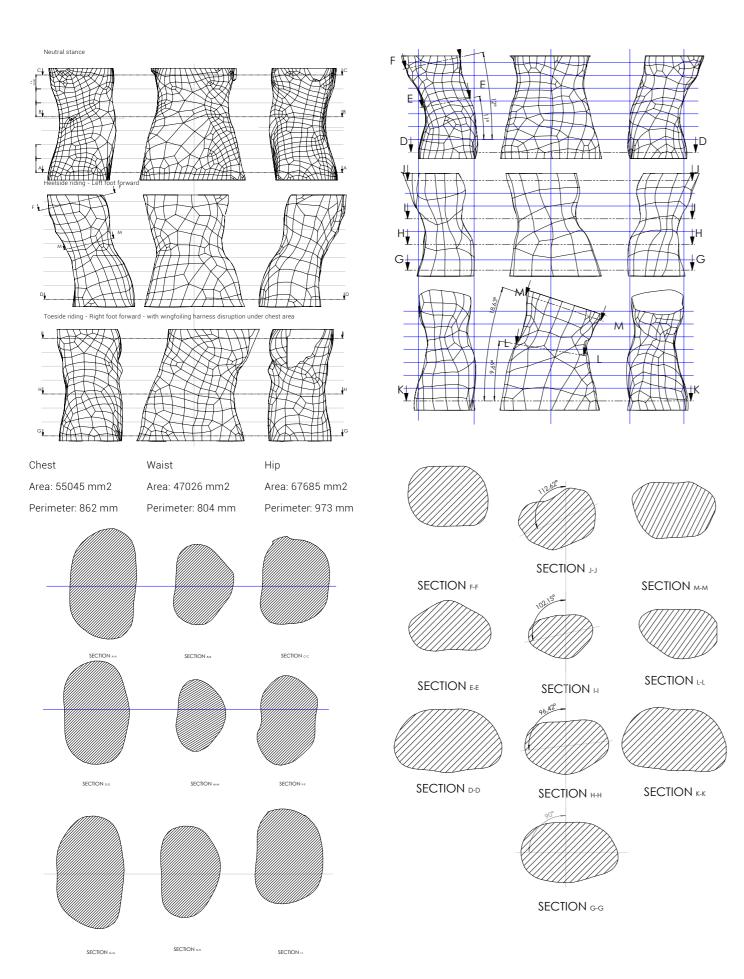


PARTICIPANT B

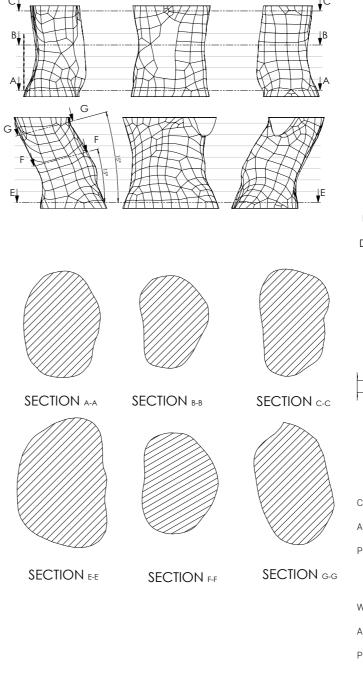




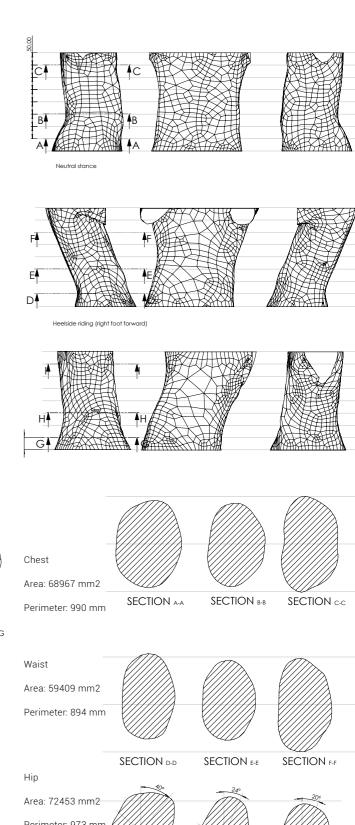
PARTICIPANT C



PARTICIPANT D



PARTICIPANT E



Perimeter: 973 mm SECTION H-H SECTION H SECTION G-G

Appendix figure 48: Participant C - Neutral - Heelside - Toeside

Appendix figure 49: Participant C - Extension - Lateral flexion - Axial

Appendix figure 50: Particpant D - Heelside riding - Toeside riding

Appendix figure 51: Participant E - Neutral - Heelside riding - Toeside riding

APPENDIX P

ANALYZING THE BODY ANGLES DURING MAXIMUM BENDING AND ROTATION OF THE THORACIC AND LUMBAR SPINE

1. RESEARCH AIM

This research is focused on analysis of the body shape during certain body positions and make a comparison with the 3D scans made in the previous research.

RQ: What angles does the participants lumbar area take during maximum extension, flexion, lateral flexion and rotation of the spine?

2. METHOD 2.1 PARTICIPANTS

A sample size of 2 was used, one male and one female. Both also participating in the previous research (Participant A & D). The participants have provided their consent to be photographed and filmed during the research, and they were aware of the activities and the purpose of the research.

2.2 TOOLS & EQUIPMENT

A phone-camera and stickers were used during the research.

2.3 RESEARCH PROCEDURE & DATA PROCESSING

The research was done in a well lighted room. The participants were asked to be shirtless and stickers were stuck on them in a raster. The points A3 and C3 are located where the iliac crest can be found indicating where probably the lowest point of the harness should be located when wearing one.

Then images were made during a neutral stance, extension, flexion, lateral flexion and axial rotation. The images made during the research were processed using Kinovea, a motion analysis software. Lines were drawn between the stickers visible in the images so the differences between the different stances could easily be seen.

3.RESULTS

Extension-Flexion: There is no extension in the thoracic spine, but a slight flexion can be found in the higher vertebrae. Most of the bending in the lumbar spine area is located at the height of the iliac crest.

Lateral Flexion: The female participant exhibits significantly higher lateral flexion than the male participant. The size of the bend on the side of the torso decreases slightly during movement, with a more pronounced decrease due to the female's higher angle. Some skin creases can be observed at the waistline during lateral bending.

Axial Rotation: No axial rotation can be observed in the male participant until the 2nd sticker from the bottom

when viewed from the back. Some displacement of the stomach can be observed lower down. In contrast, the female participant's rotation begins around the iliac crest.

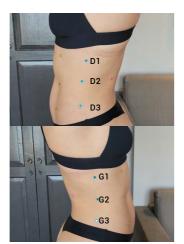
4. DISCUSSION

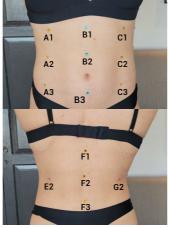
The results of this study align with previous research and the literature review, with no unexpected findings. The female participant demonstrated greater flexibility in all directions compared to the male participant, with the former representing the athletic target group and the latter representing the "weekend warrior" demographic.

The flexion and extension results did not provide any new insights compared to the 3D scan research, as most of the bending occurred in the expected location of the lumbar spine.

The shape of the torso during lateral flexion indicated the maximum size of the harness sides without compromising the range of motion (ROM). The female participant demonstrated a higher lateral flexion angle than the male, resulting in less space along the side of the body between the armpit and iliac crest on the bending side. In the female participant's shape, the area of maximum bending was a sharp corner, while in the male participant, it was a less acute angle.

Similarly, the axial rotation results did not provide any new insights compared to the 3D scan research, as most of the rotation occurred in the expected location of the thoracic spine.

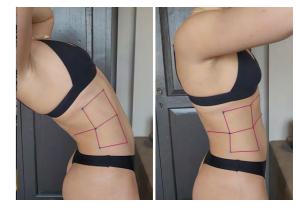


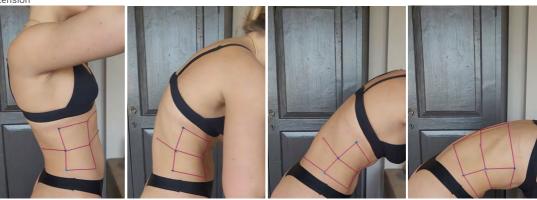


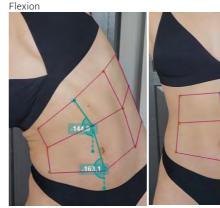
Appendix figure 52: Stickers used to indicate the bending and rotation of the torso









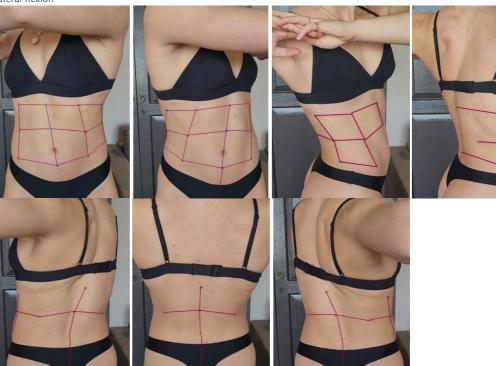






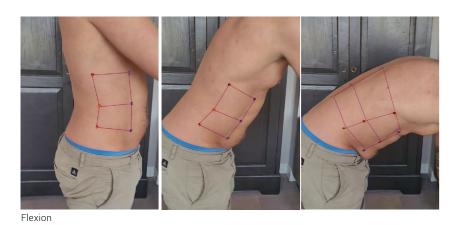


Lateral flexion



Axial Rotation

Appendix figure 53: Participant A Body Bending and rotation with stickers





Extension









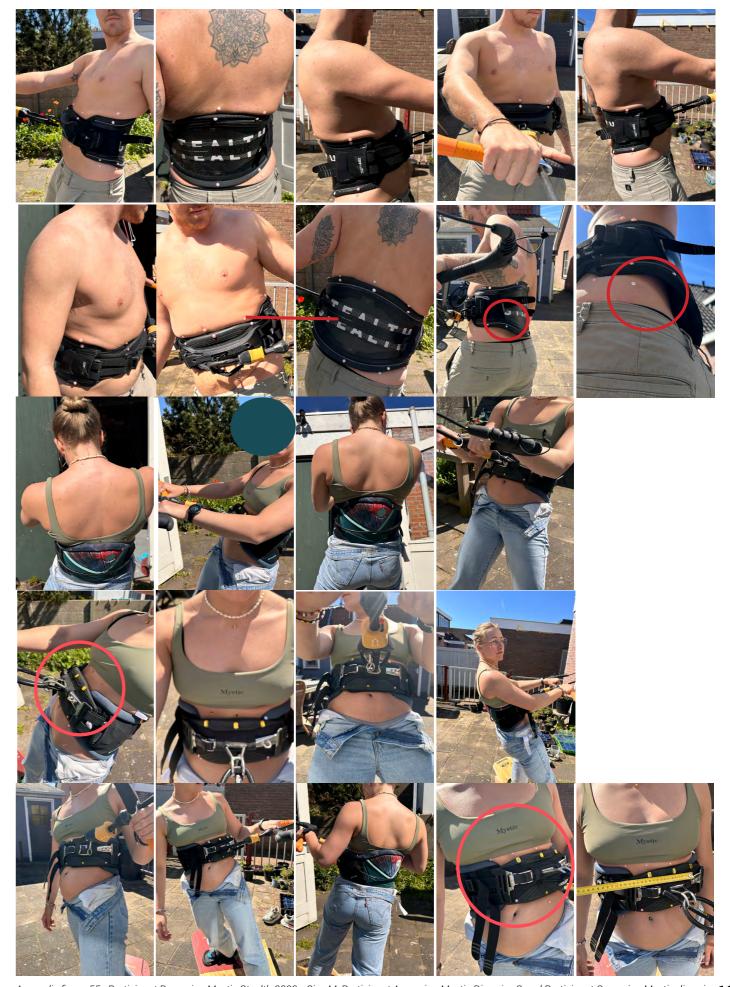
Axial Rotation

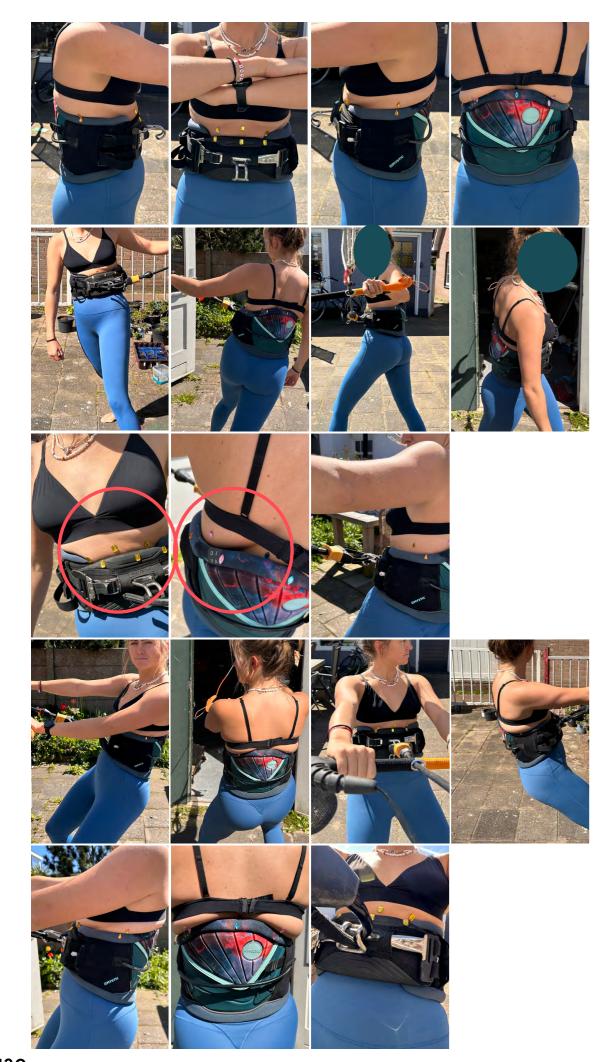


Axial Rotation

Appendix figure 54: Participant B Body Bending and rotation with stickers

APPENDIX Q
HARNESS ROTATION ANALYSIS WITH STICKERS





APPENDIX R
CROSS-INDUSTRY INSPIRATION MOODBOARD









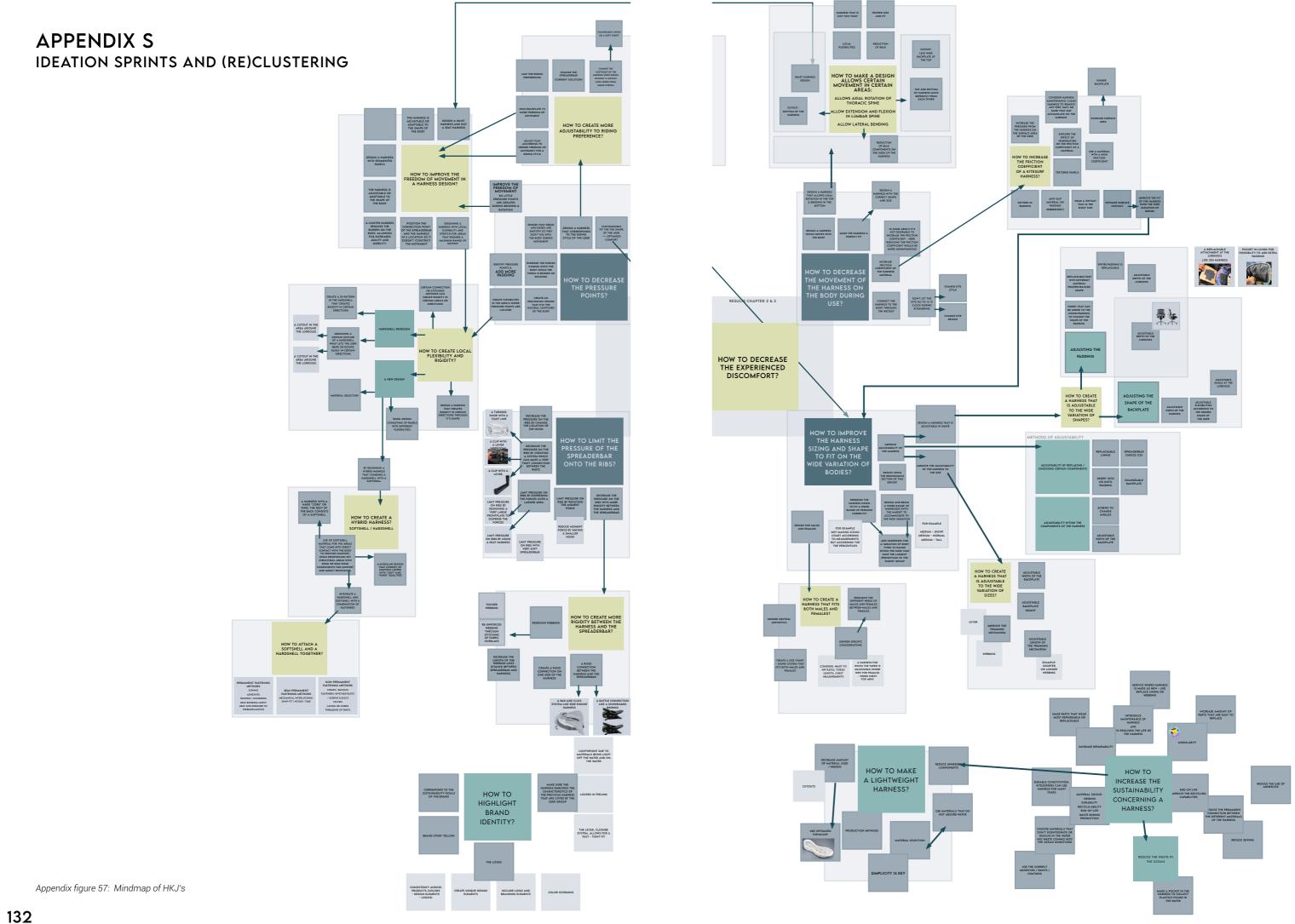




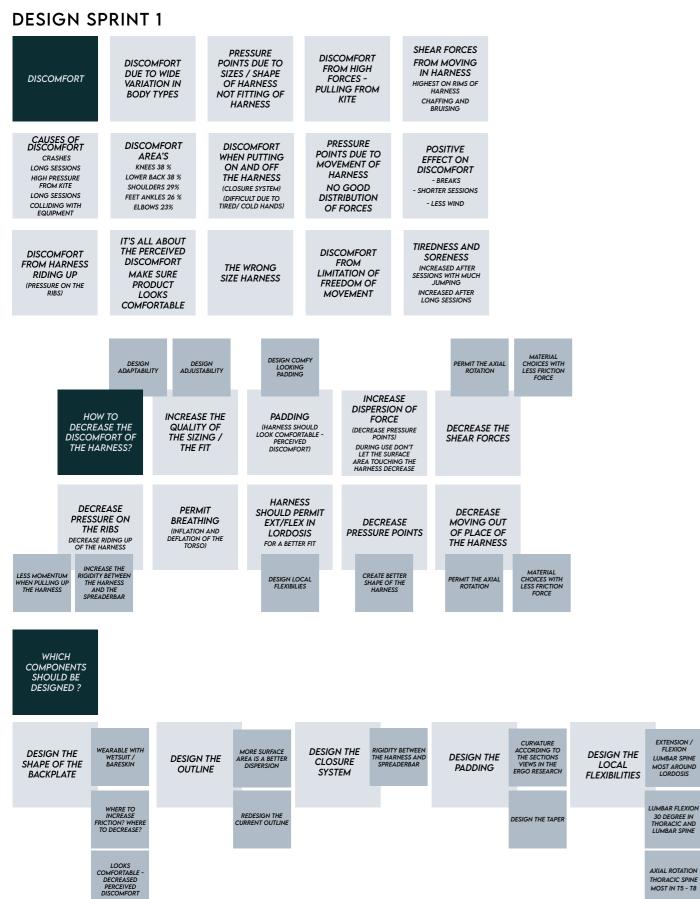








DESIGN SPRINT 2 - 8 CLUSTERS OF IDEA DIRECTIONS



Appendix figure 56: Brainstorms concerning the discomfort of the kitesurf harness, how to decrease the discomfort of the kitesurf harness and which components can be designed of the kitesurf harness.

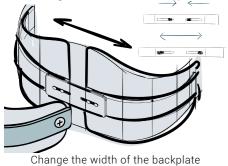


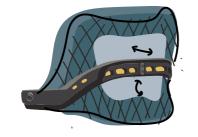
Appendix figure 58: Clustering of HKJ solutions

DESIGN SPRINT 3 - FOUR CLUSTERS OF DESIGN DIRECTIONS

IDEA DIRECTION 1: MOVEMENT OF COMPONENTS

The design introduces multiple shell parts to adapt to the variation of bodies and postures.

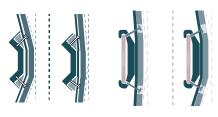


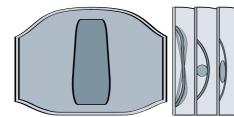


shape

hardshell "backrest" which adapts to the angle of the back

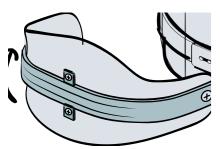
Change angel in the harness around the lordosis through an adjustbaility in the





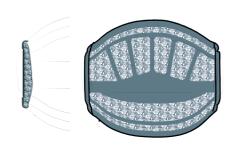
Change angle of the backplate

Padding can change in shape



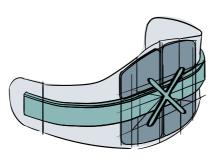


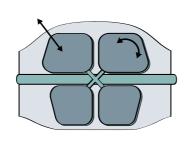
Change angle of the backplate (consists of two backplates) (inspiration from snowboarding)





re that provides both comfort and performance - topology optimization

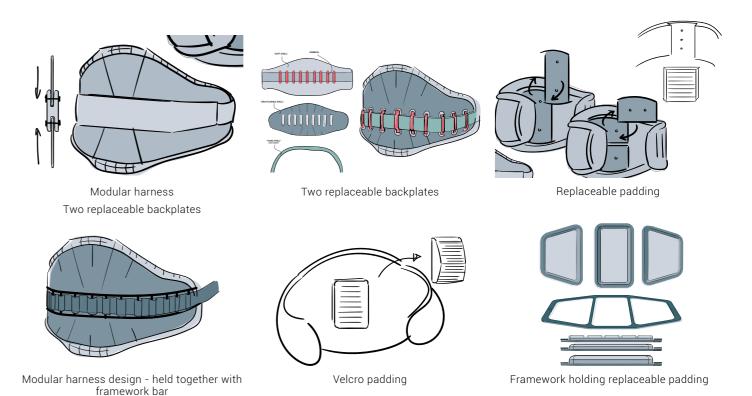




Back shell consists of 4 parts that move/ angle separately from each other

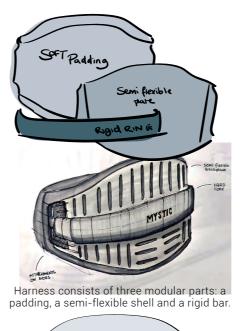
IDEA DIRECTION 2: REPLACEABLE COMPONENTS

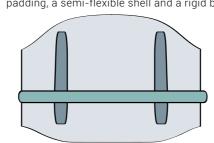
The design includes replaceable parts that allow the user to adjust to their preference and body.



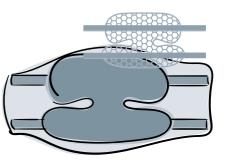
IDEA DIRECTION 3: COMBINATION BETWEEN RIGID & FLEXIBLE COMPONENTS TO CREATE LOCAL FLEXIBILITIES

Design introduces local flexibilities leading to decreased pressure points and increased freedom of movement.



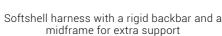


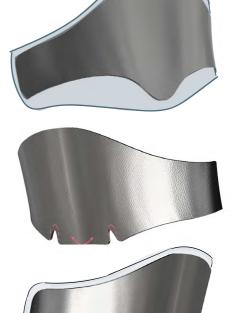
Overmolding - rigid inner frame in a certain shape/pattern



Cutouts in the sides of the hardshell



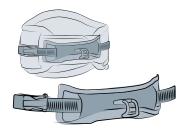




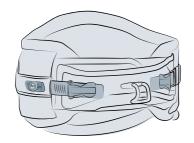
Cutouts n the shell lead to local flexibilities

IDEA DIRECTION 4: THE CONNECTION BETWEEN THE HARNESS AND THE SPREADERBAR

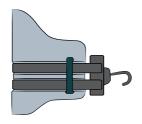
The design consists of a trimming and/or closure system.



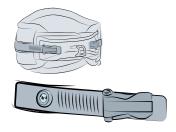
rigid ratcheting goes through entire spreaderbar



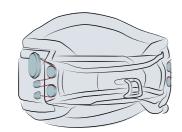
Permanent connection with screws and ratchet on both sides.



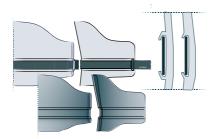
Two webbings go over the entire backplate



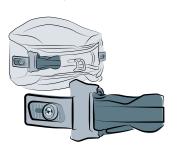
Rigid straps between harness and spreaderbar and levers on both sides of the spreaderbar



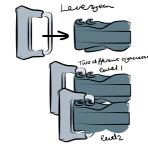
Circular ratcheting system (inspired by snowboarding boots)



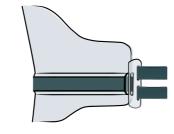
Singular webbing goes over entire backplate - extra rigid webbing



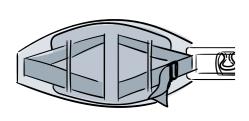
Permanent connection between the harness and the spreaderbar (connected with screws) + a lever similar to current design.



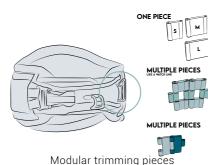
Lever system with different tightnesses possible



Singular webbing goes over entire backplate



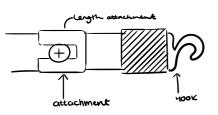
ons webbing goes back and forth over the entire back of the harness



Inspired by a watch



webbing goes through the backplate



Semi-permanent attachment



Due to attachment method the harness is pressured onto the body

APPENDIX T

CONCEPTS DESCRIPTION, DRAWINGS, PROTOTYPES, UALO

CONCEPT 1:

Description

This design consists of a backplate that adapts to the torso-width of the user.

In the research done using crosssections was found that the posterior shape of the torso is very alike between persons of the same size but persons of different sizes also had very similar posterior shapes of the torso. By substituting the original backplate consisting of one piece with a backplate consisting of 3 pieces this width can be adjusted to the preference of the user creating a harness with an improved fit. Leading to increased pressure distribution and less displacement of the harness during use.

Inspiration:

This same method for adjusting the width is used in braces to support the spine after a back operation.

RQ prototyping

Can a harness that can be adjusted in width, fit a large range of sizes?

Result research by design

A prototype was designed in solidworks using the research done on the cross-sections. The 3 parts were printed of which the shell width can be adjusted with screws. On the shells a EVA foam was glued to create the feeling of padding.

The prototype proved the design fits a size XS and M (male sizing) well by adapting the width to the bodies of both participants.

Iteration on the design after Prototype #1:

- The middle parts should be attached to one uniform padding so it's uniform and more comfortable on the torso
- The mechanism to change the size should be designed to be able to handle at least the 1000 N forces. Making the design from 3 parts decreases the strength from these pulling forces resulting in compressive forces on the design

Option: Harness design is modular through the use of multiple pieces

UALO

Unique

A hardshell harness that can be adjusted in width is new to the market.

Advantages

A harness with a better fit than an original hardshell harness

Sustainability: Design could be modular including replaceable parts

The forces of the kite are totally redirected to the backplate and no compressive forces come onto the user

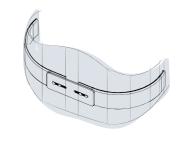
Limitations

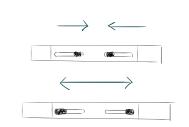
Design is more complex than the current design and might be more prone to break and be heavier

Overcoming limitations

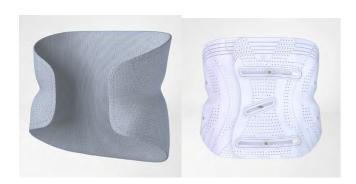
Create a lightweight design

Create a very rigid and strong construction





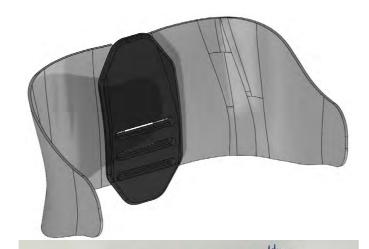
INSPIRATION

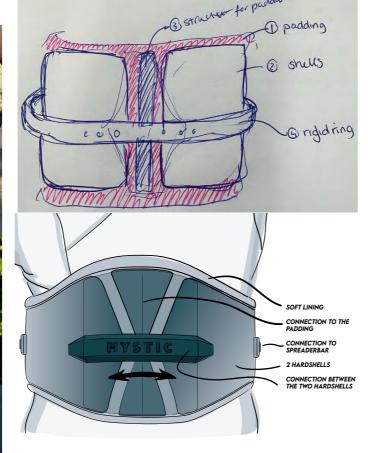


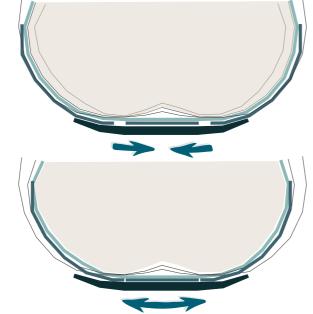
PROTOTYPE











CONCEPT 2:

Description

This design of a backplate consists of 3 different parts. These are attached at the side of the harness and can move compared to each other.

The angle of the two parts are changed and can be adapted to the user and to the movements of the user. This gives the hardshell harness some of the features fo a softshell harness while still having the support of a hardshell.

A hard outer shell is also used as connection between the spreaderbar and the shell.

There are different methods to adjust the angle of the highback. Option 2 and 3 come out as most fitting and are incorporated in the design where needed.

Inspiration

This design is a combination of a kitesurf harness and the mechanism to change the angles used in snowboard bindings

RQ

Do the parts move during movement? (if yes then how it's placed is the maximum and not a solid stance

Would it be needed to do one or both the high and low backplate?

Results

The prototype as can be found in the images on the right is a 6:10 prototype of a size M harness. The mechanism proved to work very well and shows much potential. The harness can be set on a maximum angle and the angle can decrease when the user goes from an extended to flexed posture. When moving into this flexed posture the surface area of the harness increased and moves with the stretching of the body.

UALO

Unique:

There are no harnesses on the market in which the angle of the lordosis can be changed - gives the hardshell the features of the softshell harness

Advantages:

The adaptable angle of the backplate gives the user more opportunity to tune their harness to their preferences.

The parts that can move can give more support during the different movements during kitesuring.

The ring around the harness gives high stiffness to the harness, relieving the moving parts.

The shell of the harness can be more flexible as the ring gives extra stiffness - leading to more freedom of movement for the kitesurfer.

The exact angles that are needed in the harness design can be adjusted easily by changing the location where the backplate is attached to the rigid ring. Giving much design freedom. (For example: More angle is wished in the lowback thus the location of attachement is moved more to the back giving the design more angel at the bottom

As the lowback and the highback atre two different parts different flexibility and stiffness can be designed into the shells. (For example more stiffness is needed in the highback thus a thicker shell is designed)

Design could be modular - user could replace parts with new or different shells

Limitations:

Moving parts can be problematic in a kitesurf harness that is used in sandy and salty conditions.

Overcoming limitations:

Create mechanisms that can handle the high forces and sun/salt/sand





CONCEPT 3:

Description

A harness design that combines a hardshell and a softshell design by stretching a soft lining in a rigid frame. Extra support is given to the kitesurfer at the lordosis with an adaptable "cushion". The angle and position can be adjusted to all body-types. All the parts are held together by a rigid ring, which also works as a distributor of the forces coming onto the user.

Inspiration

An office chair with adjustable support for the lordosis.

RQ

Would this kind of design potentially be used in the design of a kitesurf harness?

Results

The design proved to be very comfortable and spread the forces over the body well. Although the prototype raised questions if this would also be the case in high force situations and the surability of the harness. As the lining needs to be stretched accross the frame very tightly if this would become less tight over time the comfort of the harness would decrease. This might be a very good design for less high-force sports like wingfoiling.

UALO

Unique

Very unique design where the majority of the backplate is soft but due to being stretched around a framework. If hypothesis of design is correct no hard parts should touch the user.

Advantages

Hardshell is replaced by framework that shouldn't touch the user. Giving a softer experience to the kitesurfer. Creating the ultimate experience of a hybrid harness.

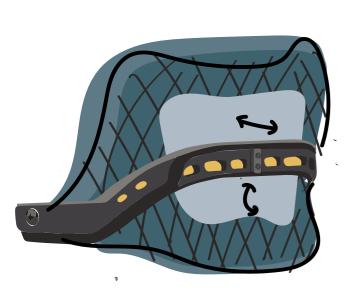
Limitations

What happens if the stretch of the lining decreases - will the effect of the harness change? Material lining might absorb much water.

Overcoming limitations

Is it possible to create a stretchy lining that is light and adsorbs no / very little water?

Use a material that doesn't lose it's tight stretch over time. New materials like Aluula could open doors to solutions like this (ALUULA Composites, 2023).









CONCEPT 4:

Description

Harness concept with adaptable semi-flexible backplates, which are attached to a rigid outer ring. These can be chosen in different shapes, and stiffnesses. This ring is in a H shape, giving it unidirectional bending behavior.

The padding is attached to the semi-flexible shells, an example for how this would look can be seen on the right.

Inspiration

The vast amount of backplate designs created during first ideation and prototyping - many worked and the quality of the outline was dependent on the shape of the user showing the need for a harness that can be adapted in shape

R(

Can the shell easily be replaced?

Results:

Testing the prototype showed how the user can easily adjust the harness to their own wishes and body. The use of so many screws might need to be reduced - If the shell can maybe be held into the frame by the shape of the two could prove to be a better design for a kitesurf harness.

UALO

Unique

User can modify the harness to their wishes. This modularity hasn't been seen in the kitesurfing industry.

Advantages

User can modify the harness to their wishes. Different shapes give a high freedom of movement or more support.

Should be very easy to change the backplates but once the perfect setup is found it doesn't require any maintenance or setting up before a session.

Top and bottom plate can be adjusted separately from each other. Also enabling the user to change the vertical position of the rigid ring compared to the body.

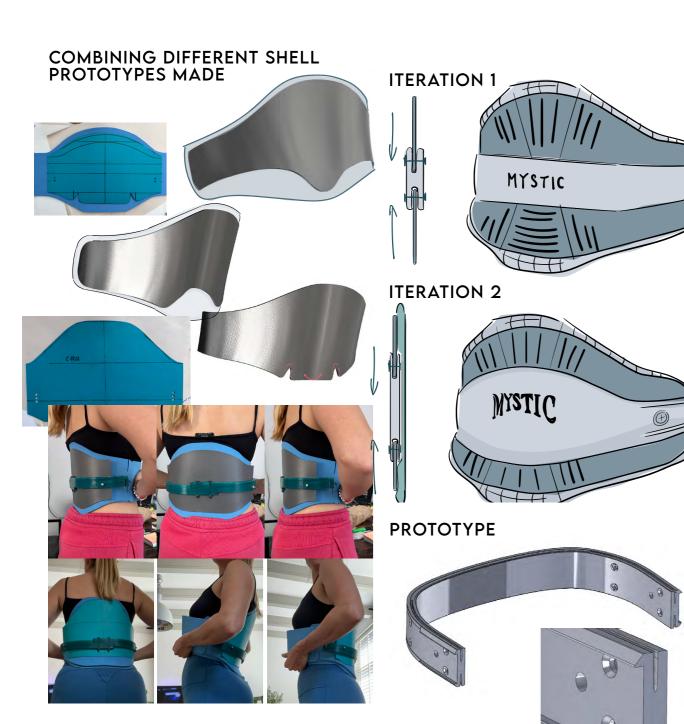
Limitations

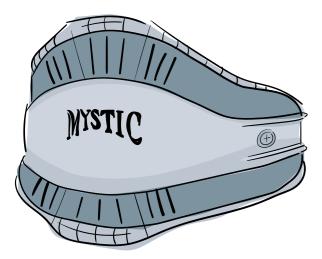
Many parts are needed and multiple screws

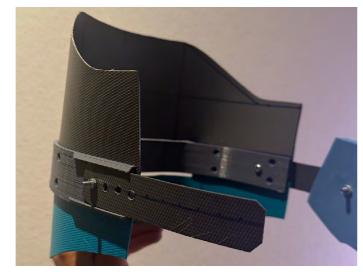
Overcoming limitations

Design the harness so that only one screw is needed per side - Combination for the connection to spreaderbar and the backplates









CONCEPT 5:

Description

A backplate with two large cutouts on the side and two rigid ratcheting systems. The harness has a inner soft lining attached to the backplate in the middle,

The backplate is pre-shaped. Due to the shape the flexibility between the top and the bottom is increased, giving the harness the correct angle for the user. The harness can also be tightened to the preferences of the user. As wider hips or upper torso might need a different shape.

RQ

Is this hardshell shape comfortable for a user of a kitesurf harness?

Results:

The shape proved to be a bit awkward on the body. Due to the smallest part of the torso being in between the two straps. The harness did fit around the body very well as it could be tightened with two straps.

Bending forward was very comfortable as the shaped allowed this movement. Bending backwards (extention) was not very comfortable as the harness is very rigid in this direction.

UALO

Unique

Although the harness distributes the forces like a hardshell harness it gives high freedom of movement to the user. Uniquely combining the properties of a hardshell and softshell harness.

Advantages

Could provide an improved fit for diversity of body types

Combining the properties of a hardshell and softshell harness. The harness can flex with the kitesurfer during a session.

Webbing can easily be eliminated in the design and replaced by the ratcheting system with gives more rigidity and can be adjusted when on the water

Limitations

The four ratchets or webbings needed for this design might lead to a chunky design.

The cutouts in the backplate could lead to decreased strength in the materials.

The design doesn't permit much flexion

Due to the natural shape of the human body having two parts to tighten the harness can prove difficult on certain body types.

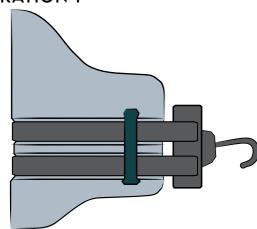
Overcoming limitations

The ratcheting system could be designed to be very sleek to overcome bulkiness of needed 4 parts

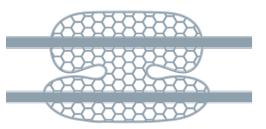
The material should be designed to overcome decreased strength due to the cutouts. This could be solved with multi-thickness.

The shell could be shaped thus that it permits the needed flexion.

ITERATION 1



ITERATION 2







PROTOTYPE













CONCEPT 6:

Description

Combining the design of concept 1 and the designs of harnesses with a rigid outer ring instead of a shell. This harness includes a ring that consists of 3 parts. The middle part being replaceable for parts in smaller and larger sizes, making this harness adaptable in width.

Inspiration

The design of a snowboard binding

UALO

Unique

This design uniquely provides a modular harness that can be adapted to the width of the user.

Advantages

A harness that fits the user better than an original hardshell harness

One harness can be designed for multiple sizes.

Sustainability: Design is modular including replaceable parts

The forces of the kite are totally redirected to the backplate and no compressive forces come onto the user

Limitations

Extra parts are needed which can be difficult for dealers/importers/clients

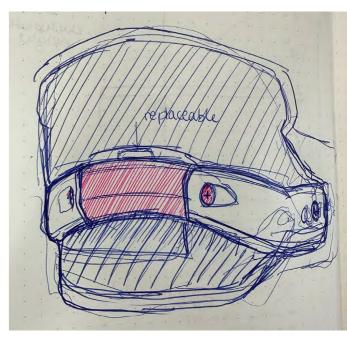
Limitations

Extra parts are needed which can be difficult for the dealer and resale agents.

INSPIRATION



DESIGN



CONCEPT 7:

Description

This concept aims for a modular design that can easily be attached to each other without the use of many screws/ mechanical parts. Creating a very simple but effective design.

RQ

Can a harness be created from 3 parts that can be connected to each other without the use of screws?

Results

The prototype shows the unique design, the design can easily be assembled. The prototype did show the weak point of the bends that keep everything together. They remind of the belt loops of jeans. If the kitesurfer were to pull very hard on them or get caught on sharp edges this could be a part where the design fails.

Due to the modular nature of the design this parts could be easily replaced though.

UALO

Unique

This design uniquely shows how a modular design could be produced.

Advantages

All the parts are easy to replace and are not connected with screw parts which can prove to be an advantage in the situation where the harness is used. The water/sun/salt/sand will not effect this harness at all.

Different ring, backplates and lining can be sold - giving the user the opportunity to customize their harness to their wishes.

Limitations:

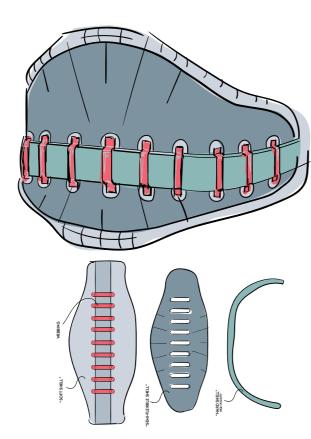
Extra parts are needed which can be difficult for dealers/importers/clients

Overcoming limitations

Make modular parts cheap

Limit the amount of parts

Modular parts are of use to multiple sizes and genders. For example a certain backplate can be used on a size M, L and XL ring.



PROTOTYPE



CONCEPT 8:

Description

This concept aims for a modular design that is attached to each other through screws. The design consists of 3 parts: A rigid back-bar, a semi-flexible shell and a padding. The combination of these three parts creates a harness in which less discomfort is found during movement due to a smaller part of the harness being very stiff. (which can't be found on the rims of the harness)

RQ

How does the shape of a semi-flexible backplate influence the user comfort?

Results

The prototype made consists of many modular semi-shells and paddings. One rigid backbar is used to test the different shapes. The design proved to be very simple to assemble.

Showing the easy to personalise the harness to the needs and preferences of the user.

UALO

Unique

This design uniquely shows how a modular design could be produced.

This design combined softshell and hardshelll

Advantages

All the parts are easy to replace and are not connected with screw parts which can prove to be an advantage in the situation where the harness is used. The water/sun/salt/sand will not effect this harness at all.

Different ring, backplates and lining can be sold - giving the user the opportunity to customize their harness to their wishes.

Limitations:

Extra parts are needed which can be difficult for dealers/importers/clients

Overcoming limitations

Make modular parts cheap

Limit the amount of parts

Modular parts are of use to multiple sizes and genders. For example a certain backplate can be used on a size M, L and XL ring.



SPREADERBAR CONCEPT 1:

This concept consists of a connection, closure & trimming system for the spreaderbar and harness. The system consists of two ratchets with a coated webbing with texture, this coating gives the webbing more rigidity. Examples of this coated webbing can be found in the images below.

The webbing is attached to the harness through the shape of the backplate, the webbing can be placed into this shape of the backplate as in the prototype shown in the image below. This webbing can also be replaced with a longer or shorter one for more customization to the size of the user.

Due to the ratcheting system with webbing with texture the harness can be tightened extra when on the water.

Due to the shape of "rail" where the webbing lies in it can't change of angle. Making sure the spreaderbar doesn't give pressure on the ribs of the user.

UALO

Unique:

The ratcheting system replacing the normal webbing

Advantages:

Harness can be tightened when the harness is in use (on the water)

The rigid webbing doesn't absorb water or stretch during use -

No bulky webbing on the side (cleaner look)

Limitations:

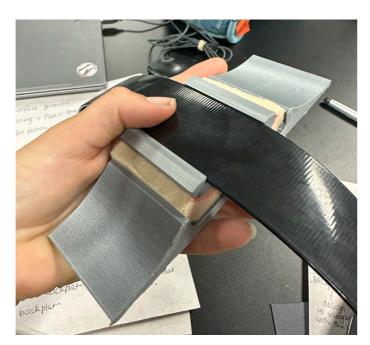
Two ratchets can lead to a bulky design

The selling of extra parts can be frustrating to users and dealers

Overcoming imitations:

Reducing the design from two to one ratchet

SUNMOLIN®



SPREADERBAR CONCEPT 2:

This concept consists of a connection, closure & trimming system for the spreaderbar and harness. The system consists of two ratchets with a solid strap as trimming system. The texture on the strap let's the rider use the strap to tighten the harness during use.

The strap is attached to the harness by feeding it into the side of the harness. The length of the webbing can be adjusted with a screwdriver - making sure there are no bulky long straps on the harness. Contributing to the clean look of the harness.

Like concept 1 the shape of a "rail" keeps the strap in place. Making sure the spreaderbar doesn't give pressure on the ribs of the user.

UALO

Unique

The ratcheting system is unique and by letting the "straps" disapear inside the harness the design gets a clean look and no excess webbing can be seen.

Advantages:

Harness can be tightened extra on the water

No bulky webbing on the side

The webbing can be shortened by letting it disapear into the harness design and tightening it with a screw

Limitations:

Two ratchets can lead to a bulky design

By attaching the webbing with one screw it is a higher risk of breaking or slipping in very high force situations.

Overcoming limitations:

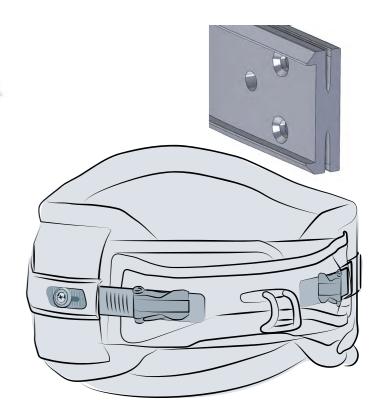
Reducing the amount of ratchets

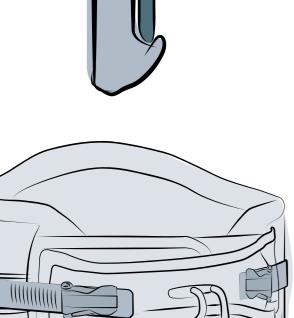
Adjusting the design to multiple screws











SPREADERBAR CONCEPT 3:

The system consists of a solid strap (textured) that goes through the spreaderbar leading to the need of only one ratchet.

The straps length can be adjusted on the side of the harness (other side from th ratchet).

The strap can move through the spreaderbar and due to the texture on the strap, when the harness is tightened it stays in place.

It is of the essence that the ratchet is very trustworthy, has enough flush (water washing sand and other dirt away) and is as flat as possible.

UALO

Unique

The use of a ratcheting system in combination with the webbing going through the spreaderbar is unique.

Advantages:

Harness can be tightened extra on the water No bulky webbing on the side

No `bulkiness of having two ratchets

Limitations:

The webbing going through the spreaderbar can lead to unwanted movement between the components

Overcoming imitations:

The unwanted movements can be overcome by using a very wide or rigid webbing.

SPREADERBAR CONCEPT 4:

A spreaderbar with a lever also used on the current Mystic harnesses. This is used in combination with rigid webbing attached to the harness with screws, the length of these can be adjusted with this mechanism.

UALO

Unique

The cleanliness of this design is unique as it is very slim and has no extra parts or lengths hanging around.

Advantages:

The closure system, The mystic lever, is a proven system

Very little webbing is needed due to the setup of the system - leading to a very clean design

Limitations

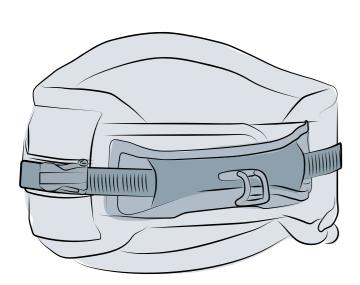
Very little trimming is possible on the beach and no trimming is possible on the water as the system must be trimmed with a screwdriver.

The system reliability relies on the screws on the sides, if htese fail or slip this could lead to dangerous situations.

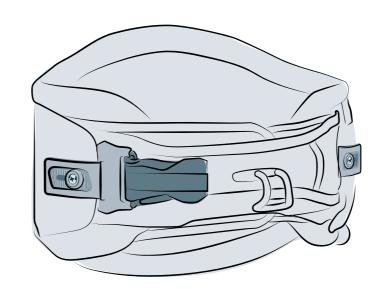
Overcoming limitations

The original lever system could be adjusted to facilitate more trimming through the lever (larger lever)

The reliability of the system could be increased by adding an extra screw to both sides of the system









APPENDIX U RESEARCH BY DESIGN - PROTOTYPING

