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PRODUCT DEVELOPMENT OF EQUESTRIAN COMPETITION BREECHES

RATSANIKU VÕISTLUSPÜKSTE TOOTEARENDUS

MASTER THESIS

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2. Conducting client-oriented research to determine main disadvantages of the products currently available.
3. Testing different materials that could fulfill the requirements of equestrian competition breeches.
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INTRODUCTION

White competition breeches are an integral part of equestrian sport that has its roots going back centuries. Although over time equestrian sport and clothing has evolved immensely, wearing white colored riding pants is still a requirement when competing to this day. Nowadays the fabrics used for breeches have evolved from natural fibers like cotton, silk and linen to high-performing technical fabrics made from synthetic fibers. At first glance white breeches can look like regular clothing, but after further inspection of the materials used it is undeniable, that the product construction and purpose is much more complex. Breeches have many similarities to common sportswear. Materials and patterns are combined in a way to improve performance and support the user's activity just like in any other sport. Horse riding is a unique sport that has a lot of factors that also influence product development of breeches. The main aspects of equestrian sportswear are understanding the rider's needs, the activities performed and the overall environment where the products are worn.

The main aim of this thesis is to develop white competition breeches that satisfy customer needs and are better than currently available products. The product minimum requirements were established based on data obtained from the customer research questionnaire. For this goal multiple different materials were tested in laboratory conditions in means of mimicking the equestrian environment. Best possible fabric was selected, and one pair of breeches was sewn. To confirm the material's quality in real life environment wear tests were performed.

This thesis is divided into two parts that total in 11 chapters. The theoretical part gives an overview of the historical background of the breeches, the environment in which the product is used and different rules that dictate the competition wear. The materials currently used for breeches and pattern technologies are also analyzed.

The practical part of the thesis is divided into two. The first part concentrates on testing the materials in the laboratory conditions. The laboratory tests are conducted on 5 different fabrics in means of finding the most suitable fabric for breeches production. The tests are chosen to imitate the natural environment where breeches are used as much as possible. The second part gives an overview of the product development processes. It includes product pattern design details, technological card, the sewing process and overview of the used machinery. This is followed by describing the performed wear tests on the finished product.

The practical part of the thesis is finished by the final chapter, which concludes and discusses all results gathered throughout this thesis.

1 EQUESTRIAN SPORT

The relationship between horses and humans dates back thousands of years. The greatest preponderance of prehistoric horse cave art appeared between 15,000 and 12,000 BC. 6000 years ago, the horse became domesticated, giving a new approach to the world. The horse's speed and power helped to increase man's mobility and played a significant role in the transfer of language, culture, and technology. [1]

Using horses for sport, where the importance is based on the outcome became popular in the 20th century. [3] Modern day equestrianism is one of the most popular sports enjoyed all over the world. In every discipline, the heritage is rich, and its practices are rooted in tradition. When thinking back to the origins of the equestrian sport, it is possible to trace a line of progression in common riding-related customs throughout the centuries. [2] More than in any other sport, these customs are related to military practices and cultural history. Many of those practices are still applied to the sport today. [3]

Equestrianism is divided into multiple disciplines. Some are Olympic Sports and other more informal disciplines. The two main divisions are English style disciplines, which in turn are divided into:

- dressage;
- para-equestrian dressage;
- show jumping;
- cross country;
- eventing.

And Western style riding disciplines, which are divided into:

- western dressage;
- reining;
- barrel racing.

Other disciplines include polo, horse ball, driving, flat racing, harness racing, skijoring, endurance and vaulting. [4]

1.1 Competitions

It is important to explore these disciplines to identify the environment to which the rider is exposed to. In this thesis the discussion will revolve around equestrian sports

that are current Olympic disciplines. Equestrian sports were first added to the Olympic program in 1900 Summer Olympics in Paris, France. [5] But the 1912 Olympics in Stockholm, Sweden is considered the landmark event in the world of equestrian sport, where horses and riders competed to perform a "military test". The test combined aspects of all three riding disciplines that are still practiced today: show jumping, dressage and eventing. [2]

1.1.1 Dressage

Traditions of dressage go as far back as Ancient Greece. Dressage is the highest expression of horse training. It's the art of the equestrian sport and is used as groundwork for all other disciplines. Dressage developed as a training method to achieve complete cooperation between the horse and the rider. [5]

1.1.2 Show jumping

Show jumping roots also date back in history to around 18th century. The discipline, as we know it today developed as a result of competition among fox hunters in English countryside. During the 20th century, jumping was dominated by the military, as the horse's ability to jump was a desired trait. [5]

1.1.3 Eventing

Eventing is the most combined discipline that puts to test the experience of the horse and the rider in all branches of equitation. It is the most demanding, since it combines dressage, jumping and a cross-country course on mixed terrain into all one competition. [5]

All three of these events require a formal attire to be worn by the riders including white breeches. Exact rules, regulations and requirements will be discussed in chapters below.

2 COMPETITION DRESS

When developing a product, understanding the environment in which it is used is important. It is also important to understand in detail how the product is used and what is required of it. A horseback rider is an athlete that must do a lot of physical exercise during training and competing. [15] This includes sweating and movement. Almost like in any other sport, the clothing that is worn during the activity must be in correspondence with the exercise.

Looking at equestrian dress, it does not resemble a standard outfit of an athlete and can be perceived even as not sporty. Like the sport itself, the dress that competition riders wear is strongly tied to traditional military and hunting attire. Equestrian competition dress requirements have remained relatively unchanged for a century. [16] It has very visible differences compared to any other Olympic sport. Although the appearance has remained largely unaffected design wise, there have been technological innovations in terms of fabrics and patterns used. Even equestrian sporting attire must be functional, performance maximizing, comfortable and aesthetically pleasing while still maintaining the traditional appearance of formality. It is a complex mix of tradition and modernity.

2.1 Rules and regulations

The combined influence of the military and hunting has led to formal standards of dress in the equestrian disciplines of dressage, jumping and eventing. The purpose of the equestrian competition attire is mainly to display elegance and dignity while also enabling the rider to move with the horse and perform physical activity without getting in the way. [16]

Equestrian competition dress is dictated by the rules and regulations of the corresponding sports organizations. The International Equestrian Federation is responsible for creating internationally approved rules and qualification systems that are essential to the integrity of the competition. They oversee the Olympic disciplines of jumping, dressage and eventing. [17] Competition dress for these disciplines also has a strict guideline. All three disciplines share the same rules about competition dress, which read as follows [6][7][8]:

- Athletes are required to wear correct dress when appearing before spectators.
- Dress must be neat and tidy.

- A rider must wear a competition jacket
- White or light fawn breeches or jodhpurs are allowed
- Boots must be black or brown
- Shirts must have a long or short sleeve and must have a white-collar, long-sleeved shirts must have white cuffs
- A white tie or choker must be worn
- Competition jackets may be any color and must have outward facing buttons.
- Jackets without a collar are allowed providing the shirt collar and tie are visible when the jacket is closed.

An example of a show jumping competition dress can be seen below (Figure 2.1).



Figure 2.1 Classical show jumping competition attire as seen in the Tokyo Olympics 2020. [18]

2.2 Understanding the rider and the environment

Equestrian sports usually requires the rider to maintain best possible contact with the horse throughout the time spent in the saddle. This means that usually the clothing riders wear is skin-tight, leaving minimal fabric barrier between the saddle and the rider

or reigns and hands. This is one of the reasons why breeches are designed to be close fitted – it helps the rider to achieve better feel and contact with the horse’s movements. This also reduces any abrasion that loose clothing might cause during riding. The breeches used in training and in competing are usually made from a very stretch fabric that maximizes comfort during movement.

Breeches are also supposed to fit comfortably into very tight, knee-high leather boots, so elastic and tight pant material helps to wear boots more comfortably. In some ways, breeches are like training leggings made for yoga or gym, but are usually made from thicker and abrasion resistant fabric, due to the environment that they are used in. [19]

2.2.1 Outdoor conditions

Equestrian competitions are held both outdoors and indoors, depending on the season and location in which the competition is held. In Europe, outdoor competitions usually start from late spring and end during early autumn.

Outdoor show jumping and dressage competitions are usually held on a grass or sand arenas with no roofing. [6][7][8] In case of an accident, the rider falls directly on the sand or grass footing. Examples of grass and sand arena can be seen on images below (Figure 2.2.1)



Figure 2.2.1 An example of a competition held in outdoor grass and sand arena. [9][10]

Eventing competitions can be held on mixed terrain, consisting of sand, grass, water jumps and terrain occurring naturally at countryside. [6] In case of an accident, the rider might fall on sand, mud, grass or directly into water. An example of a classic cross-country exercise can be seen on the image below (Figure 2.2.2). Additionally, the horse and the rider are not protected from weather conditions and are directly exposed to sun, rain and wind. This can result in wet clothing, that is much easier to stain and stains

that are prone to happen only during wet conditions. Competitions are usually never delayed because of rain, unless extreme weather conditions, like flooding or lightning storm occur. [6][7][8]



Figure 2.2.2 An example of an eventing competition cross-country trail [11]

2.2.2 Indoor conditions

Indoor competitions can be held all year round, but the most active indoor season is held from late autumn to early spring. Indoor competitions usually have a less extreme environment. The footing is made of sand and the arena itself has a roof and walls around it. It is warm and protected from different weather conditions like rain, wind, snow, sun, etc. In case of an accident, the rider falls directly on to sand.

2.2.3 Stable environment and equipment

Apart from the competitions held in indoor or outdoor arenas, there are other environments that surround the rider and the horse. One of them is the stable environment. Most of the time is spent there during the competition. This is the area where the horse resides when it is resting before or after the competition or in between showings. Stables can be built as outdoor or indoor stables (depending on the location). The common rule is to keep the stables always clean. Yet dust, hay, horsehair, wood shavings, mud from paddocks, sand from the arena are still present and inevitable in almost every stable. It is possible to get dirty by accident at almost any time, when dealing with horses. These environmental factors are mostly indirect.

There are also direct factors that are in immediate contact with the rider and must be taken into consideration as the environment in which the rider is spending time. These factors are direct contact with the horse and riding equipment. In all Olympic equestrian disciplines, it is required that the horse wears a saddle and a bridle during competitions. [7][8][9] Saddles are usually made from black or brown leather and must be regularly conditioned in order to maintain their longevity and natural characteristics. [12]

2.2.4 Regular competition day

A regular competition day is similar whether it is held outdoors or indoors. A jumping or a dressage competition does not have many differences apart from the discipline itself. Many arenas and stables can host both jumping and dressage competitions, so the environment remains mostly the same. Eventing usually occurs over a course of two to three days, but lower-level classes can also be held over the course of one day. [62]

The focus of each competition day is the horse, and its wellness must always come before anything else. Depending on where the competition is held and whether it is possible to change clothes at the destination, the rider usually wears competition wear already at the start of the day. Sometimes riders wear sweatpants over competition breeches when cleaning the horse. This protects breeches from being exposed to the elements that could dirty them. Yet the white color of competition breeches is much more delicate and even the slightest stains are immediately visible. The time spent in white breeches during a competition varies from rider to rider, depending on the number of horses they are competing with and the competition schedule. [63][64]

In case of an emergency, there is often no immediate possibility to wash the stained clothing which results to the stain setting. This can happen due to many reasons. The main reason is that the wellness of a horse comes before everything else. If rider, for example, falls off a horse during a competition and assuming there are no serious injuries, the rider will have to get back on the horse to finish the rider properly. This includes a 10-15 -minute cool down session in the saddle and additionally up to 30-minute session of walking the horse. [63]

Then there is a considerable amount of time that it takes to take off all the tack from the horse, brush it, give it water, feed if necessary. This means that more than an hour might have passed since obtaining the stain. In good weather and considering that the stained fabric is against human skin, which is 36-37C°, the stain will set quickly. If the

rider is only competing with one horse and in one class, then the day is over and change of clothes is allowed, if possible, on site of the competition. Considering if it is an outdoor competition then changing clothes immediately is not always possible. This means that a lot of time is spent on packing the equipment, loading the horse on a trailer and the journey back to the home stable. This adds a couple of more hours until it is possible to get out of stained clothes. If the rider is riding in multiple classes or competing with multiple horses, then the time spent at a competition extends from 2 hours up to 6 or even 8 hours in total. The length of a competition also depends a lot on the number of participants, how well it is organized, and breaks included in the schedule.

Different weather conditions also affect how the rider looks and feels throughout the day. In case of rain during outdoor conditions, the competition is not paused, and entire attire can get wet. This can result in even more staining. An example of competitions occurring during rain can be seen on the image below (Figure 2.2.4)



Figure 2.2.4 Competitions are not paused during rain. [33]

2.2.5 The most common stains

In the equestrian world, stains are a very common problem. During everyday training period, equestrians usually wear clothing in dark or earth toned colors so that the most common stains are not visible. During competitions, the riding environment stays mostly the same, except that the rider must wear white breeches where any type of stain is very profound. The table below shows the most common stains that a rider encounters in the environment where white breeches are worn (Table 2.2.5).

Table 2.2.5 The most common stains found in equestrian environment.

Environment	Stain	Type
Stable	Dust	Combined stain
	Hay	Protein stain
Arena	Grass	Protein stain
	Sand (including clay)	Protein stain
	Mud	Protein stain
Horse	Horsehair	Oil-based stain
	Sweat	Protein stain
	Sebum	Oil-based stain
	Saliva (foaming from the mouth can be accompanied by residue from apples and carrots)	Protein stain Tannin stain
Equipment	Leather soap	Combined stain
	Leather balm	Oil-based stain
	Leather colorant	Dye stain

The most common placement for a stain is around the knee area, inner leg and seating area. These are usually stains caused by equipment and products that are used to condition the equipment. Quality dressage, jumping and eventing saddles are usually made from leather. Leather products are almost always dyed. Materials used for leather dyeing are usually acid dyes, direct dyes, mordant dyes and reactive dyes. [28]

The saddle where the rider sits is usually made from black or brown leather and in some instances can stain clothes. For example, when moisture is introduced, leather can give off some color. [28] That in turn seeps into the breeches that are in direct contact with the saddle. Moisture can come from bad weather conditions like rain but also from the rider sweating during exercise. In case of an accident where the rider falls off a horse, staining can happen in other areas as well. Examples of most common stains can be found in Appendix 1. (A1)



Figure 2.2.5 USA Olympic dressage team. There is evident staining from the saddle in the knee and seat area after competition. [33]

Identifying the stain is important so to not damage the fabric when trying to remove it. Choosing a wrong removal method can set the stain permanently. Stains should be removed as soon as possible, as ageing and heat can set in stains and make them even harder to remove.

2.2.6 Understanding the wearer

When developing a product, understanding the environment in which it is used is important. It is also important to understand in detail how the product is used and what is required of it. A horseback rider is an athlete that must do a lot of physical exercise during training and competing. This includes sweating and movement. Almost like in any other sport, the clothing that is worn during the activity must be in correspondence with the exercise. For the wearer to be comfortable, breeches must support the activity

and have the necessary qualities. Examples of regular activities performed by the rider can be seen on the image below (Figure 2.2.6)



Figure 2.2.6 Breeches must support and not hinder any activity that is required from the rider. [27]

It is important that breeches do not restrict any movement. There is a lot of lower body movement involved when riding, starting from mounting the horse to hours spent in the saddle Breeches need to feel like leggings that are in close contact with the skin and have a certain amount of stretch that does not impede any movement. Riding pants should be tight to protect the rider's leg from rubbing in the saddle and causing sores. During jumping and eventing the rider's range of movement becomes bigger. Most movement occurs around the hip area, as during each jump the hips move back to aid the horse in clearing the obstacle (Figure 2.2.7). [13]



Figure 2.2.7 An example of the rider's movement when clearing an obstacle. [14]

3 COMMON MATERIALS AND PATTERNS USED FOR BREECHES

Breeches can be made from different fabrics, usually a combination of natural fibers mixed with synthetic fibers, for example a cotton and polyester and elastane blend fabric, or full synthetic fabrics like polyester and polyamide. There is usually a percentage of elastane added for achieving extra elasticity. Knitted fabrics are the most common choice, because of their 4-way stretch.

For achieving extra grip in the saddle, suede used to be added to the parts where breeches are in full contact with the saddle (inner thighs and bottom). Leather adds an extra layer to the pants, which might make breeches less breathable, therefore nowadays an alternative is used – silicone grips. Silicone grips are made in different colors and are positioned usually starting from the inner knee area up to the seat area, where the contact with the saddle is biggest. Silicone grips are positioned as small details situated close to each other, but far enough that there remains enough breathability to the fabric. [22]

The part of the breeches that must be fit into the boots is often made from a different material than the main fabric. Therefore thinner, more comfortable fabric is used to fit better in boots. This design is widely used by different brands, as it most likely helps to save fabric cost while not compromising wearer's comfort.

3.1 Fibre content

Nowadays the world is no longer limited to only natural fibers like cotton, flax, wool and silk. With the innovation of synthetic fibers like polyamide, polyester, viscose or elastane, natural fibers are not always the best option available, this of course depends on the product end-use. [20] It is important to keep in mind the needs for the body in relation to the demands of the sport, that help in providing a focus for selecting a suitable mix of fiber and yarn properties. [21] The goal for not only equestrian breeches but for a modern sports clothing is to provide maximum performance that is in balance with minimum weight while also being durable and comfortable to wear.

3.1.1 Polyamide properties

Polyester and polyamide are considered as the most used fibres in sportswear, but other fibres like elastane are also used, since they can be altered depending on the product needs.

Polyamide, commercially known as nylon is a synthetic fibre, that contributes to protective outerwear, insulating mid-layers, base layer and underwear as well as footwear and accessories. [21] Equestrian riding breeches can be considered as a midlayer or almost as a base layer, due to its tight-fitting design, elasticity and comfort the product needs to provide the wearer. [21]

Synthetic fibres, including polyamide are made through spinning techniques, like wet spinning, dry spinning or through newer techniques like gel spinning or microfiber spinning. This makes it possible to produce fibres, yarns and fabrics that have unique performance characteristics making them suitable to use in sports and activewear. [20]

Fibre producers create different variations of polyamide and other synthetic fibres in the extrusion process, by altering the shape of the spinneret holes. This helps to produce multi-channel filaments in a variety of shapes. [21] These developments in the fibre production make it possible to produce high-tech materials that correspond to consumer requirements of aesthetics, design and function.

It is recommended that sports fabrics that are in direct and close contact with skin are made from fibres and yarn combinations that wick perspiration away from the skin to prevent chilling, especially when stationary. Moving moisture away from the skin and maintaining a dry microclimate is important, as damp clothing layers that are in direct contact with skin cool quickly, become uncomfortable and may cause postexercise chill. Polyester tends to have better moisture wicking properties, but polyamide is more abrasion resistant, which is another important requirement for breeches. It should also be noted, that although human perspiration is individual, it is usually a bigger problem on the upper part of the body rather than perspiration through lower part of the body. Thus, in this case, the ability to be abrasion resistant outweighs the fabric moisture wicking abilities. [21]

Polyamides have distinct advantages favourable both to manufacturers and users. [23] Polyamides are though, strong and durable fibres that are useful in a wide range of textile applications.

The main characteristics of polyamide fabrics are [21][23]:

- tear and abrasion resistant;
- low absorption capability;
- fast drying;
- no loss of solidity in a wet condition;
- crease free;
- rot and seawater proof;
- good thermal resistance;
- good resistance to chemicals, oils and fats.
- partly hydrophilic in nature;

The spectacular balance of elasticity and resilience that polyamides have provide a high level of dimensional and structural stability. These characteristics are evident in some of the products like women's hosiery, sportswear and automotive timing belts for example, which are often made of polyamide. [23]

Polyamide also has negative qualities, for example when exposed to UV radiation over a long period of time, a photo-oxidative degradation process begins, which results in material loss of strength. To combat this problem suitable UV stabilizers are frequently used to minimize the degradation process. [21]

3.1.2 Viscose properties

Viscose, also known commercially as rayon, is a man-made semi-synthetic fibre made from wood pulp cellulose. The manufacturing process of viscose includes dissolving the wood into a pulp solution, which is washed, cleaned and bleached. Then the solution undergoes treatment to create fibres. These fibres are then spun into yarns. [65][66]

Viscose is generally soft and comfortable, with great draping properties. Viscose characteristics can be modified depending on the processing, additives and finishes that are applied to the fabric. [67]

Although viscose is very absorbent it is not always a bad characteristic. In sportswear, viscose absorbs perspiration and allows it to evaporate from the skin. For this reason, viscose is a popular option for summer fabric. Material absorbency also allows it to be easily dyed. [67]

The main characteristics of viscose are [65][66]:

- lightweight;
- breathability;
- absorbency;
- durability;
- does not trap heat;

Viscose is not very resistant to abrasion due to having inelastic fibres. It also loses strength when wet, which might result in stretching out of the fabric and shrinking. These are some of the reasons why viscose is often blended with other fibres. Adding viscose to some other fabric blends will help in achieving softness and breathability.

3.1.3 Elastane properties

It is not common that a yarn made 100% of one type of fibre is able to accomplish all customer needs. All fibres have good qualities and poor qualities, it all depends on what is the final expectation of the product. Fibre blending is a way to combine fibres so that good qualities are emphasized, and poor qualities minimized.

Although blending might be carried out at any stage before the spinning operation, it is best to blend the fibres as early as possible in the processing stage, as this assures the best blend possible. There are many reasons why blending the fibres is carried out – for colour effects, for improving the texture, to change or alter fabric appearance, handle or improve performance. [21]

Simple body movements like bending the elbows or knees stretches the skin by as much as 50%. [20]. Movements with more effort that are involved in active sports including equestrian sports require even more stretch. If there is a dramatic difference between the skin's elasticity and the lack of elasticity in conventional fabrics, restriction of movement to the wearer can occur. In addition, garments lose shape and consequent performance. [20]

Elasticity or in other words ease of movement is a desired fabric property for breeches and sportswear overall. Fabrics that stretch enhance comfort, fit and the ease of putting on and taking off the clothing. Stretch can also help in providing good shape retention.

If the stretch is high power elastomeric, it can also provide a valuable supportive function, for example provide muscular support.

There are three types of stretch yarns [21]:

1. 'Elastomeric' are those where elastic recovery is a fiber property. Although elastomers may be used on their own, they are often covered with a nonelastic yarn such as polyamide or polyester.
2. Crepe or 'over spun' yarns are those where the high degree of twist in the spinning process makes the yarn pull back on itself.
3. Texturized yarns are those whereby a false twist is manufactured during the production of synthetic yarns. Other materials have highly elastic properties, e.g., special polyesters such as polybutylene terephthalate (PBT). These materials are used in swimwear, support garments such as athletics garments, skiwear, leotards and increasingly in comfort stretch general clothing. PBT is less susceptible to degeneration in chlorine or sunlight, which could also be a useful quality in breeches and equestrian sports overall, as the clothes are often worn outdoors and in direct sunlight. [21]

Elastane yarns contribute significant elastic properties to all types of fabric: circular knits, warp knits, flat knits, wovens and nonwovens. Elastane yarn's main function is to provide controlled stretch and recovery characteristics that enhance all fabrics and garments, adding comfort, freedom of movement and provide a lasting shape retention.

Good fabric recovery means sportswear garments provide a longer lasting fit, keep their body-hugging shape throughout constant wear and regular washings. Properly lasting fit also eliminates chafing and reduces drag. [23] Even a small amount of an elastomer can enhance fabric elasticity. The fabric end-use determines how much elastane is needed, but as little as 2% elastane is enough to improve fabric's elasticity and shape retention. It is recommended to use as much as 30% of elastane for high-performance garments, such as active sportswear including equestrian sports. [23]

3.1.4 Use of elastane together with other materials

It is not common that a yarn made 100% of one type of fibre is able to accomplish all customer needs. All fibres have good qualities and poor qualities, it all depends on what is the final expectation of the product. Fibre blending is a way to combine fibres so that good qualities are emphasized, and poor qualities minimized.

Although blending might be carried out at any stage before the spinning operation, it is best to blend the fibres as early as possible in the processing stage, as this assures the best blend possible. There are many reasons why blending the fibres is carried out – for colour effects, for improving the texture, to change or alter fabric appearance, handle or improve performance. Special categories of blended yarn have been developed to exploit fibre characteristics. [21]

Simple body movements like bending the elbows or knees stretches the skin by as much as 50%. [38]. Movements with more effort that are involved in active sports including equestrian sports require even more stretch. The figure below shows just how much some of the body's key stretch points stretch the skin around the area (Figure 3.1.3). If there is a dramatic difference between the skin's elasticity and the lack of elasticity in conventional fabrics, restriction of movement to the wearer can occur. In addition, garments lose shape and consequent performance. [38]



Figure 3.1.3 Key stretch points on the body that are important considering the product end use. [39]

In this case elastane is not used alone but blended with polyamide or other materials, the appearance, care label instructions and thermal characteristics of a fabric are dependent on the dominant fibres in the fabric. [38]

3.2 Fabric construction

Sportswear fabric is usually made from lightweight warp and weft knits. They provide ease of movement and stretch through their stitch construction and thus fit like a second skin. Weft knit fabrics are relatively voluminous and open in construction and through that they are air and water permeable providing good insulating properties as well as breathability. Weft knits are a popular choice in intimate apparel, base layer garments, swim wear, cycling wear, team wear as well as in open mesh garments, linings and

fleeces. Weft knits offer a better stretch around the body and warp knits provide a better, more stable support. [21]

Woven fabrics are generally strong, relatively rigid, and hardwearing and tend to be used for outer layer sports garments. [21] Breeches are usually made from both knitted and woven fabrics, but knitted materials are more common. With knitted fabrics it is easier to achieve a 4-way stretch but woven fabrics can provide more overall support.

3.3 Patterns and styles

Inspired from the deeply rooted traditions and influenced by regulations, breeches style can be described as classical and not sporty. Although some traditional features have been replaced by the advancements of modern technologies, the overall design remains mostly unchanged.

There are multiple style options to breeches that come down to the rider's own preferences. Breeches are identified by their waistband, that usually has a zipper and button fastening. Belt loops are also a common feature, because breeches are often worn with a belt. High, medium and low waisted options are available, but high waisted breeches are more popular, since they tend to provide more comfortable fit. [22]

For achieving extra grip in the saddle, leather imitation or suede material can be added to the parts where breeches are in full contact with the saddle (inner thighs and bottom). Leather adds an extra layer to the pants, which might make them less breathable, therefore nowadays an alternative is used – silicone grips. Silicone grips are made in different colors and are positioned usually starting from the inner knee area up to the seat area, where the contact with the saddle is biggest. Silicone grips are positioned as small details situated close to each other, but far enough that there remains enough breathability to the fabric. [44] Examples of silicone grips and breeches with leather imitation can be found in Appendix 2 (A2)

The part of the breeches that must be fit into the boots is often made from a different material than the main fabric. Since this area is protected by boots, there is no need to have thick and abrasion resistant fabric there. Therefore thinner, more comfortable fabric is used to fit better in boots. Visual examples can be found in Appendix 2 (A2)

Breeches inseam stitching is moved slightly away from the middle of the inner leg. The bottom stitching is moved closer to the waistband and inner leg stiches are moved closer

to upper part of the leg or closer to the knee. This prevents the inner seams from cutting into the leg. [24]

Back or front pockets are a popular addition to breeches. They are mainly used for design purposes or for keeping small items in your pockets. Additional design elements like stitching, logos, embellishments and crystals can be used to elevate the overall look. Such design additions must be subtle to still pass the imposed regulations. Example of white competition breeches and details can be seen on image below (Figure 3.3.1). Additional examples of different breeches designs can be found in Appendix 2 (A2)



Figure 3.3.1 An example of white competition breeches with silicone grips, zipper, hook fastening, logo, crystal embellishments, pockets, and belt loops. [26]

4 CUSTOMER-ORIENTED PRODUCT DEVELOPMENT

When the goal is to create an improved version of an already existing product, it is important to first know the customer needs and expectations. Breeches are a very specific product to be working with. It is not considered a fashion clothing but a technical sportswear, that's main goal is to be practical.

Customer oriented product development is a suitable method to map out product needs and requirements, since the product developed has a very specific market. This also helps to establish product minimum criteria. [34]

When conducting a client-oriented product development, the main driving force are client needs, not particularly innovations in technology. It is possible to use client-oriented product development on creating the product concept, generating further ideas and developing the product based on client requirements. [35][36]

The main goals of client-oriented product development are [34]:

- improving product quality;
- improving customer satisfaction;
- reducing time to design;
- lower costs during designing and manufacturing;
- enhancing performance and reliability.

Customer oriented development provides a structured method for translating customer requirements into the engineering specifications. This method includes many steps, that help to correctly write down gathered information and helps in developing the final product.

The main steps of customer-oriented product development are:

1. gathering raw data from customers;
2. interpreting the raw data in terms of customer needs into technical language
3. creating the product specification sheet, in where the needs are translated into product parameters;
4. organizing the product parameters into hierarchy of primary, secondary and if necessary, tertiary needs;

5. benchmarking;
6. establishing the relative importance of the parameters;
7. Choosing the parameters and creating the final specification.

Following these steps and creating the product parameter sheet is what helps the product developer truly understand customer needs. This information is mainly gathered through conducting a questionnaire. A structured method for gathering data from customers remains useful and can lower the inherent risk in developing a radically different product. [36]

4.1 Previously conducted customer research

The first amount of customer data was gathered during the author's bachelor's degree thesis titled "*Ratsutamiseks mõeldud valgete võistluspükste parendamise võimalused*" ("Opportunities for Improving White Colored Equestrian Competition Breeches"). The data was gathered through a questionnaire, which was put together specifically for the target customer group and was enough to gather all necessary information that was needed for product development. The questionnaire was first conducted in March 2019. [37]

The key customer group for this questionnaire were equestrian sportsmen who were active in competing in the three following disciplines: show jumping, dressage and or cross country. The questionnaire creates a high-quality information channel directly from the customer. Gathered data gives information on customers experience with the product and the use environment of the product.

During the initial customer-oriented research, 34 key group riders' answers were gathered and analyzed. Research was conducted through an online questionnaire made in Google Forms, which was a comfortable method to receive anonymous answers and has a possibility to analyze the results both as a total sum 10 and individually. The questionnaire was made of 12 compulsory questions and one elective question. As a practical guideline for most products, conducting a fewer than 10 interviews are probably inadequate, and 50 interviews are probably too many [36]

Compulsory questions included general questions, where each respondent was asked to specify their gender, competition class (children's, junior, youngster, senior or amateur) and discipline. In addition, it was asked to specify how often does the respondent participate in competitions.

One question asked the respondent to write down their preferred brand of breeches. Respondent had the option to choose a brand from the list provided in the questionnaire or write their own option. In open answer or elective questions, the respondent was asked to write what they like and don't like about their competition breeches. Although this question is not so specific, it is important to add questions of such nature into customer-oriented research, as it can give the developer a possibility to map hidden customer needs. These are needs that the customer thinks of on their own, without the research bringing their attention to a specific product parameter or problem.

The respondent was also asked to write whether they wear breeches depending on the season and specify their choice. The goal of this question is to understand whether the customer prefers different breeches parameters or qualities depending on whether they are competing outdoors or indoors.

Rest of the questions were targeted questions, where the responder was asked to specifically measure product qualities based on a 5-point scale. This helps the developer to gather specific and measurable product parameters. Additionally, responders were asked to mark if they have had situations where their breeches have gotten wet due to the rain and how has this affected the visual look and feel of the product.

The last question of the questionnaire was an elective open-answer question, in case the responder had any additional comments or ideas regarding competition breeches. The questionnaire can be found in Appendix 3. (A3)

All results are analyzed in chapter 5.

5 ANALYZING ADDITIONAL DATA FROM CUSTOMER-ORIENTED RESEARCH

The second round of the questionnaire was conducted in 2021 February, in which additional 11 riders shared their answers. The total number of riders who filled out the questionnaire is thus 45. This number of answers was enough, as no new ideas or drastically different answers were recorded, therefore the data gathering could be halted. Research was conducted through an online questionnaire made in Google Forms, which was a comfortable method to receive anonymous answers and has a possibility to analyze the results both as a total sum and individually. The questionnaire was made of 12 compulsory questions and one elective question.

Questionnaire results were analyzed. Graphs are used for better understanding of the results. The gathered answers give a complete overview of how satisfied the customers with current products available on the market and helps the developer to map out the main problems.

All 45 responders were women.

All responders are active equestrian athletes and take part of competitions at least a couple of times during the year. The responders are divided into 5 classes. The class divisions are taken from Estonian Equestrian Federation regulation of participating in the competitions.

The gathered results are divided:

- 15 children (33,3%, age up to 16 years)
- 9 amateurs (20%, no age limit)
- 12 juniors (26,7%, age 17-18 years)
- 6 youngsters (13,3%, age 19-21 years)
- 3 seniors (6,7%, age starting from 21)

Between 45 responders, the disciplines were divided into following:

- 37 show jumpers (82.2%)
- 4 dressage riders (8.9%)
- 10 cross-country riders (22,2%)

The bigger part of the responders are active participants in competitions, 67,9% participate each month or 10-12 times per year, the rest of the responders participate at least 2-3 times per year.

The most popular breeches brand mentioned was Equiline (22,2%), followed closely by HV Polo (20%). Horze, Kingsland, and Fair Play got 6 (13,3%) mentions each. John Whitaker was chosen by 5 (11,1%). Pikeur and ELT each received 4 (8,9%) mentions. Less popular choices were Mountain Horse, Animo (each 3 mentions), Equi-Themé, and Spooks were mentioned twice and HKM, Podium, RS Champion, QHP, JH, Pai and La Valencio were all mentioned once.

Open answer questions are harder to group and present in a uniform way, but they are important to ask if the goal is to receive as much information as possible. Therefore author has analyzed all open answer questions and grouped them into graphs for easier understanding.

Results of best breeches qualities mentioned by the responders are shown as a graph below. (Figure 5)

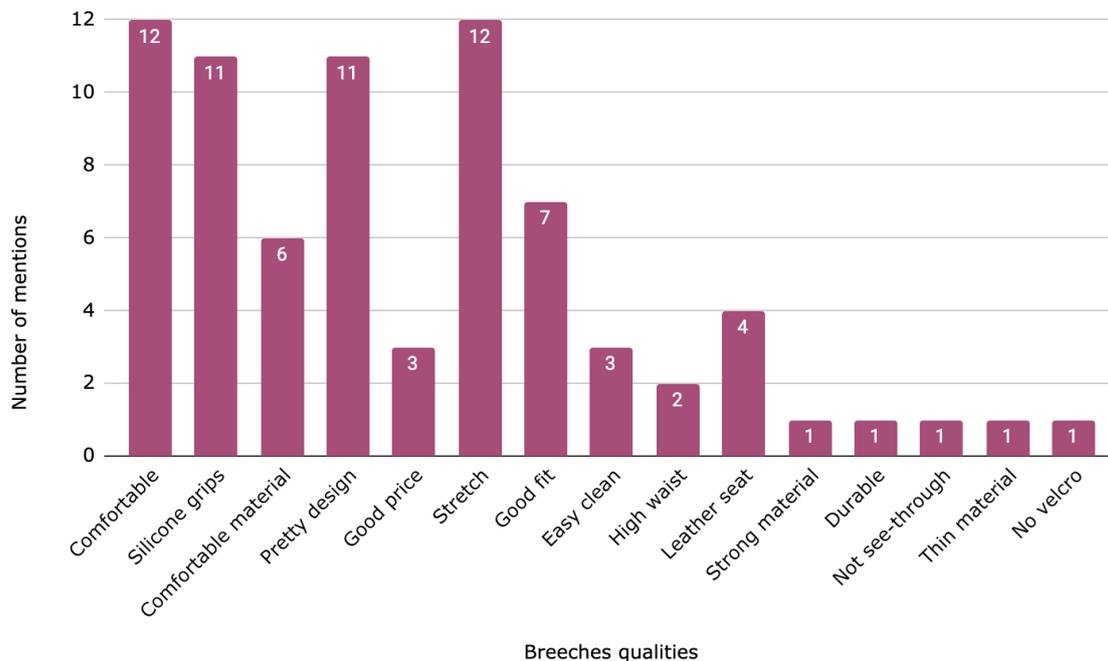


Figure 5. Best breeches qualities mentioned by the responders.

In the first open answer question the respondent was asked to mention their favorite qualities about their breeches. The most mentioned qualities were comfortable to wear (not specified why exactly) and stretch. The second most important qualities are Silicone

grips and pretty design. Good fit was also mentioned a considerable amount of time. Some responders mentioned that they specifically like the comfortable material, which is why it was not place into one category as overall comfortability. Four responders mentioned that they like the leather seating. Good price was mentioned less, including with breeches being easy to clean. High waist was mentioned only two times and other parameters shown on the graph were mentioned only once.

Results of worst breeches qualities mentioned by the responders are shown as a graph below. (Figure 5.1)

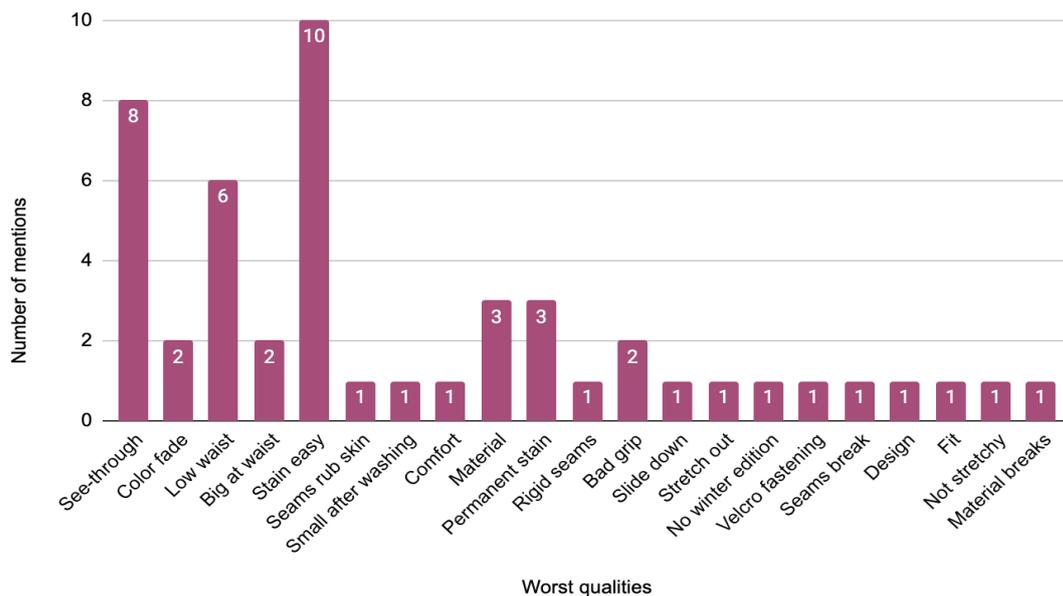


Figure 5.1. Worst breeches qualities mentioned by the responders

The graph illustrates that the worst quality that responders mentioned is that the breeches stain too easily. Another important negative quality is that the material is see-through. Low waisted breeches are also disliked. Uncomfortable material and permanent stains that are impossible to wash out are both mentioned three times. Color fade, unregulatable waistband and bad gripping are also qualities that are mentioned more than once. Rest of the qualities shown on Figure 2 are all mentioned only once.

When asked whether the responder wears different breeches depending on the season, 10 responders answered that no, they do not have different breeches depending on the season. Two people answered that they do not wear different breeches but have old breeches with them just in case something happens. Two people answered that they wear different breeches in the summer, so that it would not be too warm. One rider mentioned that they do not have other pairs of competition breeches due to the high price. One rider said that they wear old breeches when it is raining outside, since the

saddle colors the breeches brown when it gets wet. Two riders prefer thicker breeches during the winter period.

On a guided question, responders were asked to mark how important given parameters are on a 5-grade scale. The highest graded quality was easy care. The least important quality was low waist. The results were calculated by taking all the points into account and calculating the average.

Results of responders' grade to given breeches qualities are shown as a graph below (Figure 5.2)

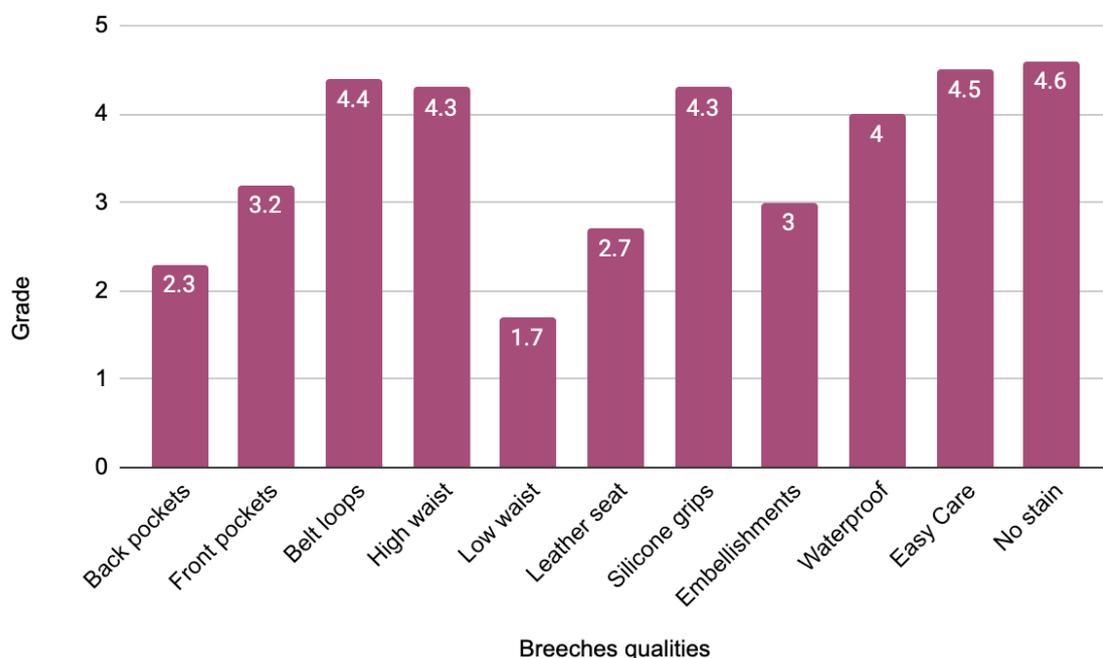


Figure 5.2 Responders grade to given breeches qualities

After calculating the average of questionnaire given product qualities, we can measure the importance of specific parameters. The highest grade was given to no stain quality of the material and easy care is a close second. Belt loops are the third most required element, closely followed by high waist design and silicone grips. Waterproof material is also required, based on the responder's results. Most of the design elements like front pockets and embellishments are with medium importance. Leather seat and back pockets are less important and low waist received the lowest grade out of the provided qualities.

All responders were asked to give an example of a situation where breeches were unexpectedly no longer usable. The meaning behind unexpectedly is that the breeches

were not just unusable because of the long use or because the rider had grown. The main complaint was because of a stain, that was impossible to wash out.

Results of responders' answers to why breeches are no longer usable are shown as a graph below. (Figure 5.3)

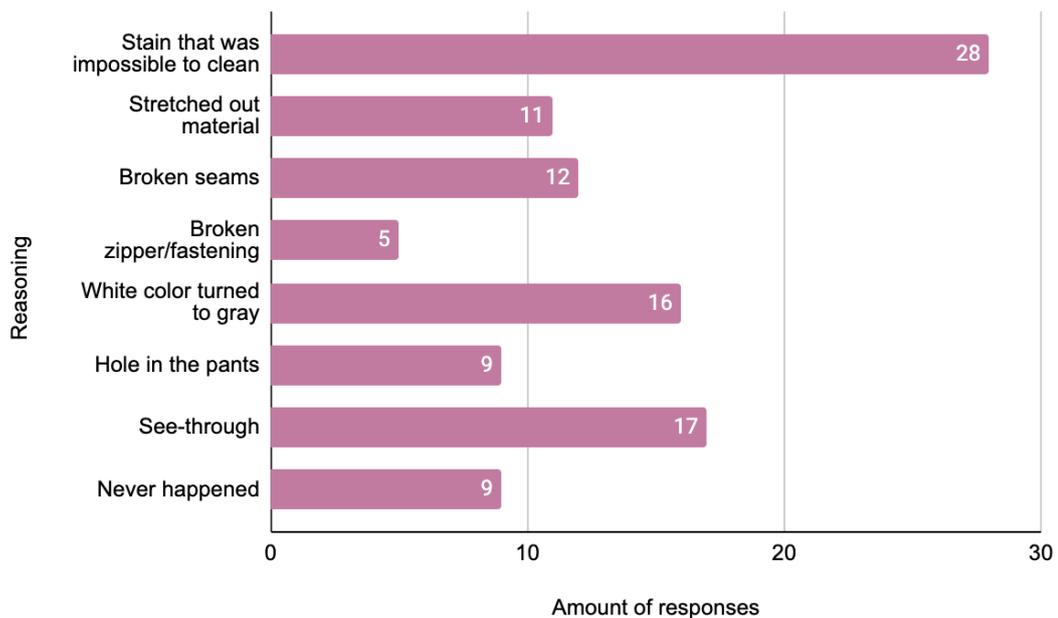


Figure 5.3 Reasons behind breeches being no longer usable

Under 11th question responders were asked whether they have encountered a situation, where breeches became wet due to rain. 71,1% (32) responded yes and were asked to give additional information on what happened after the breeches got wet. The most popular answer was that breeches became uncomfortable to wear and a close second was that breeches got dirty and stained much faster due to being wet. 15 responders experienced that breeches became see-through. Three people said that nothing happened after pants became wet and one person mentioned that they did not dry for the beginning of her next class and since she did not have any extra pants, she felt very uncomfortable and cold.

All results of responders' answers to consequences after breeches getting wet are shown as a graph below. (Figure 5.4)

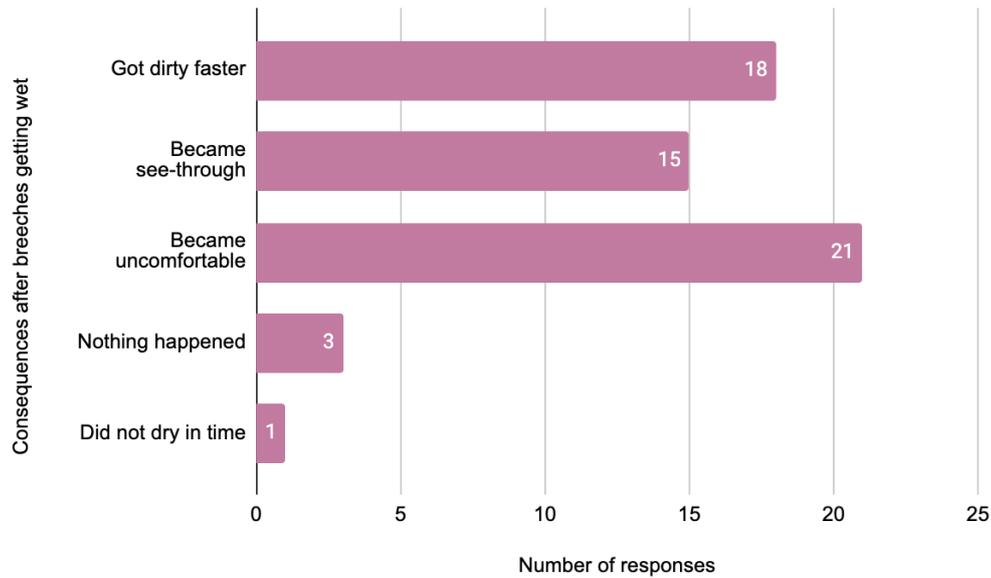


Figure 5.4 Consequences after breeches have gotten wet due to weather conditions

The last question of the questionnaire was voluntary, but gave a possibility to add prepositions, additional comments, and ideas. Four responders left their comments. One suggested to use a sturdier material. The second rider recommended to use an extra non-staining material on the area that is in most contact with the saddle (inner thighs and seat). Third comment proposed to use an extra layer of material for women’s breeches for period leakage protection. The last comment was that the rider finds it very hard to find good fitting breeches, since she is very tall and most of the pants are too short for her.

In conclusion it can be said that there were enough answers received to conduct a proper mapping out of the customer needs and problems with currently available breeches. Questionnaire results gave a good starting point and understanding of what the product has to do and in what conditions and environment it is being used. Like previously said, staining and easy care is the main problem in the breeches. There were also a lot of complaints considering design and it was possible to gather that high waisted breeches, with belt loops and silicone grips are the most sought after. The material is often see-through which is also a big problem and should be considered when developing new product. Comfortable fit, stretchy material and front pockets with not too many embellishments are they main key elements when considering fit and design.

Also, the main competitors were mapped out. For further analysis the three most voted brands will be considered: Equiline, HV polo and Horze.

5.1 Product requirements

First it is important to analyze and write down all raw data gathered from respondents in the exact same wording that the respondents used. Responders positive and negative opinions are written down in their own language and identified as needs (Table 5.1) Needs were then graded on a 5-grade scale to measure how important each need is. The more a specific need was mentioned, the higher grade it received. Grading is important to help the developer understand what need should be considered when developing the product and what needs are less important and will not define the product. All raw data that was gathered and identified as needs can be found in Appendix 4. (A4)

It is important to mention, that breeches as an apparel product do not have any standard minimum requirements that could be used as a reference. Breeches are a sportswear product and fabric or, product properties are not specified or regulated in any way.

5.2 Identifying customer needs

In total there were gathered 39 customer needs from raw data. These needs were then translated into 36 product parameters. Parameters are customer needs that are translated into technical language and help to understand customer needs in a more specific way. It is wise to measure the importance of each parameter. In total there were 23 parameters that were graded „5” – very important, 2 parameters that were graded „4” – important, three parameters that got a grade „3”- less important and seven parameters that are graded „2” are considered not important second table of report main body first chapter). This helps the developer to understand the most crucial aspects of what the product must provide for the customer and what needs are less important and do not need too much resource and time to develop. It is wise to put all the resources to finding how to improve or develop the product parameters that hold biggest importance for the customer.

Table 1.6.2. Customer needs translated into product parameters

No.	Parameter	Importance
1	White fabric color	5
2	Close fitting	5
3	Embellishments	5
4	Elastic seams	5

No.	Parameter	Importance
5	Durable material	5
6	Pilling resistant fabric	5
7	Abrasion resistant fabric	5
8	Silicone grips	5
9	Good grip in the saddle	5
10	Minimally visible grip aids	5
11	Elastic fabric	5
12	Smooth fabric	5
13	Elastic calf part	5
14	Machine wash allowed	5
15	Easy care material	5
16	Stain resistant fabric	5
17	Dry cleaning allowed	5
18	High waist	5
19	Zipper fastening	5
20	Button fastening	5
21	Tight woven fabric	5
22	Belt loops	5
23	High quality seams	5
24	Water resistant fabric	4
25	Calf part from thinner fabric	4
26	Competitive price	3
27	Regulatable waistband	3
28	Front pockets	3
29	Affordable price	2
30	Leather seat	2
31	Leather seat with silicone grips	2
32	Anti-shrinkage finishing	2
33	Silicone gripping on the inside of the waistline	2
34	Back pockets	2
35	Silicone grips only on knee area	2
36	Embellishments on the back	2

After parameters are graded and there is a clear understanding of what needs to be considered when improving an old product or developing a new product, a specification sheet can be created.

5.3 Required properties for breeches materials and different methods to test those materials quality

Testing fabrics can help understand its qualities better. It is important to select fabrics that would perform well based on what they are used for. For determining material properties different tests can be performed

Determination of fabrics air permeability

The air permeability test is widely used in the textile industry to define the intrinsic characteristics of fabric. A fabric's air permeability is greatly influenced by its material and structural properties, like shape, value of pores of the fabric and yarn, fabric weave, raw material of the yarns, set of yarns and much more. [46]

This test shows how well the fabric allows the passage of air to go through it. It is of importance for several fabric end uses, for example industrial filters, tents, sail cloths, raincoat materials, shirting, etc. [53]

This parameter influences the thermal comfort properties of fabrics. The air permeability of a fabric depends on its air porosity. The more porous the fabric, the more permeable it is. Construction factors and finishing techniques influence how permeable the fabric is. [53]

Determination of resistance to surface wetting

The goal of this test is to identify which fabric is more water resistant. Water resistance and permeability is important, as competition breeches are often worn outdoors where it might rain, or splashes of water might occur. The better fabric permeability, the higher chance that breeches will stay clean and dry for a longer period. At least three samples should be tested per fabric. [47]

Determination of abrasion resistance of fabrics by the Martindale method

The goal of this test is to determine fabrics resistance to abrasive wear for a predetermined number of rubs. [49]

Stain testing

On textile materials, stains can be described as local deposits of soiling or discoloration that show some degree of resistance when removing by laundering or dry cleaning. Removal of such stains can create critical issues in garment care. [2] If a garment has stains, its appearance can become dull, stiff and vulnerable to insects. Color loss or

abrasion may occur, when removing stains. Stain removal is affected by the age, extent and type of stain and the type of fabric. When removing a stain, the fiber content, fabric construction, dye and finish characteristics should be considered, because similar stains may react and respond differently on different materials. If a stain remains on the fabric after removal methods, it may lead to product failure. [51]

There are multiple types of stains. They can be classified according to their characteristics as water- or solvent soluble or insoluble. Method of removal can also be used as a classifier. The types of stains are shown in the table below (Table 5.3)

Table 5.3. Types of stains [51]

Stain type	Examples
Protein stain	Milk, blood, albumen, pudding, baby food, mud, cream, egg, gelatin, vomit, ice cream
Tannin stain	Beer, alcoholic beverages, soft drinks, fruit juice, berries, coffee, perfume, tea, tomato juice
Oil-based stain	Hair oil, automotive oil, grease, salad dressing, butter, lard, suntan lotion, face cream
Dye stain	Cherry, mustard, color bleeding in the wash
Combination stain	Candle wax, ballpoint ink, lipstick, shoe polish, tar, eye makeup, barbecue sauce, gravy, hair spray, tomato sauce.

In the equestrian world, stains are a very common problem. During everyday training period, equestrians usually wear clothing in dark or earth toned colors so that the most common stains are not visible. During competitions, the riding environment stays mostly the same, except that the rider must wear white breeches, where any type of stains is very profound. Table shows the most common stains that an equestrian encounters in the environment where white breeches are worn (Table 5.3.1).

Table 5.3.1. Most common stains found in equestrian environment.

Environment	Stain	Type
Stable	Dust	Combination stain
	Hay	Protein stain
Arena	Grass	Protein stain
	Sand (including clay)	Protein stain
	Mud	Protein stain
Horse	Horse hair	Oil-based stain
	Sweat	Protein stain
	Sebum	Oil-based stain
	Saliva (foaming from the mouth can be accompanied by residue from apples and carrots)	Protein stain Tannin stain
Equipment	Leather soap	Combination stain
	Leather balm	Oil-based stain
	Leather colorant	Dye stain

The main stains encountered are protein stains, oil-based stains and in some cases combination and dye stains.

The goal is to imitate the mentioned stains and see how well they can be removed from fabric.

3 types of stains should be tested, with the focus on protein and oil-based stains.

For imitating protein stains, grass, mud and sand can be used.

Another common stain is from leather products like soap and balm, that should be tested in a form of combination stain and an oil-based stain. This stain can be reproduced by actual leather soap that has common ingredients (so that it imitates other brand leather soaps) and leather balm meant for horse equipment. A rider is in direct contact with the saddle, and it is usually common to clean your tack before each show, meaning that breeches are also in direct contact and abrasion with the products.

The main ingredient in a regular leather soap is glycerin, which is a component of fat or oil. Glycerin soaps are usually translucent, making them suitable for different color leathers. [52]

Leather balm is applied on top of the glycerin soap to nourish the leather. This is also a product that is in direct contact with the breeches and should be tested for staining on the material. The main ingredients in most leather balms are lanolin and beeswax. Lanolin is a wool wax or wool grease; it is oil based and the main goal of using lanolin is to soften the leather. Beeswax does not moisturize the leather as well, but it helps to waterproof the leather and sealing in the moisture to keep the leather supple.[52]

Saddles need very regular conditioning, because they are used daily. Weathering, moisture, dust, dirt and regular wear all affect the leather. Riders usually clean and condition their tack at least once a week and every time before a competition. The chances that breeches are going to be in direct contact with the leather care products is very high. [52]

Usually, equestrian competitions last for a whole day, in some instances several days. It is not always possible to wash the stains off immediately. To replicate the real environment to the maximum, the stains should be tested when they have been dried off. This could also help to understand how well it is possible to remove all possible staining from white fabric.

6 PRODUCT DEVELOPMENT PROCESS

The development process of breeches consists of the following steps shown below (Figure 6).

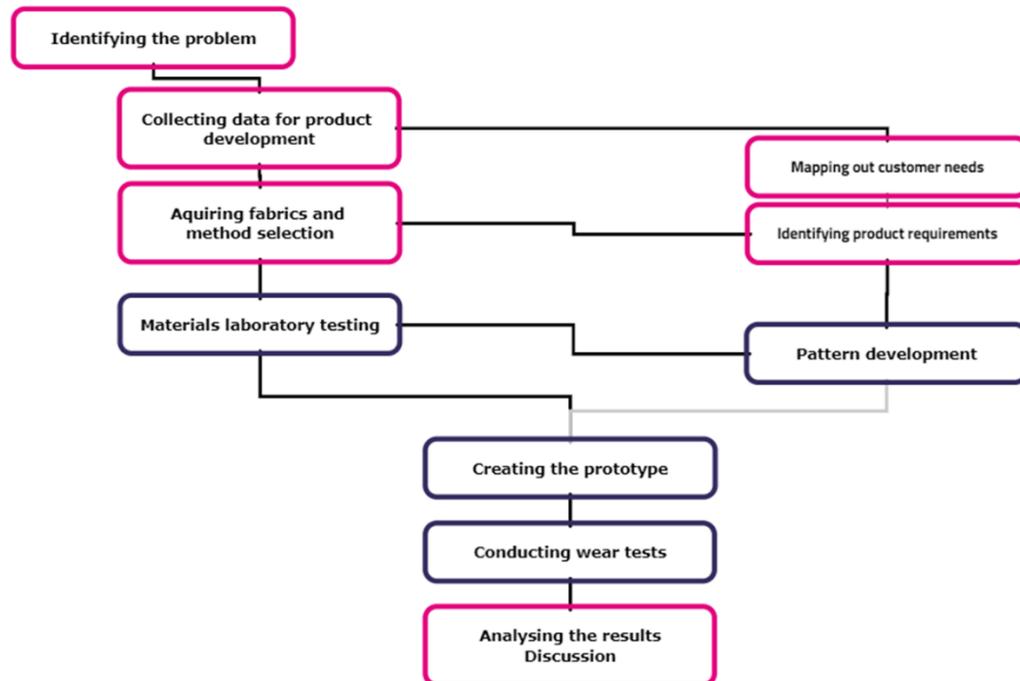


Figure 6. Breeches product development process.

After researching about the product environment and analyzing all gathered customer data it is possible to move on to next product development stages. Not all processes are done in a linear sequence. Some of the shown steps can be done in parallel processes.

6.1 Specification sheet

When creating specification sheet, it should be noted that many parameters can fit for one need. Each specification has a unit it can be measured in. It can be a specific measurable unit for example like grams or an unmeasurable unit that is harder to define uniformly.

Specification sheet does not include parameters that were graded „2” or less, as they do not hold enough importance for the customer and do not create any additional value for the product.

In total there were 17 product parameters identified. The final specification sheet helps to measure specific product properties, that when implemented, adapted or improved

will help to produce a product that can satisfy all customer needs, since the specification sheet is based on customer raw data. The complete specification sheet can be found in Appendix 5. (A5)

In conclusion, the most important parameters that should be considered when developing the product are:

- white colored fabric;
- product pattern;
- material composition;
- product durability;
- product fastenings and embellishments;
- high waist accompanied with belt loops;
- high quality seams;
- silicone grips in the knee, inner thigh and seat area;
- elastic and thinner fabric use on the calf area;
- easy care;
- fabric weave;
- stain and water-repellent fabric or finishing;

After creating the specification sheet, other steps of customer-oriented product development can begin.

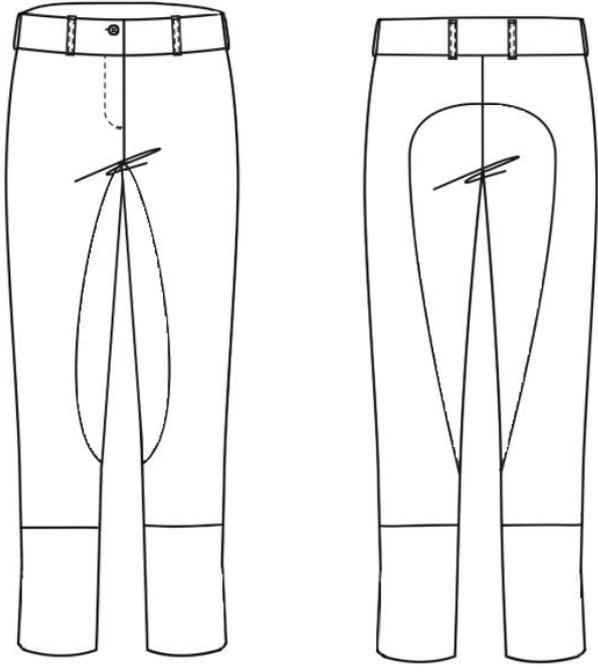
6.2 Creating breeches technical card

Product technical card includes all necessary information about product size, seam allowances, stitching, fusing, all fabric details including supplier information, product care information and furniture. It also includes a technical drawing.

Product technical drawing shows how the product should look like and contains all elements the final product has. The technical drawings were created in digital software Kaledo Style.

Table 6.2 Breeches technical sheet

Equestrian competition breeches					
Customer	Product type	Season	Model no:	Tailor	Patternmaking
Anna	Competition breeches	2022 S/S	EQBR-1	Anna Leppik	Anna Leppik
Fabric art.	8839	Started:	01.01.2022	Size	36
Product nr	1	Finished:		Women	

	<p>SEWING TECHNOLOGY:</p> <p>Seam allowances:</p> <ul style="list-style-type: none"> 0.5 cm – belt loops, zipper 0.7 cm -sides seams, calf detail, inseam, zipper yoke 1.0 mm – waistband <p>Stitches: four-thread overlock (514)</p> <p>Double coverstitch (406)</p> <p>Double chainstitch (401)</p> <p>Lockstitch (301)</p> <p>Fusing: zipper yoke, waistband, belt loops</p>
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REMARKS AND COMMENTS

Fabrics:

Main fabric: knitted elastic fabric

Supplier: Germany, S4Y

Width: 148 cm

Fiber composition: 64% PA, 32% CA, 4% EL

Care label text: Wash garment inside out 

Fusing: all bias nonwoven interlining. Mass per unit area 35g/m². Density of adhesive spots: 17 spots/cm².

Fusing mode: gluing temperature 110-132 °C, pressure 3bar, time 10-15 sec.

Permitted maintenance for interlining: Machine wash 40 °C, iron 150 °C, dry clean, tumble dry.

7 CHOOSING MATERIALS FOR BREECHES

Based on established parameters, 5 different fabrics were chosen to be tested as potential materials to sew breeches from. Three of the fabrics were bought on the Estonian market and two of the fabrics were bought from Germany. The materials bought in Estonia were chosen as a result of onsite visual inspection. The materials bought from Germany were chosen based on the product description provided by the seller online. Additional information and descriptions of the fabrics can be found in the table below (Table 7).

Table 7. Five fabrics acquired for product testing

Fabric	Color	Distinction	Composition	Construction	Characteristics	Origin
1	White	Eggshell color	77% Polyester 23% Elastane	Knitted	Matte, smooth finish, 4-way stretch	Abakhan, Tallinn
2	White	Blue hue	80% Polyester 20% Elastane	Knitted	Shiny, slippery finish, 4-way stretch	Kanga-džungel, Tallinn
3	White	Yellowish white	50% Polyester 30% Viscose 20% Elastane	Knitted	Matte, smooth finish, resembles cotton	Kangas ja Nööp, Tallinn
4	White	Diagonal pattern	60% Viscose 35% Polyester 5% Elastane	Woven	Smooth matte finish, one way stretch only	Stoff 4 You, Germany
5	White	Slight gray hue	64% Polyester 32% Viscose 4% Elastane	Knitted	Smooth matte finish, 4-way stretch	Stoff 4 You, Germany

7.1 Acquired materials descriptions

As all the fabrics that will be tested are going to be white, it is important to identify them in some way that will minimize the chance of them being mixed up. Thus, fabrics are numbered and additionally labeled according to their tone hue or distinct feel. The fabrics that have been found so far are labeled as Fabric 1 – white, Fabric 2 – blue, as it has a slight blue hue to it and Fabric 3 – cotton, because it feels like cotton to the touch. Fabric 4 is the only material that is woven, and Fabric 5 has also slightly cotton like feel and is much heavier than the rest of the fabrics.

Fabric 1

Fabric 1 has a natural white color with no distinctive hue. The fabric is slightly see-through when pulled which is not ideal for sewing breeches, but with correct pattern or if used with inner lining, it could be a good option for spring-summer season wear.

Fabric 2

Fabric 2 has a slight blue hue, but it is intense enough for the fabric to be blue in color, but significant enough to differentiate it from other fabrics. It is slightly see-through but compared to Fabric 1 seems to be a bit denser and heavier. It is not an ideal option for sewing breeches, but with the correct pattern or if used with lining it could be a good option for outdoor season wear.

Fabric 3

Fabric 3 has cotton-like feel and look. It is very easy to distinguish this fabric from the rest of the options. The color is white or natural white. It is a woven, medium-weight fabric which could be compared to a cotton and polyester blend, but according to the label has no cotton in it. It is not very see-through. It is not an ideal option for sewing breeches, but with the correct pattern or if used with lining it could be a good option for outdoor season wear.

Fabric 4

Fabric 4 main distinction is its weave. When buying the fabric was described as a 4-way stretch. Upon arrival it turned out that it is much thinner than described and stretches only in one direction. It is rather thin and not too heavy but could be a suitable option for breeches.

Fabric 5

Fabric 5 has a natural white color that under some lighting can look slightly gray. The fabric feels heavier compared to other fabrics. It has a slight cotton like feel which is caused by the viscose content.

Auxiliary materials

Abrasive cloth – required for carrying out the Martindale test for abrasion resistance and pilling, matting and fuzzing resistance tests.

Backing felt – required for carrying out the Martindale test for abrasion resistance.

Polyurethane foam - required for carrying out the Martindale test for pilling, matting and fuzzing resistance test.

Detergents required for stain testing

In addition to testing multiple stains on different fabrics, the goal is to test whether the type of detergent has any effect on the outcome and how well the stain is removed. Choosing the detergents was based on the type of fabric and product was being washed. It was decided to use a detergent that was specifically designed for washing white clothing, a detergent that was meant for sports clothing and a standard detergent from ISO6330:2021.

The best option for white clothing found was Mayeri – all care concentrated detergent for white fabrics. It contains oxygen based bleaching agent with activator, which removes stains like blood, coffee, tea, etc. and bioactive enzymes that break down strong stains like chocolate, egg, blood, etc. It efficiently removes dirt both in lukewarm and warm water. [54]

The best option found for washing sports clothing was Mayeri – Sport wash laundry liquid. This is a laundry liquid that has special formula created for activewear. It removes sweat and other unpleasant smells from clothing. It is easy to wash out from fabrics and therefore helps to maintain the fabrics initial properties like breathability and water resistance. It does not contain optical whiteners, phosphates or fabric softeners. Suitable for machine and hand wash. [54]

It is recommended to use specialized sports wash detergents on activewear, since fabrics used for sports clothing differ from regular everyday wear fabrics. Sportswear fabrics usually have very high-tech characteristics like breathability, moisture-wicking properties, water resistance, thermoregulation, etc. These fabrics are often more porous from regular fabrics, to maintain these high-tech abilities. The particles from regular detergents can often set in between sports fabric fibers and clog them, reducing the clothing's moisture wicking properties and breathability. In addition, the residue from regular detergent and fabric softener which is clogged in fabric pores can be an ideal breeding ground for bacteria and fungi. The detergent created for sportswear leaves no residue while still effectively cleaning the material and removing all unpleasant smells. [55]

The standard detergent used was a standard ECE non phosphate reference detergent (A), suitable to use in ISO6330:2021 standards.

7.2 Testing methods

Based on what is required of the breeches a selection of testing methods was chosen (Table 7.2). These tests mimic the actual environment in where the product will be used.

Table 7.2 Testing methods for determining best fabric for breeches

Product parameter	Test name	Standard number
Thickness and weight	Determination of mass per unit area using small samples	ISO 12127:2000
Pilling	Determination of fabric propensity to surface pilling, fuzzing or matting (Martindale method)	ISO 12945-2:2020
Wetting	Determination of resistance to surface wetting (spray test)	ISO 4920:2012
Abrasion resistance	Determination of abrasion resistance of fabrics by the Martindale method	ISO 12947-1:2001
Air permeability	Determination of permeability of fabrics to air	ISO 0237:2000
Stain resistance	Selection of stains based on product environment	-

All tests were conducted based on the ISO standards that are mentioned under each test. All fabrics were conditioned prior to testing according to ISO 139:2005 – Textiles – Standard atmosphere for conditioning and testing – Amendment 1. The room temperature for each conditioning was measured at 20°C (±2.0°C) and RH of 65% (±4.0%). The samples were conditioned for at least 18 hours prior to testing.

7.2.1 Determination of mass per unit area using small samples

The standard for this test is ISO 12127:2000. This standard describes methods for the determination of the mass per unit area using small samples in the standard atmosphere for testing. It is applicable to woven and knitted fabrics. It may also be applicable to fabrics produced by other techniques. [45]

At least three samples should be tested per fabric.

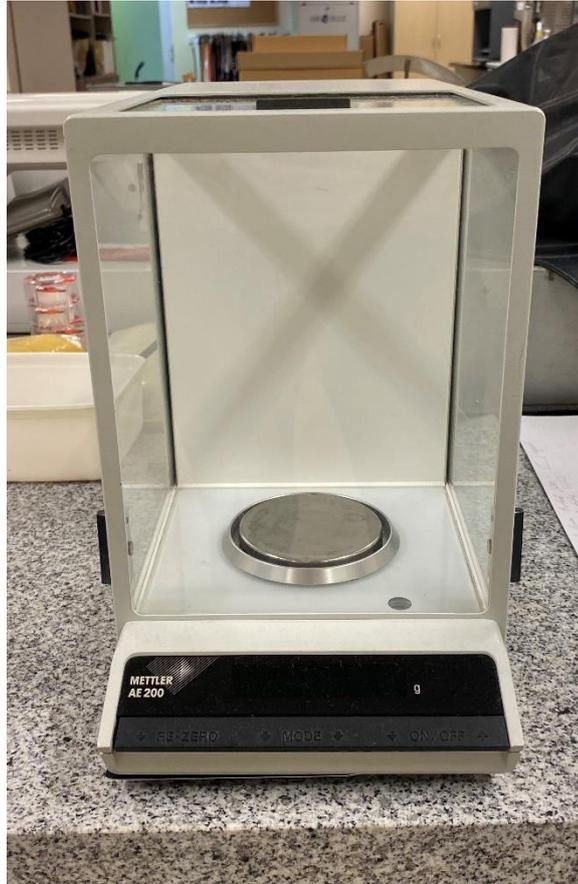


Figure 7.2.1 Scale used for determining fabric sample weight

7.2.2 Determination of fabrics air permeability

This test is conducted according to the standard ISO 9237:2000 – Textiles – Determination of permeability of fabrics to air. It is applicable to most types of fabrics. Air permeability is when velocity of an air flow passes perpendicularly through a test specimen under specified conditions of test area, pressure and drop time. The air passing through a given area of fabric is measured. [46] At least three samples should be tested per fabric.

The pressure drop for apparel fabric is 100 Pa. The fabric is measured from 10 different points on the fabric, both sides. Fabrics with different surface textures on either side can have a different air permeability depending on the direction of the air's flow. The pressure is normally expressed as $l/m^2 \times s$. Typical ratings can be from 2 to 2000. [46]

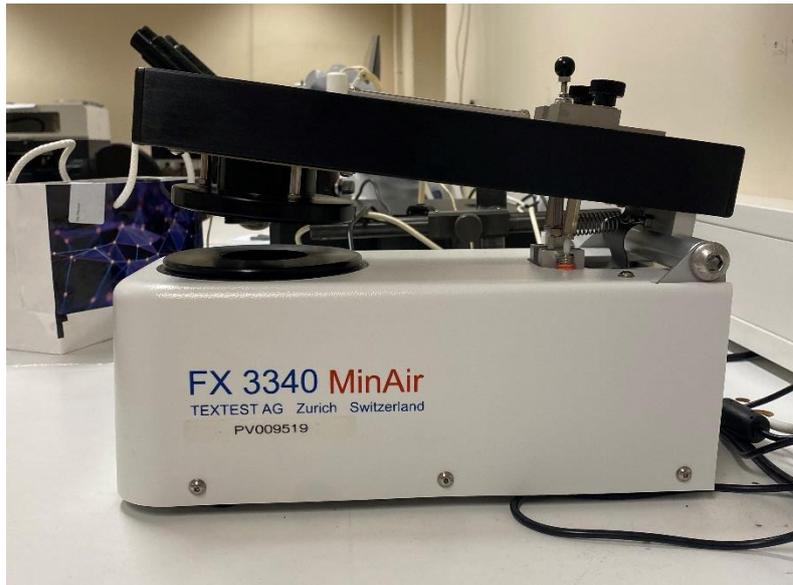


Figure 7.2.2 Machine used for determining air permeability.

7.2.3 Determination of resistance to surface wetting (spray test)

This test was performed according to standard ISO 4920:2012. This International Standard specifies a spray test method for determining the resistance of any fabric, which might or might not have been given a water-resistant or water-repellent finish, to surface wetting by water. It is not intended for use in predicting the rain-penetration resistance of fabrics, since it does not measure penetration of water through the fabric. [47]

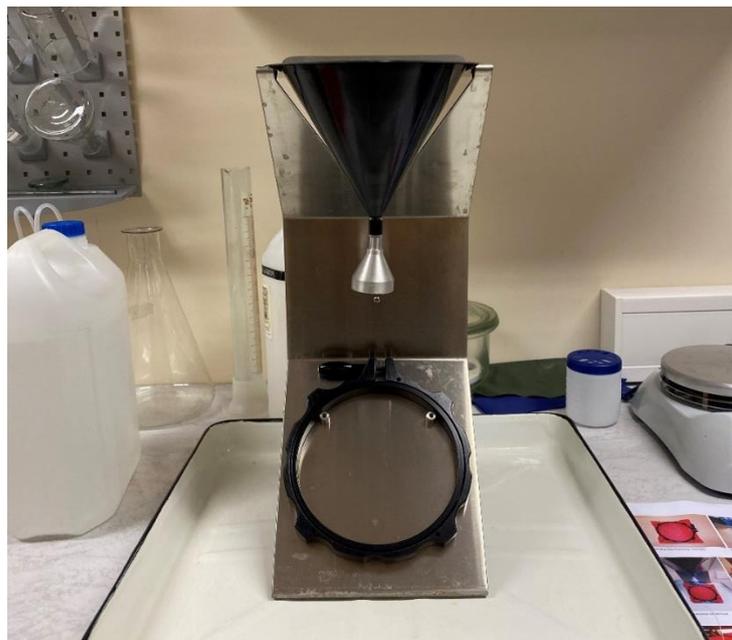


Figure 7.2.3 Equipment used for spray testing.

7.2.4 Determination of fabric propensity to surface pilling, fuzzing, or matting

The standard for this test is ISO 12945-2:2020. This document specifies a method for the determination of the resistance to pilling, fuzzing, and matting of textile fabrics using a modified Martindale method. [48] At least three samples should be tested per fabric. This test requires a Martindale testing machine.

The number of rubs performed on the test samples in total is 7000. A weight of $155 \pm 1\text{g}$ must be added to each sample, as required in the standard. Each sample must be evaluated at 125, 500, 1000, 2000, 5000 and 7000 rubs. Changes in pilling, fuzzing and matting must then be evaluated on a scale 1-5, where pilling and matting is evaluated in the following way:

- Very serious
- Serious
- Moderate
- Slight
- No change



Figure 7.2.4 Martindale testing machine used for pilling and abrasion resistance tests.

7.2.5 Determination of abrasion resistance of fabrics by the Martindale method

The abrasion resistance test is conducted according to the ISO 12947-1:2001 standard – Textiles- Determination of abrasion resistance of fabrics by the Martindale Method. This test is suitable for testing knitted fabrics.

According to ISO 12947-2:2016 standard, it is required to add a nominal pressure of 9 kPa to each sample. This is for fabrics that are intended for apparel and household textiles. [50]

The test intervals for abrasion testing are described in the following table (Table 7.2.5)

Table 7.2.5 Abrasion resistance test intervals

Interval steps	Evaluation intervals (rubs)
Every 1000 rubs (Up to 6000 rubs)	1000 – 2000 – 3000 – 4000 – 5000 – 6000
Every 2000 rubs (From 6001 to 20000 rubs)	8000 – 10000 – 12000 – 14000 – 16000 – 18000 – 20000
Every 5000 rubs (From 20001 to 50000 rubs)	25000 – 30000 – 35000 – 40000 – 45000 – 50000
Every 10000 rubs (Over 500001 rubs)	60000 -... + every additional 10000 rubs)

The individual test results are expressed as the number of rubs of the inspection interval prior to the endpoint of each test specimens being reached.

7.2.6 Stain testing

3 types of stains were be tested, with the focus on protein and oil-based stains.

For imitating protein stains, grass, mud and sand were used. One of the mixtures was made from grass. A suitable amount of grass was collected and then blended into a runny paste for more comfortable application. It was important to maintain the actual green color of a grass stain and make the application process easier for all samples.

For sand stains, sand from the riding arena was used. The sand was moistened with distilled water for easier and more uniform application process.

Oil-based stains were reproduced with actual leather soap that has common ingredients, so that it imitates other brand leather soaps and leather balm meant for horse equipment.

The amount of standard detergent used was 20g, as recommended in the ISO6330:2021 standard.

The amount of detergent for white colored fabrics used was 50ml.

The amount of sports wash detergent used was 55ml.

7.2.7 Laboratory instructions for stain tests

Equipment

1. Fabric samples
2. Ballast weight with the same (in accordance with the ISO 6330:2021 standard)
3. Washing machine
4. Staining agents: sand from the riding arena, grass, leather conditioner and leather soap
5. Thread and needle
6. Clean white material for sewing the samples on (ex. towel)
7. Washing detergents: standard washing detergent (in accordance with the ISO 6330:2021 standard), washing detergent for sports clothing, washing detergent for white clothing
8. Drying oven
9. Gray scales
10. Color assessment cabinet

Procedure:

1. Cut out 80mm x 80mm the samples from the fabric that is being tested. For each stain 3 fabric sample pieces were used. This resulted in 27 samples per fabric, in total 81 samples.
2. Prepare the stains, if needed. Apply each type of stain to 3 different fabrics. Each stain should be represented on three samples per fabric and per detergent. This results in each stain being applied to 27 samples in total. For a more uniform application, use a stencil made from cardboard or plastic.
3. Let the stain sit for 5 minutes on the fabric.
4. Remove the stain excess from the sample and place it on an oven drying rack.
5. Place the sample in an oven at an average of 37 °C until samples are dry.

6. Remove dry samples from the oven and sew them on a towel. Each towel must have a set of each stain and fabric, resulting in 27 samples in total. Attach the samples facing up.
7. Weight the total mass of 27 samples including the towel. The total weight of a washing machine load must be 2kg. Calculate how much ballast weight is needed.
8. Measure out the amount of detergent needed for a washing cycle according to the total washing load weight and detergent manufacturers recommendation.
9. Add the samples that are sewn on to the towel, ballast weight and detergent to the washing machine and set the washing cycle to synthetic. Water temperature should be 40 C°. Set centrifuge to 1000 cycles.
10. When the washing machine cycle is finished, remove the samples and let them air dry.
11. After the samples have dried, remove them carefully from the towel.
12. Measure the staining of each sample under a color assessment cabinet using grayscale.
13. Repeat the process with the rest of the detergents and samples.



Figure 7.2.7. Stain application process



Figure 7.2.8 Grass stains seeping into the samples



Figure 7.2.9 Sand stain application

7.3 Results and discussion

Each fabric was evaluated individually, and every test result was analyzed separately. Test results were compared between the fabrics and the best performing fabric was selected per each test. Then overall results are analyzed.

7.3.1 Determination of mass per unit area using small samples results

Each of the samples were cut out using a template and then weighed. The individual results of Fabric 1, Fabric 2, Fabric, 3 Fabric 4 and Fabric 5 are shown in Appendix 6 (A6).

Based on the results the heaviest material is Fabric 5 weighing at 330g/ m². Fabric 1 weighs the least at 201 g/ m². Fabric 3 has a similar weight to Fabric 5.

One of the main requirements for white competition breeches is that the fabric would not be see-through. Based on visual inspection, Fabric 5 is the least see-through material out of the five fabrics and Fabric 1 is the most transparent. Based on the test results and visual inspection, it can be concluded that in this case fabric transparency and weight are in correlation.

7.3.2 Determination of permeability of fabrics to air results

The individual measurements of Fabric 1, Fabric 2, Fabric 3, Fabric 4 and Fabric 5 are shown in Appendix 6 (A6). All fabrics were measured 10 times from the fabric right side and 10 from the left side. No samples were cut out for this test. The fabric was used as a whole, and test sites were selected along the whole width and length of the fabric.

The test results show that Fabric 1 is most permeable by air. Fabric 1 left and right side of the fabric received almost the same results. Right side standard deviation was a little bit less than on the fabric's left side.

Fabric 2 had an average air permeability of 385±47 l/m² for the right side and 369±25 l/m² on the left side. The standard deviation was much smaller on the fabric's left side.

Fabric 3 showed that its right side has almost twice as big air permeability than its left side. Compared to other fabrics, Fabric 3 has medium range of air permeability.

Based on the results Fabric 4 is least permeable by air. Fabric 4 is the only woven fabric, which could explain why the results differ the most. This fabric seems to have much tighter construction than the rest of the four knitted fabrics.

Fabric 5 had second lowest air permeability. It is also the least transparent fabric based on visual inspection. This could suggest that Fabric 5 weave construction is tightly knitted.

When developing breeches, it is good to have some air permeability so that product breathability is achieved. Too much air permeability could mean that the material is too loosely woven for it to be used as fabric for breeches.

7.3.3 Determination of resistance to surface wetting (spray test) results

Conclusive test results for all five fabrics are shown in table below (Table 7.3.3). Additional images can be found in Appendix 6 (A6).

Table 7.3.3 Determination of resistance to surface wetting test results

Fabric	Average grade
1	4
2	2
3	0
4	0
5	2

In conclusion, Fabric 1 performed best in the surface wetting test as only slight random sticking or wetting was identified. Second best fabric was Fabric 2 and Fabric 5, where the wetting occurred beyond the spray points. Fabric 4 and Fabric 5 performed worst out of all fabric tested, as complete wetting of the entire specimen was detected. These results suggest that in rainy conditions Fabric 1 would perform best and stay the cleanest, as it is rather resistant to water. Fabric 2 and 5 would be the second-best options out of the fabrics tested, although not ideal, as the wetting area was quite large. Based on the results Fabric 4 and Fabric 5 would get wet and uncomfortable to wear in rainy conditions, since the water spread and soaked the material entirely.

7.3.4 Determination of fabric propensity to surface pilling, fuzzing or matting results

The results for Fabric 1 and Fabric 2 were evaluated at grade 5, as no change in the fabric surface was identified at any intervals they were measured at. Some of the fuzzing could be identified when evaluated at a very specific angle, but the change was insignificant.

Results on Fabric 3 were measured to be moderate, as some pilling and fuzzing was easy to identify already during the first rubbing intervals.

Results on Fabric 4 and Fabric 5 it was easier to identify slight pilling and matting of the surface than compared to Fabric 1 and Fabric 2. The pilling was not as visible as on Fabric 3.

Test results suggest that Fabric 1, Fabric 2, Fabric 4 and Fabric 5 would all be suitable for sewing breeches, since no strong pilling, fuzzing or matting was identified even after 7000 rubs. Wearing breeches during horseback riding means that there is a lot of friction involved and using fabric that is not very susceptible to pilling means longer product lifetime. Individual results of each fabric can be found in table below (Table 7.3.4)

Table A6.4. Individual results of each fabric after pilling, matting and fuzzing test

Fabric	Number of rubs					
	125	500	1000	2000	5000	7000
1	5	5	5	5	5	5
2	5	5	5	5	5	5
3	4	4	4	4	4	4
4	5	5	4	4	4	4
5	5	5	5	4	4	4

7.3.5 Determination of abrasion resistance of fabric by the Martindale method

All five fabrics behaved in the similar way and no thread breakage was identified, the results are expressed in a summarized form.

Table 7.3.5 Abrasion resistance test results

Fabric	Number of rubs	Comment
1	50000	No thread breakage was identified
2	50000	No thread breakage was identified
3	50000	No thread breakage was identified
4	50000	No thread breakage was identified
5	50000	No thread breakage was identified

Overall, no thread breakage was identified in any of the five fabrics tested. Fabric 3 and Fabric 4 showed some pilling and fuzzing in the beginning of the test at the interval on 1000-6000 rubs. After that the pilling disappeared and no thread breakage was identified. An example of the pilling can be found on image below (Figure 7.3.5)

The test was concluded after 50000 rubs as there was no evidence of thread breakage in any of the fabrics. Since the tested fabrics are intended for apparel textiles, it was

decided not to continue with additional rubs. The 50000 rubs are enough to suggest that the tested fabric would hold up well as apparel textile.

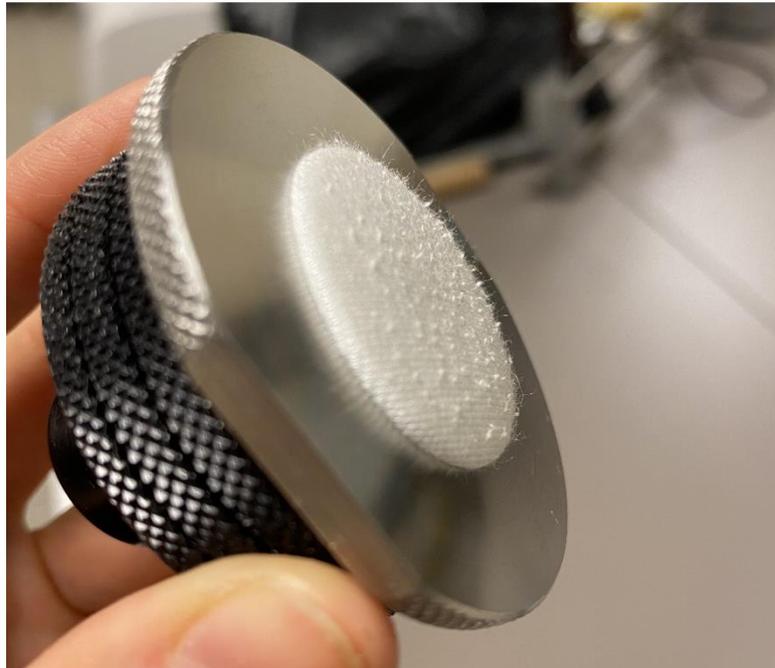


Figure 7.3.5 An example of pilling that occurred during the first rubbing intervals of the abrasion resistance test. The sample shown is Fabric 3.

7.3.6 Results based on stains

In total, three types of stains were tested on three different fabrics and washed with three different detergents. Then the stains were dried, and each sample was individually assessed with a grayscale in a color assessment cabinet. Using a color assessment cabinet ensured, that all samples were evaluated under the same light conditions.

The analysis of the results will be divided into two parts. The first part will concentrate on assessing how each stain behaved on each fabric. The second part will analyze whether different detergents managed to eliminate the stains more effectively.

Grass stains

The fabrics behaved differently when grass stain was applied. On Fabric 2, Fabric 3 and Fabric 4 stain seeping occurred during application process, which resulted in a much larger stain (figure) On Fabric 1 and Fabric 5 no stain seeping occurred during the application process.

When the grass stains were washed, Fabric 3 showed most discoloration. The whole sample was affected by seeping and was measured to differ the most from the etalon

sample. Fabric 2 also showed slight discoloration while Fabric 1 was least affected by grass stains. Fabric 4 and 5 were also very little affected with grass stains as they were almost impossible to identify.

Sand stains

Sand stains were least visible on Fabric 1 after application and drying. The stains did not seep and colored Fabric 1 only slightly. For Fabric 3 the stain seeped more than with other fabrics, but not as much as grass stain. The sand stain was most visible on Fabric 3 and Fabric 4 and some seeping occurred, but not as much as with grass stains. Fabric 2 and Fabric 5 behaved in a similar manner during application. The stains on Fabric 2 and Fabric 5 were more visible than on Fabric 1, no seeping occurred.

When the sand stains were washed, Fabric 3 once again showed most discoloration. The whole sample was affected and differed in color compared to the etalon sample. Sand stains were least visible on Fabric 1 and moderately visible on Fabric 2 and Fabric 4 and Fabric 5. Fabric 4 and Fabric 5 stain seeping during application was also identified after washing procedure.

Stains from leather soap and leather balm

The mixture from a leather soap and balm was slightly yellowish due to the waxes and oils it contained. This stain was the lightest of all stains in terms of color but hardest to remove. No seeping occurred on any of the samples. No fabrics had any strong discoloration after the washing procedure, but all fabric samples had an oil stain clearly visible even after washing and drying. The stain was a mixture of a transparent and slightly yellowish mark on each sample.

7.3.7 Results based on detergents

The goal of stain testing was also to measure whether different washing detergents can do a better job at eliminating specific stains. All results are shown in a table in Appendix ... Three tested detergents were Standard detergent, Mayeri Sports wash detergent and Mayeri All Care detergent for white textiles.

Standard detergent

The standard detergent showed best results in removing the grass stain. It removed the stain completely from Fabric 1 and Fabric 2, Fabric 4 and Fabric 5 and also showed good results on Fabric 3.

For sand stains, the standard detergent worked well on Fabric 1 by removing the stain completely. For Fabric 2, Fabric 4 the stain was slightly visible and Fabric 3 and Fabric 5 the staining was even more visible.

Standard detergent performed worst with the oil-based stain made from leather conditioner and leather soap. This stain remained visible on all five fabrics equally.

Detergent for white colored fabrics

The detergent meant for white fabrics showed best results in removing grass stains. It removed grass stains from Fabric 1 and Fabric 2, Fabric 3, Fabric 4 and Fabric 5 completely. Grass staining was slightly visible on Fabric 3.

This detergent worked well in removing sand stains from Fabric 1. On Fabric 2 and Fabric 3 and Fabric 5 the sand stains remained very visible. On Fabric 4 the staining remained slightly visible.

Mayeri detergent for white fabrics eliminated leather care stains from Fabric 1 and Fabric 3 and Fabric 5 but not to full extent. On Fabric 2 and Fabric 4 the staining was even more visible.

Sports wash detergent

The sports wash detergent worked best on removing grass stains from Fabric 1, Fabric 2, Fabric 4, and Fabric 5. The staining was slightly visible on Fabric 3.

The sand stain was completely removed from Fabric 1 but remained slightly visible on Fabric 2 and Fabric 5. On Fabric 3 and Fabric 4 the sand stain was most visible.

After washing with the sports wash the leather care staining was least visible on Fabric 3, Fabric 4 and Fabric 5. The stain remained most visible on Fabric 1 and Fabric 2.

In conclusion, based on the grayscale analysis of the stains, the easiest stain to remove was grass staining. Grass stains were removed from Fabric 1, Fabric 2 and Fabric 5 with all three detergents used. The grass stains on Fabric 4 and Fabric 3 were more difficult to remove, but the worst result was achieved by Mayeri detergent for white fabrics. Standard detergent and Sports wash liquid detergent achieved same results on Fabric 3.

Sand stain was second easiest stain to remove. Once again, all detergents managed to remove a sand stain from Fabric 1. Sand stains on Fabric 2 were a bit more visible after washing with Standard detergent and Sports wash, but most visible after washing with

detergent for white fabrics. Sand stain remained the most visible on Fabric 3, no matter which detergent was used.

Oil based stain made with leather care products turned out to be the most difficult stain to remove. The best detergent in removing this type of stain was detergent for white fabrics. It managed to remove the stain almost completely from Fabric 1 and Fabric 3. The second-best detergent was sports wash detergent, that performed best on Fabric 5 and worst on Fabric 1. Standard detergent removed the stain equally from Fabric 1, Fabric 2, Fabric 4 and Fabric 5, but the stain remained still visible.

Based on this laboratory test, it can be concluded that it was easiest to remove staining from Fabric 1. Fabric 1 remained clean almost with every detergent and grass and sand stains were almost always completely removed. Fabric 2 is slightly more prone to staining and it is slightly harder to remove stains from this fabric, but the difference is not that major. Compared to Fabric 1 and Fabric 2, Fabric 3 showed worst results in removing stains and all three types of stains were still visible after washing with different detergents. Some of the stains also remained visible on Fabric 4. Gray-scale together with etalon fabric was used to determine the staining.

Images from the testings can be found in Appendix 6. (A6)

7.3.8 Conclusions from the testing

In conclusion, all fabrics performed in a similar manner compared to each other. This could be because fabrics had the same construction, apart from Fabric 4 and similar fiber composition. None of the fabrics had any special finishes.

Fabric weight is an important factor for choosing breeches material. Heavy yet elastic fabric can offer a closer fit and support to the rider and is not transparent. See-through white fabrics are a big issue in currently available products so eliminating that defect was an important goal. Based on weight results, Fabric 5 was measured to have the biggest mass per unit area at an average weight of 330 g/m². This suggests that Fabric 5 would perform best as breeches material. Fabric 1 was measured to have the lowest mass per unit area at 201 g/m². Fabric 1 was also the most transparent and thinnest fabric when visually inspected. Fabric 1 alone would not be suitable to sew breeches from and would require pattern modifications so that the seating area would be less see-through. This would either require sewing in a double layer or using other fabric in the seating and knee area.

Fabric 4 average air permeability on the right side of the material was measured at an average of 135 l/m². Having too low air permeability may suggest that the fabric is not very breathable, which is a necessary quality for sportswear. Fabric 5 had medium air permeability compared to other fabrics. The right side of Fabric 5 air permeability was measured at 202±4 l/m². This suggests that this fabric allows more air flow passing through the textile, providing comfort property to the wearer. Fabric 1 had the highest air permeability results at 673±42 l/m². Being too permeable by air is also not good for fabric like breeches, since it suggests that the fabric construction is possibly too thin and might not provide enough support when wearing breeches.

In spray test, Fabric 1 received best results out of all fabrics tested. The wetting of Fabric 1 occurred only at the spray testing points and did not spread around the face of the specimen. After tapping the specimens, the fabric remained almost completely dry. Fabric 2 and 5 were second best in spray tests. With these fabrics some wetting occurred, but the whole specimen did not get wet. Fabric 1, Fabric 2 and Fabric 5 would all be suitable options for breeches. Fabric 4 and Fabric 3 got completely soaked after spray test. This suggests that in case of a rider getting splashed with any liquid, the liquid would spread much wider than with any of the other four fabrics tested.

The pilling tests showed that Fabric 1, Fabric 2 and Fabric 4 are least prone to pilling, matting or fuzzing even after prolonged wear. Fabric 3 and 4 were slightly more prone to pilling after 7000 rubs, but overall based on these results all fabrics performed well and not strong pilling occurred.

For abrasion resistance, all fabrics performed very well. None of the five fabrics tested had any thread breakage even after 50000 rubs performed.

In stain testing the hardest stain to remove overall was sand stain. Sand stains remained visible in some level on at least one sample of each fabric. Grass stain was the easiest to remove. Oil stains were also hard to remove from all fabrics, but since this stain was almost transparent, it was not as visible on the samples as for example sand staining. Fabric 1 performed best in stain tests. Fabric 2 and 5 performed adequately compared to other fabrics. Some sand, grass and oil stains remained visible on some samples, but nothing that would require additional washing or use of other chemicals. Fabric 3 and Fabric 4 had some stain samples that would require additional removal techniques. These were the fabrics where similarly to spray wetting, stain seeping also occurred the most. The stains spread over a much larger area when applied and were harder to remove and more visible after washing and drying.

Overall, based on these results it was decided that Fabric 5 would be the best candidate to sew breeches from. It did not perform best in every test, but it received great results in test that mattered the most. The biggest advantage of Fabric 5 is the heavy weight of the material, good air permeability, resistance to pilling, abrasion resistance and adequate resistance to staining. This fabric would not require any additional modifications to the breeches pattern, it is not see-through, has enough elasticity and would provide enough support for the rider.

8 PRODUCT SEWING PROCESS

After testing and selecting the most suitable material, prototype production could begin. This requires creating the patterns, preparing the fabric for sewing, buying necessary details for the product like button and zippers, creating the sewing technology with seam cross-sections.

8.1 Process of creating the breeches pattern

Creating a pattern for a technical product like breeches can be time consuming. Using a CAD/CAM software can speed up the process, since all changes, measurements and pieces can easily be modified. It is also possible to create multiple versions of the patterns and tweaking them without it affecting the base pattern. For this process Gerber Accumark was used. It is a leading software application that can be used to create patterns in 2D and 3D. [25]

The base for the pattern was created based on a leggings pattern online. [60] Then the pattern was modified and elements that are unique to breeches were added. The leggings pattern was chosen as a base since breeches are also supposed to be tight fitting and made from elastic fabric. Measurements for the pattern were taken off the author.

First for creating the base pattern for leggings the measurements were taken of waist, hip, thigh, knee, ankle and ankle rise. After leggings base pattern was done it was modified to add zipper yoke details, waistband details, an elastic calf detail and belt loop details. All seam allowances were added digitally to the patterns.

Fusing details were done for waistline, belt loops and zipper yoke pieces and added digitally to the pattern.

Then the pattern was plotted out on a printer specifically designed for pattern plotting. This was done with help of ACG Nyström Eesti OÜ who provide pattern printing services.

A maquette was sewn before cutting out the pattern from the main fabric. A maquette was sewn from a fabric with similar properties to the main fabric. The goal for a maquette is to see whether additional changes to the pattern are required. Although sewing a maquette might be time consuming, it helps to identify possible problems with the pattern before wasting main fabric.

After sewing the maquette, the pattern required minimal changes in terms of pant length and waistline height. The pattern was accordingly modified digitally and sewing the cutting the details from the main material Fabric 5 could begin.

All pattern pieces can be found in Appendix 7. (A7)

8.2 Breeches sewing technology

Creating and documenting a sewing technology sheet is important for getting a better understanding of the necessary steps in completing the product. A sewing technology sheet helps in creating the same product multiple times. In case of a defect or product malfunction, it is possible to trace the sewing steps using the sewing technology sheet order of succession and identify the processes that could be responsible for the defect.

Breeches sewing technology order of succession contains seam schemes for better understanding on how to construct the product step by step. The seam scheme drawings were made in Kaledo Style software. The complete order of succession with stitch schemes can be found in appendix.

8.2.1 Fusing used for breeches

Some of the breeches' details required fusing before sewing. These details are waistband, belt loops and zipper yoke. Fuse lining provides extra strength and durability to these details and reduces their elasticity. Since the breeches fabric is very elastic, sewing details like waistband and zipper is more challenging. Also, it is desired that the waistband hold the pants in place and provide more support. Fusing helps to keep the zipper in place during wearing and washing the garment and helps to keep the waistband's shape and supporting properties.

Using fusing on belt loops gives them more firmness and strength. Fusing prevents the belt loops from stretching out over time. This way the belt loops hold the belt in place for a longer period of time, even after washing and frequent use.

The fusing was provided by Tallinn University of Technology. The fusing was a nonwoven white material with adhesive spots that melted into the fabric when heat was applied. Fusing was attached using industrial iron. Additional information on the fusing material can be found in appendix.

8.2.2 Stitches used for sewing breeches

The breeches were sewn in TalTech textile building laboratory. For this product different types of sewing machines were used. Since elasticity is an important factor for the breeches, most of the stitches were 4-thread overlock stitches. This stitch is flexible and covers the edge of the knitted fabric, preventing fraying. Using a four-thread overlock provides stronger and more durable stitches. [61]

Five-thread chain stitch was used for sewing zipper details. This stitch creates more durable and stronger seams and is a common choice for giving more elasticity to the garment and is a suitable option for knitted and elastic fabrics. [61]

Regular lockstitch was used for sewing the waistband and belt loops. This stitch type is usually not suitable for knitted and elastic fabrics. In this case the goal was to secure the waistband and belt loops in a way that will decrease their elasticity, so lockstitch was a suitable option. [61]

The buttonhole on the waistband was sewn using a special buttonhole sewing machine, which also creates a lockstitch but, in a zig-zag pattern. This results in a durable and strong buttonhole.

All stitches were sewn with white polyester thread.

8.2.3 Furniture used for breeches

In addition to fusing and the main fabric, other furniture elements were used. These elements were a button and zipper.

The zipper was bought from Kangas ja Nööp store. It was a white 15cm zipper in white color.

The button was also bought from Kangas ja Nööp store. It is a gold-colored single hole button with glitter design on the top. Button size was 2cm in diameter and 0.2cm in height.

The final result can be seen on image below (Figure 8.2.3)



Figure 8.2.3 Breeches prototype

9 WEAR TESTS

The idea behind a wear test is to test product function, not fashion. Although laboratory tests can predict how a garment will behave in certain conditions, wear tests can give insight on how the garment performs. The goal of a wear tests is to understand whether the final product responds and satisfies client needs. By performing wear tests on a selected target group of customers it is possible to receive valuable constructive feedback about how well does the product fit, how comfortable it is and whether there are any limitations. Based on the feedback it is possible to update the product and make some redesigns in case they are needed. Wear tests help to identify any major flaws with the product before any large-scale production. Although wearing tests can be time consuming, they give valuable insight, and it is cheaper to fix product flaws in the beginning of the manufacturing process. Wear tests are a popular practice in sportswear brands, where product function is more important than it being fashionable. [57][58]

Breeches is a unique garment that must perform well in a specific environment. The fabric chosen to sew the breeches from was tested under laboratory conditions and wear tests can help to understand whether the final product functions well in real life conditions. Breeches were sewn based on client-oriented feedback and wear tests can help to confirm, whether the product satisfies client needs.

9.1 Participant for the wear test

The selected participant was an actively competing horseback rider who has experience with white breeches. The participant has competed in indoor and outdoor conditions. It was important that the participant has experience with different weather conditions, which the participant confirmed they have. The participant's previous experience with competition conditions and environmental factors can result in a more detailed and constructive feedback for the product tested in wear tests.

9.2 Wear test conditions

The wear tests were conducted based on the example of a regular competition day that is described above in chapter 2.2.4. (Chapter 2.2.4) The wear tests were performed

over the course of one day. The rider was asked to imitate a regular competition day and to include all regular preparation procedures that are a part of it.

The wear test was conducted in the beginning of May on a cloudy day. The product was worn in the stable indoors during preparation procedures. Preparation procedures included brushing and cleaning the horse, and during cleaning the saddle, bridle and other parts of the tack. The riding part of the wear test was performed outdoors. Other procedures performed during the wear test included walking the horse (by hand, not in saddle) and tacking off the tack in the stable.

9.3 Wear test evaluation form

A wear test evaluation form helps to understand the wearer's experience in a more constructed and organized way. The evaluation form guides the wearer to pay attention to specific details that could otherwise go unnoticed. It also helps to achieve a concrete structure for the test, which can be recreated in case of additional testing or if more than one person is trying out the products. [58][59]

The participant was asked to review the product and was given an evaluation form. The evaluation form was created specifically for this wear test and includes questions specific to the equestrian environment and sports. The evaluation form was created in Google Forms environment as a questionnaire. This way the form can be accessed from a computer or a smartphone and filled in during the process of wearing the product. The evaluation form can be found in Appendix 9 (A9)

9.4 Wear test results

The wear test results showed that Fabric 5 performed well in the real environment conditions. Based on the wear test participant experience, the breeches were comfortable to wear and did not hinder any activity. High-waisted design was said to be very comfortable and provided support during riding. The wear test participant mentioned, that high-waisted riding pants are often hard to find, yet are much more sought after, than medium or low-waisted breeches. The fabric elasticity was described to be enough, as breeches were comfortable to move in, climb in the saddle and during riding. The fabric was also thick enough so that the rider did not feel uncomfortable or afraid that skin or underwear is visible during wearing breeches.



Figure 9.4.1 Wear test participant tacking up the horse indoors.

The participant liked that there was a calf detail made from thinner fabric. Thanks to that the riding boots were easy to put on and required no additional high-knee socks for keeping the pants in place. This helps to eliminate additional layer of clothing which usually adds more warmth during physical activity.

Breeches technical parameters that were tested in the laboratory conditions showed similar results during wear tests. For example, after 45 minutes of riding when most of the abrasion occurs, left breeches looking completely undamaged. No pilling, fuzzing or matting of the breeches was identified.

Since breeches were worn during cleaning the tack and brushing the horse, they were exposed to multiple potential stains. Breeches remained completely clean after these

procedures and did not pick up any dust, debris, or horse saliva residue on the surface of the fabric.



Figure 9.4.2 Preparations before riding.

The biggest staining factor was the saddle, in which the rider sat. The saddle was freshly cleaned with leather soap and leather care conditioner was applied before using the saddle. Leather care products eliminated any dust from the saddle but left the skin conditioned and slightly shining. The shine was a thin residue layer of the leather conditioner. It is a common practice to clean tack before competitions. The combination of natural leather, leather soap and conditioner left no stains on the breeches seating area, but according to the wearer it usually leaves a stain on previously worn white breeches. This is a good indicator that selected fabric performed well with such staining agents.



Figure 9.4.2 The material is not see-through.

The rider did not ride under rainy conditions and there was no direct contact with arena sand or grass, so these stains could not be tested directly on the breeches and compared to laboratory results.



Figure 9.4.4 Breeches during wear test performed in the saddle.

After the experiment the breeches were washed with Mayeri sports wash detergent. The was cycle was for synthetic wear and water temperature 40 degrees. After washing breeches were left out to dry on a drying rack. The product looked new after one wash.

Overall, the product performed well, the customer was satisfied, and positive feedback was received. Based on these results no additional modifications or changes to the pattern- or fabric need to be made.

10 FINAL DISCUSSION

Product development process has multiple steps, that contribute to the succession of the product. Competition breeches are a very specific product that has very specific requirements and environment in which they are worn. The white color that is required of the competition breeches creates an even more demanding circumstance. It is not easy to keep white clothing clean in general and equestrian environment is rather dirty and unpredictable in terms of unexpected staining. In addition, breeches are required to be high-performance in terms of athletic wear. They must be breathable, moisture wicking, elastic, provide support. be durable and not be see-through. In addition, equestrian wear like breeches is exposed to heavy friction in the saddle. Developing such a product requires complete understanding of the wearer's needs and product environment.

Conducting client-oriented research gave valuable insight to product requirements. Since there are no minimum requirements established for equestrian apparel, it was very important to gather client opinion on the product requirements. Conducting a questionnaire helped in gathering necessary data that the product development was based on. The main requirements of the product were high elasticity, high waist for more comfort and support during riding, belt loops on the waistline, thinner and elastic calf part, comfortable fabric, breathability and durability in terms of stains and abrasion resistance.

Based on client requirements 5 different fabrics were obtained as potential materials to sew breeches from. To determine the best possible fabric out of five, a selection of laboratory tests were chosen to be performed on the fabrics. Laboratory results helped in comparing the fabrics and understanding how these materials would potentially perform in the real environment. Laboratory results showed that Fabric 3 was the least suitable candidate for breeches, as this fabric did not perform well in spray tests or stain tests. It was also too permeable by air. Fabric 1 and Fabric 5 were both great candidates for sewing breeches out of, since they showed good results in stain testing, abrasion resistance and pilling resistance. Unfortunately, Fabric 1 was too lightweight to be able to provide enough support and would require modifications to the pattern to hide the see-through areas. Fabric 5 was the heaviest out of the five fabrics and would provide enough support for the rider.

When the fabric was chosen, other product development processes could continue. A pattern was digitally created and plotted out based on Fabric 5 parameters. Sewing from

Fabric 5 required no additional modifications to the pattern. After the product was sewn, wear tests could begin.

Wear test was an important part of the product development process due to the very specific environment in which the product is used. It is not always possible to imitate the real-life environment in the laboratory conditions. Since horses are animals and the circumstances around them can often be unpredictable, it was good to bring the prototype for additional wear tests. Wear tests made it possible to test the product for pattern design, abrasion resistance, stain resistance specially to leather care products and overall comfort. Stain tests concluded that no additional modifications to the pattern are required. Breeches provided more support than the wearer's regularly used competition breeches. The material was able to support the rider yet remain elastic and comfortable throughout all activities. Breeches got some staining from leather saddle in the seating area but were easily removed after one wash cycle. Wear test results suggest that all previous product development steps were successful and that laboratory testings predicted well how the fabric would behave in the real environment.

The combination of laboratory tests and wear tests give security, that the product is able to satisfy all customer needs and is a durable and long-lasting option for competition wear. It would be hard to achieve the same success if even one step of the development process was not conducted. It would be most likely impossible to achieve the same results if there was no client input in the beginning of the development process. If laboratory testing would have not been done and some other fabrics were chosen, the product might not have performed as well during the wear tests in the actual environment. Unfortunately, due to the time limitations it was impossible to sew prototypes out of all five fabrics that were tested. This would have given even more valuable insight and additional comparisons could be made. Such product development including all mentioned steps should be used on all specific high-performance garment to achieve best possible results.

SUMMARY

White competition breeches are a high-performance sportswear garment that plays an important role in the equestrian sport. There are multiple different brands of breeches available in today's market, but customers are still left dissatisfied with the product. Current products lack certain qualities like durability, are see-through, hard to maintain clean and are not always comfortable to wear. The aim of this thesis was to develop white competition breeches through applying customer-oriented product development processes to create a product that can satisfy all customer needs.

This thesis describes the multiple steps that were taken in order to achieve the goal of creating the perfect product. First establish product parameters and minimum requirements. Since breeches are considered sportswear apparel, there are no regulations on product minimum requirements. Customers were asked on what aspects of their current products they like and dislike. The minimum requirements established for this product were based on the gathered data from customer-oriented questionnaire results. Based on the received information, product specification sheet was made. All following product development processes were based on the forementioned specification sheet.

After understanding the environment in which breeches are worn and customer needs, the search for most suitable fabrics began. This seemed to be a challenge, as the availability of white high-performance sportswear fabric that is elastic and thick enough was scarce. Eventually 5 different options were bought, of which three originated from Estonia and two from Germany.

A selection of tests was then chosen to be tested on the five fabrics to determine the best possible material to sew breeches from. Fabrics were tested for air permeability, wetting, abrasion resistance, pilling resistance and their mass per unit area was determined. A selection of most common stains encountered in the equestrian environment were also identified and tested on the fabrics in laboratory conditions. Based on the test results and product requirements it was decided that Fabric 5 was the best possible option to sew breeches from. It performed great in abrasion resistance and pilling tests, well in stain tests and had good air permeability. Some fabrics performed better in spray tests, but Fabric 5 other parameters outweighed the rest of the fabrics.

Based on required product parameters and Fabric 5 properties, product technical sheet and patterns were made. Fabric 5 was thick enough that the breeches could be sewn without any interlining. The pattern was made for high-waisted breeches, that have a elastic calf part for extra comfort and belt loops for more support during riding.

Fabric 5 was used to sew breeches prototype for wear testing. The wear tests were an important part of product development, as breeches are a very specific garment, and its fabric properties cannot all be predicted in laboratory testings. To understand how well the fabric would perform, testing in real environment was important. The participant for the wear test was chosen based on their extensive experience as an active and competing horseback rider. The feedback from the wear tests confirmed, that the product fit was comfortable, the material was elastic yet supportive enough and the fabric was not see-through. Fabric properties that were tested in laboratory conditions performed in the same manner during wear test. Most importantly, the no stains were identified on the fabric after the wear tests. Breeches were washed and dried after the wear test and showed no signs of change in color, elasticity or fit.

In conclusion, creating a product based on customer needs can be challenging, but with proper research and understanding the product use environment and requirements, it is possible to achieve. Search for a suitable fabric based on product requirements can be time consuming. Testing fabric properties prior to production can give valuable insight and help in selecting the best possible materials. Fabric properties also have an influence on pattern design and overall comfort and fit of the product. Fabric testing combined with product wear tests can yield good results in creating a successful product that satisfies customer needs and does not have the limitations of currently available products.

In conclusion, the thesis goal was achieved. In combination of thorough background and environment analysis, careful fabric selection, multiple laboratory tests and wear tests, a product prototype was created that satisfies customer needs. The created product specification sheet, technical data sheet and patterns will help in manufacturing the breeches on a smaller or larger scale.

KOKKUVÕTE

Ratsutamiseks mõeldud valged võistluspüksid on kõrge sooritusvõimega spordirõivas, millel on oluline roll ratsaspordis. Tänapäeva turul on saadaval mitmeid brände, kes toodavad võistluspükse, kuid need ei rahulda kasutajate vajadusi. Olemasolevatel toodetel puuduvad olulised omadused nagu vastupidavus ja mugavus. Lisaks on nad tihti läbipaistvad ning neid on raske hooldada. Selle magistritöö eesmärk oli luua valged võistluspüksid, mis on arendatud lähtudes kliendikesksest tootearendusest ja rahuldavad kõiki tarbija vajadusi.

Antud magistritöö kirjeldab kõiki protsesse, mille käigus loodi tarbija vajadustele vastav toode. Esiteks pandi paika toote parameetrid ning nõuded. Kuna ratsapüksid on spordirõivas, ei ole tal konkreetseid standarditega sätestatud miinimumnõudeid millest lähtuda. Selleks, et koguda vajalikku infot toote nõuete kohta viidi läbi tarbijauuring, kus paluti hinnata turul saadaolevate toodete häid ning halbu omadusi. Ratsapükste parameetrid ja omadused on toodud välja spetsifikatsioonilehena ning põhinevad tarbijauuringust saadud vastustele.

Ratsapükste materjalide valikul lähtuti keskkonnast ehk sellest, kus ja kuidas toodet kasutatakse, misjärel algas otsing sobivate materjalide leidmiseks. Sobivate materjalide leidmine osutus oodatust oluliselt keerulisemaks, kuna valget värvi, piisavalt elastset ja paksu kangast oli Eesti turul väga vähe saada. Kokkuvõttes suudeti leida viis erinevat kangast, mis võiksid kõik olla potentsiaalselt sobivad valikud ratsapükste õmblemiseks. Kolm nendest kangastest pärinesid Eestist ning kaks olid tellitud läbi interneti Saksamaalt.

Tulenevalt toote kasutustingimustest ning tarbija vajadustest valiti välja katsemeetodid, mille abil selgitada välja kõige sobilikum kangas ratsapüksteks. Katsemeetodite eesmärk oli testida kanga parameetreid laboritingimustes, et prognoosida kangaste käitumist erinevatest tingimustes, millega ratsanik pükse kandes kokku puutub. Valitud katseteks osutusid õhuläbilaskvus, veehülgavus, vastupidavus pillingule, vastupidavus hõõrdekindlusele. Samuti mõõdeti kangaste pindtihedust. Lisaks testiti laboratoorsetes tingimustes kangaste vastupidavust plekkidele. Plekke valiti vastavalt ratsutamise keskkonnas enim levinud määrdeainetele. Lähtudes laborikatsete tulemustele valiti välja kangas, mis oleks kõige sobivam ratsapükste õmblemiseks. Selleks osutus kangas 5, mis saavutas väga head tulemused õhuläbilaskvuse katsetel, hõõrdekindluse ja pillingu katsetel ning oli piisavalt vastupidav plekkidele. Kuigi osad kangad näitasid paremaid tulemusi näiteks veehülgavuse katsetel, olid kangas number 5 tulemused kokkuvõttes siiski paremad, kui ülejäänud neljal kangal.

Lähtudes võistluspükste parameetritest ja kangas number 5 omadustest, loodi toote tehniline kaart ja lõiked. Kangas 5 oli piisavalt tihedalt kootud ning paks, et püksid sellest kangast ei vajanud täiendavat voodrit. Lõiked olid loodud kõrge värvliga pükste õmblemiseks, millel on lisaks veniv sääreosa, lukuga esikinnis ja vöötripid.

Toote prototüüp sai õmmeldud kangast number 5. Seejärel viidi läbi kandmistestid. Ratsapükste näol on tegemist väga spetsiifilise tootega ja kõiki toote keskkonnatingimusi ei ole võimalik jäljendada laboritingimustes. Kandmistestid on oluline osa tootearendusest, sest võimaldavad testida nii toote kui ka kanga käitumist tegelikes tingimustes, et vajadusel viia sisse täiendavad muudatused. Toote kandjaks valiti välja ratsutamiseiga igapäevaselt tegelev ratsanik, kellel on ka suur võistluskogemus nii sise- kui ka välitingimustes. Kandmistestidelt saadud tagasiside kinnitas, et toote istuvus oli väga hea, materjal oli veniv kuid samas pakkus piisavalt toetust ning püksid ei paistnud läbi. Kanga omadused, mida sai katsetatud laboritingimustes näitasid sarnaseid tulemusi ka kandmistestil. Kangal ei tekkinud tugevaid plekke. Pärast ühekordset pesu säilis toote venivus ja püksid nägid välja kui uued.

Toote loomine tuginedes kliendikesksele tootearendusele võib kohati osutada keerukaks väljakutseks, kuid kui viia läbi piisav tasutauuring toote kasutustingimuste ning tarbija vajaduste kohta on võimalik luua teistest parem toode. Materjalide testimine enne masstootmist annab väärtuslikku informatsiooni ja võimaldab prognoosida kanga käitumist konkreetsetes tingimustes. Selliselt on võimalik määrata parim kangas, mis peab vastu selles keskkonnas, milles teda kasutatakse. Kanga omadused mängivad suurt rolli toote lõigete loomisel ja üleüldises toote mugavuses ja istuvuses. Materjalide testimine laboratoorses tingimustes kombineeritult kandmistestiga aitab kaasa tarbija vajadustele vastava toote loomisel.

Kokkuvõttes sai magistritöö eesmärk täidetud. Eelnev toote keskkonna- ja tarbijavajaduste analüüs, hoolikas kangavalik ning mitmete katsete läbiviimine aitas luua prototüübi, mis on kooskõlas tarbija vajadustega. Töö käigus loodud spetsifikatsiooni leht, toote tehniline kaart ja lõiked aitavad edaspidi kiirendada tootmisprotsessi nii väiksemates kui ka suuremates kogustes.

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APPENDICES

APPENDIX 1 Most common stains on breeches



Figure A1.1 These stained breeches are a result of one weekend competitions. Stains from boots, saddle, slobber and grass can be identified. [29]



Figure A1.2 These breeches have brown staining around the seating area from a brown saddle. [30]



Figure A1.3 A pair of white breeches competing in eventing cross country. Staining is evident all around the clothing, to the point of breeches no longer looking white. [31]

APPENDIX 2 Patterns and styles used for breeches



Figure A2.1 Example of Equiline breeches where the lower part of the pants is made from different, usually thinner material for more comfort. [40]



Figure A2.2 Example of breeches that have silicone grips placed around the knee area [41]



Figure A2.3 Example of full grip breeches. This means that the silicone grips are placed around the whole seating area for better reinforcement in the saddle. [42]



Figure A2.4 An example of faux leather seat breeches. In this case the seating area is made from suede leather imitation fabric that helps in better grip in the saddle. [43][44]

APPENDIX 3 Client-oriented questionnaire for gathering customer data on breeches

1. Sugu *

Märkige ainult üks ovaal.

Naine

Mees

2. Võistlusklass *

Märkige kõik sobivad.

Harrastaja

Laps

Juunior

Noor

Senior

3. Spordiala *

Märkige kõik sobivad.

Takistussõit

Koolisõit

Kolmevõistlus

4. Kui tihti osaled võistlustel ratsanikuna? *

5. Millise firma võistluspükse kannad? *

Märkige kõik sobivad.

- Fair Play
- Equi-Thème
- Mountain Horse
- HV Polo
- John Whitaker
- ELT
- Cavalleria Toscana
- Animo
- Kingsland
- Samshield
- Spooks
- Horse Pilot
- Equiline
- Pikeur
- Horze
- Muu: _____

6. Mis meeldib praeguste võistluspükste juures? *

7. Mis ei meeldi praeguste võistluspükste juures? *

8. Kas kannad vastavalt hooajale erinevaid võistluspükse? Kui jah, siis miks? *

9. Palun märki olulised omadused võistluspükste juures 5-palli skaalal *

1 = ei ole üldse oluline 5 = äärmiselt oluline

Märkige kõik sobivad.

	1	2	3	4	5	Ei oska hinnata
Tagataskud	<input type="checkbox"/>					
Esitaskud	<input type="checkbox"/>					
Vöötripid	<input type="checkbox"/>					
Kõrge värvel	<input type="checkbox"/>					
Madal värvel	<input type="checkbox"/>					
Täisnahad	<input type="checkbox"/>					
Silikoonist gripid	<input type="checkbox"/>					
Ilukaunistused	<input type="checkbox"/>					
Vähemäärduvad	<input type="checkbox"/>					
Veekindlad	<input type="checkbox"/>					
Kerge hooldada	<input type="checkbox"/>					

10. Palun too mõni näide, kus võistluspüksid on muutunud ootamatult kasutuskõlbmatuks

*

Märkige kõik sobivad.

- Plekk, mis ei tule enam pesus välja
- Välja veninud materjal
- Rebenenud või hargnevad õmblused
- Katkine lukk või nõõp
- Valge värv on muutunud kiiresti halliks
- Pükstesse on tekkinud auk
- Püksid paistavad läbi
- Pole kunagi juhtunud sellist olukorda
- Muu: _____

11. Kas on ette juhtunud olukordi, kus püksid said märjaks vihma tõttu? *

Märkige ainult üks ovaal.

- Jah
- Ei

12. Kui vastasid eelmisele küsimusele "jah", siis palun kirjelda pükse märjaks saamisel

Märkige kõik sobivad.

- Püksid määrdusid kergemini
- Püksid muutusid läbipaistvaks
- Püksid muutusid jalas ebamugavaks
- Midagi ei juhtunud
- Muu: _____

Muud ettepanekud

APPENDIX 4 Identified product needs gathered from customer data

Table A4. Identified product needs gathered from raw customer data after a client-oriented questionnaire

Customer raw data	Identified need	Importance
Comfortable	<ul style="list-style-type: none"> • Elastic fit • Close fitting 	5
Good silicone grips	<ul style="list-style-type: none"> • Silicone grips at knees, thighs and seat • Better grip in the saddle 	5
Soft material	<ul style="list-style-type: none"> • Smooth material • material pleasant for the skin 	5
Comfortable material	<ul style="list-style-type: none"> • Elastic material 	5
Pretty design	<ul style="list-style-type: none"> • Classical design • Embellishments 	5
Behind part is pretty	<ul style="list-style-type: none"> • Good seams on the seat • Embellishments on the back 	2
Good price	<ul style="list-style-type: none"> • Affordable price • Competitive price 	2
Very elastic	<ul style="list-style-type: none"> • Elastic seams • Elastic material 	5
Full silicone grips	<ul style="list-style-type: none"> • Good grip in the saddle • Silicone grips at knees, thighs and seat • Silicone grips positioned close to each other • Silicone grips cover a large area 	3
Good fit	<ul style="list-style-type: none"> • Close fit • Elastic fit 	5
Do not get stained easy	<ul style="list-style-type: none"> • Easy care material • stain resistant material • stain resistant finishing • Correct care label 	5
Easy to clean	<ul style="list-style-type: none"> • Machine wash allowed • easy care material • stain resistant material • Stain resistant finishing • Correct care label 	5
High waist	<ul style="list-style-type: none"> • High waist • possibility to wear shirt tucked in 	5
Leather seat	<ul style="list-style-type: none"> • Faux leather seat 	2
No velcro fastening at the bottom	<ul style="list-style-type: none"> • Elastic material at the bottom that requires no extra fastening • thinner material used at the calf 	5

Customer raw data	Identified need	Importance
Strong material	<ul style="list-style-type: none"> • Abrasion resistant • pilling resistant • wear resistant material 	5
Durable	<ul style="list-style-type: none"> • Wear resistant material • pilling resistant fabric • abrasion resistant fabric 	5
Comfortable during riding	<ul style="list-style-type: none"> • Elastic fabric • close fit • elastic seams 	5
Not see through	<ul style="list-style-type: none"> • Tight woven fabric • Thick enough fabric 	5
Both silicone girps and leather seat	<ul style="list-style-type: none"> • Good grip in the saddle • Faux leather seat • Silicone grips 	2
Too thin material	<ul style="list-style-type: none"> • Breathable materials • Not see through material 	5
Comfortable calf part	<ul style="list-style-type: none"> • No extra fastening • Thinner fabric • Elastic fabric 	5
See through	<ul style="list-style-type: none"> • Thick woven fabric • Thick enough fabric 	5
Uncomfortable low waist	<ul style="list-style-type: none"> • High waist 	5
Ugly colour	<ul style="list-style-type: none"> • Bleaching allowed • Machine wash allowed • Dry cleaning allowed • Correct care label 	5
Big at the waistline	<ul style="list-style-type: none"> • Belt loops • Button fastening • zipper fastening 	5
Get dirty fast	<ul style="list-style-type: none"> • Easy care fabric • Stain resistant fabric • Stain resistant finishing • water resistant fabric 	5
Seams chafe	<ul style="list-style-type: none"> • Elastic seams 	5
Shrink after washing	<ul style="list-style-type: none"> • Elastic fabric • Elastic seams • Anti-shrink finishing • Correct care label 	4
Not regulatable waistline	<ul style="list-style-type: none"> • Belt loops • Button fastening • Zipper fastening 	5
Stain does not come out	<ul style="list-style-type: none"> • Easy care fabric • Stain resistant fabric • Stain resistant finishing • Machine wash • Bleaching allowed • dry clean allowed 	5

Customer raw data	Identified need	Importance
	<ul style="list-style-type: none"> • Correct care label 	
Yellow color	<ul style="list-style-type: none"> • Machine wash • Bleaching allowed • dry clean allowed • Correct care label 	5
Gripping not strong enough	<ul style="list-style-type: none"> • Good grip in the saddle • Silicone grips at knees, thighs and seat • Silicone grips positioned close to each other • Silicone grips cover a large area 	5
Do not stay up without belt	<ul style="list-style-type: none"> • Belt loops • Button fastening • Zipper fastening 	5
Stretch out fast	<ul style="list-style-type: none"> • Elastic fabric • Elastic seams • Durable fabric 	5
Seams frail	<ul style="list-style-type: none"> • Elastic seams • Good quality seams 	5
Design	<ul style="list-style-type: none"> • Classical design • Embellishments 	5
Slippery material	<ul style="list-style-type: none"> • Good grip in the saddle • Silicone grips at knees, thighs and seat • Silicone grips positioned close to each other • Silicone grips cover a large area 	5
Break easy	<ul style="list-style-type: none"> • Durable fabric • Elastic seams • Elastic fabric 	5
Shirt comes out of the waistband	<ul style="list-style-type: none"> • High waist • Silicone gripping on the inside of the waistband 	4

APPENDIX 5. Product specification sheet

No.	Parameter no.	Specification	Importance	Unit
1	1	Fabric color	5	Margin
2	2	Product pattern	5	Margin
3	5,6,7,11,15	Material composition	5	%
4	12, 21	Fabric weave	5	Margin
5	23	High quality seams	5	Margin
6	8,9,10	Silicone grips	5	Margin
7	13	Elastic calf part	5	Margin
8	14, 17	Care requirements	5	Margin
9	18	High waist	5	Margin
10	19	Zipper	5	Margin
11	20	Button	5	Margin
12	22	Belt loops	5	Margin
13	16	Stain resistant finish	5	Margin
14	24	Water resistant fabric	4	Margin
15	25	Thinner material for calf part	4	Margin
16	26	Competitive price	3	€
17	27	Regulatable waistband	3	Margin

APPENDIX 6 Results from fabric testings

Table A6.1. Determination of mass per unit area results

Sample no.	Fabric 1	Fabric 2	Fabric 3	Fabric 4	Fabric 5
	Weight (g/m ²)				
1	206.7	261.3	335.4	241.6	328.3
2	197.1	262.9	334.1	256.4	334.6
3	200.4	267.6	329.6	249.8	329.6
Average	201.4	263.9	330.0	249.3	330.8
Standard deviation	4.9	3.8	3.0	7.4	3.3

Table A6.2. Fabric 1, Fabric 2, Fabric 3, Fabric 4 and Fabric 5 air permeability test results

Sample no.	Fabric 1		Fabric 2		Fabric 3		Fabric 4		Fabric 5	
	Right side (l/m ²)	Left side (l/m ²)	Right side (l/m ²)	Left side (l/m ²)	Right side (l/m ²)	Left side (l/m ²)	Right side (l/m ²)	Left side (l/m ²)	Right side (l/m ²)	Left side (l/m ²)
1	652	652	337	318	242	237	138	139	206	211
2	634	634	350	369	250	233	124	140	201	224
3	690	690	429	400	243	230	125	141	198	226
4	697	697	447	408	240	233	131	136	198	247
5	700	700	457	375	227	246	131	137	199	250
6	740	740	375	360	236	249	138	135	198	210
7	722	722	415	374	246	259	139	137	207	195
8	656	656	370	367	244	248	138	140	205	201
9	643	643	332	345	245	246	141	138	206	194
10	603	603	347	378	242	246	149	140	209	192
Average	673	673	385	369	421	242	135	138	202	215
Standard deviation	42	42	47	25	6	9	7	2	4	21

Table A6.3. Examples of the spray test results

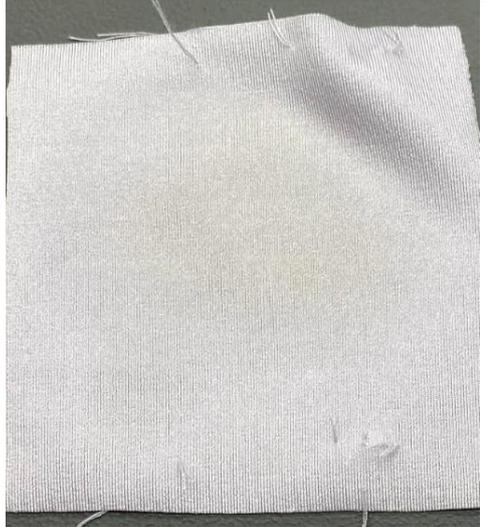
Fabric	Example of a sample	Description
Fabric 1		Slight random sticking or wetting of the specimen face
Fabric 2		Partial wetting of the specimen beyond the spray points
Fabric 3		Complete wetting of the entire face of the specimen
Fabric 4		Complete wetting of the entire face of the specimen

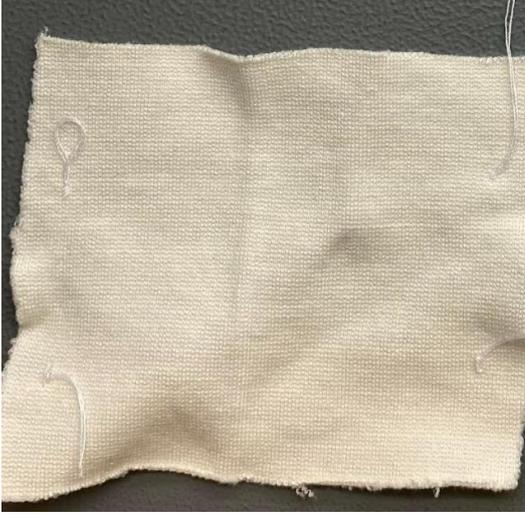
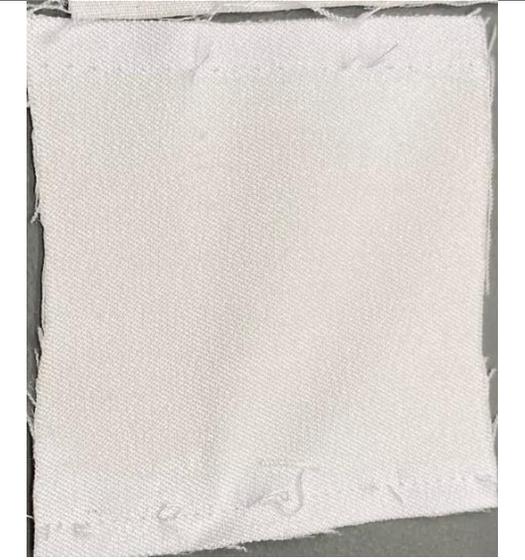
Fabric	Example of a sample	Description
		
Fabric 5		Complete wetting of the specimen face beyond the spray points

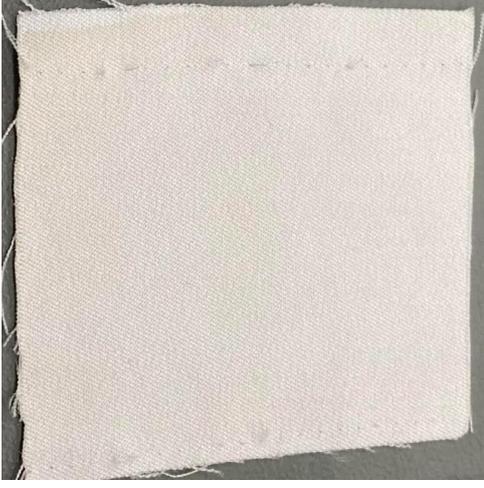
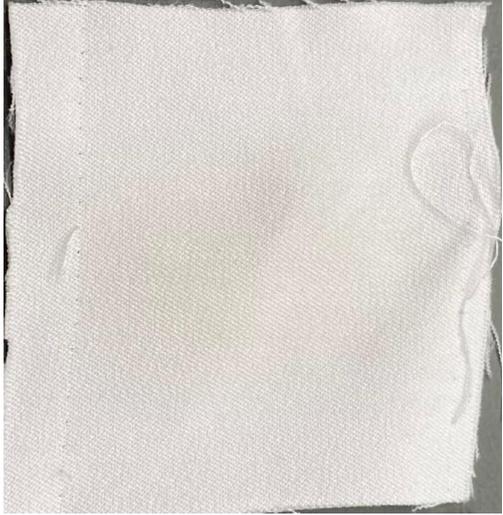
Table A6.5 Examples of the most visible stain test results

Fabric	Stain type	Example	Description
Fabric 1	Grass		The stain is not visible on the sample

Fabric	Stain type	Example	Description
	Sand		The stain is not visible on the sample
	Leather care		Some staining is visible in the middle of the sample
Fabric 2	Grass		Staining is visible in a circular manner on the sample.

Fabric	Stain type	Example	Description
	Sand		Staining is visible in a circular manner on the sample.
	Leather care		Staining is visible in the middle of the sample.
Fabric 3	Grass		Staining is visible in a circular manner on the sample.

Fabric	Stain type	Example	Description
	Sand		The whole sample is evenly stained and discolored.
	Leather care		Staining is visible in the middle of the sample.
Fabric 4	Grass		The whole sample is stained almost from edge to edge.

Fabric	Stain type	Example	Description
	Sand		The whole sample is stained almost from edge to edge.
	Leather care		Staining is visible in the middle of the sample.
Fabric 5	Grass		Sample is almost completely clean.

Fabric	Stain type	Example	Description
	Sand		Sample is almost completely clean.
	Leather care		Staining is visible in the middle of the sample.

APPENDIX 7 Breeches pattern

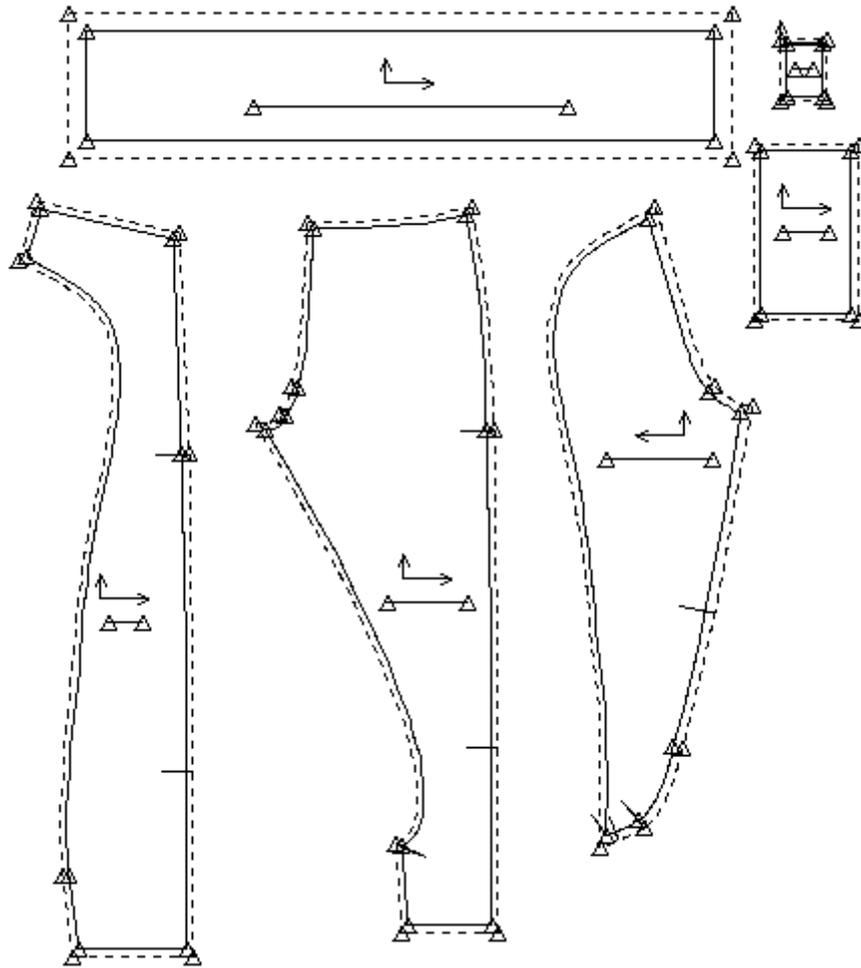


Figure A7.1 Breeches main fabric pattern

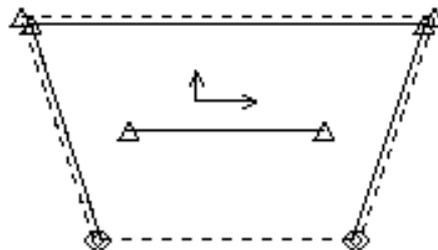


Figure A7.2 Breeches detail fabric pattern

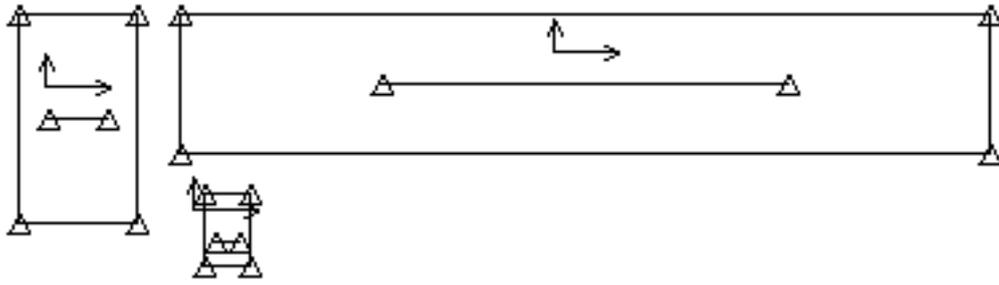
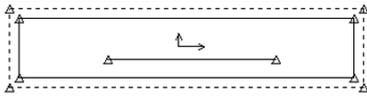
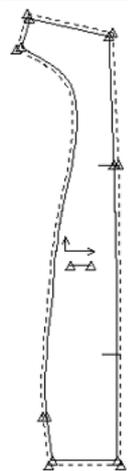
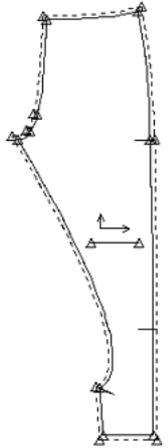
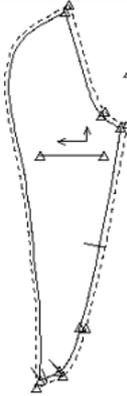
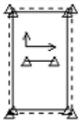
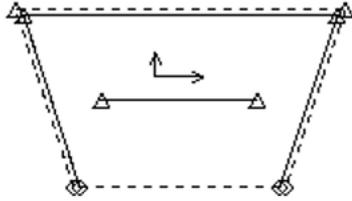
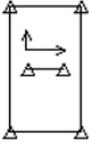
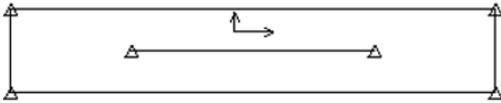


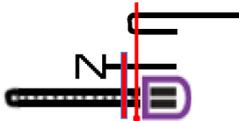
Figure A7.3 Breeches fusing details pattern

Table A7. 1 List of patterns

Piece name	Piece image	Fabric	Pieces	Flips
Waistband P1		White thick elastic	1	1
Pants back P2		White thick elastic	2	1
Pants front P3		White thick elastic	2	1

Piece name	Piece image	Fabric	Pieces	Flips
Seating P4		White thick elastic	2	1
Belt loop P5		White thick elastic	6	1
Zipper yoke P6		White thick elastic	1	2
Calf P7		White thin elastic	2	2
Zipper fuse F1		Fusing	1	2
Waistband fuse F2		Fusing	1	1
Belt loop fuse F3		Fusing	6	1

APPENDIX 8 The sewing technology of breeches prototype

No	Operation description	Machine/stitch type	Technical conditions	Stitch scheme
1	Cutting out all details	By hand	-	-
2	Fusing the adhesive lining detail with fabric	Industrial iron	Temperature 110°C	
3	Sewing the seating detail	514	Seam allowance 0.7 cm	
4	Sew zipper yoke	514	Seam allowance: 0.5 cm	
5	Sew zipper to yoke	301	Seam allowance 0.7 cm	
6	Sew zipper yoke to front piece	514	Seam allowance: 0.7 mm	
7	Sew zipper in front center	401	Seam allowance 0.7 cm	
8	Sew back and front pieces together	514	Seam allowance 0.7 cm	
9	Sew calf detail to the pant	514	Seam allowance 0.7 cm	
10	Sew crotch seam	514	Seam allowance 0.7 cm	

11	Make belt loops	301	Seam allowance 0.5 cm Stitch type: 301	
12	Sew waistband one side to main fabric, then fold and sew other side to main fabric		Seam allowance 1 cm Stitch type: 301	
13	Sew buttonhole	107	Buttonhole size: 1.8 cm	
14	Attach button	By hand	-	-
15	Final quality control	Visual inspection	-	-

APPENDIX 9. Wear test evaluation form

Breeches wear test evaluation form	
Age	27
Gender	Female
Horseback riding experience	20 years
Competition experience	7 years
Main discipline	Training in dressage and show jumping. Competing mainly in show jumping. Experience in few dressage and cross-county competitions.
Test location	Kurtna ratsatall, Harjumaa. Riding was done outdoors and getting ready and preparing the horse (cleaning, tacking up) was done indoors in the stable.
Weather conditions	13 degrees outdoors. Cloudy, no rain
For how long the breeches were worn indoor	In total for about 3 hours. It took about 45 minutes to clean tack and get the horse ready. Outdoor training took about 1,5 hours, of which 45 minutes were spent in the saddle and the rest was spent beside the horse. Then 20 minutes were spent untacking and cleaning the horse again and putting away the tack.
For how long breeches were worn in the saddle	45 minutes
Color of the saddle used for riding	Black
When was the last time you applied leather care products on the saddle	30 minutes before riding.
Leather care products description	Leather soap with glycerin (F.M Italia), applied with a sponge. Leather balsam in spray bottle (Bense&Eicke), polished with a sponge. Leather balsam contains glycerin and coconut oil.

Breeches wear test evaluation form	
Overall comfort of breeches	Breeches were comfortable to wear. Biggest difference noticed was the higher waistband, which provided comfortable support during riding. Breeches were comfortable to wear in the boots.
Were you able to perform all necessary actions comfortably	Yes, nothing was pressing or constricting the movement.
Compared to your current product that is worn during competitions	Previously worn breeches are from HV polo. Previous breeches exposed lower back during getting in the saddle and during jumping. Some older breeches also had stretched out knee areas.
Was the fabric comfortable	Yes. Elastic and not see through. It was not so slippery in the saddle like some other fabrics.
Did the garment have a good fit	Yes, the fit was snug and not loose but not constricting either.
How did the garment look after wearing	It looked fine, no apparent breakage or staining, only some staining in the seat area where they were in contact with the saddle, but nothing very visible.
Did any of the following instances occur during wearing the breeches: Falling off a horse Spilling something on the breeches Horse rubbing against the breeches	Horse rubbed against the breeches but no staining occurred.
General comments	Would wear the product during competition. Wore them with belt which elevated the look and made them more comfortable.