THE INTERACTIVE BODYSUIT

GRADUATION REPORT

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THE INTERACTIVE BODYSUIT

A TEXTILE BASED WEARABLE FULL BODY MONITORING SYSTEM FOR PHYSICAL THERAPHY PATIENTS

The Interactive Bodysuit
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Abbreviations:
PT: Physical Therapy; PTs: Physical Therapists
RT: Rehabilitation Therapy
MSC: Musculoskeletal Chain
FBMS: Full Body Monitoring System
QoL: Quality of Life

SUMMARY

This project focussed on the use of smart textiles for full body posture monitoring and exploring the potential of a tight fitting catsuit to measure posture close to the body. A full body monitoring system (FBMS) that is wearable and easy to use, was found to be most relevant in the domain of first line care physical therapy(PT). As the form of the product was set in the beginning of the project, the ViP analysis was used to gain insight in the Domain of physical therapy, the context the FBMS is used, the qualities of the interactions users have with the FBMS and the features of the product.

A fully textile based wearable system for monitoring postures is complex but not impossible. In terms of research in the field of wearable textiles, recent developments has shown a surge in possibilities and posture sensing abilities. The identified target users are female physical therapy patients with a young family who experience lower back pain. Prevalence of lower back issues are highest among musculoskeletal conditions and issues related to lower back pain have a large influence on the rest of the body. Here the posture changes due to poor posture behaviour, creating deformities in the body. These deformities can be measured by adapting strain resistive sensors to textile based sensors and integrated them in a tight fitting bodysuit. For this purpose, the zigzag stitch, shieldex 2-ply silvercoated yarn and 85% lycra proved most successful in obtaining a useful sensor signal. Here, posture and change in posture could be measured and provide the user with direct haptic feedback on their posture with vibration motors.

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PROJECT INSPIRATION

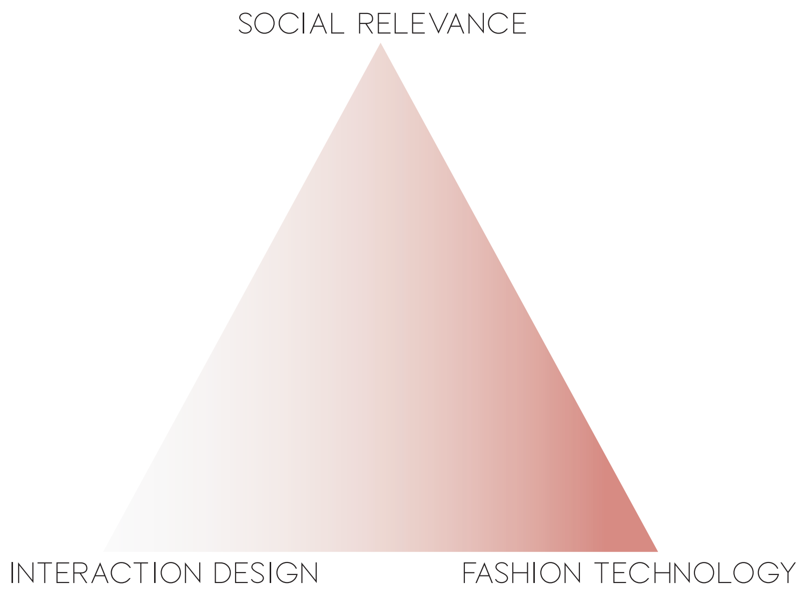


Figure 1. Project focus

Personal ambitions
My hobbies and interests have always been a mix between fashion, technology and, more recently, interaction design. Through design side projects and electives, my interests have grown towards interaction design, electronics and prototyping. I enjoy tinkering, creating and conceptual fashion design in my free time. I'm very passionate about this, but that is not going to save the world on its own. For this project, I want my design to combine my passions into a project that is relevant to society(fig. 1). For this, I chose the domain of physical therapy, as I have a history of needing this care. Furthermore, I want to push my existing knowledge of textiles and the future of fashion technology.

1. INTRODUCTION

The products we use on a daily basis are getting smarter every day (Lee & Shin, 2018). From simple data tracking with your smartphone or wireless connections between your products, to using biometrics to track personal behaviour. What's smart about these products is that they facilitate insight in our own data and can help us to improve ourselves. In recent years, these smart technologies have been strongly developing in the fields of fields of fashion, sports and consumer goods (Omoregie, 2016; Mcnulty, 2019) into products that are wearable. Products such as the Fit Bit for tracking biofeedback, i.e. heart rate, smart shoes that record running data or complete suits that track muscle activity during work outs(fig. 2-4) are examples of smart technology that can be worn by the user and is therefore called Wearable Technology.

Figure 2. Fit Bit

Figure 3. Altra IQ shoe

Figure 4. Hexoskin

These wearables are often incorporated in garments, creating Smart Textiles. Especially in sports there have been great displays of what wearable technology can do for both consumers and athletes. By applying technology to fashion, performances can be improved, injuries reduced and training personalised (Ohio University, n.d.). With an estimated value of $2,8 billion (Ohio University, n.d.), a lot of companies and start-ups are jumping in the gap of reducing bulkiness and improving the user-product interactions in tracking out bodies.

Where commercial wearables are often seamlessly integrated, bulkiness and obtrusive technology is still the standard in healthcare (Wise et al., 2000) as healthcare providers struggle to adopt these devices and related technologies due to varying degrees of socio-technical development (Yoon et al., 2020). From a health consumer perspective, the use of wearable devices are becoming increasingly popular in healthcare services, particularly given the increasing interest in health, well-being, disease prevention, and fitness, transitioning from traditional treatments to more value based care (Lee, 2020). In the transition from treatment to prevention, wearables are able to continuously monitoring the human's body activity and collect various physiological data to increase the quality of human's life(Vijayalakshmi et al., 2018), but it also increases the need for self-management. This need is not on driven by critical patients, but also by healthcare insurance companies and governments, attempting to cut healthcare spending (Eikelenboom et al., 2016).

A domain where continuous body monitoring and self-management are key, is physical therapy. Physical Therapy is a paramedical treatment that deals with complications and support of the human musculoskeletal system (Shaik & Shemjaz, 2014). What sets physical therapy apart among other healthcare areas, is that therapists evaluate patients' complaints, perform a physical examination and draw up a treatment plan together with the patient. As part of their treatment plans, therapists routinely prescribe home exercise programmes. These programmes are typically long term and their success often requires patients to adhere to them for several weeks, even months. Here, adherence means both following advice, as executing their advice correctly. Although highly effective, the majority, as many or over 65% of patients, does not adhere to them(Abramsky, 2018). This puts much of the responsibility of recovery on the patient and their self-management skills, with the physical therapist playing a supporting role (KNGF.nl, 2020). Therefore, therapy success is based on the interaction between patients and their therapist and their motivation and ability to adhere to the treatment plan(Bassett, 2003).

Because so many of the treatment process happens outside of the therapy sessions, it is difficult for physical therapist to monitor the progress patients are making and their ability to adhere to the treatment plan. One of the issues in regards to adherence, is wrongful interpretation of the given assignments (Abramsky et al, 2018). Frequently, patients who seek physical therapy are not body conscious in regards to their body and how they use their body in daily life. A few examples of this behaviour are sitting too long in the same position, hunching over keyboard when typing or working in compromising posture when doing hard manual labour. But it also means failing to understand how an exercise is done and replicating that movement with their own body (Engelsman, 2018). This is problematic, because patients can both lose trust in the process as well as overcompensate for affected areas or cause potential harm. And whereas other rehabilitation domains started to use wearable technology to distantly monitor patients, only a few methods can successfully capture biomechanical feedback. These methods range from motion capturing and goniometers (2D) to motion tracking with markers(3D). These methods are often fixed or require special spaces and assistance, which cannot be operated at home by the patient himself (Dupler, 2019).

To successfully measure posture at home, wearable sensors must be comfortable, while providing accurate sensor data (Gioberto, Compton & Dunne, 2016). Garments are intimate and close to the body therefore having the natural ability to monitor the body (Jansen, 2020). Garments that are close to the body and often worn for their comfort during exercises, is athletic apparel with loads of stretch. Sports apparel comes in different styles, such as tops, shirts, leggings and leotards, also one as a one-piece suit covering both upper and lower body. It was found that the leotard garment was able to measure posture most accurately compared to the current state of art motion capturing system with 3D markers. The securing of the leotard between the legs provides a point of counter-force against the garment riding up during full extension(Gioberto et al., 2016). The leotard is therefore the most viable option providing both comfort and accuracy.

To ensure comfort for the user and their desire to wear a monitoring system at home, hard and rigid sensors, wires and other electric components cannot be used. Furthermore, the clothing will be used during exercising and therefore must be washable. In terms of production, adapting soft goods, such as clothing, to hard goods it interferes with regular garment production processes, making the garments expensive to produce. Therefore a wearable sensing solution that is soft, washable and easy to integrate into textiles should be used. The field of integrating electronic components into textiles is called Smart Textiles; a complete integration where the yarn or textile itself becomes the component, is defined as Textile Based(Bosowski et al., 2015). and will be the chosen solution space for this design research.

In recent years, many textile based sensing solutions have been researched to measure movements and posture(Gioberto et al, 2016; Mattmann, Amft, Harms & Tröster, 2007; Gioberto & Dunne, 2014; Berglund, Coughlin, Gioberto & Dunne, 2014; Tangsirinaruenart & Stylios, 2019) as well as wearables that use textile based sensing solutions to both measure and provide direct feedback through a haptic sensation with the intention for the user to improve their posture in the moment(Soler, 2010; Schrevers, 2017) but often tackling only one part of the body. This project continues to expand on the opportunities of posture monitoring by turning it into a full body suit, catering to the needs of physical therapy patients by measuring the functioning of the entire musculoskeletal system (MS).

1.2 DESIGN BRIEF

Body positioning is the relative alignment of the different parts of the body. Proper posture is defined as "a balanced muscular and skeletal state through the proper alignment of body segments" (Annesi, 1998; Buckle & Devereux, 2002). Any modification of, excessive pressure or tension on tissues and/or structures can result in a wide range of problems (Annesi, 1998; Mahmoodi & Sharifian, 2014).

Patients who need therapy for body posture need help strengthening their musculoskeletal chain (MSC). Exercises focus on training the whole body to restore balance in and between muscles supporting the MSC. However, training the MSC carries certain risks. In alignment, each movement affects another. All movements need to be executed correctly to avoid harm in the chain.

In physiotherapy, the effect and success of treatment often depends on patient adherence with therapy instructions and/or advice. Non-adherence occurs in 50% of all cases across literature. Non-adherence after PT sessions in particular is a big contributor to relapse(Sluis & Hermans, 1990), and affects nearly two thirds of all patients (Dool & Schermerl, 2018).

Physical therapists experience a persistent range of issues prohibiting therapy compliance. Limited body consciousness in patients, incorrect execution of exercises and loss of discipline in doing homework are common reasons (Interviews, 2019). For Physical Therapists, it can be difficult to determine what kind of feedback to give patients. It is not always clear whether lack of progress results from doing homework incorrectly or from lack of discipline or motivation. For patients, not seeing a direct relationship between (non-)adherence and results can be frustrating (Interview; De Kuiper, 2019). They can become skeptical of and unmotivated for the treatment and further adherence. Due to insurance policies, patients often need to reach therapy goals within a limited number of sessions, putting high expectations on both PT and patients. Therefore, the problem statement and design goal, are formulated as followed:

Problem statement

Patients and therapists need help in monitoring posture, movements and progress in a non-invasive way during the process of physical therapy. To exercise regularly and correctly, and to avoid relapse, patients should be stimulated, empowered and have access to guidance both during and outside of therapy. This monitoring should also provide PTs with insights to help patients in a more personalized way.

Design Goal

I am designing a Full Body Monitoring System (FBMS), in the form of a soft interactive bodysuit that can be worn during and outside of physical therapy sessions for patients that need aid in executing (movements in) a correct posture. Interaction feedback enables users to adjust posture and generate data for themselves and therapists to track progress.

2. DESIGN METHOD

2.1 WHY CHOOSE VIP?

For this project, I saw the potential in the tight fit of a catsuit to measure movements and posture close to the body. I wanted to engineer a product based in fashion, but using interaction technology to address healthcare problems pervasive in society. The decision to make the interactive catsuit the focal point of my design process means I needed to find the appropriate target group, identify their (latent) needs and the context in which the final product can make a difference. To address this, I chose Vision in Product design (ViP; Hekkert & Van Dijk, 2011) to structure the design process, applying an adapted version of this model to better fit the starting point and approach of this project.

The core element of ViP is understanding what kind of interaction fits a specific context and which interaction will lead to the desired goals for the stakeholder(s). instead of coming up with product demands, a vision for the relationship between the user an the product. By understanding this relationship, you are able to understand how a new product will fit the context. It simultaneously describes users concerns, needs, desires and matching product qualities. The interaction defines how the product is used and experiences and what value arises from the relationship between the user and the product.

In figure 5, the original ViP method is shown. First, a *Domain* is selected, describing the *Area* in which the design will make an impact. What follows is the *Deconstruction phase*. In this phase, the current (*Past) Product*, the *Interaction* with that product, and its application (*Past*) *Context* are analysed. Deconstruction sets the foundation for *Designing*. From here, a New Context, Interaction and a *New Product* can be designed. Because a product idea is at the starting point for the new design, which at it's core is an interactive product, I am using the ViP method to discover the appropriate context, interaction qualities and product demands. To eliminate the unknowns from big to small, I adapted the ViP method by changing the order of going through the phases (fig. 6). The new order is: Domain, Context Level, Interaction Level and finally Product Level. By following this order, it is revealed why and where there are user and market needs for an interactive catsuit.

Besides the undefined Domain, the biggest gap of knowledge is the context the interactive suit will be performing in. Next, the Interaction Level contains the most unknowns as a multitude of interactions are happening on a daily basis. But which ones are most problematic? And what kind of interaction qualities would allow for desired behaviour in the future? By defining the Past and Future Interaction first, flaws in the Past Product caused by current product qualities can be evaluated. From there, future product qualities can be derived that allow for desired user outcomes of the interactive catsuit.

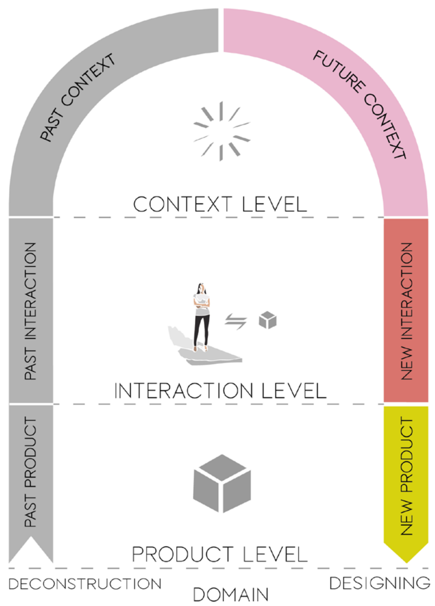


Figure 5. Traditional ViP Method

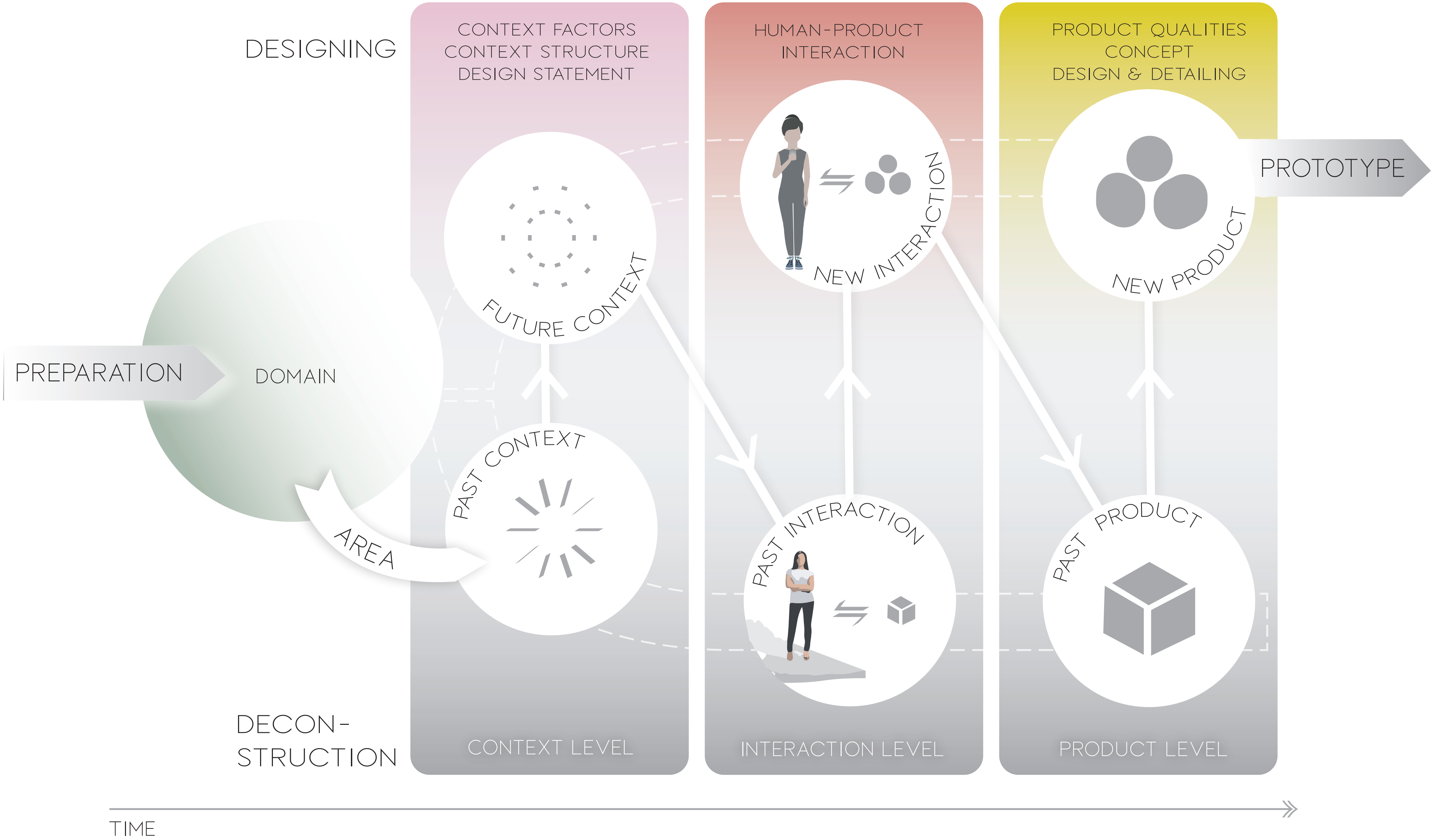


Figure 6: ViP Process Summary

2.2 READERS GUIDE

The first step is narrowing down the domain and it's stakeholders. Second, I analysed the Past Context to find stakeholder (latent) needs. From here, the ideal Future Context of where and how it can make the most changes can be shaped by applying the Factor Analysis. Here, Factors are observations, thoughts, theories, regulations, considerations, beliefs or opinions, which are value free descriptions of observed phenomena. Having clearly identified the target user and their needs in the Context Level, Past Interaction inadequacies arise and Future Interaction alternatives could be determined and designed In the Interaction Level. By comparing existing (Past) Products that could potentially support the desired interaction, but are somehow lacking, necessary design interventions could be identified, while simultaneously revealing the New Product gap in the market. By using the ViP method to my advantage, I envisioned my context, target user, interaction and product qualities, revealing why this product should exist.

Domain
Before we can analyse the context, interaction and products levels, the domain to which these insights are relevant needs to be determined. For this project, the domain is found within the field of Physical Therapy and must first be specified due to a broad range of available therapies. Within the domain, the main stakeholder is chosen. This stakeholder will be further investigated in the context. A qualitative study using a semi-structured interview guide and Grounded Theory Method (GTM; Straus & Glaser, 1960) analysis was conducted.

Context Analysis
For deconstruction of the current context, a literature study was conducted on the KNGF guidelines for current PT treatment standards. To establish future context, comprehensive trend and development research was conducted. The outcomes determine the factors that will be considered and evaluated in the Factor Analysis, which in turn will determine the direction of the design intervention. The results were then validated through an online survey with the interviewed physical therapists. Furthermore, a study into the current experiences of physical therapy patients was conducted via a survey due to Covid-19. This phase concludes by defining our main persona and how their needs should be addressed.

Interaction Analysis
Taking information derived from the context analysis and the newly determined future context, an interaction analysis is conducted on the current forms of interaction present in relevant PT situations. From this, ideal interaction qualities can be determined which can be used to define design parameters as we head into the product analysis phase.

Product Analysis
A market analysis was conducted to compare current products and find market gaps. Combining the Context, Interaction and Product analyses, the new product qualities, required for conceptualisation, arise.

After the product analysis, a technology literature review was performed on current smart textile sensing solutions. By conducting a multitude of experiments, the best product solutions to were identified (e.g. textile & sensors). By using the method of a moadboard, the final design was made

Strategy
How all of this information should be used to develop a full functioning mobility sensing suit in the future, two design roadmaps were creates to provide an overview of the future vision for the FBMS.

CONTEXT CONSISTS OF ALL KINDS OF FACTORS THAT AFFECT THE WAY PEOPLE (MIGHT) PERCEIVE, USE, EXPERIENCE, RESPOND OR RELATE TO PRODUCTS. IT DESCRIBES THE NATURE OF THE HUMAN-PRODUCT INTERACTION. CONTEXT FACTORS ARE CONDITIONS OR PATTERNS IN THE WORLD OBSERVED BY THE DESIGNER.

Figure 7: ViP; Hekkert & Van Dijk, 2011

3. ANALYSIS WITH VIP

3.1 DOMAIN ANALYSIS

The area within PT that could benefit most from an interaction intervention will be the domain for this project. A wide range of treatments and therapy styles exist. A few examples are: remedial therapy, massage therapy, manual therapy and rehabilitation therapy. To identify the most viable domain for an interaction intervention, a qualitative research was conducted including 9 professionals connected to physical therapy.

Method
A series of interviews were conducted. Participants were chosen based on a diverse professional background and thus comprehensiveness in answers gathered for comparison, influencing selection of therapy style(s) to be included in the domain. Core subjects of the investigation were challenges faced by the professionals.

In total, 7 physical therapists, 1 rehabilitation therapist and 1 neurologist were selected for interviewing using Facebook requests, network recommendations and LinkedIn requests. The physical therapists are all in first line care. A neurologist was consulted to deepen understanding of neurological causes in recovery treatments as they can have a big impact in physical therapy recovery.

Due to Covid-19, most participants were interviewed over the phone, others face to face (F2F) in their office. Interviews were conducted using a semi-structured interview guide. Semi-structured entails that the interviewer is free to probe further if necessary. Consent and answers were recorded using a video camera and transcribed using Sonix.ai. Next, all answers sharing similarities were clustered using the Grounded Theory Method (GTM). These findings were transferred to an Excel file. Results are statements made by participants and qualitative data in the form of clustered answers. Results were then evaluated and used to construct a Persona. A schematic overview of the procedure is given in figure 8. The full questionnaire and research can be found in Appendix 2-3.

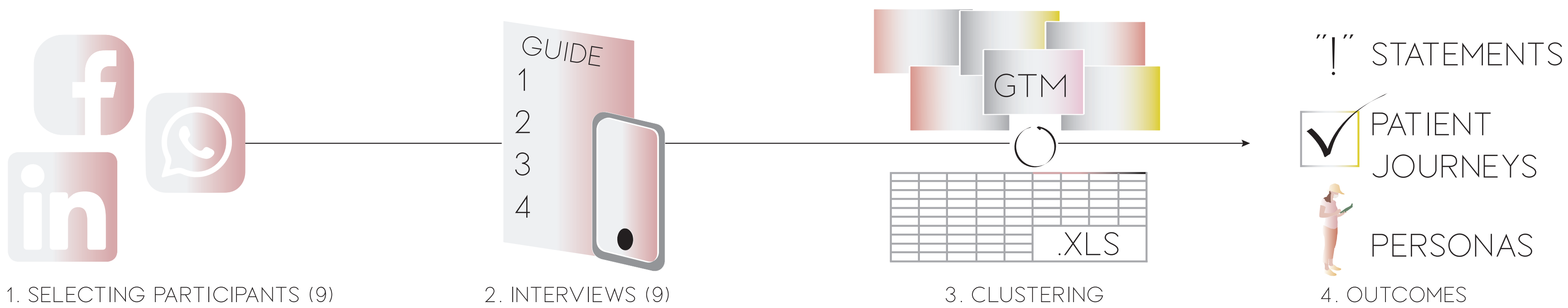


Figure 8. Procedure of conducting the Interviews

The semi-structured interview was comprised of four sections The introduction section was meant to open up the conversation (sensitizing). The Broad questions served to explore the current state of their profession. Next, they were asked to answer specific questions about their experiences in their profession such as clientele, challenges, exercises and needs. Finally, all were asked about their vision for an interactive FBMS. They were completely free to speak their mind about how such a feature would look or be used in the future.

The outcomes of the interviews serve to identify stakeholders and their needs. Next, one stakeholder is selected as the main user of the FBMS. This selection is based on their needs and whether these needs can be addressed by a user-product interaction. This is accessed by mapping main stakeholder's healthcare journey in the domain. The journeys are created to reveal the differences between areas in a compelling way.

Interview Guide

1. **Introduction questions**
   Sensitizing the interviewee for the upcoming sections.
2. **Broad questions**
   What are current positive and negative experiences in their profession?
3. **Field specific questions**
   What are typical therapy solutions they provide to which conditions? And for whom?
4. **Vision questions**
   How do they see an FBMS in the future benefitting them and their patients?

Results

The results were grouped in an overview(Appendix A3.1). From all interviews, answers that shared similarities could be grouped into six categories: Stakeholders, Motivation, Exercising at home, Transmission of knowledge (about their body, complaint and lifestyle choices influences), different Patient Groups, and Measurability. The latter five categories will be further elaborated on in the Past Context Chapter. Below, the most important outcomes for determining the domain, are presented.

All four sections were used to define the Domain. The answers to Broad and Vision questions helped to give a direction to which Area of the Domain the project should move in to. Answers to section 3: field specific questions are on a contextual level and will therefore be discussed in the next chapter. Some of the current positive experience from PTs include the patient contact they have on a daily basis (2x), that patients trust their capabilities and that they are satisfied(quote x). Negative experiences are low motivation(3x), missing out on daily progress(3x), issues with HIC(2x), not doing homework/exercises(5x) and patients not following advice(2x). The latter two results will play an important role in the Context Analysis. Problematic behaviors were skewed expectations of the therapy, health insight not increased, therapy compliance(3x) and perform or interpret exercises differently from given homework(5x). Patients could use some help with the execution of their exercises(2x), overviewing all body parts at once, guidance and increasing self-management by adapting information to their personal understanding. The results of the broad questions helped lay a foundation .

In table 1, the main insights from the interviews are presented. These results contribute to understanding the Domain. Stakeholders and how the stakeholders would potentially experience the domain are discussed next.

Participant	Method	Main Insights	Main challenges	Vision
General PT (Works with multicultural people)	Phone Call	• Oncological and Post-op patients are very driven • Continuing sport, "under guidance", outside of PT would be very beneficial for maintaining health • Motivated patients often have a busy lifestyle	• PT works best when people are motivated • People often misinterpret home exercises and perform them wrong • Patients should train more individually to increase therapy success momentum	• Gathering information about muscles and exercises for the whole body, not focussing on a specific area. •Often sees patients with manual labour intensive jobs: wants to track behaviour
Sports PT	F2F	• How to connect trust of people in their own body to learning from a suit?	• People with movement problems are overcompensating in other areas	• How to balance overcompensation and (re)learn healthy movement behaviour
Manual Therapist	Phone Call	• Patients with low body-spatial awareness need help in executing movements in correct posture • Higher educated working women with families want to heal fast	• Insight in what people are doing during the course of the day • Posture is a habit; habits are hard to change	• Patients gaining insight posture and learn how to feel this. • A tool to motivate patients, as lack thereof is detrimental to their recovery process
Anthroposophical vision	F2F	• Arms play less of a role in the vertical MS-chain, but help in exercises. • How do people exercise at home?	• Within healthcare, too less time for making people aware of their body • Hard to keep people motivated	• Stimulating core balance, posture correction and preventing Kyphosis • Feedback on spatial body posture
General PT	Phone Call	• Repeating exercises at home is difficult • Many complications stem from wrong posture • Patients overestimate their performance	• Difference between patients interpretation of an exercise and correct execution. • Patients learn wrong behaviour at home	• Measuring bending of joints • Discover/monitor movement restrictions • Left/right difference in body
General PT/Geriatrics	Phone Call	• Large responsibility on PTs for diagnosis • Seeing improvement is the 'reward' for PTs • Analysis of walking pattern is very expensive	• Creating insight in a correct posture • Habit change is difficult to achieve in sessions of 20-30mins	• Show patients how their behaviour influences the pace and extent of their complaint
General PT (works with business owners	Phone Call	• Complaints can arise from other parts in the MS-chain, which at first don't seem affected • Hernias: regain trust in body	• People don't know their own limitations • When training the whole body, exercise balance is very important.	• Create awareness how the MS influences all body parts in the vertical MS chain • Gain insight in why recidive occurs
Neurologists	Phone C	• Increased use of personal health environments	• Compliance of patients to therapy	• Need to measure movement behavior
Rehabilitation Therapist(RT)	F2F interview and tour	• Rehabilitation deals with multidisciplinary trauma • with RT, a lot of time is spent training at home • Using digital platforms to prepare exercises	• Low access quantitative measuring devices • Diagnosis with hallway analysis en 6 minute walk test is work-intensive	• Quantify qualitative goals of patients over long period of time • New measurement tool for diagnosis

Table 1. Overview of outcomes of the interviews

Stakeholders

In the statements of the interviews three stakeholders are repeatedly mentioned: Patients that require a full body approach, Physical Therapists and Health Insurance Companies (HIC). HIC are involved as they control the amount of insured sessions, insurance policies and covering expenses for additional medical equipment. For them, (anonymous) quantifiable results about treatments could replace expensive equipment. However, the FBMS would only serve as an instrument to derive information from for policy making, hence a passive interaction. For therapists, the FBMS is beneficial to better track patients' progress, gaining insight in the body and use it as a motivational tool to optimize their treatment. The FBMS would serve as a collaborative tool between patient and therapist, which is still partly a passive interaction. Due to their passive nature of the interaction between them as stakeholder and the FBMS, both HIC and Physical therapists will not be chosen as the main stakeholder(fig. 9).

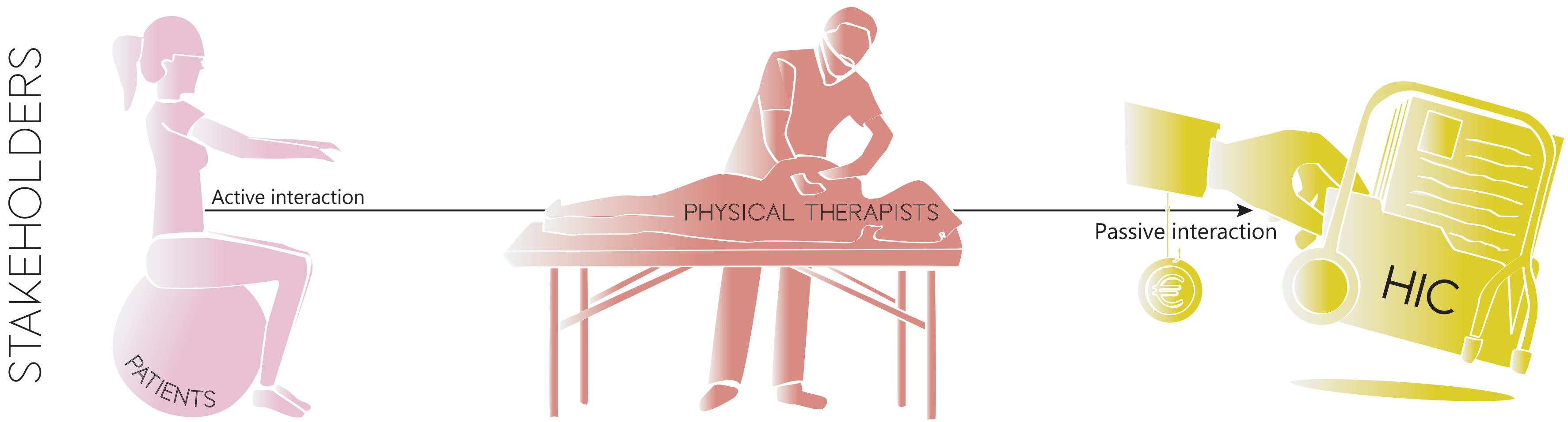


Figure 9. Three main stakeholders: Patients, Physical Therapists and Healthcare Insurance Companies (HIC)

Physical Therapists also mention that, to increase momentum in the healing process, patients should train more often individually. Changing your posture is difficult and requires focus and motivation(Kriek, 2019). Especially young people and people with families are highly driven to regain their health(Interviews; Pijls, 2019). As suggested by the physical therapists in the interviews, a demographic was chosen aged 20-55. This age category

is in line with national prevalence; 62% of the patient population seeking treatment falls in this group (Dool & Schermer, 2018). Besides prevalence, this patient group has a high acceptance rate of technology and physical fitness to get in a suit. After 55 other complications arise and above 65 people are more in need of geriatric therapy(Interviews; De Kuiper, 2019).

After reviewing all answers, two distinct therapy areas emerge: First Line Physical Therapy (PT) and Rehabilitation Therapy (RT). The difference: RT focuses on multiple areas of the body that are often heavily impacted by accidents or disease, while PT focuses on individual conditions (e.g. excessive strain injuries). This mainly shows in their primary need for diagnostics tools versus the need for motivational tools and reducing relapse for PTs. To describe the differences in approach to treating patients, patient journeys were created (fig. 10-11) from the answers in Appendix 3.2. The patient journeys illustrate both distinct and overlapping needs found in PT and RT, of which one can then be chosen as a central focus for this project, thus establishing the domain.

First Line Physical Therapy

In figure 10, the journey of a patient using the FBMS according to PTs' vision is shown. To help patients better in understanding the impact of their daily behaviour, e.g. sitting too much behind a desk or manual labour, the FBMS could identify causes and problematic behaviour underlying their complaint(s) (1). During PT sessions, only a fraction of patients' physical behaviour is visible. Therefore, it would be valuable to get behavioural feedback outside of sessions(2). In-session, the FBMS is used for intake measurements and supports a diagnosis (3). When taking the FBMS home (4), it can help with motivation, creating an exercise routine and learning to execute exercises correctly. Feedback from the FBMS guides patients who train individually, while still receiving guidance and reassurance (5). By tracking movements, progress becomes measurable: distinction between sessions and individual effort over time is visualised in graphs on a patient's smartphone. In the short term, seeing your efforts and tracking which exercise you did and in which quantity, the influence you have on the healing process becomes visible and can stimulate motivation (6). In the long term, norms and thresholds can be set for relapse indication (7).

Figure 10. Physical Therapy Patient Journey with FBMS

Rehabilitation Therapy
In figure 11, an example of a patient journey using the FBMS according to RT's vision is shown. Patients coming in for full body rehabilitation are often subjected to a Gait Analysis or walking tests. These tests are highly informative, but require adequate space and materials, and are labour intensive to evaluate, resulting in long waiting lists (1). RT patients often need a wide variety of exercises from different healthcare fields besides PT. When a patient wears the FBMS (2), it can help with tracking their progress and interaction effects within and between RT exercises (3). The FBMS can also offer help with relearning everyday activities at home, for which patients are often at risk of overcompensation (4). Rehabilitation goals are set by a patient's individual expectations for success. Added value could be found in quantifying Quality of Life by combining a multitude of measurements, rather than quantifying singular motions (e.g. being able to bike 1,5km) (5). Monitoring progression could potentially predict future recovery. It could show a patient how much effort they need to put in to maintain improvement. Tele-Health tutorials can be linked to FBMS to track and correct exercises execution (6).

Conclusion Domain Analysis
Both overlapping needs and distinctions were found between two different areas of physical therapy. In RT, there is a need for a small scale, easy to use diagnostics tool to analyse walking patterns and track quality of life progression. This need would translate into a wearable, but passive measurement tool. Within PT there is a wider variety of needs, which could be addressed through user-product interaction, creating tailored exercises and tracking. As the scope of this project focuses on improving health through interaction between the patient and the FBMS, its potential lies in the domain of first line PT. The solution space will be narrowed down further to a personal interaction between the user and technology. In the context analysis, feedback from patients will further specify how an FBMS can aid them when training independently.

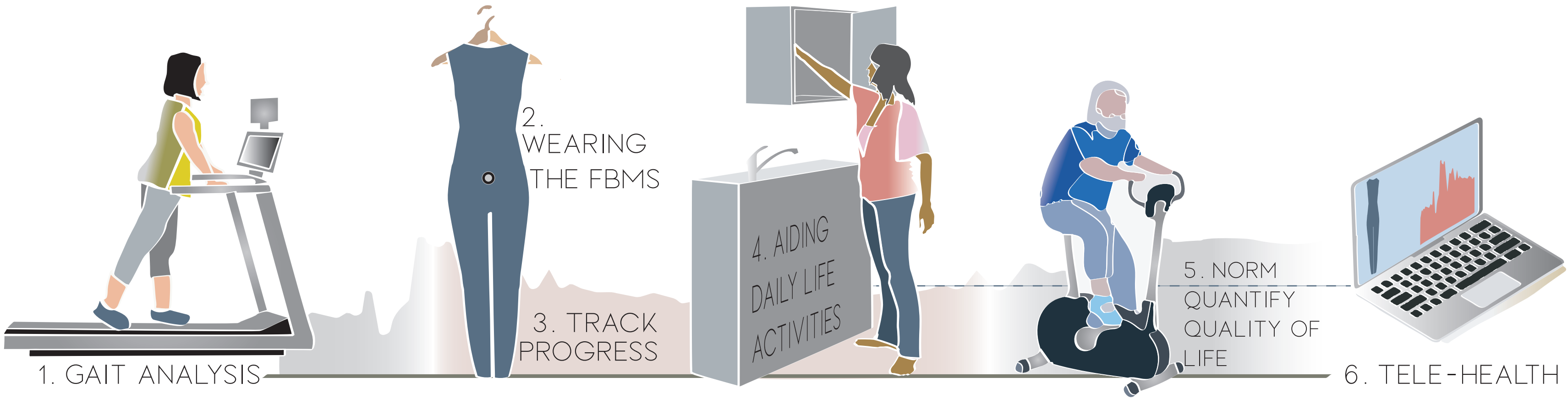


Figure 11. Rehabilitation Therapy Patient Journey with FBMS

“The context is that part of the world which puts demands on the form; anything in the world that makes demands of the form, is context”
(Alexander, 1964)

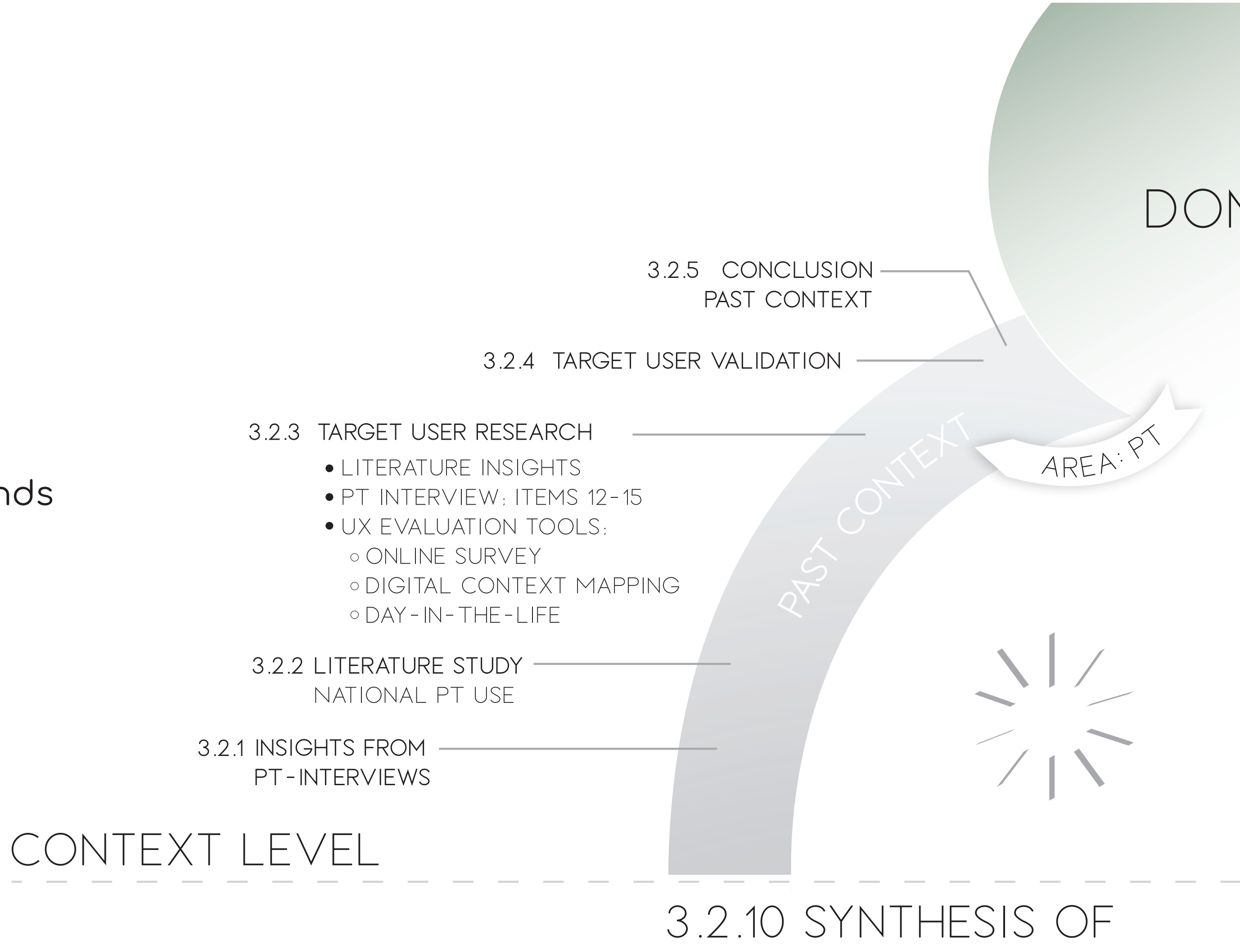
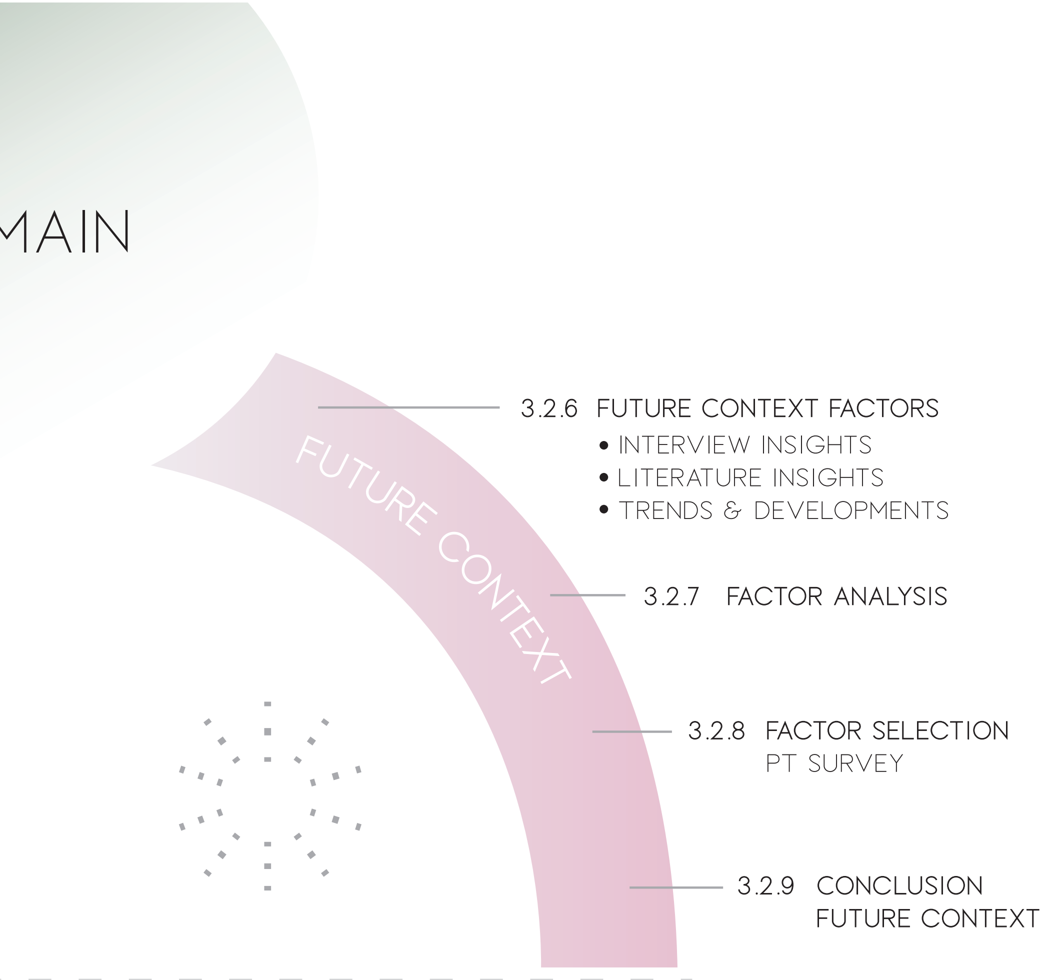


Figure 12. Overview of Context Analysis Level

3.2 CONTEXT ANALYSIS



CONTEXT ANALYSIS:

- CHOICE OF TARGET USER
- KEY CONTEXT DRIVERS
- DESIGN STATEMENT

The analysis of the Context Level aims to connect current needs in the Past Context with trends and developments for Future Context possibilities. The outcomes presents supporting and defining drivers for the design of the FBMS in its future context.

Research Methods
The context analysis consists of two parts: *Past Context* and *Future Context*. The Past Context analysis explores conditions that require a full body therapy approach by comparing section 2 and 3 from the PT interviews (page 14) with a literature study of current KNGF guidelines for physical therapy to understand which challenges, conditions and user needs are most suitable to be addressed with an FBMS, and why. The patient profiles resulting from the latter research were then shaped into personas, connecting conditions with patient characteristics. The persona most viable to address with the FBMS is selected as the target user for this project and validated using a digital questionnaire version of context mapping, conducted among actual patients.

Where the Past Context uncovers differences among conditions, the *Future Context Analysis* aims to find overlapping needs in the domain of PT to uncover the full potential of the FBMS and give direction to which *Interaction and Product Qualities* the FBMS must possess. A *Factor Analysis (ViP; Hekkert & Van Dijk, 2011)* evaluates all factors that influence the context the FBMS will be operating in. The included factors are derived from the Section 4 of the interviews with PTs, the KNGF guidelines and Trends & Developments scouting, and clustered to give direction to the design of the FBMS. The selection of clustered factors to include in the design of the FBMS, is further prioritized through feedback from interviewed PTs using an online questionnaire. After the Context Analysis, the target user and their needs and benefits are established to be addressed in the Interaction Analysis.

PAST CONTEXT

3.2.1 PAST CONTEXT INSIGHTS FROM INTERVIEWS

The interviews with PTs at the beginning of the analysis phase, served as input for multiple analyses throughout this project. Relevant for the context analysis are the results from section 2: broad questions and 3 field specific questions. Here, these results are further explored.

Results from the Interviews
PTs generally hold very positive attitudes towards patient contact. However, they also share some concerns. Quotes from the interviews were adapted to English (Appendix 3.1) and used as statements for storytelling, revealing challenges and needs in the past context. The storyline below builds upon the results from the domain analysis:

Negative experiences often arise when motivation for homework drops and PTs "find it difficult to motivate patients" and "stay motivated" themselves. It is hard to "achieve behavioral change in 20 minutes" if people don't improve on self-management. Feeling the "pressure from insurance companies" to speed up treatment, not being able to check "what people do at home" and losing track of progress is perceived as a downside to their profession.

Additional problems arise when people are unable to repeat an exercise correctly at home and create new bad habits. This is especially true for "people who are spatially unaware of their body". These patients could use some help with "remembering how an exercise approximately goes and how it is properly done". "Adjusting posture is very difficult for a lot of people" because changing it consists of paying attention to multiple areas at once, which we are not used to". This is because "It is not just an individual area, but a chain problem" and "the body must be realigned again".
Properly implemented, an FBMS can answer many, if not all, of the needs identified in the investigation.

3.2.2 LITERATURE REVIEW

As discovered in the domain, there are six topics playing a role in working with PT patients. To uncover more information about Motivation, Exercising at home, Transmission of knowledge (about their body, complaint and lifestyle choices influences), different Patient Groups and Measurability. The past context will focus on finding more information through a literature study about these five remaining topics.

Research questions
- Are experiences from PTs reflected in literature?

Motivation:
- What challenges are PT's facing in motivating patients?
- Why do patients lose/lack motivation to do exercises?

Exercising at Home (Homework)
- Why is it important for patients to exercise at home?

Transmission of knowledge
- Why is knowledge about the body important in the PT process?

Different patient groups
- Which patient groups are distinguishable in the domain of PT?

Measurability
- What parameters are involved in the evaluation of patients?

Results from literature review
Patients generally put trust in the diagnosis skills from their PTs, as 57% of cases is diagnosed without a GP intervention. Concerns from PTs are also reflected in the top 10 most frequent complications they treat (32,8%), of which 18,9% have physical complications involving exercises for multiple areas in the body to correct people's posture. This includes: pain in the neck (6%), up- and lower back vertebrae (4%) and lower back-pelvic floor (2,1%). (Nivel, 2017). What was discovered from the interviews with PT's, is that these problems have multiple origins: bad posture, behavioural habits or acute or chronic conditions. These problems require a holistic

body approach as the muscles supporting the spine are not balanced. From table 1, PTs reported an increase in pressure to record progress by HIC, This is reflected by the increasing use of measurement instruments. The Patient Specific Complaint list (PSK) is used most in 53% of all medical history reviews. Here, the patient selects 3-5 complaints relevant to them, establishing a leading position for patients' directions in therapy. Thus, the need for patients to stay equally motivated to the PT to bring treatment to a successful conclusion is cemented in agreement (Dool & Schermer, 2017).

Homework and motivation issues

Despite the cooperative tone of treatment, patients do not always faithfully follow advice and instructions from their PTs. Non-compliance by patients is estimated by Dutch PTs to be at least in 33% of all short term treatment and 80% after their sessions have ended. However, it is not just lack of motivation that causes these large numbers (Bartlett, 1982; Dishman, 1988; Rissman & Zimmer-Rissman, 1987).

In a study by Sluijs and Hermans (1990) of 1681 patients, 72% mentioned having received homework and 54% received advice. Almost a third of them had trouble executing those exercises (fig. 13). With proper implementation, the FBMS can address ~35% of these restraints, all besides lack of time (32%), pain (25%) and other (7%). People forget how the exercise is done or lose an external incentive when sessions end and pain subsides.

Not following PTs advice, such as "keeping back straight when standing", occured in 38% of all studied cases. The difference between advice and exercises, is that the latter often adds an activity to one's daily life and the former demands structural change. Patients gave various reasons for not (fully) following through on advice (fig. 14). The FBMS design should address these obstacles and overcome them with tailored interaction.

Patient group demographics

The national averages on PT complaints and care also provide insight into the demographics of PT use. Currently, approximately 60% percent is female. Females, regardless of age, are also more prone to neck and back problems than males(Nielen et al., 2020). From all PT patients, over a third are aged 45-64 and over a quarter 18-44, estimating that approximately half of the PT uses are within the age group of 20-55. On average, people use 10 sessions. This creates a reasonable, but short period in which to use the FBMS and learn from it. Short term use could apply to 24% of the patients and long term to another 26% (Dool & Schermer, 2017). The results from the interviews and national averages will determine which conditions to select (fig. 15 - step 1) from the KNGF guidelines and determine the target user to address with the FBMS. Knowledge transmission and measurability are further explored in Appendix 3.

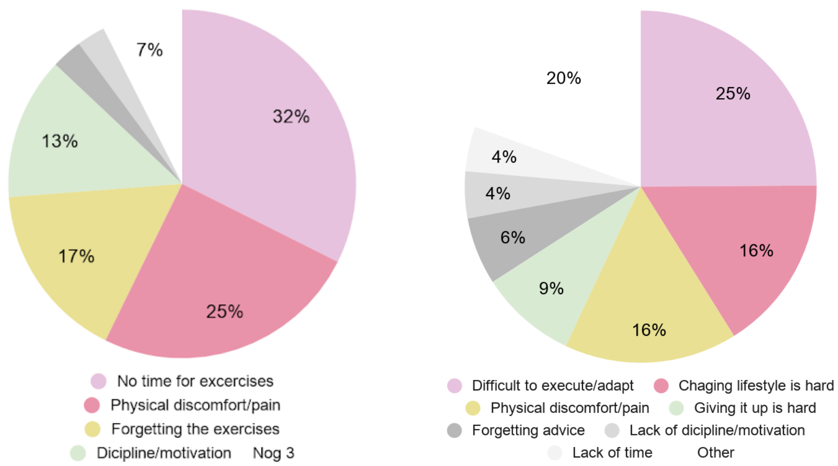


Figure 13-14. Patients' issues in following homework instructions and advice

3.2.3 TARGET USER RESEARCH

Method
From patients, we narrow down the condition and characteristics best served with a FBMS in a Persona. The persona creation process for this project is illustrated in fig. 15. First, past context conditions are selected (1) and divided into Patient Groups (2). The demographic, social environment and lifestyle that often coincides with these conditions, are linked to create a number of representative Personas (3). These were validated through user research (4), resulting in our target user persona (5). Due to the Covid-19, the personas were first composed from research and validated afterwards. Lockdown measures did not allow for in-person approaches such as focus groups. Interviews and surveys were conducted to validate a persona. See Appendix 4 for the full research.

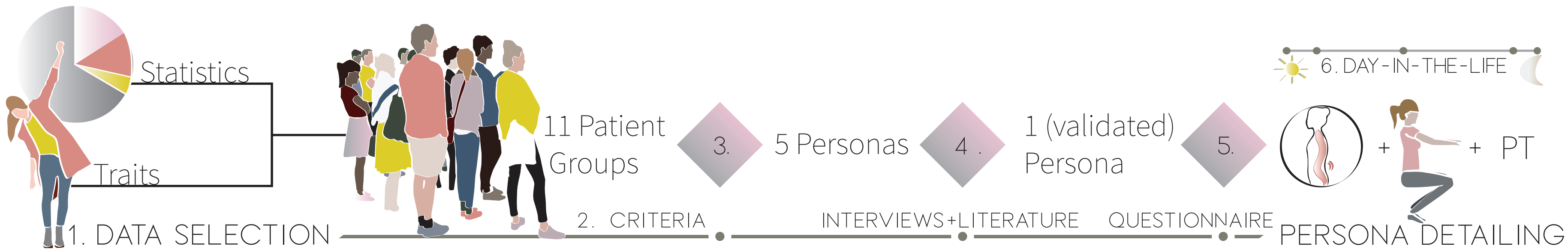


Figure 15. Persona creation process overview

Results & conclusions
Eleven patient groups appeared after clustering interview transcriptions: Muscle Fascia, Muscular Diseases, Oncology, Psychosomatic symptoms, Central Neurological Disorders(CVA), Spinal Problems, Hernia, Arthrosis, COPD, KANS and Joint Complaints (Appendix 4.3). Selection criteria for which group to consider for the FBMS, emerged during the clustering:

1. Primary goal is a personal interaction between the user and their exercises
2. Patient's physical functioning is improving, and not degenerating (treatment serves to alleviate their suffering)
3. The focus of the treatment plan is changing full body posture and movement behaviour

]The FBMS serves as means for interaction between its user and the exercise. It's a means to increase motivation; when continuously receiving feedback you are able to do less and less, if one is still able to even wear a suit, it could be demotivating (Appendix 4.2). Also, there must be a direct link between posture and movement behavior, not merely full body training. Five patient groups were shaped into personas (fig. 16) and reviewed by two PTs. The other groups deal with chronic conditions that are degenerative (except for muscle fascia). From the five remaining personas, lower back issues are most common. This is often caused by incorrect posture and further impacts other areas of the body. Looking at the selection criteria and prevalence numbers, lower back issues are most suitable to address with the FBMS as well as offering the largest sales market. When translated into a persona, it becomes very relatable to society's current situation. Therefore, the persona of Maria is welcomed as our target user!

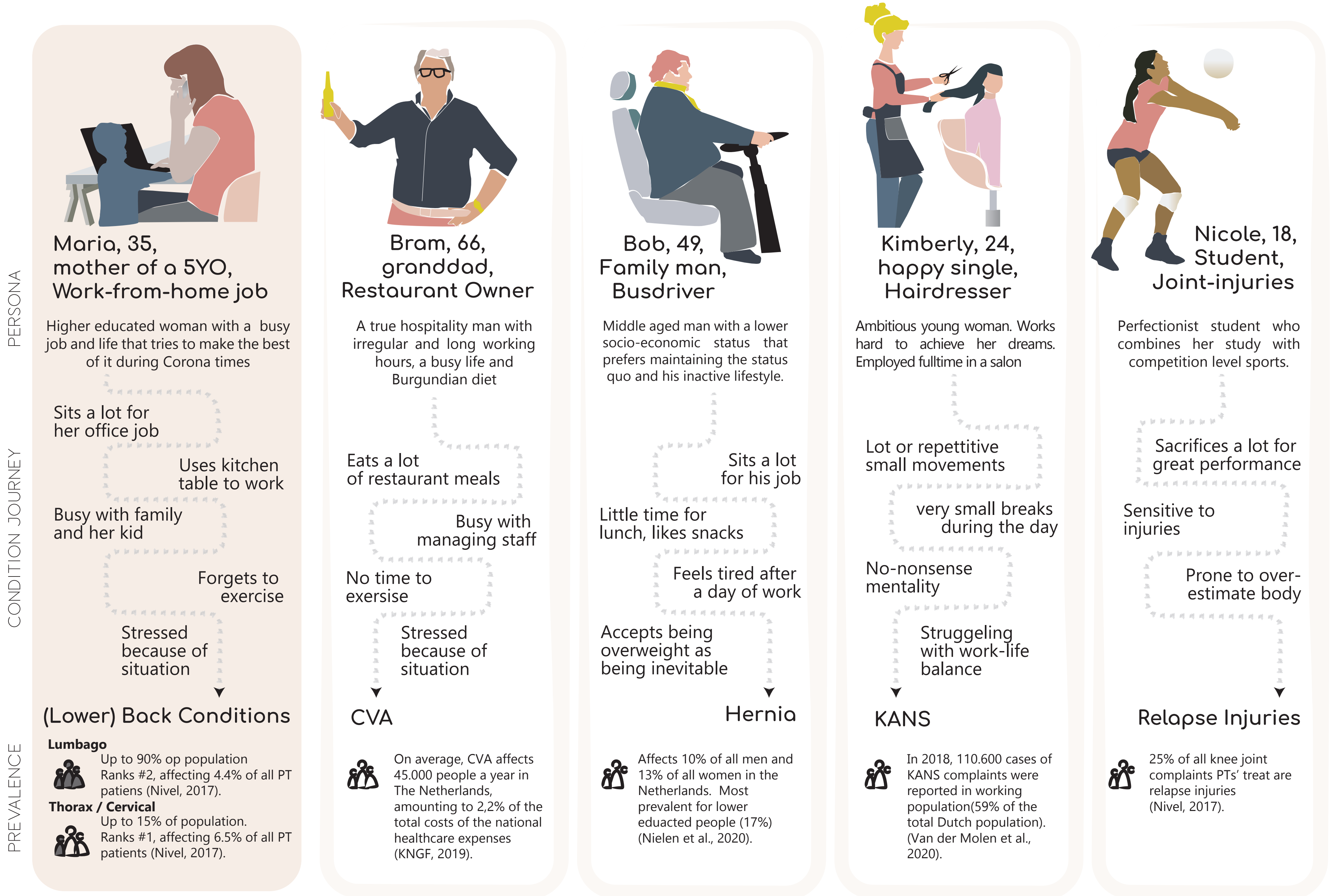


Figure 16. Persona Overview

3.2.4 TARGET USER VALIDATION

The gender of the persona for lower back issues was not just an abstraction from prevalence numbers, as a number of variables have been identified as disproportionately impactful on women in the development of lower back problems. To highlight a few issues impacting their health, the following information provides details.

Validation by literature
According to Kriek (2019), feeling down about yourself, due to stress or misfortunes, weighs the body down in an almost literal sense. Our mental state impacts our physical state. One of those issues is body dissatisfaction. Body-image dissatisfaction is higher in women than in men (Calogero, & Thompson, 2010). Body insecurities following pregnancy can compound these issues, causing even more strain (Kilpela, Becker, Wesley & Stewart, 2015). Our persona Maria is a young mother, homeschooling her 5 year old during lockdown while juggling family and work, which can be very stressful. Even more so, as early research suggests lockdown measures involving children and care take a bigger toll on women (Flaherty, 2020) as women have been reported to take up more mental and emotional workload in the household (Daminger, 2019).

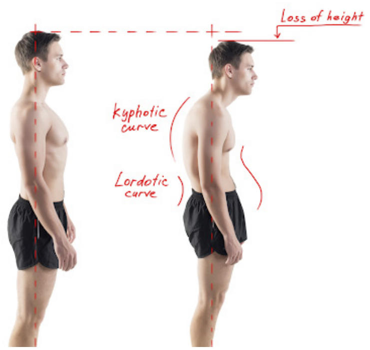


Figure 17. Predominant disrupted body posture

Even without additional negative self-image, (child)care tasks or stress invoked by self-quarantining, working on a computer in an un-ergonomic work space, such as Maria's kitchen table, increases the prevalence of musculoskeletal problems (Fathi, 2016). Risk factors include "not using suitable chairs, incorrect way of sitting and lack of movement". Something Maria clearly struggles with. As a results of this, forward head posture (85%), drooping shoulders (90%), pectoral kyphosis (70%), pelvic tilting (65%), bowed knees or X-shaped legs (40%),and ankle rotations(30%) are most common posture anomalies. Especially sitting too long, enhancing lower back pain, and hunching over the keyboard, curving the upper back excessively (Kyphosis), causing neck and back pain (OSGPC, 2015). These postural deformities are often interrelated (Singla & Veqar, 2017).

Having to focus on others all day long leaves little time or brain space for exercises that require focus and energy, let alone lead to behavioural change (fig. 17). With this in mind, Maria could use a little help and encouragement. Besides getting a better workspace and seating position, the focus is now on exercises to counter problems caused by unawareness.

As the persona of Maria is based on clustered interview and literature review outcomes, it is important to validate the persona with experiences from actual women who are currently using physical therapy.

Validation with current PT patients
Previously, PTs described patient group characteristics and how it affects treatment. In order to validate the constructed persona, the theoretically based persona characteristics were tested against a small sample of actual patients (N=3). The goal of the questionnaire was to explore experiences of women currently in PT, matching the selected persona, and to use this information for validation.

Method
Qualtrics Survey Software was used to construct the questionnaire and distributed online using Facebook posts and Whatsapp and aimed at women fitting the persona profile of Maria. The questionnaire contains 6 sections, of which the first four double in function as sensitizing questions for Context Mapping in section 5. To explore latent needs and experiences, the analog context mapping method was adapted to be used digitally. Using the heatmap function, participants could select pictures to convey their feelings about their (failures in) home exercises and elaborate on these feelings in a text box below. Participants digitally consented at the beginning of the questionnaire. For the full questionnaire and results, see Appendix 4.4.

The main research question was: How do women experience progress in therapy and doing PT exercises at home? From the results, a day-in-the-life profile was created (fig. 18), illustrating mediating and moderating influences from the past context on their life. Following up on these influences, an overview of the impact on the body from daily life is presented, with accompanying postural deformities(fig 17).

Results
The survey was filled in completely by three out of six female participants. Therefore, this research is considered more explorative than quantitative.

Among the participants, neck, shoulder and joint pain were indicated for their PT treatment, stemming from an incident and overloading of the body. And all of them mention sitting too much, which is unhealthy for the body as well. Reasoning behind choosing to participate in PT is getting rid of pain during movement and, more importantly, getting rid of the fear of pain for movement. This is an important factor in perceiving quality of life. Two participants mention they are happy with the results they have achieved, of which one says she was happy the PT trusted her with self management. One participant remains unsure. It is noticeable that this participant does seem to have the most issues with following through on her exercises at home. In general, reasons for not doing exercises is forgetfulness, but this doesn't result in guilt over failure to comply with exercises.

The two participants that mention feeling good about their process and see results, have no problem with doing their exercises. However, the person that does not feel like this, answered she has troubles keeping motivation sometimes. Overall, participants feel happy and healthy while doing their exercises, indicating positive feelings towards following up on their homework. The experience with a physical therapist should be Fun, Happy, Easy and Together. Different was confirmed two times, indicating that it would be nice if exercises are changed up. Finally, Participants felt unhappy and somewhat guilty(but not too much) for not doing exercises. Perhaps feeling somewhat insecure about it. This, the FBMS should counter.

Conclusion
Maintaining a rhythm appears to be important for participants in avoiding the latter does not happen too often. Having something in place, whether tangible or as a service, could be a solution to keep up the work patients need to put in themselves to make the treatment successful.

This outcomes tie in with the persona of Maria, having a hectic life as a mother of a five year old. To visualised what a day in the life of Maria might be like, a Day-In-The-life Profiles was made to explore certain behaviours and how that is affecting her life.

Key Insights in context from Day-In-The-Life

How to achieve good posture and proper execution of the most common exercise (the squat; identified from PT interviews) are explored. Understanding of posture in rest and exercise is crucial for the development of the FBMS in application focus.

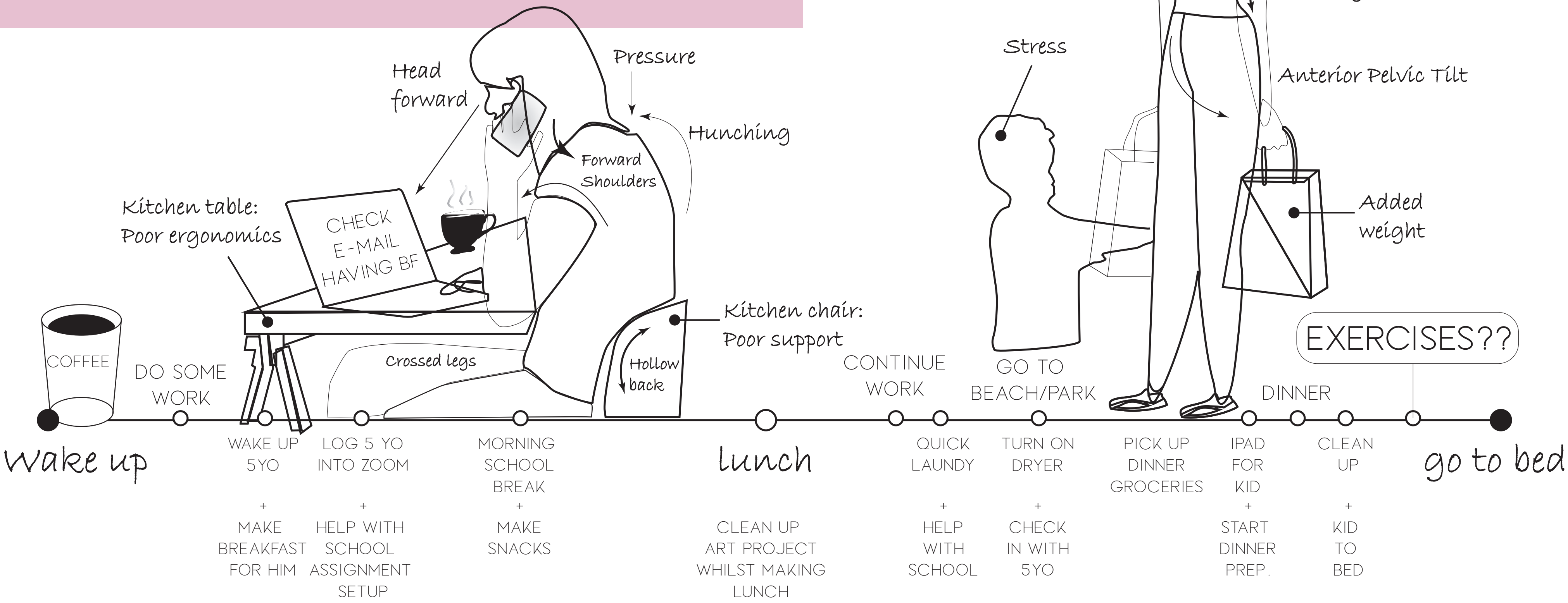


Figure 18. Day-in-the-life of our target user and postural deformities resulting from daily behaviour

3.2.5 CONCLUSION PAST CONTEXT

The past context describes the world around the stakeholders in terms of observations, challenges, needs, desires, thoughts and experiences. Here, some factors were found to be holding back our main stakeholder, the patient, in their goal of fully recovering from lower back issues and actively prevent relapse.

To gather information about the context of PT and collect insights about personal experiences with this profession, nine semi-structured interviews were held and the outcomes clustered for overlapping needs. From the interviews, first line care physical therapists expressed their experiences with their profession and patients as well as desires for wearable technology to be used at home by patients. From the interviews, both RT and PTs expressed a desire for distant full body monitoring of patients.

The challenges PTs face, can be categorized in six groups: motivation, adherence to exercising at home, transmission of knowledge, working with different patient groups and measurability of patients complaints. Motivational issues mainly consist of patients losing motivation during treatment, which happens a variety of reasons: Not seeing progress, not being able to fit PT's advice in their lives or patient-therapist interaction. When motivation drops, it becomes difficult for PTs to keep motivation their patients, as for successful outcomes, patients need to be equally motivated to work on their recovery. In thirteen percent of the cases, exercises at home are not performed due to loss of motivation. Literature further suggest that the majority of all patients do not adhere to the advice and homework physical therapist give them. Other reasons for not adhering relevant to the FBMS are forgetting the exercise or how it is properly done and not seeing progress. In this, transmission of knowledge about their body is key, because it increases their insight in their own behavior and influence they have on their recovery, health and their control over preventing relapse and maintaining a healthier lifestyle.

From the different patient groups, lower back issues were found to be most applicable to monitor with the FBMS, as the prevalence of this condition is highest in society, it impacts many other areas in the body, the origins of the condition are applicable to many people due to poor ergonomic working condition during the Covid-19 pandemic. The adaptation of the condition to real user experience of this condition, was done through creating a persona based on the interviews and validate them through a literature study and a user validation research with three women currently in physical therapy. The most important insights form this research was that patients complaints generally stem from overloading the body in their work or free time and wish to solve these problems through physical therapy. They all received homework exercises, however some found them to be hard to adhere to because they forget. Although the questionnaire response was to small to draw direct conclusions from, respondents who do adhere to the exercises and started to experience joy in working out, also noticed their results more and felt good about their progress. Therefore enhancing the need to not only using the FBMS for monitoring purposes, but also as a motivational tool that highlights successes.

To give an overview of the origins of the causes of the condition of spinal conditions influencing lower back issues, a Day-In-The-Life profile was drawn based on the target user selections and validation research. From here, the main postural deformities the FBMS should sense and provide feedback on were found: Hunching(Kyphosis), forward rotated shoulders and tilting the pelvis forward(anterior tilt).

In the future context, the factors that address these issues in the past context are selected and analysed.

FUTURE CONTEXT

3.2.6 FUTURE CONTEXT FACTORS

Building the future context the FBMS will perform in, is done by collecting building blocks (drivers) for that future and are called Factors. Factors are observations, thoughts, theories, laws, considerations, beliefs or opinions and can be both factual or true to the designer, but are always value free descriptions of world phenomena. A context should be built up from as many different factors as possible, making it interesting, detailed and salient enough to allow new, innovative design to emerge from it (ViP, 2011). Factors can be found anywhere, but withing this project, have its origin in the interviews, KNGF guidelines and trend & technology scouting on the internet.

In the past context, differences in current needs between conditions and patients groups were explored. The future context aims to finds drivers, a direction for a new design on how to respond to those needs and why. All factors involved in this are assessed on relevance and influence through the Factor Analysis in the next paragraph. In table 2, PTs described how the would envision utilizing the FBMS in the future (see page x for method); these wishes formed the jumping off point for gathering factors for the factor analysis.

Factors that play a role in the future context according to PTs
Common feedback from PTs is that they want to gather information about patients' body posture at home and use that information to give feedback in their sessions. One interesting vision is for users to "visually (see) what you do (wrong) or how far you bend (a squat easily goes wrong)" and to "try again with visual feedback and compare results". It could especially help "people who are very body unconscious". These statements reiterate the patient journeys and project objective for the FBMS.

Wishes	Utilization	How does it help the therapist?	Help the patient?	Desired information?
• "Measurement for company doctors", • for people (25-65), • For heavy working conditions" • "Signal for sitting too long in the same position" • "assume a certain position" • "core balance" • "backward balance" • "Posture correction" 2x • "register movements" • "How one exists in space" • "stimulating exercises with registering"	• "How is posture during the day" 2x • "as a feedback mechanism" 2x • "see yourself moving in image" 2x • "difficulty estimating balance" • "activate and stabilize" • "relieve tension by tilting pelvis" • "left / right difference" 3x • "Seeing on toes or heels" • "how many nº joints bend, replace measuring movement with gonio " • "Finding an explanation for injuries/recidive" • "important for motivation to demonstrate things" • "preferably that a patient works with it himself"	• "Help with initial and final measure-ment for insurer" • "use outside treatment" • "that you can compare those results" • "the patient has recovered earlier and is stimulated in his / her recovery."	• "create body awareness in space in patients who are not" (3x) • "Faster recovery through targeted exercises.	• "Do tests": "left / right measurement", "24-hour measurement", posture, legs and torso • "see how someone walks: a step has many phases" • Recidive/ chronic complaints • "feedback on their posture during the day and difference with and without a suit" 3x • "Do...exercises and the.. is in the position we want it" • "whether people stick to what you give them ... or maybe give them too difficult an assignment" • "see body in 3D", "posture and freedom of movement" • "simple info about progress, improving fitness. should be stimulating. Making it clear whether a patient is doing it often enough, improving movement." • "people who are very body unconscious...give feedback through an external tool... and then they can correct themselves" by "getting feedback on their position

Table 2. Factors from PTs for future use of the FBMS (Source: PT-interviews - Section 4)

Factors from literature
To understand needs across the domain of PT, a literature study was performed on the KNGF guidelines outlining current PT practices. The full review can be found in Appendix 8. The most important factor topics are: COVID, working from home, moments of success, therapy compliance, education, behavioural change, stimulating active lifestyle, self-management, therapy frequency and intensity, MSC complications, body consciousness, load and resilience of the body, relapse prevention, transition to daily life, therapy styles, parameters, Tele-health, Intensity, and therapy bodysuits. Some are highlighted below:

Changing inactive behavior but also taking a more active role in the care process (*self-management*) are examples of *behavioral change*. For a good results in PT, behavioral change is often necessary. *Motivation* is needed to change a certain behavior. In addition to intrinsic motivation that comes from a patient himself, a physical therapist can help change behavior with coaching and education.

Experiencing moments of success is an important reinforcing stimulus that increases the sense of self-efficacy, *motivation* and *empowers* patients. *Highlighting succesmoments* by making achieved results explicit can be done continuously within the training course and by graphically depicting progress made and give positive feedback on it. Explicit attention must also be paid to achieving the set goals and the positive effects that this has on the thinking, feeling and acting of the client.

Some people are able to adjust the *load* to their physical and mental capacities (*resilience*). In case of pain and other symptoms, they adjust. However, some cannot creating physical health problems. The relationship between spatial awareness, body functioning and limitations is part of patient's *body unconsciousness* and should be overcome with feedback.

Trends & developments scouting
For the future on healthcare between 2020-2030, a wide variety of trends and developments emerged for phycical theraphy healthcare. An overview of the outcomes and some of the relationships given in fig. 19.

An interesting insight from this, is how Covid-19 advanced digitilisation of healthcare and remote, decentralised care solutions. This in return relates to a trends where third party start-ups are reinventing healthcare sulutions. As society becomes more critical of what care they receive for what they are paying for, the demand for based care increases.

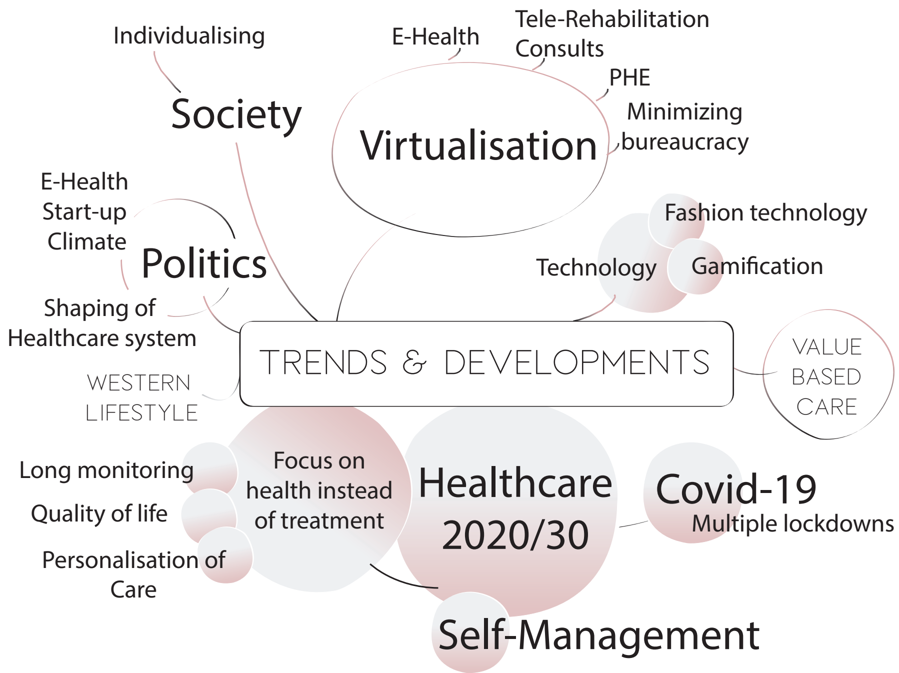


Figure 19. Selection of Clusters in the Factor Analysis

3.2.7 FACTOR ANALYSIS

Method

As described in the previous paragraph, factors are the building blocks of the future context and the description of those factors are value-free. In the factor analysis, the factors are accessed on their relevance, meaning: are they relevant to the domain of PT as well as interesting and novel enough to look at the domain with a from a new perspective. Factor selection is an intuitive process, which should be free from moral judgment, but is largely affected by values of the designer. The Factor Analysis aims to identify common drivers for a context in which therapy is successful for PT patients. The outcomes of the analysis aims to define the future context and give direction on how to respond to it.

To ensure variety in factors, four types are introduced (fig. 20) to ensure variety. The gathered factors will be categorized into types and evaluated on their relevance, appeal, novelty and appropriateness. Using the method of writing with post-its, the factors were gathered, almost intuitively. To reduce the complexity of the initial set of factors, individual factors were grouped into piles creating Meta Factors. These could be abstracted further into Common Quality Clusters(CQ). Between the Common Quality Clusters, relationships emerged creating Emergent Quality Clusters(EQ), see fig. 21.

The result of the clustering process is twofold: a storyline that connects the clusters and reveals their underlying relationship(s) (KNGF guidelines) and a dimension quadrant (trends & developments study) directing the design of the FBMS.

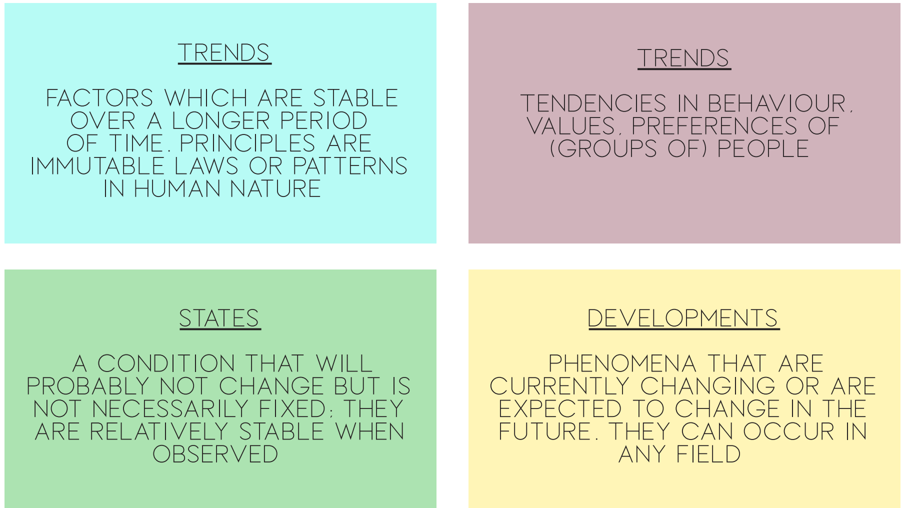


Figure 20. 4 factor types distinguished in ViP(Hekkert & Van Dijk, 2011)

Figure 21. 3 Cluster types (ViP; Hekkert & Van Dijk, 2011)

Main Research Questions

1. **What are the main patterns that describe the structure of the future context?**
2. **In which part of the future context will the FBMS position itself to make an impact on the lives of our target user?**

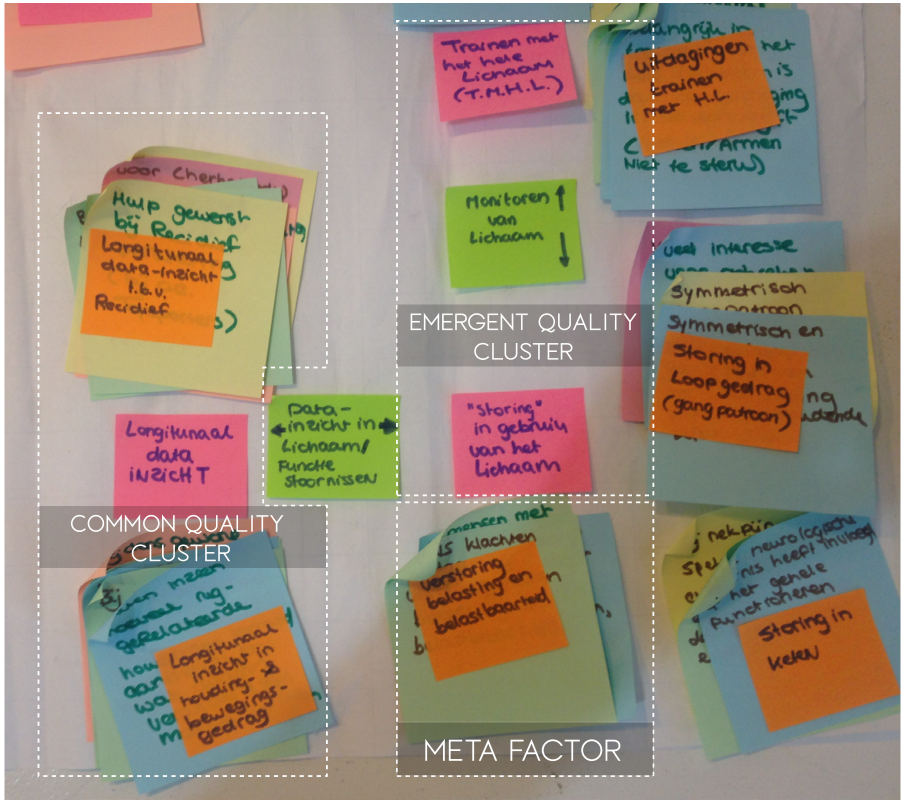


Figure 22. Selection of Clusters in the Factor Analysis

Results RQ1: structure of future context

The bright orange post-its represent the grouping of individual factors to Meta Factors. The Common Quality Clusters(bright pink) were made by finding the commonalities between the Meta Factors. An example of that process is the "Longitudinal Data Insight" cluster, which groups "insight in relapse" with "insight in posture & movement behavior" (fig. 22).

Between Common Quality Clusters, relationships and patterns emerge that connect all of them together. These form the Emergent Quality Clusters and are labeled bright green. The arrows display interrelated dynamics. In figure 22, two CQ Cluster "Longitudinal Data Insight" and "incorrect use of the body" are related, revealing the EQ Cluster "Data insight in physical functioning".

The first research question is answered by rearranging the position of both CQ and EQ clusters, so that a chain is formed by the relations between the clusters. This chain can be described as a storyline narrating drivers and user needs necessary for future design interventions.

In figure 23, the relationship described above is schematically drawn. The pink elements (CQ Clusters) form the basis for the new interaction qualities and the green elements (EQ Clusters) are what the new product should facilitate. The full outcome of Meta Factors, Common Quality Clusters and Emergent Quality Clusters can be found in Appendix 5. A Summary of the CQ and EQ Clusters is given in Figure 23.

In figure 23 below, the common quality clusters and the relationships that emerged during clustering are presented. It appears that Data registration, Data Feedback, Motivation and Self-management have a central relationship in the future context. Secondary clusters in the dotted line, such a disruptive elements and and training parameters are important in the design, but do not directly affect other clusters.

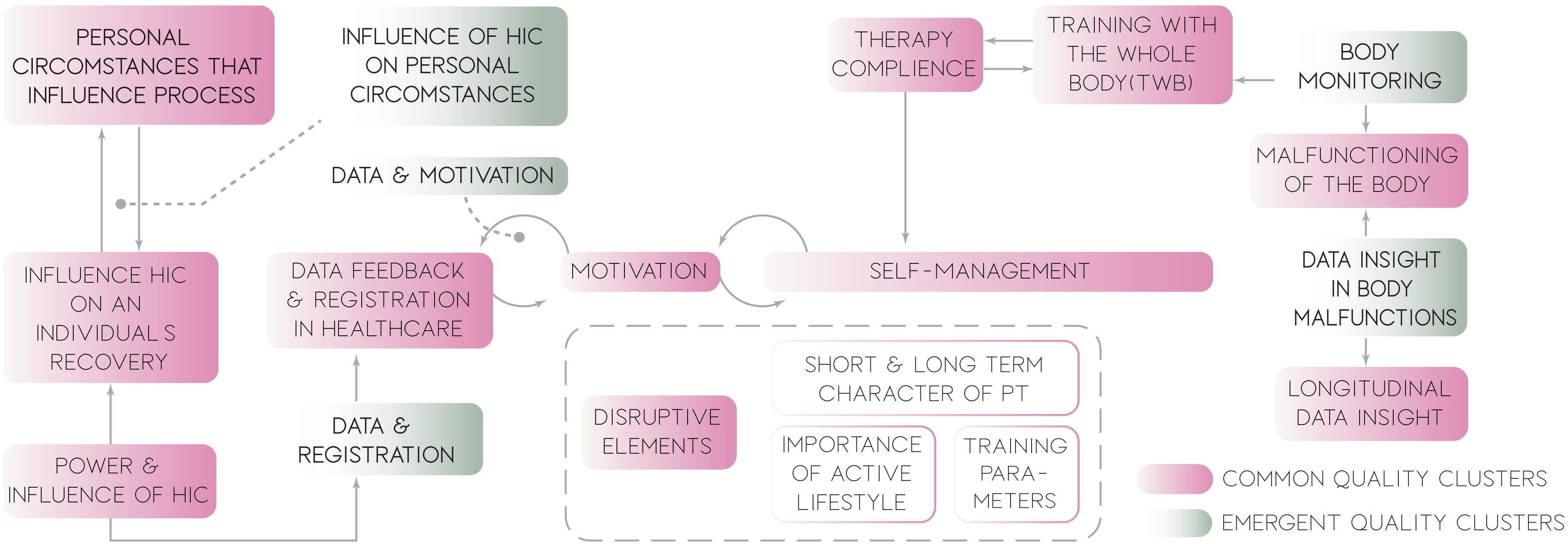


Figure 23. Overview of factor clusters shaping the Future Context for use of the FBMS and the relationships between them

Describing the future context: an emerging storyline narrating the Future Context

“For PT patients, an active lifestyle, therapy compliance and doing home exercises determine long and short-term outcomes. Cutbacks by HIC and individualisation in society drives the need for self-management and data registering. This abundance of data could be valuable when recorded appropriately: serving as feedback to motivate patients, create awareness and increase therapy compliance for faster recovery. With this, the role of PT changes; shifting the focus from healing to prevention. Longitudinal data insight and (distant)monitoring will play an important part in that transition.”

Directions for future design interventions

In figure 23 the variety and complexity of the initial individual factors was reduced reavealing a coherent structure describing the main patterns in the future context. From here, it is important to decide on a position on how the FBMS will make an impact on the lives of our target user. To determinde this position, the clusters were placed along two axes with opposing dimensions. This way, 4 quadrants emerged revealing the direction of how the cluster would impact the direction of the design. As decided upon in the project brief up upfront of the project, motivation and user interaction play an important part in the design of the FBMS. Therefore, these are decided upon as the two axis dimensions (fig. 25).

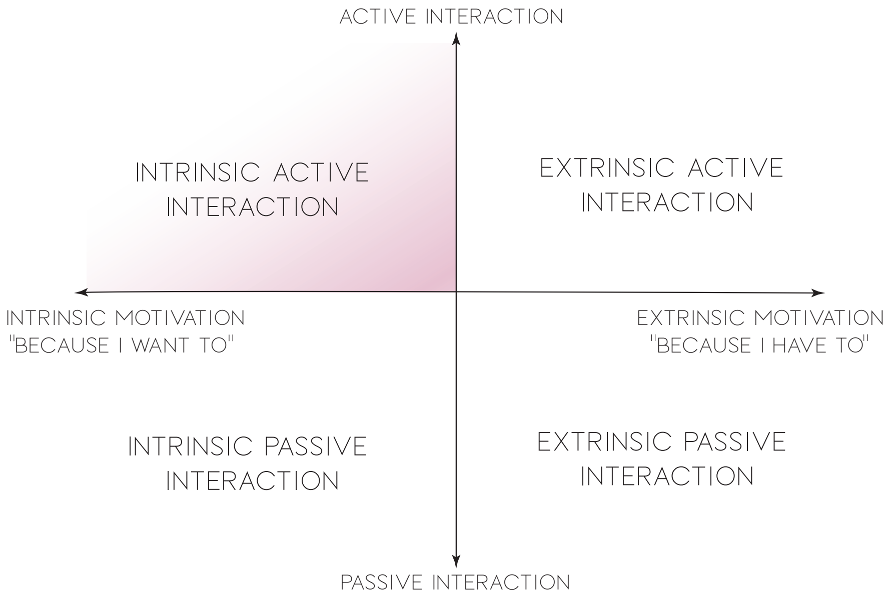


Figure 24. Positioning in quadrants

Results RQ2: Positioning of the design in the future context

For taking a position in the future context, the CQ and EQ clusters (pink and green label, fig. 22) were accessed on the nature on the impact that would have on the target user. As decided upon in the project brief and reiterated in the domain, there was a conscious decision to use the FBMS as an personal product-user interaction. This means the user is having an active interaction with the suit that impacts their behaviours. Therefore, this dimension is chosen. As discovered in the past context, intrinsic motivation plays an important role in changing behaviours and self-management. Therefore, these directions are chosen on the axes, resulting in the Intrinsic Active Interaction position (fig 24).

For placing the CQ and EQ clusters in the quadrants, the potential impact of inclusion those factors was accessed on how the users would interact with the FBMS and where their motivation to do so would come from. The placement of the clusters in each quadrant is shown in figure 25. Here, the orange indicates the clustered trends, generating the element of novelty. The dotted lines represent the relationship(s) between the CQ and EQ clusters and the future trends. These relationships describe the causal reactions between the clusters and what trends will be the driving force behind the position of the clusters.

The clusters that are included in the final position are: *Motivation, Data Feedback & Registration* and *Self-Management*. These clusters are driven by *Increasing interests in own health*, *Focus on own health instead of condition*, *Personalisation of care and Value based healthcare.* The latter Trend is in it's turn driven by the *Rise of E-health* and availability of *Personal Health Environments*. These clusters were placed in the Intrinsic -Active Interaction quadrant, as they allow for a new product users can have an active interaction with and motivates them intrinsically.

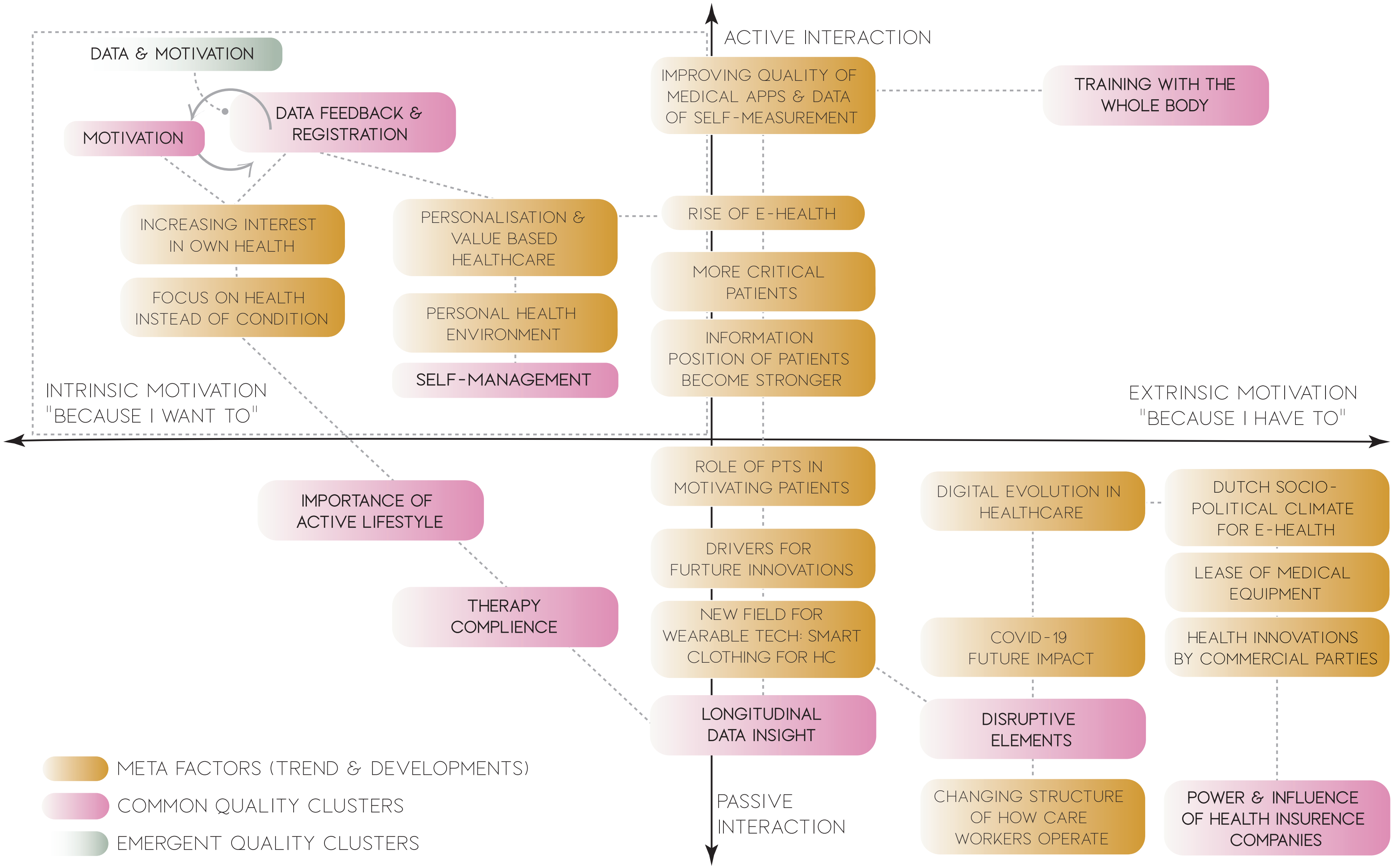


Figure 25. Four quadrants of Factor Analysis outcomes to determine the position of the design of the FBMS

3.2.8 VALIDATION OF FACTOR ANALYSIS WITH

The expertise of PTs was enlisted to prioritize the final selection of factors and validate the outcomes of the factor analysis. Through a questionnaire, PTs could rate the importance of the different clusters and provide feedback. Questionnaire results were used to support final selection of factors to include in the design of the FBMS. The full questionnaire can be found in Appendix 5.1.

Method

Qualtrics was used to create an online questionnaire for PTs to give feedback on the outcomes from the Factor Analysis. The questionnaire consisted of 5 parts(table 3). The results were downloaded to an Excel File. The main research question was: What needs, trends and developments will play important roles in the future of physical therapy?

Section	Section purpose	Items
1. Meta factor review	Rating priorities in qualities the suit should inhabit	14 items; 5 point likert scale
2. Common quality cluster review	Rating importance of individual clusters underlying the qualities in section	30 items; 5 point likert scale(29), 1 open text entry
3. Trends & developments	Rating the importance of trends most likely to influence PT	18 items; 5 point likert scale(18), 1 open text entry
4. Vision	Feedback on direction and initial Design Statement	2 items; 5 point likert scale(1), 1 open text entry
5. Interest in collaboration	Giving personal information to be contacted for testing purposes	2 items; multiple choice(1), 1 open text entry

Table 3. Factor Analysis validation questionaire items

Results

Results are displayed in table 4, showing scores equal to 4,6 or above (5-point Likert scale ranging from 1 “strongly disagree“ to 5 “strongly agree”). In total, five responses were recorded. Results for sections 1-3 show mostly items scoring 4,75 or above. Results for section 4 indicate “strong” and general agreement with the design direction, as displayed by the number of participants who chose those answers.

Conclusion of validation research

The high scores of “enhancing motivation of patients through data” and “increasing self-management” reiterate and reinforce Factor Analysis results. All PTs (strongly) agreed to the design direction, verifying the outcome of the factor analysis. In conclusion, enhancing motivation of patients through data and increasing self-management should be done through a new interaction that channels a patient’s intrinsic motivation and actively involves them with their own data. The questionnaire feedback verifies the Factor Analysis and drivers within the future context.

	Answers							
Items	Sum Average: 4,6≥			Sum Average: 4,75 - 4,8				
1	Insight into the patient's personal circumstances	Detect defects in the use of the body	Increase motivation among patients	Directly read data from body, register and receive feedback	Maintaining an active lifestyle			
2			Measure achieved success to motivate	Being able to emphasize self-management	Visualize the influence of self-management on recovery / fitness	Inspection under or overload on body	Being able to detect faults in chains	Being able to register movements
3			More commitment to Self-management	More interested in own health	Patients are increasingly critical			
4	Strongly agree	2						
	Agree	3						
5	Recruiting and guiding	3						
	No	1						
	Other	1	Ja, mits dit ook binnen ons Revalidatie centrum op dat moment ook mogelijk is					

Table 4. Overview highest scoring factors in user validation research

3.2.9 CONCLUSION FUTURE CONTEXT

Target user
From the past context, the target user of female lower back patients were chosen and their struggles and origin of complaints in daily life revealed. The future context explored these struggles, needs and drivers to change this through a factor analysis.

Stakeholder needs
From the interview and literature, it was found that self-management, and the skills user have to take control over their healthcare process, will play an important role in the future of the healthcare landscape. Smart technologies and wearables developed in the recent years give patients the tools to acquire a stronger position in their healthcare process, and will focus more on then principle of prevention over treatment. This principle is already the objective in PT, but to counter the lack of motivation for adherence the FBMS should tap into the natural intrinsic motivation of a individual patient. The patient-therapist interaction should focus on highlighting successmoments, not only based on patient's own, often biased, perception of quality of life, but also allow for objective data to be part of the feedback conversation during sessions. By following the data, physical therapist can help change behavior with coaching and education.

From the factor analysis, it was found that the main patterns in the future context that point in the direction of addressing user needs with intrinsic motivation and an active interaction which will provide feedback, are the relationship between motivation and data feedback and registration because it is based in society's general increasing interests in own health, as more and more products around us are getting smarter and allow for simple tracking with our smartphone and desire to focus on own health instead of condition. Because healthcare providers demand more self-management, patients in return are demanding more personalisation of treatment. Having the data to back their demands and personal belief systems stored in personal health environments, this leads to more value based healthcare.
The intrinsic motivation and active interaction, is therefore the position the FBMS is taking in the context for a design intervention that impacts both the interaction between the user and their personal attitudes, the user and their home exercises and the patient-therapist relationship. These relationships and the qualities of the interaction and necessary principles to improve current interactions for patients to reach their goals, are further elaborated on in the Interaction Analysis.

To validate the outcomes of the factor analysis, of which the factors were largely based in literature, the real life experience of PTs with actual patients was consulted through a small scale questionnaire (N=5). The clusters and individual Meta Factor clusters were presented and PTs could select and give feedback to which factors and trends they think will drive the future landscape of physical therapy. The outcomes validate the conclusions drawn from the factor analysis.

Key Context drivers
Considering all relevant building blocks for the context, a hierarchy between them can be established based on the outcomes of the validation of the factor analysis(fig. 26).

On the top half of the pyramid, the user needs driving the design of the FBMS, are stacked. The priority of the FBMS should be enable user to correctly execute their homework as this is the unsupervised part of the PT process where harm can be inflicted in a patient's body. In order for them to be able to perform their homework, and to correctly do so, motivation and the correct interpretation of an exercises is necessary. Working down to the middle of the pyramid, the building blocks of which that driver is founded is presented. At the base of the pyramid are the

3.2.10 SYNTHESIS OF CONTEXT ANALYSIS

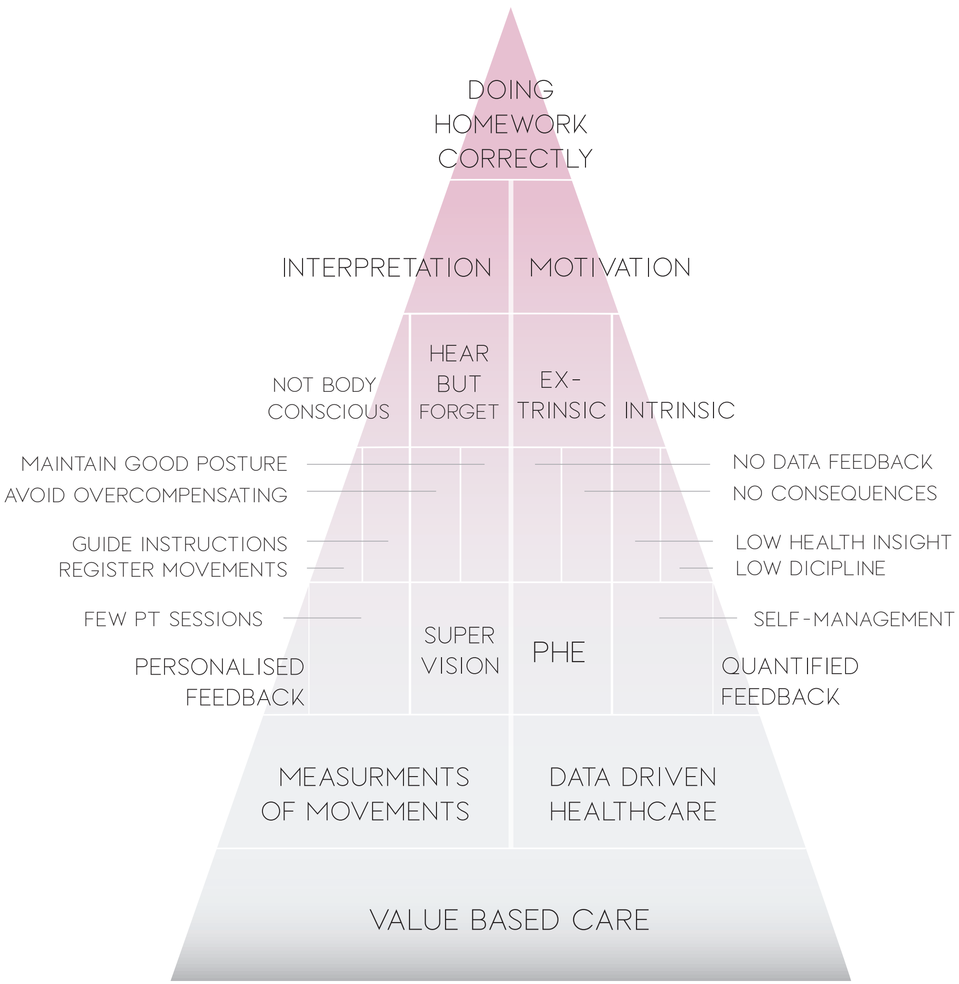


Figure 26. Pyramid of context factors driving the demand for the FBMS

drivers based in trends and developments. The core driver for easy to use wearables for at home full body posture monitoring in the domain of PT, is Value Based Care. Going up to the middle of the pyramid, is where both trend driven context factors and user needs driven context factors meet, describing the patterns and relationships in the context and need for the FBMS as a whole.

Design statement
The results from both past and future analysis can be synthesized in the design statement:

"I want women who suffer from lower back conditions and struggle with executing home exercises to improve on their body consciousness and increase motivation by providing a textile based wearable product that creates value based care and improves the patient-therapist relationship."

Reflections
In the project, the focus is on Maria as the target user. This choice does not exclude other applications or patient groups, as the FBMS can be applied to any condition practicing exercises and monitoring progress.

"The interaction is somewhere inbetween the product characteristics and the thoughts and the emotions of the user"
(ViP)

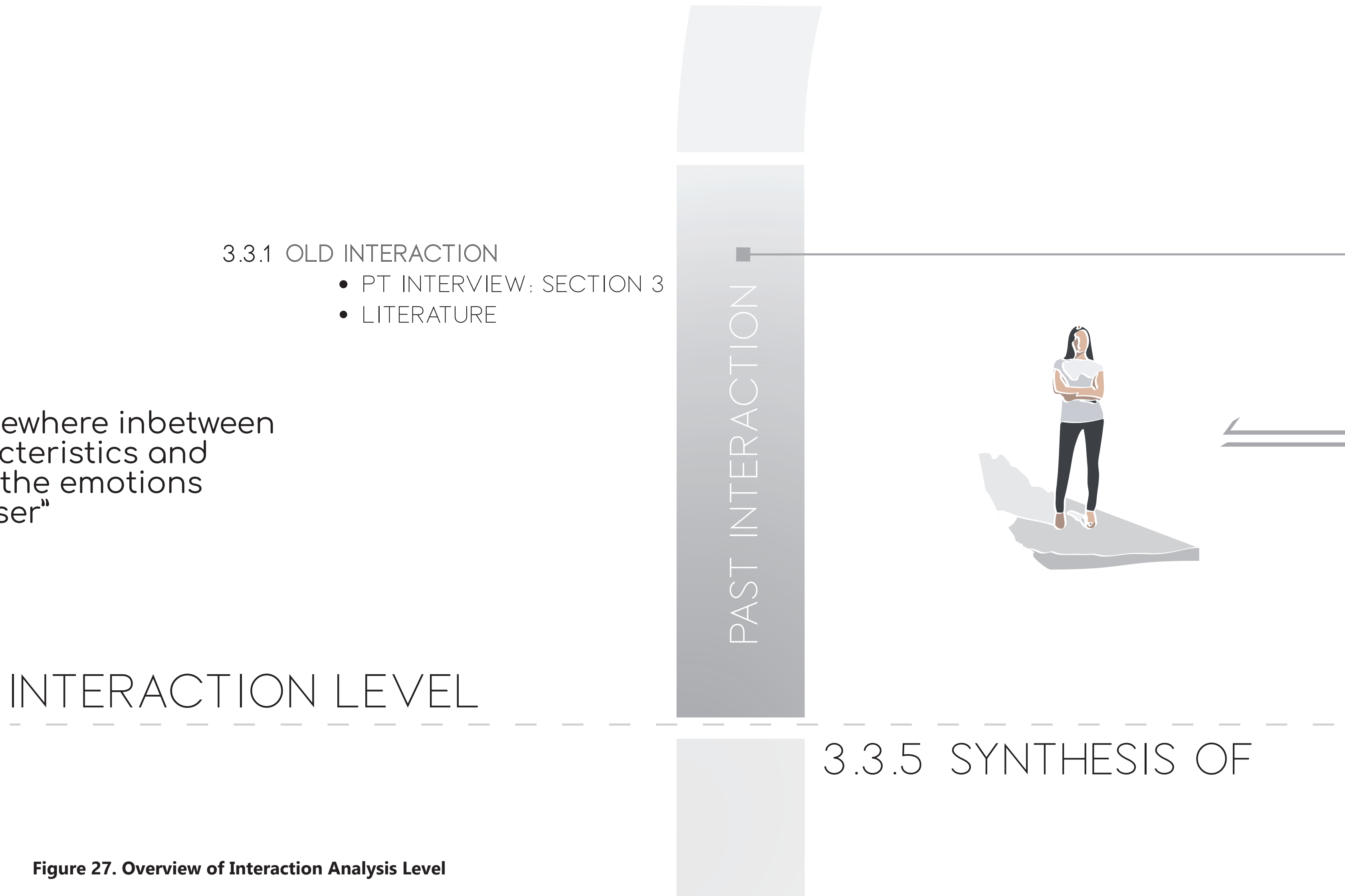
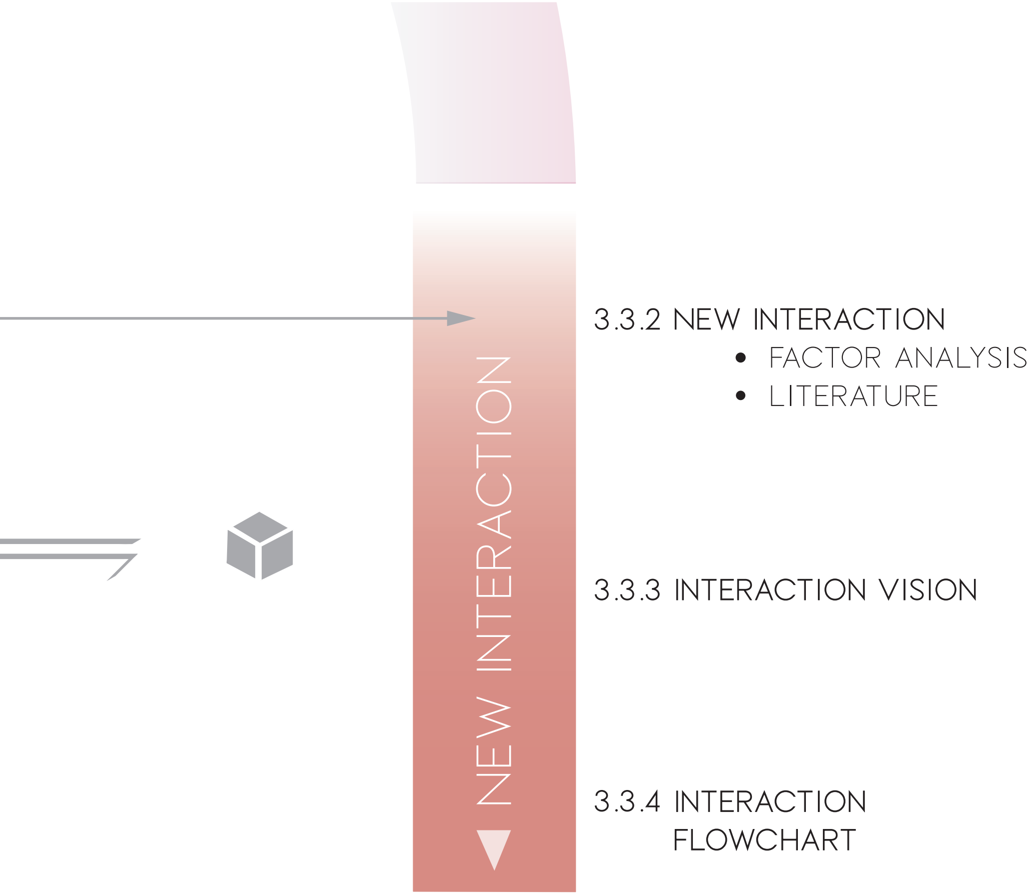


Figure 27. Overview of Interaction Analysis Level

3.3 INTERACTION ANALYSIS



INTERACTION ANALYSIS:

- INTERACTION DESIGN STATEMENT
- INTERACTION QUALITIES
- INPUT FOR PRODUCT PROPERTIES

As the context has been defined in the previous chapter, this chapter focuses on the exploration of interaction qualities. In the Interaction Analysis(fig. 27), an overview is given on how current interactions are limiting success and how new concepts for interaction solutions can change this.

Interactions in Physical Therapy

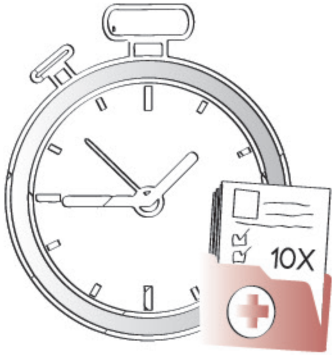
As established in the context, motivation plays a big part in the success of physical therapy treatment outcomes and changing certain behaviours to avoid future relapse. However, when patients are not doing what they said or said to commit to, PTs find it difficult to stay motivated and motivate their patients. This impacts the interaction between patients and PTs in a negative way. Issues with motivation for committing to home exercises and change behaviours are mainly psychological (Vink, 2020). Therefore, concepts from behavioural psychology are reviewed and introduced as a solution to transform current interactions, into new ones.

Method

A method to express the interaction vision, is by using images, words or analogous situations that express the same values. For this project, a visual conveying the same properties that the FBMS should embody was analysed. The outcomes reveal the desired interaction qualities.

Finally, what people will experience when using the FBMS is defined in an interaction definition. Combined with the Context analysis, the Interaction Analysis results in the goals users will achieve using this product and what that would mean to them which is the starting point for demands for new

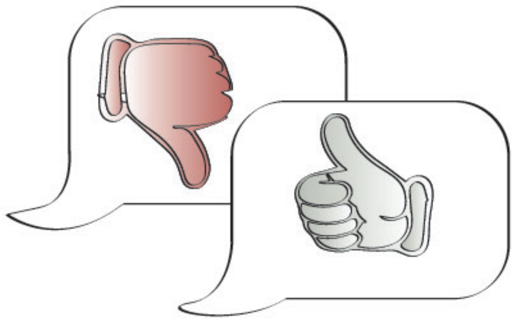
3.3.1 PAST INTERACTIONS



Patient's attitudes towards their health

In the majority of the intake sessions, PTs use the Patient Specific Complaints(PSK) method, they try to frame a patient's condition in their own experience. In this interaction, PTs can never be sure whether someone tells the whole story. The tailoring of their therapy is partially based on patients' qualitative descriptions and how they believe the complaint started. The problem is, PTs don't know what people do at home or work that contributed to this complaint in the first place and have to trust what a patient is telling them.

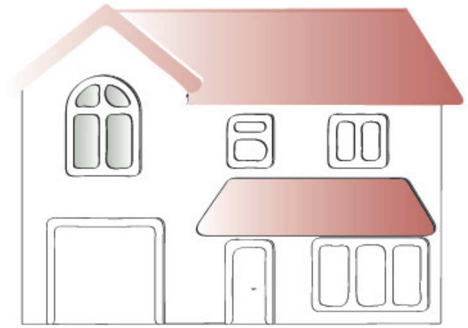
A third issue, is that patients often have high expectations of their PT and their methods. These expectations are hard to uncover and to address in the limited insured 20 min sessions.



User-Therapist Relationship

A large part of a PTs job is to motivate patients to work on themselves and change habits that contributed to their current condition. Are they scared of pain or hurting themselves at home without their PTs? Or are they lacking discipline to adhere to homework? These can be of a positive, encouraging tone or a more negative tone when focussing on consequences when failing to comply or change. Deciding on the tone of this interaction is difficult, as the PT has to assess on a personal basis, how a patient will be influenced most effectively.

Difficult in this situation is, these pep talks are only based on the visible (lack of) progress and what the patient is telling them. There is no direct quantitative data to support their arguments and visually show consequences to their patients' actions.



Patient-Home Exercise Adherance

To treat complaints within a few therapy sessions, keep momentum of progress and to have a lasting effect, patients need to perform exercises at home in between sessions.

The context analysis showed patients have difficulties in remembering the exercises and advice and could need some encouragement in keeping up discipline. When at home, people struggle to find time, focus and intrinsic motivation to follow through. Current solutions are written sheets(2D) given to patients to remember the exercises or videos(3D) in a personal health environment. The latter is still new and does not aid people who need to overcome their body-unconsciousness. 2D sheets often do not provide enough visual stimuli on how to do exercises correctly.

3.3.2 NEW INTERACTIONS

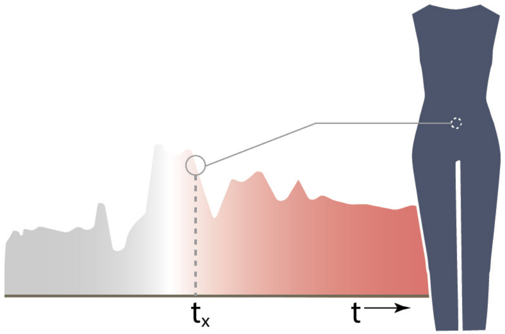


Figure 28. FBMS feedback

Quantifying the self

This concept uses data tracking technology to represent human behaviour in numbers. Algorithms analyze the data to identify underlying patterns and correlations. The data is typically visualized using simple techniques, such as heat maps, percentages or graphs available on a smartphone(fig. 28) .

By seeing yourself in numbers, you can compare new data to previous results, or to others and increase motivation to improve(contingent rewards). A current example is the popular Strava app. This self- association within a community to be a direct motivator to maintain tracking(Gimpet et al., 2013). After a small relapse, losing motivation could be prevented by comparing to personal history of progress.

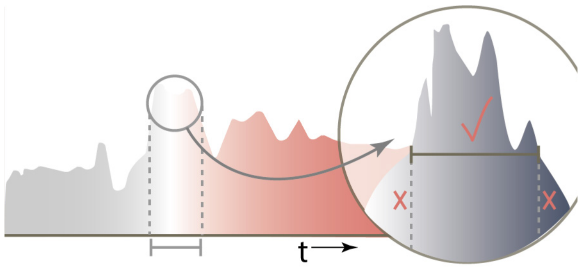


Figure 29. Highlighting success

Window of efficacy

In this context, a window of efficacy is the range between the quantified self values where the user should maintain equilibrium between all desired values(fig. 29). When wearing the FBMS, the user should not rely on the suit to tell the user whether an exercise is done right or wrong, which is a binary feed- back loop, but show them the effects of their muscle control in a range where they should stay in. This way, the feedback becomes interactive as the user will try to maintain their feedback within the range. Hence, feedback has a goal setting function from itself (Ilgen et al., 1979) and allows for behaviour change (Powers, 1973).

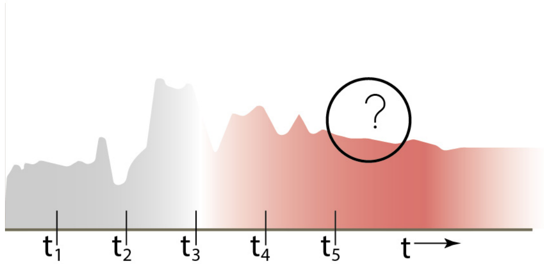


Figure 30. Track long term progress

Real time feedback

Value based care strives to optimize treatment by tailoring the approach to a patient's condition, so it is of most value to them. It treats them in the most effective way that is manageable for the individual. When certain goals are not manageable it will show in the data(fig. 30).

Instead of negative feedback from their therapist about not doing their homework, users will now receive more goal oriented feedback. PTs can find out where patients struggle to offer more fitting exercises and advice. Through interaction with the suit and resulting stats, patients and PTs have an objective shared tool to discuss further treatment.

HAVING THE RIGHT EQUIPMENT
HAVING ACCESS TO THE NECCESARY TOOLS AND KNOWING HOW TO USE THEM TO FINISH THE PROJECT SUCESSFULLY

GENTLE & CARING
BEING GENTLE WITH YOURSELF AND ALLOWING TO LET OTHERS HELP YOU TO TAKE CARE OF YOURSELF.

REFLECTION
INSIGHT IN PHYSICAL BEHAVIOUR (OF THE CAR) REAS-SURING FEEDBACK OF DOING A GOOD JOB

TRUST THE PROCESS
WHEN THINGS DONT SHOW PROGRESS, KEEP GOING

CONTENT, PROUD FACE
FEELING IN CONTROL OF THE PROCESS, IS MOTIVATED TO WORK ON THE CAR

DOING IT BY HERSELF
(BUT BEING PART OF A TEAM)
WORK ON THE WHOLE BODY BY HERSELF, BUT FEELING EMPOWERED BY HER TEAM

FULL BODY WORK
GETTING THE BODY BACK TO A FIT STATE

HIGHLIGHTING SUCCESMOMENTS
LOOKING BACK AT THE JOURNEY WITH YOUR BODY AND MAINTAIN .MOTIVATION TO KEEP ON WORKING

Figure 31a. Interaction Vision

3.3.3 INTERACTION VISION

The interaction vision describes the relationship between the user and the FBMS and how it will help the user achieve their goal as set in the design statement in the context analysis. This relationship, called interaction, defines how the product is used, experienced and what that means to the user. Finally, the envisioned interaction for the FBMS can be described by a range of qualities.

Method
For building the interaction vision, the method of using an analogous situation from another Domain was used to explore the research questions and uncover the qualities, meanings and experiences users will have using the FBMS.

Research questions

1. **Qualities**
   - What qualtities does the interaction possess?
2. **Meaning**
   - What will using the product mean to the user?
3. **Experiences**
   - What does the product allow them to do and feel?

To see the appropriate interaction between patients and the FBMS from a fresh perspective, an analogous situation was chosen that emulate the goals set in the design statement. An important aspect of the statement was to feel assured and in control of your own process to increase motivation. An analogous situation that to some degree shared this relationship between the user and the artifact used in the situation, was the situation of a woman restoring her used car (fig. 31a).

Results
The analogous situation was chosen because the woman seems to care for her car with a positive, relaxed attitude and being able to see the results of her work by the progress of state of the car. In figure 31a, the *qualities* can be derived from the situation could be derrived first: Pride, Having the right equipment, Gentle and Caring, Doing it herself, but being supported by a team, Reflection, Getting the body back to a fit state, Trusting the process and highlighting succesmoments.

The above mentioned qualities *mean* something to the user. Focussing on the quality of control, one of those *meanings* could be from taking notes from the user validation research: the interaction can change the relationship between user and PT, by giving them more control over how they receive care. Here, it means giving the user a more central position in the decision process of which care to receive when the user feels she is not making progress as much as she would like. It could mean that the FBMS mediates expectations between patient and therapist and help with therapy adherence by providing tangible arguments for both PT's and patient's belief systems.

Letting users *feel* more in control while doing their exercises allows them to feel they have an influence in their process, which is an important factor in the success of PT treatment. By highlighting these succesmoments, users can become more motivated to do their homework short term and discover benefits of changing their behaviour in the long term.

Conclusion: Interaction Vision
Now that the qualities, meanings and experiences are explored, the interaction vision could be defined as:

"I want physical therapy patients, who need to train with their whole body, to feel assured, empowered and in control of their recovery process by gaining feedback, access and insight into their physical behaviors, thereby increasing their motivation and self-management."

Interaction Vision definition

3.3.4 INTERACTION FLOWCHART

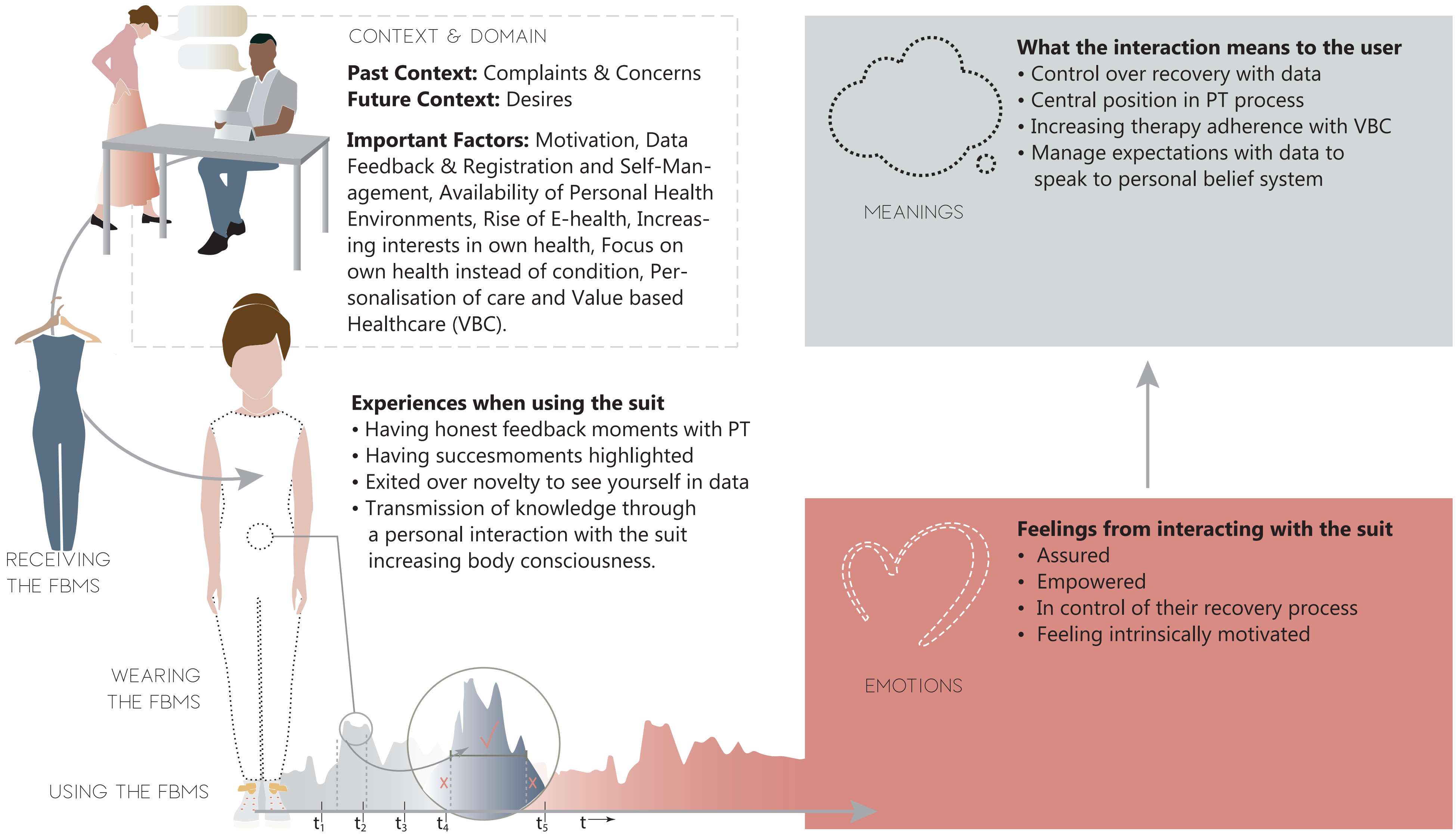
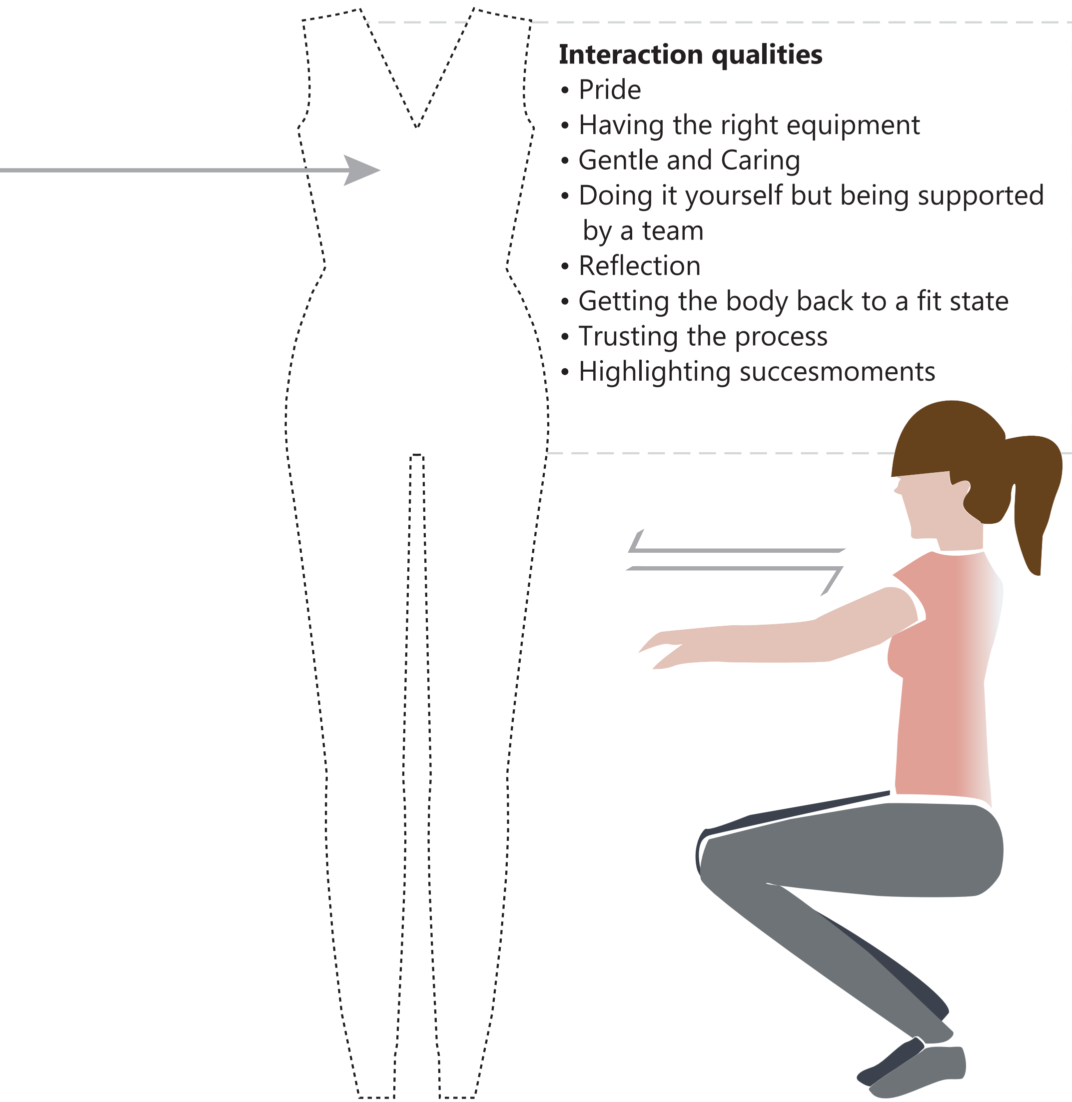


Figure 31b. Interaction Flowchart

3.3.5 SYNTHESIS OF INTERACTION ANALYSIS



In the old interaction, patients only have a short window to express their concerns, while PTs only have limited, standardized resources to evaluate them. Patients struggle with doing their homework while PTs struggle with having patients following their advice and doing their homework correctly. An intervention to get users excited about quantifying themselves and trying to develop themselves is what should motivate them, while also delivering an objective to base feedback on.

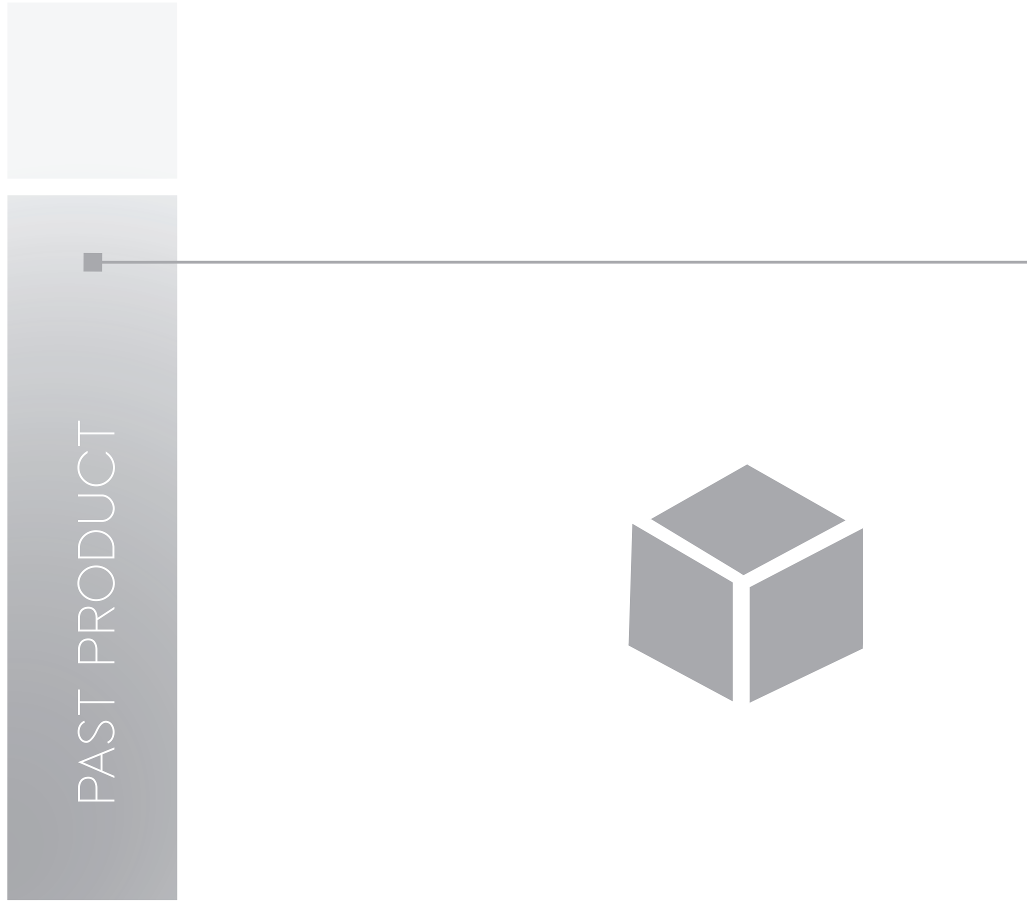
Connecting the important complaints and concerns in the Domain of PT and the Past Context, which are Motivation, Exercising at home, Transmission of knowledge (about their body, complaint and lifestyle choices influences, users with Lower back complaints and Measurability with the design position of the Future Context: Intrinsically motivated active interaction, the direction for which past interactions should be addressed. These are the short intake moments, moments of feedback when motivation is low and not doing their homework.

To change these interactions users have in their PT process, the FBMS aims to facilitate positive relationship between the user and the suit so that they can reach their goals set for their PT process and maintain this behaviour on the long term. This is done through the new interaction qualities: the novelty of seeing yourself in data, being able to track this data and compare the data to, for instance, highlight success moments or that a bad day is not representative for all their previous efforts.

These interaction qualities have direct implications for the product qualities, as the interaction defines the relationship between the context and the product. In the product analysis, the flow chart (fig. 31b) will be the starting point to explore past and future product qualities with.

PAST PRODUCT

3.4.1 CURRENT EXCERCISES
3.4.2 CURRENT MARKET SOLUTIONS
3.4.3 PAST PRODUCT SYSTEM
3.4.4 PAST PRODUCT FEATURES



PRODUCT LEVEL

SYNTHESIS OF

Figure 32. Overview of Product Analysis Level

3.4 PRODUCT ANALYSIS

NEW PRODUCT

PRODUCT LEVEL:

- SMART TEXTILE SENSOR OPTIMISATION
- INTERACTION TECHNOLOGY INFRASTRUCTURE
- PROTOTYPE & NEW PRODUCT DESIGN

In the previous chapter, the new interactions between the user and the FBMS were established and defined in the interaction vision. Te elicit this interaction vision, the product must possess certain qualities. By defining these qualities, the user will experience the FBMS as laid out in the interaction analyses and positioned in the future context. By defining the product qualities, the last link in the chain between the three major levels in ViP (context, interaction and product) and the last part in shaping the design vision for the FBMS(fig. 32).

Method

First, we look at the current exercises user do with in the past context. From here, we can look at how users achieve their goal without the FBMS. From this, features to be included in the design can be derived. By exploring these features in current market solutions, the product qualities and features of the Past Product can be established. By deconstructing the past product, it can be determined what are current benchmarks as well as what needs to be improved. From here, the desired product qualities and features are established. These in return result in product demands. Pugh's checklist was used to determine all product demands.

Results & conclusions

The results from the Product Analysis phase determine how the FBMS will communicate with the user and how the users communicates with the suit: how does the suit sense posture and how will the user receive and understand feedback. The outcomes of this final analysis level will be directly used in the Sensor Development and Conceptualisation chapters before the Designing phase of the suit can take place.

PAST PRODUCT

3.4.1 PRODUCT USE: POSTURE CONTROL & EXERCISES

Correct posture

The ideal posture is presented in fig. 33. The center line represents the postural line of gravity of which the center sits in the waist (Trew & Everett, 2005). This posture alignment can be achieved by following the steps in fig 34a-d (Man Flow Yoga, 2017). A good posture is the base for any further exercising to battle posture related conditions. Therefore, the recognition of standing up straight in the correct full body position is the minimum qualification for proof of concept.

Correct squat

A common mistake is starting from the knees(Fig. 35a-b). The first thing people do when they want to squat is bend the knees. Not only does that make a proper squat impossible, it also places unnecessary stress on the knees (Medvesek, 2019). This position also demands focus on multiple areas at once: arched back and knees width. Therefore, this position is chosen for proof of concept for the placement of the sensors. For a more detailed overview of correcting posture and squat errors, see Appendix 7.2.

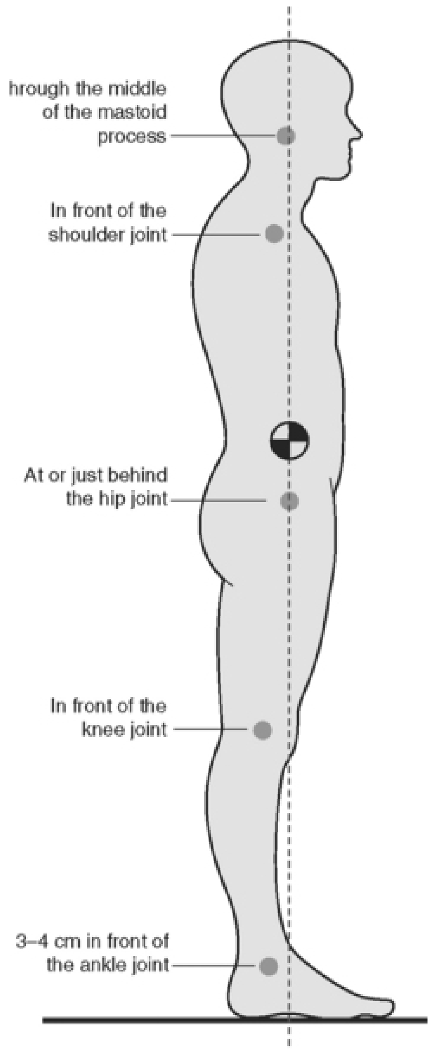


Fig. 33. Correct posture (side view)

Fig. 34a. Correct base

Fig. 34b. Activating legs

Fig. 34c. Activating core

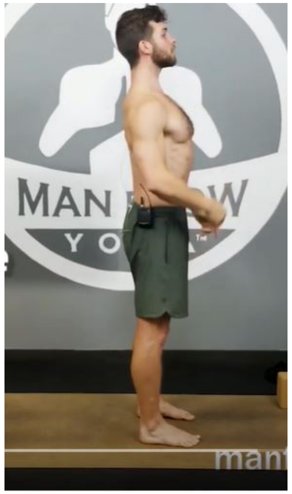


Fig 34d. Elongating spine

Fig. 35a. Mistake #1: Start from knees

Fig. 35b. Correct squat posture

3.4.2 CURRENT MARKET SOLUTIONS

Figure 36. (Past) Products on the market

From the user validation research in the context analysis, it was shown that one of the exercises PT patients do, is the squat. PTs also mention they like to give the squat as a homework exercise, because it trains multiple areas at once and strengthens the core which plays an important role in maintaining proper posture and combatting lower back pain. It is important to evaluate what proper posture is first, before assessing what products are on the market targeting this segment of user needs. A scientific standard for what proper posture is and what parts of the body are involved is shown in figure 33. As discovered in the context analysis, maintaining this posture proves to be difficult due to the target users daily life influences an behaviour.

Results Market Analysis

Current market solutions that possess the features necessary to counter deviating from proper posture, relearning positive postural habits and tracking movement, are gathered in figure 36. Here new market solutions were added to a prior extensive market analysis done by Schrevers (2017). A full overview can be found in Appendix 1. One of the biggest group of competitors are the TruPosture shirts(€175). The monitor the position of the spine and give feedback to the user by buzzing and show their posture along the proper norm to see their deviation real time. Another product is the Navi yoga leggings, tracking leg movement according to a set program to guide user through a yoga session in the right position. Other solutions contribution to parts of the FBMS are the Anodyne(posture correcting shirt), Racer back bra(posture correcting sports bra), Catapult (static back braces), fit bit(tracking biofeedback), Strava(sharing biofeedback). By studying current market solutions, a gap was found in for full body posture monitoring while doing exercises because product either monitor (parts of) the upper body of lower body. Full integration of healthcare around the user is also missing. To further understand the market gap, past product qualities and features are explored next.

3.4.3 PAST PRODUCT SYSTEM

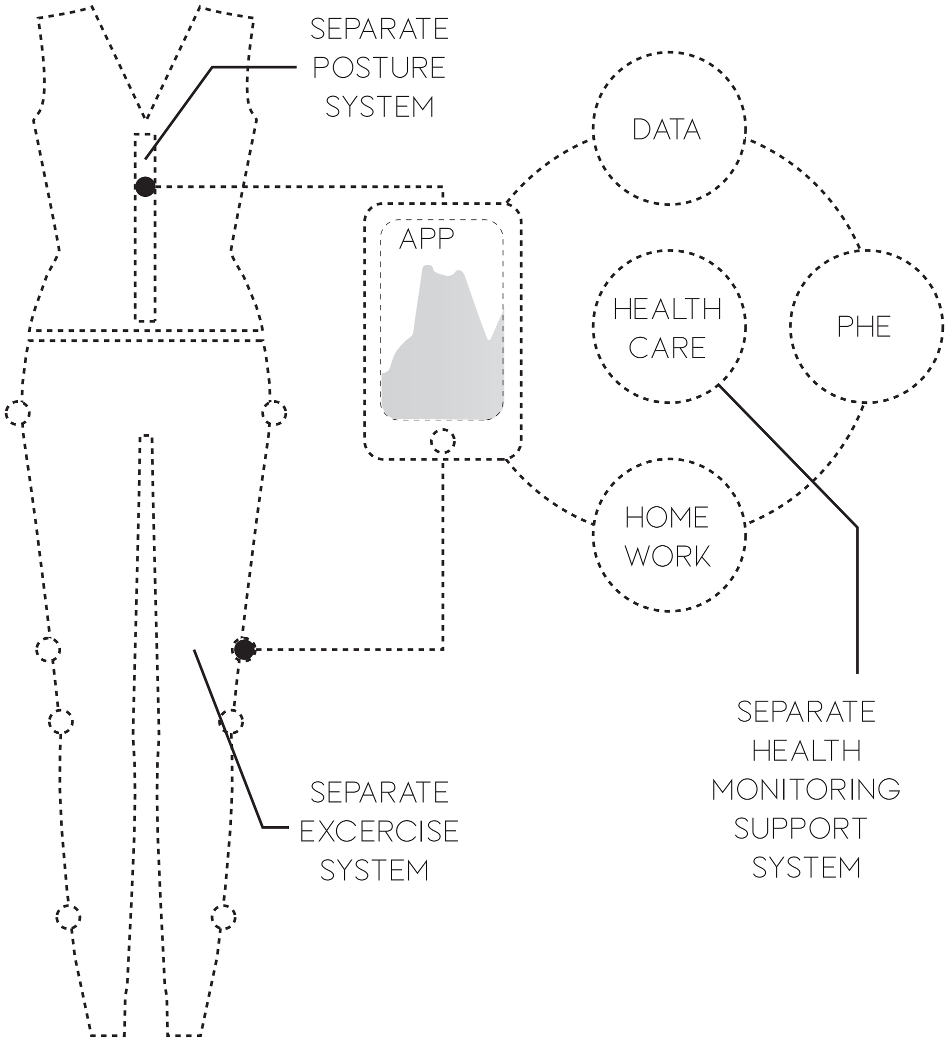


Figure 37. Past Product system

From the market research, four systems are involved in what the FBMS aims to comprehend to create an interaction between the user and the product that will intrinsically motivate them to do their homework. Here these systems are described and what qualities it offers to the user (fig. 37).

Past Product systems
Current market solutions offer separate solutions to the context demands and interaction qualities. First is the system of posture monitoring along the spine. The TruPosture back monitoring shirt only measures the posture of the upper body. The Navi yoga leggings only measure whether the bottom part of the body is well-aligned for the exercise. This leaves out an important parts of the body in maintaining good posture.

Another part of the FBMS is that the data the suit measures should be transformed into overviews relevant to the user as well as the physical therapist. Many of the aforementioned product offer their own app, but this does not allow for the user to track both upper and lower part of the body in the same system. The combination between healthcare and data is now often stored in separate Personal Health Environments (PHE). Although the individual products offer qualities helpful for the user, they do not offer an holistic and seamless experience between the product and receiving feedback.

By having analysed the past product qualities and features, now the new product can be described.

3.4.4 PAST PRODUCT FEATURES

Market research shows there is a gap in the market for full body posture monitoring. Competitors that currently offer products that come close to the envisioned functionalities for the FBMS, are briefly reviewed below(fig. 38a-b).

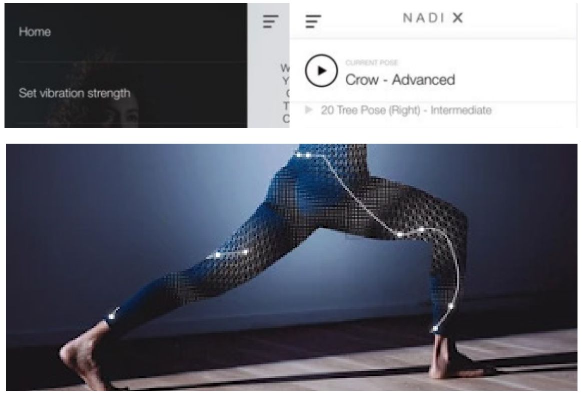


Figure 38a. Nadi x Wearables yoga pant

Figure 38b. Monitoring back posture with app

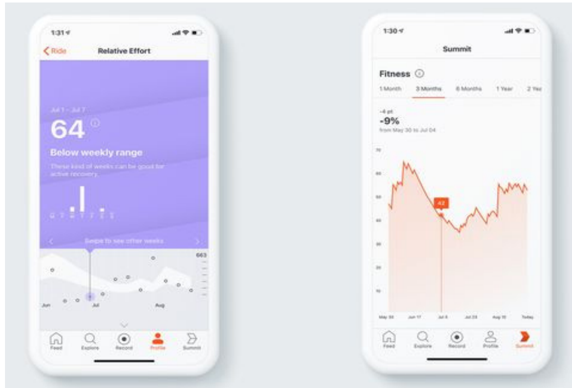


Figure 38c. Strava monitoring system

Monitoring posture during movement

The Nadi yoga pants tracks posture during movement to follow a pre-set sequence of poses. The user can set these and follow along with tutorials. The algorithm reacts to the movement and posture for the expected yoga position. Not being in the right position & posture, triggers haptic feedback with vibration pods clicked into the legging. This is done through interaction with your smartphone. The leggings are washable and charge through USB. progress can be tracked. These leggins are commercially available(Wearable X, n.d.). Downside is they only measure the bottom half of the body.

Giving spinal feedback

The TruPosture shirt aims to train correct back posture. It has five integrated sensors along the spine and the app gives real time feedback on the position of the spine against the norm. It gives both visual (app) as haptic feedback with vibrations when posture needs correcting. The shirt is machine washable and charges with usb (truposture, n.d.). Downside is its design with a zipper, obtrusive sensors and looser fit around the body. There are other shirts, more gym focused, sleek commercial alternatives, but these focus on muscle activation and biofeedback, not spinal posture.

Short and long term tracking

For the collection and analysis of generated data, various are apps available to connect your tracking device to. According to the insight that it motivates users to continue tracking when they are involved in a community, an app like Strava is interesting. This is a commercial social media platform for sharing tracking results. However, for medical use this data must be kept private. Therefore connecting to such an app is not an option. It is inspiring in the way it connects and gives users insight in the long and short term achievements.

NEW PRODUCT

3.4.5 NEW PRODUCT SYSTEM

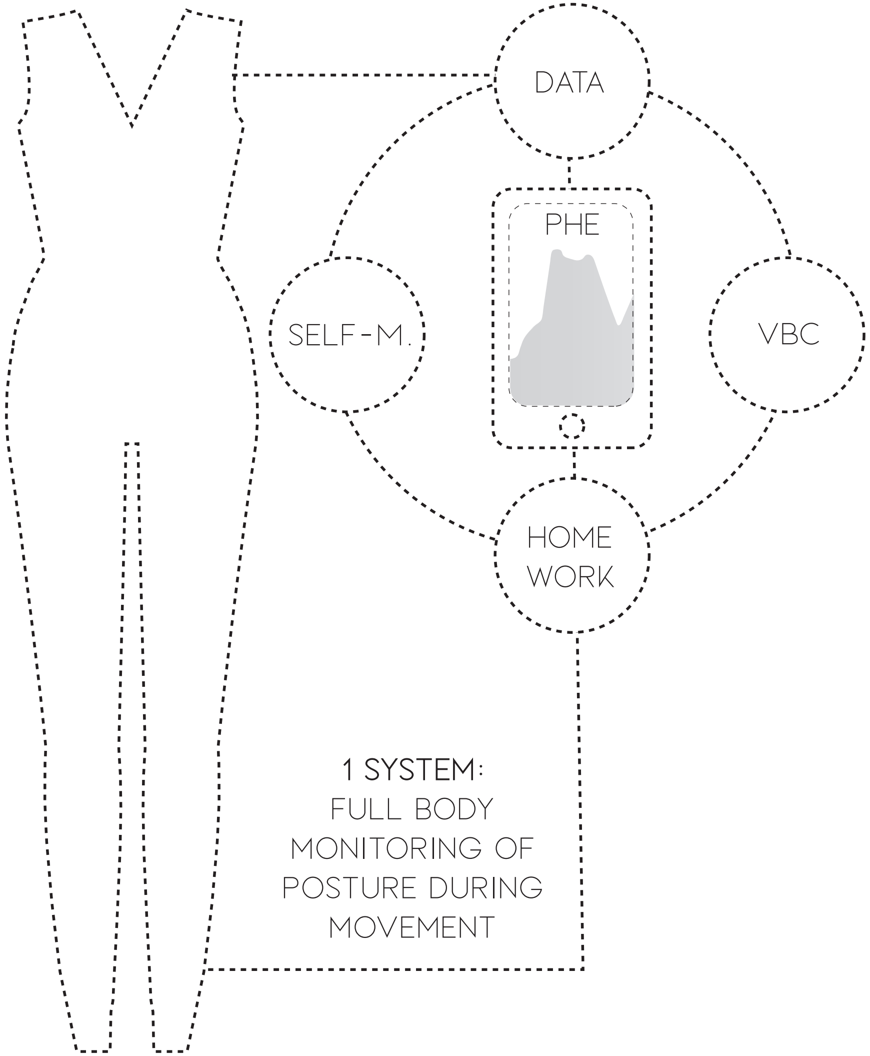


Figure 39. New Product system

From the past product systems, it appeared that current market solutions are not targeting user needs as defined in the previous context and interaction analysis. This is because the product qualities and features are not properly integrated with one another.

New product systems
As described in the introduction, the shape of a catsuit offers the potential to measure feedback from the body closely to the skin. By integrating the top and bottom garment into one suit, there are no more separate parts of the body, but the system of measuring the body has become one. This is also closest to reality as for lower back problems the body has to be treated as one system(fig. 39).

Next, the system of visual feedback on your posture and healthcare must be integrated as one for the user to experience a seamless interaction. By centralizing the personal healthcare environment, both patient and PT can now start using the data for feedback moments. This will allow the users to be more in control of their own data and use this to better their PT process and receive value based care.

To allow for these qualities and a positive user experience, product features that facilitate this, are described next.

3.4.6 NEW PRODUCT FEATURES

All further product qualities and demands have been assessed using Pugh’s checklist and can be found in Appendix 7.1.

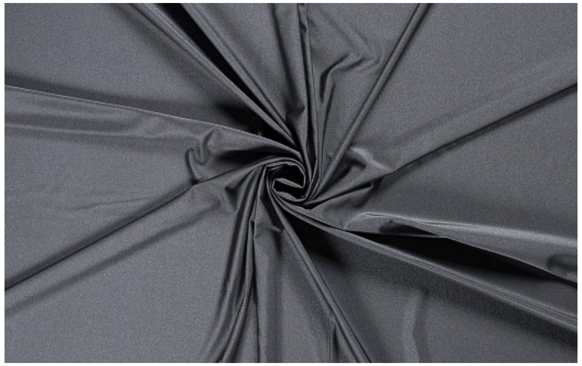


Figure 40a. Lycra Material

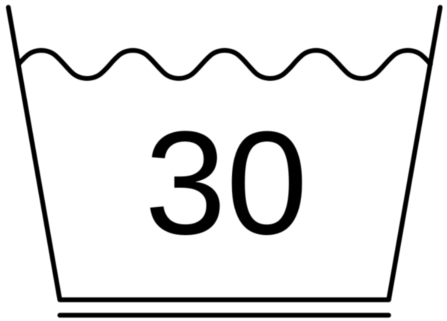


Figure 40b. Washability

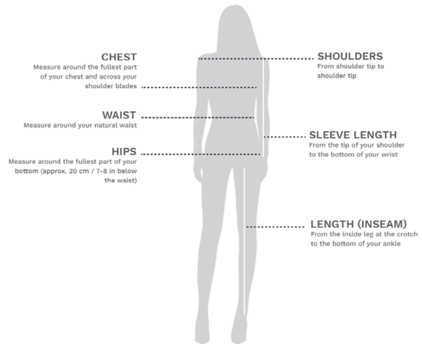


Figure 40c. Size system for everyone

Soft Lycra material

The FBMS should be made of stretchy, soft material, which comes in the form of weft knitted lycra (fig. 40a). To ensure uninterrupted movements and comfort, the material must at least stretch 200% and stretch back to its original orientation. This is achieved with lycra consisting of at least 15% Elastane. The stretch of the fabric should not be affected by stretch properties of the sensors. The user should feel both powerful and comfortable with getting a sense of the future.

Ease of use

The lycra should contribute to the ease of wear and ease of use. The design and material must allow any user to get into the suit as they would get into regular athletic apparel. The connection of the suit to the app must be seamless and data must be collected in the app automatically when the suit is on. The user should only need to open the app to view results. The suit can be treated as synthetic apparel and be washed at 30°C washing cycle (fig. 40b).

Perfect fit

The use of lycra should also guarantee every user a full body perfect fit. The suit will become available in 9 sizes: 3 width sizes: XS-S, M-L and Xl-XXL and three length sizes: petite, regular and tall. For the production of the prototype, the size M-L regular will be used due to the fact that this sizing is most apparent in Dutch women(CBS, 2019). The suit must have a snug fit to secure proper measurement of the stretch in the fabric and sensors (fig. 40c).

BECOMING STRONG DOESN'T START IN THE GYM. IT STARTS IN YOUR HEAD.

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3.4.7 CONCLUSION PRODUCT ANALYSIS

As described in the previous chapters, the FBMS must contain certain qualities in order for the features to connect to the user as it was intended to. The features of the FBMS are:

- **Stretch lycra material**
- **Ease of use**
- **Perfect fit**

For wearable technology to be accepted by the user, especially textile based wearables, the product must feel soft and comfortable to wear. The quality of the stretch of lycra, makes the suit literally hug the body.
The ease of use, should provide the user with ease of mind, so that there are still barriers between the intention to use the suit and actually doing home exercises. The perfect fit should not only secure the wearable part of the product, but also the mental aspect of trusting the technology.

To convey the emotional qualities to the user, aesthetic qualities play a mayor role in the perception of the FBMS. A means to explore aesthetics is a moodboard. The intentions for the product character of the FBMS are shown in figure 41. The suit be perceived as an intelligent system that is there to support you. It exist for the user to feel guided as they would when working with their physical therapist and the experience should surprise them as though they feel part of the future.

The integration of the wearable textiles in the catsuit, should be done in a powerful, but elegant way by keeping a sleek design. The aesthetic qualities to achieve this can be directly derived from the moadboard:

- **Dark colors**
- **Blue, cool tones**
- **Strong lines**

This moadboard, which sums up the necessary product qualities, should already be incorporated in the design of the prototype as it will affect the first impression users will have in the user test. This will have implications for the selection of fabrics, such as color or texture, and choice of materials.

In the next chapters, the focus will be on developing the sensors and creating sensors concepts. In the design concepts for the sensors, these product qualities will be applied.

4. SENSOR DEVELOPMENT

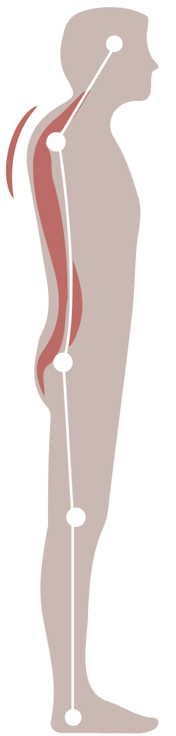


Figure 42a. Kyphosis

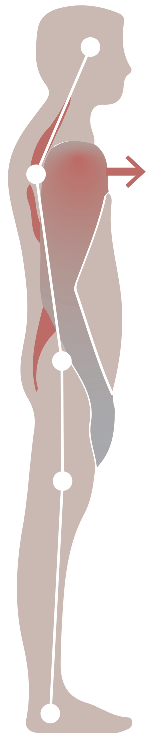


Figure 42b. Forward-rotated shoulders

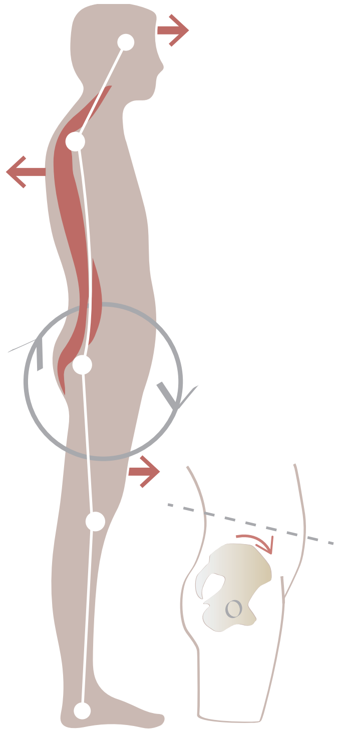


Figure 42c. Anterior Pelvic Tilt

Summary postural deformities most present in the context
Hunching over the keyboard creates an excessive curve in the upper back, This deformity is called *Kyphosis*. This lowers the shoulders and moves the Thorax backwards. By sitting in a hunched position, the shoulders *rotate forward* . Sitting for long periods of time creates tight hip flexors & lower back muscles plus weak abdominal, glutes and hamstring muscles, *tilting the pelvis* clockwise. This further creates an arched back and abdominal distension. This in turn moves the body forward over the feet and overstretches the knees (OSGPC, 2015)

4.1 CREATING A STRAIN SENSOR

As described in the New product system chapter, the new product system of the FBMS will monitor posture by measuring body feedback along the entire musculoskeletal system(MSC). As discovered in the Target User Validation, the main postural issues patients with lower back problems are facing, are *Kyphosis*, *Forward rotated shoulders* and *Anterior Pelvic Tilt* (fig. 42a-c).

Sensing postural deformities by strain
By comparing these body posture deformities to the ideal posture, each deformity displays a unique pattern of displacement of body parts in relation to each other in the MSC. By capturing and measuring the direction of the displacement(s), the patterns can be identified and monitored for posture feedback. The product features of the FBMs such as the tight fit and the high stretch character of the lycra material, allow for these displacements to be closely followed along the whole body. These body part displacements, are pushing against the lycra, and locally deforming it causing strain. By measuring this strain and the pattern in which the strain varies, the FBMS can sense posture and identify movement.

To sense strain in a material, a strain gauge is used. Regular strain gauges however are too rigid to use in fabrics, but in principle they measure strain by converting the elongation to an electric output. By measuring the change in the electric signal, the position of the body can be determined.

Method
In the chapters, the formats for sensing strain, the most viable material(s) to use for sensor, the ideal characteristics the sensors should inhibit and the variables in the design and production of the sensor that influence the output signal of the sensors are explored through a literature study and a series of experiments.

Conclusion strain sensor formats

Textile sensors that measure strain come in three main formats: *Strain resisitve, Strain inductive* and *Strain capacitive* (figure 43-45). Bot strain inductive and resistive yarns are made from traditional textile fibres and coated or blended with thin filaments of stainless steel, copper or silver, with the exception of conductive single yarns(fig. 47). These sensors can be made with different materials in a variety of forms that make them suitable for integration in garment. They can be placed in nearly every location of the suit. However, strain capacitive sensors cannot be integrated as seamlessly into the design as a stitched or fabric made sensor, as it will always consist of two layers. Therefore, strain resistive and strain inductive are further investigated.

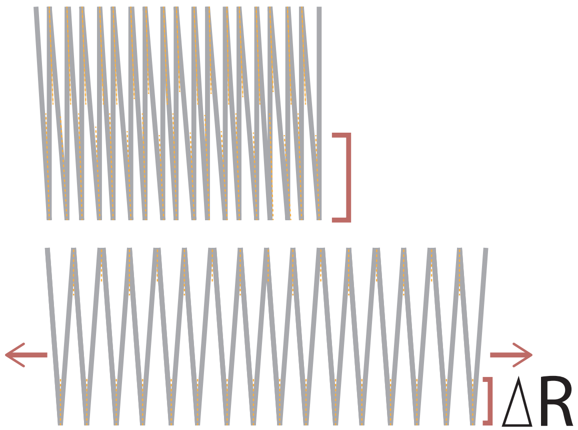


Figure 43. Strain Resisitve with conductive thread

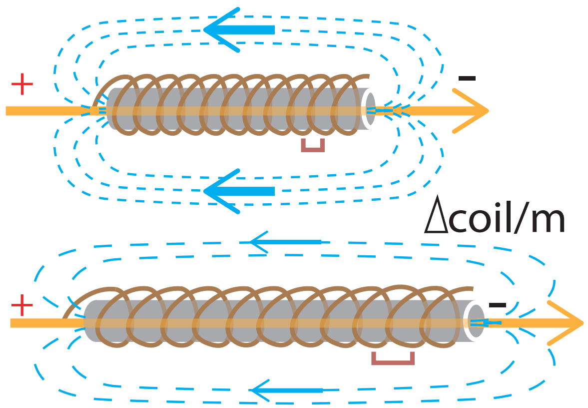


Figure 44. Strain inductive coil wire

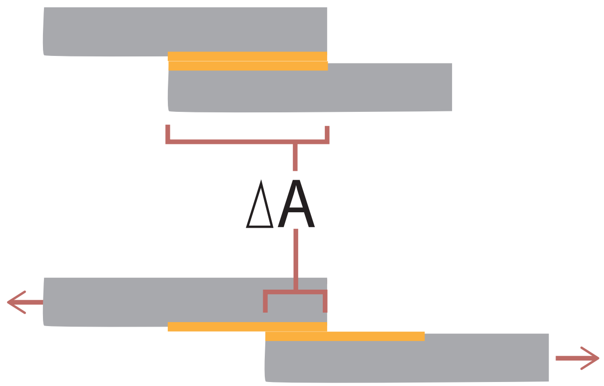


Figure 45. Strain capacitive

Stretching conductive materials will pull apart the surface area where particles touch. This will decrease conductivity and increase the resistance. By measuring the change in resistance, the strain can be determined. The best results are obtained with silver plated nylon yarns, such as Shieldex or Lamé Lifesaver(Jansen, 2020) in 2- or 4-ply thread to reduce noise and increase reliability (Greenspan et al., 2018)

Inductive sensors are made with conductive thread. This thread can be stitched in lines next to each other(fig. 49: Liu et al., 2020) or coiled along an elastic wire(fig 44: Tavassolian et al., 2020) that is fixated onto the garment. By pulling the fabric apart, the magnetic flux created by the current through the wires changes due to the change in proximity of the conductive material. By measuring the change in flux, the strain can be determined.

Strain capacitive sensors are often made from flexible polymers coated with a conductive layer. Capacitive sensors are made by two overlapping conductive plates (electrodes). When fabric strains pull on the separate sides of the sensor, the overlapping surface between these plates decreases. The amount of overlapping surface determines the conductivity, thereby measuring the strain.

4.2 EXPLORATION OF TEXTILE BASED SENSING SOLUTIONS IN LITERATURE

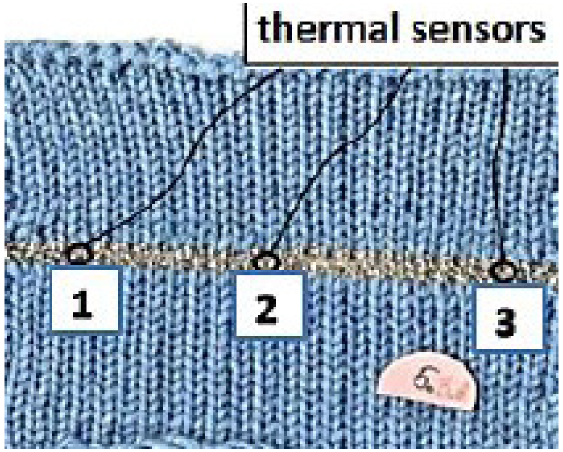


Figure 46. Knitted resistive sensor

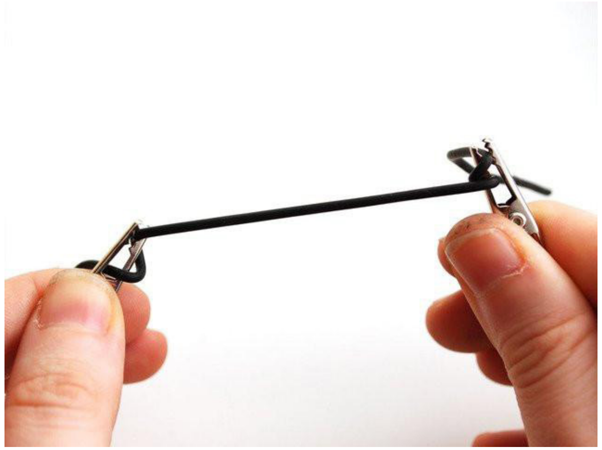


Figure 47. Conductive single yarns (Adafruit, 2020)

Figure 48. Knitted conductive fabrics(Lycra)

Knitted fabrics allow for comfort with it's breathability and inherent stretch. The structure of a knit consists of rows of yarn loops, which are intertwined consecutively. This loop structure gives the material it's characteristic stretch, even though the yarns themselves are not(Jansen, 2020) In a knitted strain sensor, functional yarns can be embedded. However, knitting machines are intricate and time consuming to program. Hence, this production method does not allow for rapid prototyping required for this project.

Conductive single yarn sensors have the benefit of high accuracy. These yarns are often constructed of a conductive rubber type (Jansen, 2020) or conductive film applied to a stretchable textile substrate(Mattman, Clemens & Troster, 2008). A downside to these sensors, is that the material of these yarns are usually thicker and stiffer than the material of the garment itself, affecting integration. The difference in stiffness will restrict the use to a working limit of at least 10% or lower.

Conductive fabrics, such as Electrolycra and Medtex 180, are knitted with conductive yarn that is blended with Elastan. Using conductive lycra to measure strains in a large surface is not viable, as fabric samples of 15x3 cm already showed large hysteresis(Liu et al., 2019) and the material is prone to moist and overstretching (Schevers, 2016). However, Grassi et al. (2017) proved that by 100-200% overstretching and laser cutting small strips, a decent working range and GF could be obtained. The solution of using strips is promising to construct a sensor with.

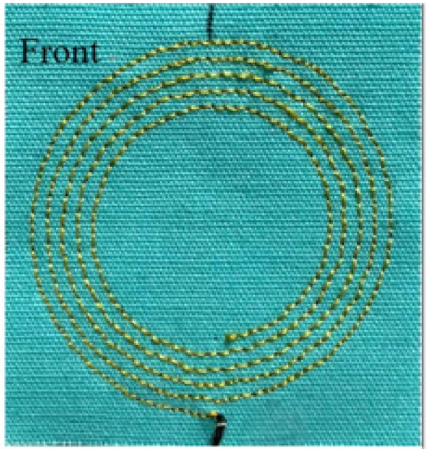


Figure 49. Embroidered Inductive sensor

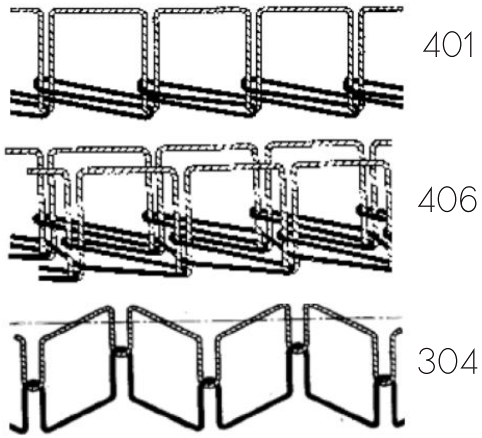


Figure 50. Stitched strain resistive sensor

Embroidered sensors allow for wireless and batteryless data transmission due to induction. In figure 49, Liu et al. (2020) created a sensor of two embroidered coils, called Planar Coupling Coils, in the pattern of a spiral with a non-conductive fabric in between. When strain is applied, the mutual inductance changes and can be detected with a CPC sensor. Using a signal generator and analyzer connected to a NFC coil antenna, sensing information can be extracted. However, this only serves as a passive sensor, whereas the FBMS intends to create a closed sensor-actuator circuit within the suit. Requiring additional equipment, this option is not viable.

Stitched strain sensors can be added at any time in the construction process, are unconstrained of placement and length while minimizing the effect of the properties of the textile substrate (gioberto & Dunne, 2014). The sensor response relies on the stitch geometry but more prominent of the textile substrate(Dupler & Dunne, 2019).
From literature, the Chain stitch(401; Dupler et al, 2019), 2-Needle Bottom Coverstitch (406; Dupler et al, 2019; Gioberto et al., 2016) and ZigZag stitch(304; Greenspan et al., 2018) all showed good working ranges with a stretch limit above 30% and acceptable sensitivity in response to applied strain.

Conclusion literature study textile sensors
For the creation of a smart textile sensor, multiple options were explored. Single yarn sensors were able to recognise a wide variety of body postures. but unable to respond below 10% strain levels (Mattman & al., 2008). This is problematic when static posture is measured.

Sensors made from conductive fabric with bigger surfaces displayed large irregularities in resistance after use and being washed. However, small 15mm wide strips look promising(Grassi et al., 2017).

Inductive sensors, both fixated and embroidered, do not offer the seamless design as fabric or stitched resistive sensors, due to additional measuring instruments and external wires.

Finally, stitched and fabric sensors have a benefit over knitted sensors as they can be easily added and altered during both the prototyping and garment manufacturing process, while preserving comfort for the user. With these outcomes presented, a strain resistive sensor, either from stitched or conductive lycra, is favored.

In the next paragraphs, the development and testing of a textile strain sensor is explored. Here, the ideal characteristics, testing methods and sensor creation methods are determined.

4.3 IDEAL CHARACTERISTICS OF A TEXTILE STRAIN SENSOR

The ideal sensor gives a stable signal over time, that is reproducible and reliable, and is linear to the elongation(figure 52; 1). In contrast to metal strain gauges, textiles consist of yarns that exhibit structural relaxation if the garment is under tension, creating drift(fig. 51). Drift is where the response of the sensor, ΔR, changes over time compared to resistance measured at the beginning(R0). Drift is influenced by electronics, repeated stretching, changes in environment(temperature, sweat, humidity) or being washed(Schevers, 2017) and should be minimised.

Low Hysteresis

The second graph in figure 52 displays the result of the relaxation, called hysteresis. Hysteresis occurs when the relaxation causes the sensor to retract in a different way compared to the stretching. As long as there is no hysteresis involved, non-linear behaviour is acceptable as each measured signal, expressed as ΔR/R0, can be linked to a corresponding strain value(figure 52; 3).

Besides hysteresis, stretching the sensor beyond it's stretch limit, Emax, will also result in two different corresponding points as the sensor will invert it's prior response behavior(figure 52; 4). Hence, the ideal sensor should have a suitable working range(Fig. 53) and low to zero hysteresis.

High sensitivity

The measure for the response to strain is the gage factor, GF, and describes the sensitivity of the sensor. According to Eq.1., every n% elongation, will result in a n% resistance increase. A sensor with a small gage factor will fail to produce a reliable reaction as it will be difficult to distinguish actual responses from drift. Therefore, the ideal gage factor will lie between 0,5 ≥ GF ≤ 2(Jansen, 2020).

$$GF = \frac{\Delta R/R0}{\varepsilon} \quad \textbf{EQ. 1}$$

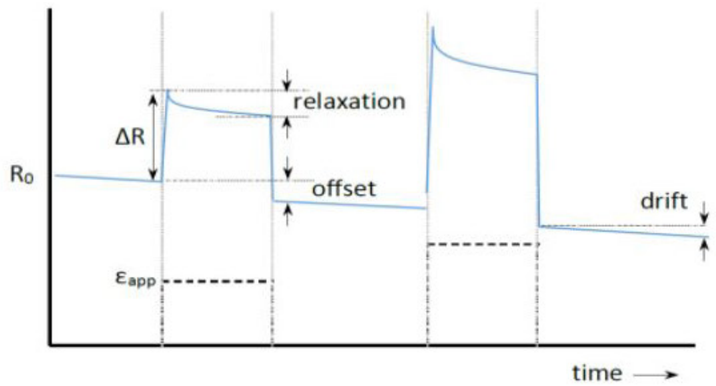


Figure 51. Schematic response of sensor after applied strain steps (Jansen, 2020)

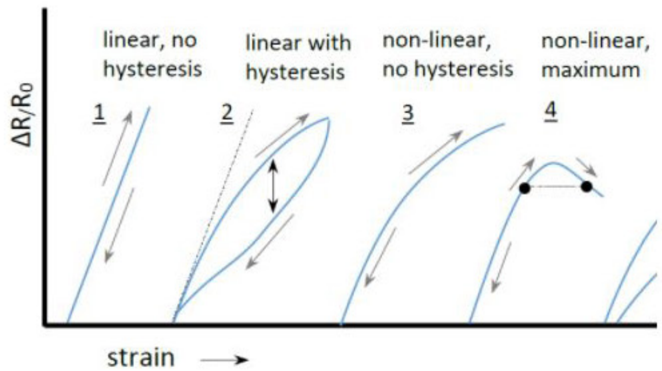


Figure 52. Non-linearity and hysteresis (Jansen, 2020)

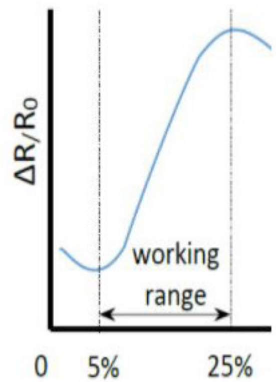


Fig. 53. working range example (Jansen, 2020).

4.4 ASSESSING STRAIN SENSOR CHARACTERISTICS

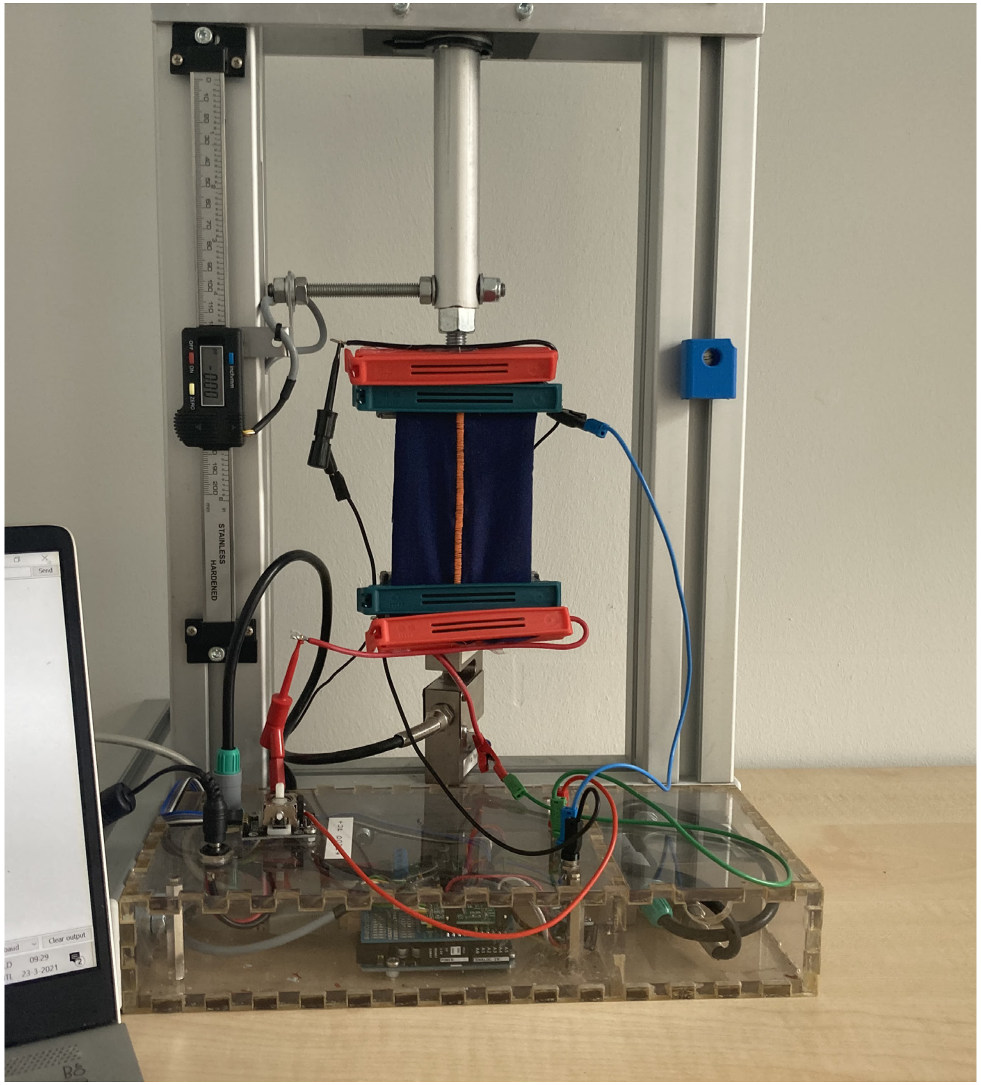


Figure 54. LETT Tensile Tester set-up

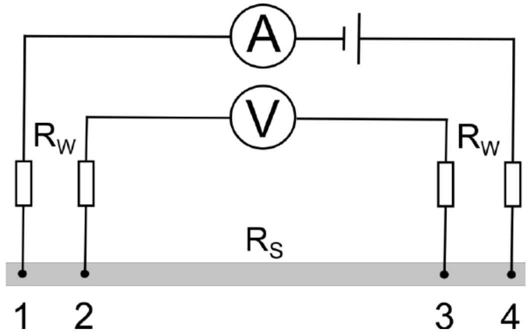


Figure 55. 4-point measuring principlewire

The change of resistance within the conductive thread, is only a small signal. This signal can be easily distorted due to the natural occurring resistance in the wires connecting the electrodes to the multimeter. To measure only the resistance change over the stitching, a four point measuring set-up(fig. 55) is used in the LETT tensile tester set-up(fig. 54). This set-up uses separate pairs of current-carrying and voltage-sensing electrodes.

To measure R over the sensor, 4 clamps were produced using food clips and conductive velcro to capture the signal. The LETT set-up produces 4 rows of data in the 96000 baud serial monitor of the Arduino program: dE(mm), R(Ω), dU(V), and time. Sensors were subjected to 3 programs: SE1I(E=10%, v=10mm/s), SE2I(E=20%, v=20mm/s) and SE3I(E=40%, v=40mm/s). Using Excel, 3 graphs were created: 5 cyclic tests(R over time), Hysteresis curves(R over E) and Gage factor(ΔR/Ro/E).

4.5 SENSOR DESIGN VARIABLES

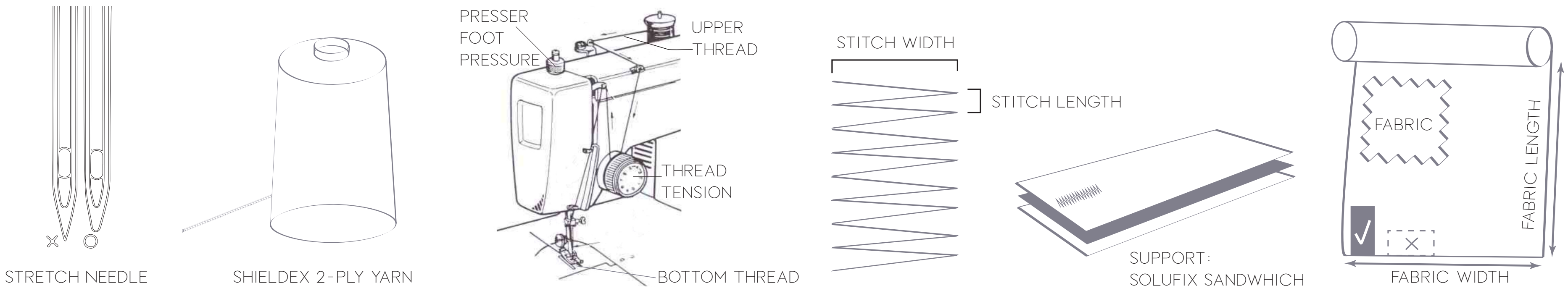


Figure 56. Overview of sensor design variables influencing sensor response

Before placements of sensors could be determined and sensor concepts developed, pre-testing of materials was necessary. Trial and error tests were performed to uncover all variables influencing the sensor response. Selected materials were based on recommendations from literature and what as accessible in the faculty laboratory. Finally, these variables were optimized to produce the best possible result per sensor type(fig. 56). A detailed documentation and results of this process can be found in Appendix 6.

Stitched Sensors

First, different types of available yarn were reviewed(Appendix 6.1). In accordance with Jansen (2019) and Greenspan (2018), Shieldex 2-ply silverplated nylon produced the highest ΔR. The feeding of the yarn can be done through both top and bottom, but Shieldex 2 ply thread is thick and frictious. By feeding it through the upper thread, it must pass many tension elements, creating high strains in the yarn causing it to break easily. When fed through the bobbin, it only passes one tension medium, which is the bobbin case, increasing reproducibility(Appendix 6.2). Next, the stitch geometry was defined.

ZigZag Stitch geometry variables

There is not much detailed precedent in literature, besides the assumption of increasing stitch density to improve sensitivity(Jansen, 2019). There are four variables directly involved in sewing a stitch: Stitch Width(SW), Stitch Length(SL), Upper Thread Tension(TT) and Bobbin Tension(BT). By shortening the Stitch Length, stitches are sewn closer together, increasing stitch density. Widening the Stitch Width increases the contact area. The thread tensions must be adjusted accordingly to allow for the desired dimensions. Different combinations were tested but ultimately the optimal response depends on the combination between substrate, support material, thread tensions and sewing machine. However, as a rule of thumb: SW: 5, SL: 0,5, TT: High and BT: 25% less than regular thread.

To support the substrate and sewing machine with stitching such dense stitching, the lycra substrate must be reinforced. This material is called Vlieseline and prevents tunneling and improves transportation. This concept was first tested with thin paper, but iteration showed best results with self-adhering in-water soluble paper called Solufix. The best results were obtained when the fabric is sandwiched in between(Appendix 6.9). These variables directly affect the reproducibility of the sensor. Next, are the variables that influence the response and sensitivity.

2NCS and Chain stitch geometry variables
Only one variable was involved in creating successful stitches with Shieldex 2-ply: the bottom thread tension was set to zero(Appendix 6.3). No reinforcement with Solufix was necessary.

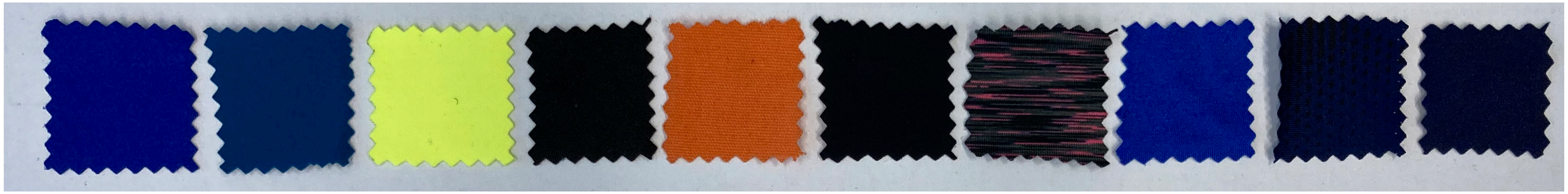


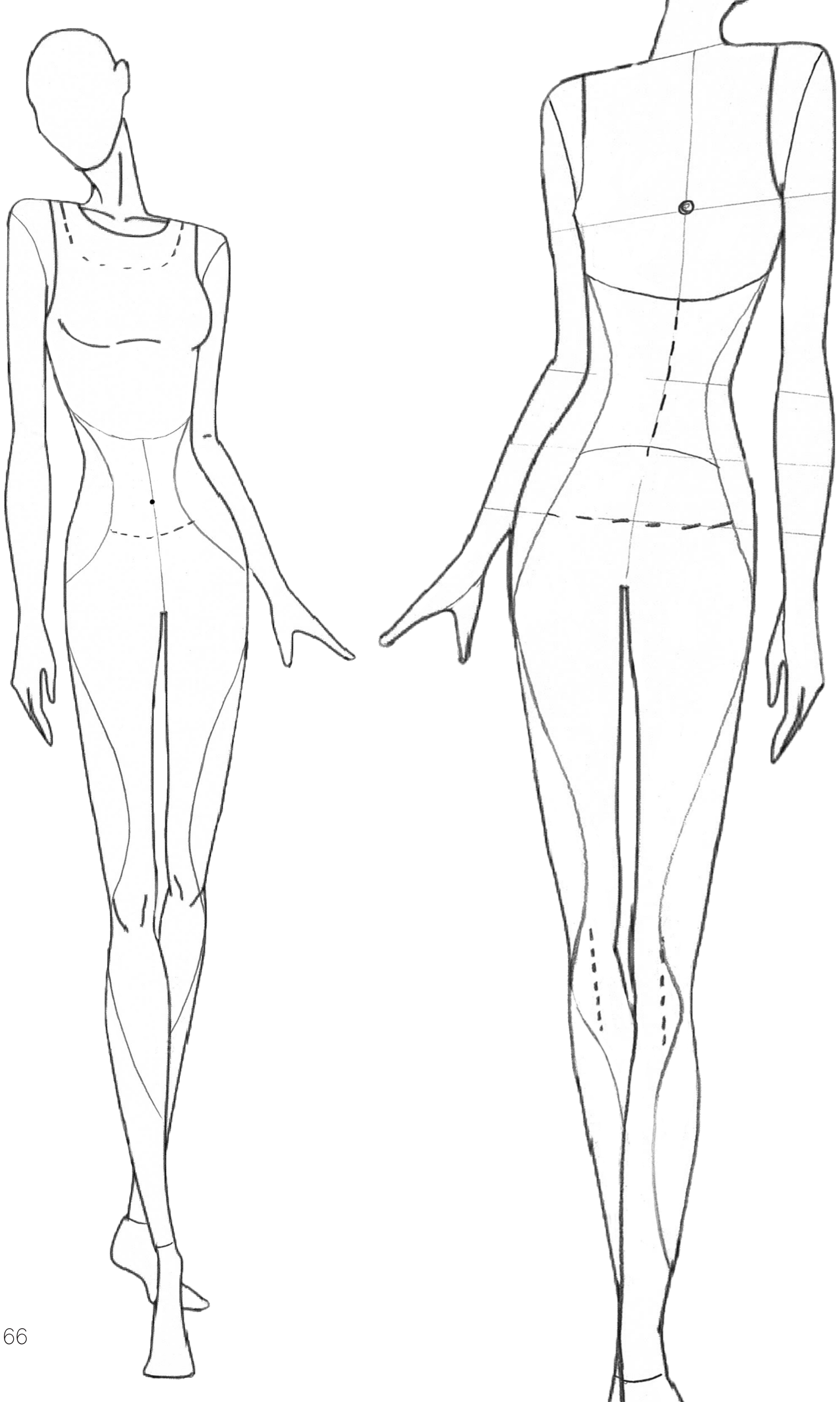
Figure 57. Overview of lycra materials

Stitched sensor substrate
The response of stitched sensors relies heavily on the physical properties and anisotropy of the substrate to which it is stitched(Dupler & Dunne, 2019; Greenspan, 2019). Many different materials have been used, such as cotton, Polyester and Polyamide(Nylon) blends. To create a strain sensor, it must contain at least 3% elastane. In total 10 lycra and 3 scuba fabrics have been evaluated(fig. 57). The most commonly used fabrics in sportswear are Nylon and Polyester (Umar et al., 2016). The best performing blends are considered: 85% Nylon and 93% PE. A denser knit scuba fabric is added for comparisons. To test the effect of anisotropy, a test was performed on 3 types of polyesters to see whether the bodysuit pattern should be cut in the length or width of the fabric: being cut in the length proved to give the best results(Appendix 6.9).

The sewing machine a sensor is produced with, heavily influences the outcome of the sensor. Three different machines were used, of which the Pfaff Kayser 69 sewing machine produced the stitching results. This is my personal sewing machine. With this machine, future results are described. This machine allows to change the pressure of the presser foot on the fabric, change of bottom thread tension and a larger variety of different presser feet.

Conductive Lycra
For concept development, conductive lycra is also included. Five com-mercially available lycras were tested: MedTex 130, Shieldex 130B, MedTex 180, Shieldex-Silitex en Elektrolycra(Appendix 6.7)). In line with Schrever's (2017) work, MedTex 180 proved to have the best resistive response and properties.

Conclusions sensor design variables
For the production of the sensor concepts, the best performing combinations were found to be: Zigzag, Chain stitch and 2NCS on 85% Ny and Medtex 180 the best conductive fabric. For each strain sensor type, all variables were identified for optimal sensor production.



4.6 CONCEPT 1: CHAIN STITCH

One of the stitch geometries that proved to work best according to literature(Dupler & Dunne, 2019), is the 401 chain stitch. The chain stitch is sewn on to lycra substrate using a coverstitch machine with only one needle(Fig. 58). This should be the left needle, to optimize success of the stitching (Andrevo, 2020)

The chain stitch measures strain as the strain in the fabric stretches the upper thread, therefore pulling the bottom loops together, creating a shortcut for the signal to travel through (fig. 59). This decreases the resistance.

Method
Within the chain stitch geometry, the Shieldex 2-ply conductive thread is fed through the bottom looper. To successfully achieve this, the least amount of tension should be applied in the machine threading infrastructure. For testing, a 150x80 mm 85% Nylon Substrate was used.

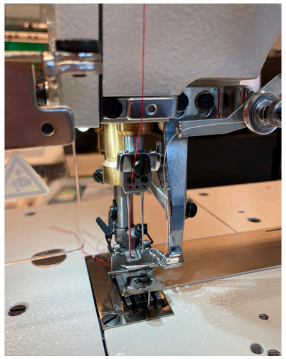


Figure 58. Coverstitch

Figure 59.Chain stitch sensor substrate

Left: Figure 60. Design sketch for suit design with chain stitch sensors

Results

At first, the chain stitch shows a good working range of $\Delta R \approx 9\ \Omega$ (Fig. 61). With a negative gage factor consistently hitting between the desired range (0,5-2), the sensor's sensitivity is good. However, the chainstitch does show quite some hysteresis, which is undesirable(fig. 62).

Compared with literature, this is consistent with the works of Dupler & Dunne (2019). In their research, the Chainstitch compared to the 2NCS has a better GF, but shows more hysteresis than the 2NCS in every anisotropy.

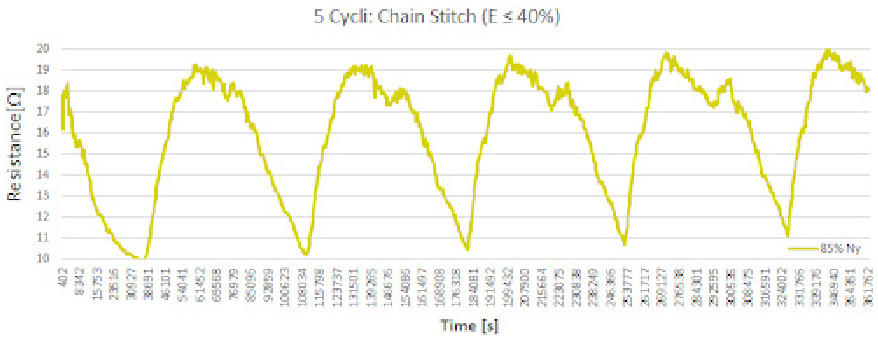


Figure 61. Cyclic test: Chain stitch

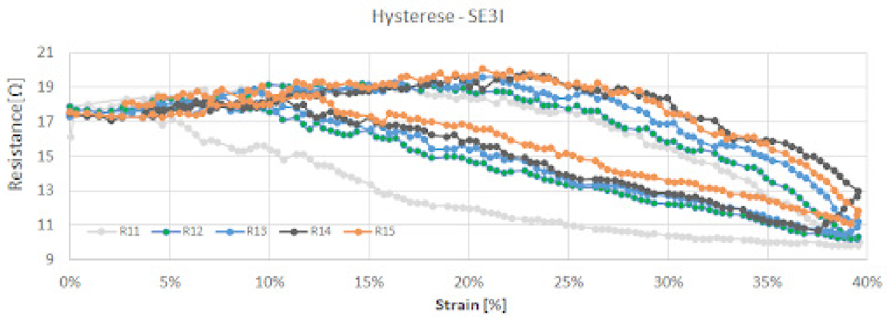


Figure 62. Hysteresis curves: Chain stitch

4.7 CONCEPT 2: 2 NEEDLE BOTTOM

A second applicable stitch geometry is the 406 Two Needle Bottom Coverstitch, or short, 2NCS. (Gioberto et al., 2016; Dupler & Dunne, 2019.) This stitch is sewn on to fabric using a coverstitch machine using the left and right needle (Fig. 63). Just as the chain stitch geometry, the conductive thread is fed through the bottom looper.

For potential measuring with the 2NCS geometry, the sensors will be stitched on the outside of the suit in one line of 100 mm. The design of the electrical circuit is identical to the chain stitch concept.

For the testing of this concept design, a double knit scuba fabric was tested alongside 85% Nylon. Both substrates were 150x80mm.

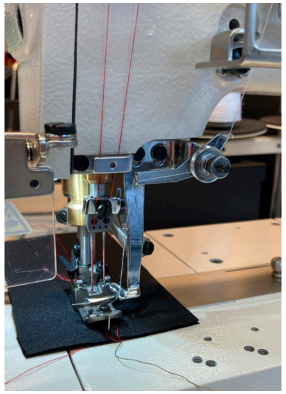


Figure 63. 2NCS setup

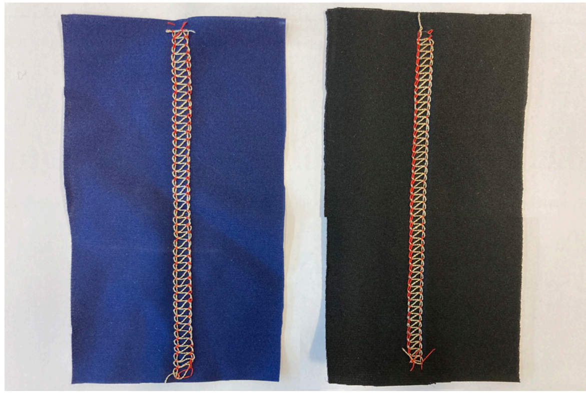
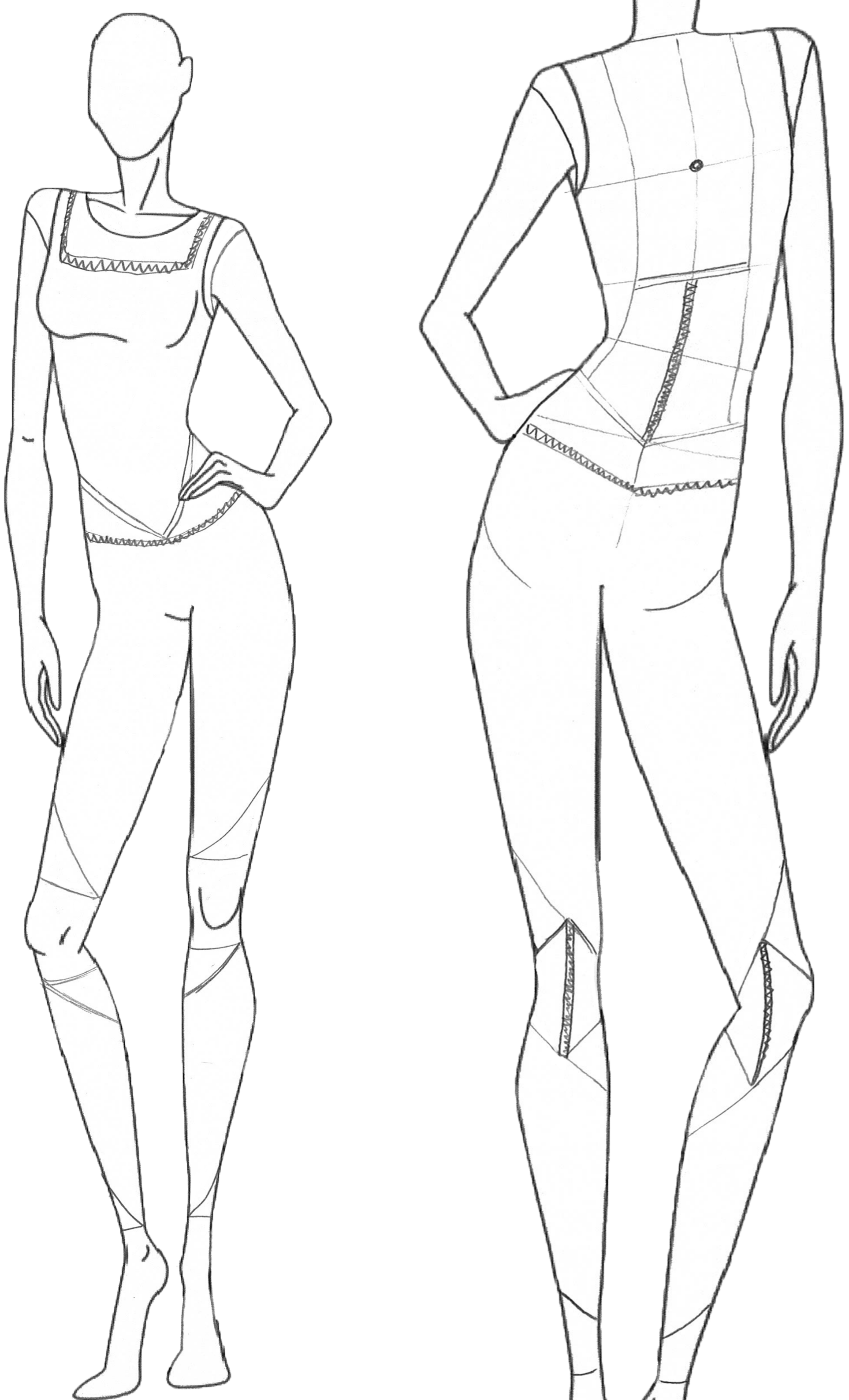


Figure 64. 2NCS sensor substrate



Left: Figure 65. Design sketch for suit design with 2ncs sensors

Results

The 2NCS measures strain as the fabric stretches the upper thread, therefore pulling the bottom loops together, creating a shortcut for the signal to travel through. This decreases the resistance.

Of the 2 substrates, the Scuba fabric shows the best working range [ΔR ≈ 9 Ω] (fig. 65). The hysteresis curve in figure 66 of the scuba substrate, shows that there is an initial resistance to the strain and the change of resistance only starts at E = 10%. The Scuba Fabric does show a better performance in hysteresis than the chain stitch. After the initial stretch, the negative gage factor fluctuates around the minimum of -0,5. With the use of the scuba knit fabric, the sensor's sensitivity would reach the bare minimum. However, the 2NCS also shows quite some hysteresis (Rh), which is undesirable.

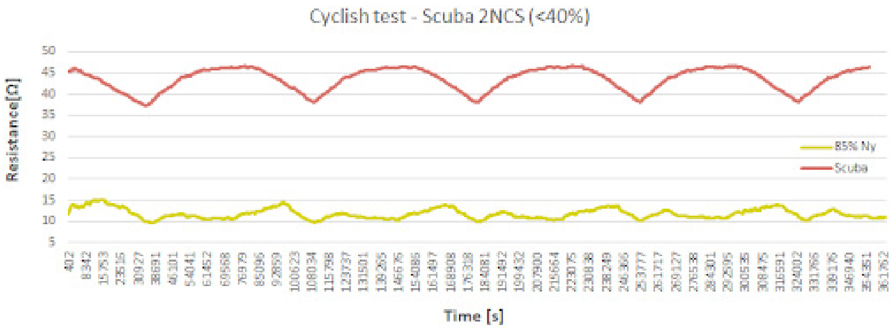


Figure 65. Cyclic test: 2NCS

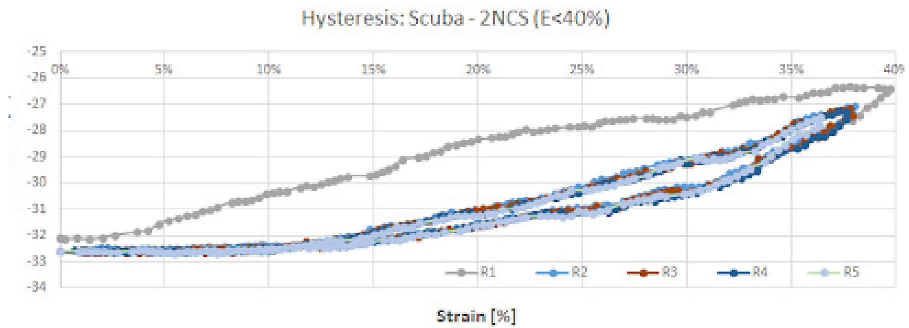
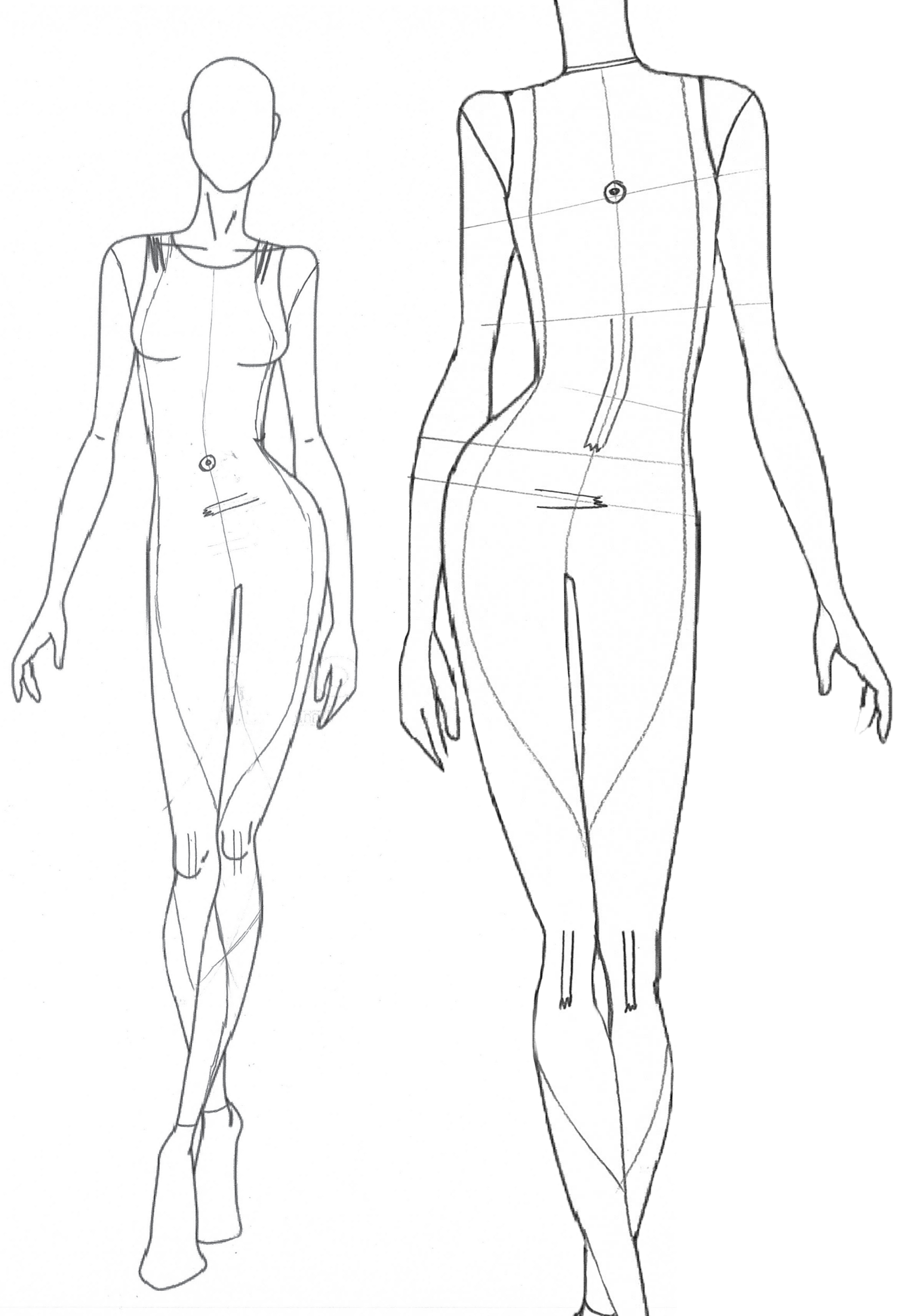


Figure 66. Hysteresis curves: 2NCS



4.8 CONCEPT 3: ZIG ZAG STITCH

A third and final stitch geometry is the 304 ZigZag stitch. This stitch is sewn on to fabric using a regular sewing machine(Fig. 69). The conductive thread is fed through the bobbin for best results(Appendix 6.4).

Method

Multiple fabrics have been reviewed for the performance of the ZigZag stitch: Nylon (Tsangiri et al., 2019), Polyester (Greenspan, 2018) and from previous tests the Scuba knit. For the testing of this concept design, a double knit scuba fabric was tested alongside 85% Nylon and 85% Polyester. All substrates were 150x80mm.

Figure 69. ZigZag sensor on substrates

Left: Figure 70. Design sketch for suit design with zigzag stitch sensors

Results

As the ZigZag stitch measures strain as the fabric stretches the ends of the individual stitch further apart, breaking up the shortcuts for the signal and lengthening the amount of thread it has to travel through. This increases resistance. Of the 3 substrates, the Scuba fabric showed the highest resistance change[ΔR ≈ 20 Ω] (fig. 71). The hysteresis curve in figure 72 of the scuba substrate, shows that there is an initial resistance to the strain and the change of resistance only starts at E = 10%. Even though it shows a smaller working range and resistance change[ΔR ≈ 5 Ω, the 85% nylon fabric shows close to zero hysteresis and no initial resistance to stretch.

Therefore, the 85% Nylon is selected: a Low Rh is more favorable than a bigger ΔR and below 10% resistance to stretch might only sense movement and not postural changes.

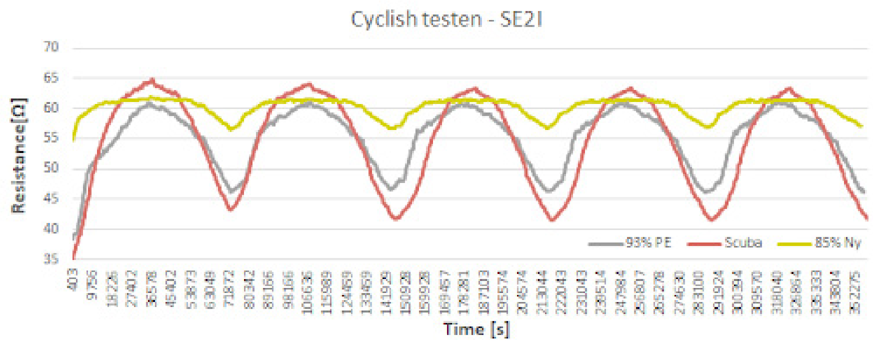


Figure 71. Cyclic test: Zigzag stitch

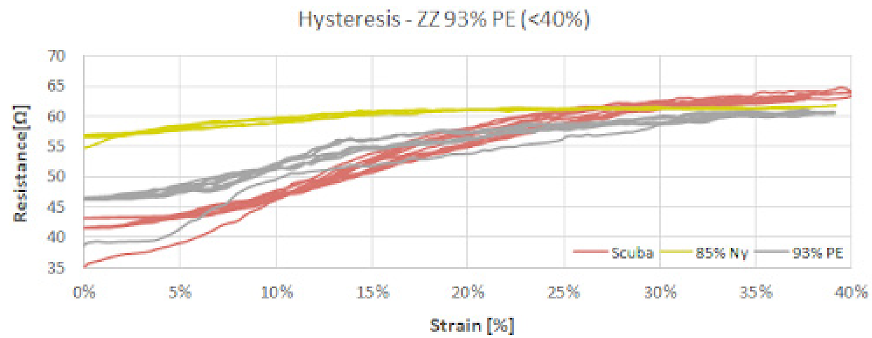
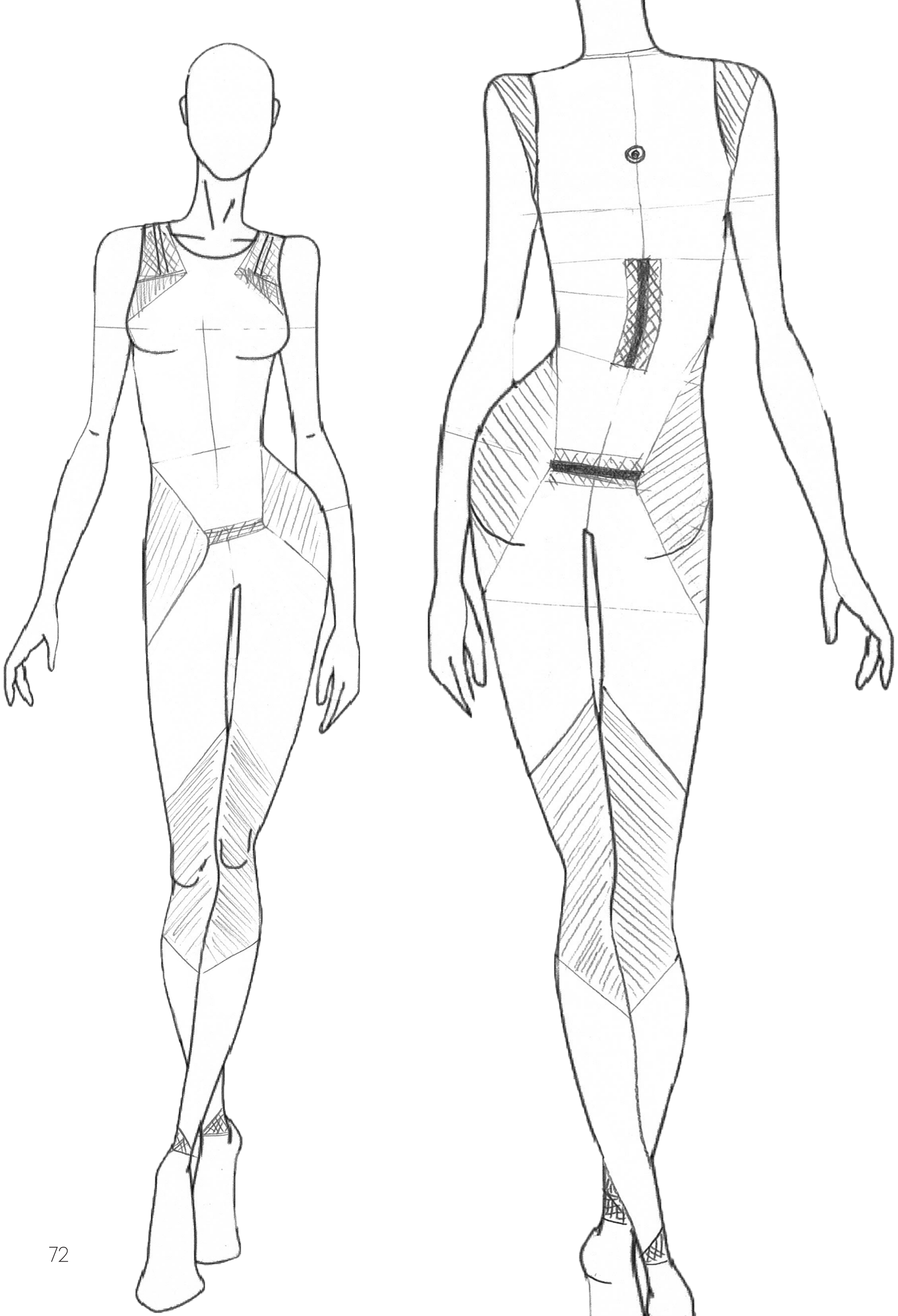


Figure 72. Hysteresis curves: Zigzag stitch



4.9 CONCEPT 4: CONDUCTIVE LYCRA STRIPS

Besides stitched sensors, there is another strain resistive smart textile available: conductive lycra(Schrevers, 2016). This material is laser cutted in 15x150 mm strips for precision cutting and pre-stretched a 100% (Grassi et al., 2017).

In the pre-testing of this material group, MedTex 180 was found to be the best performing conductive lycra. However, these strips need to be integrated in the suit with some type of connection: textile adhesive(Gütermann Textiellijm HT2 30g) or stitching(2NCS). In garment production, connecting two flat layers of fabric is done using the 2NCS. For testing, a 150x80 mm 85% Nylon Substrate was used. The three test patches are shown in figure 73.

Figure 73. left to right: Conductive lycra strip and strip glued, strip stiched to 85% Ny substrate

Left: Figure 74. Design sketch for suit design with conductive lycra sensors

Results & Conclusion Conductive Lycras

The conductive lycra measures strain as the fabric stretches apart, it connects the different knitted loops, creating shortcuts for the signal and shortening the amount of thread it must travel through. This decreases resistance.

Of all concept substrates, the individual Medtex 180 strip showed the best result resistance change[ΔR ≈ 60 Ω] (Fig. X). This strain resistive behavior and sensitivity leads to a stable gage factor over the whole working range.

However, after integrating this strip, it did not generate the desired response(Fig. X). The resistance differences are smaller and the dip in the top of the graphs shows that the stretch limit has been reached. This is also shown in Fig. X. The 2NCS integrated lycra strip shows large hysteresis between 0-15% stretch. The initial peak also shows that the resistance increases between 0-15% is positive, where it actually should decrease

The ideal response of MedTex 180 could not be used as a fully integrated

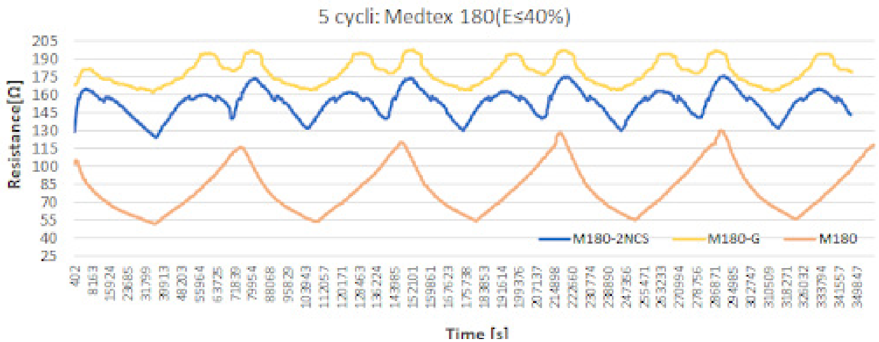


Figure 75. Cyclic test: of Medtex 180, M180-2nCS and M180-Glued

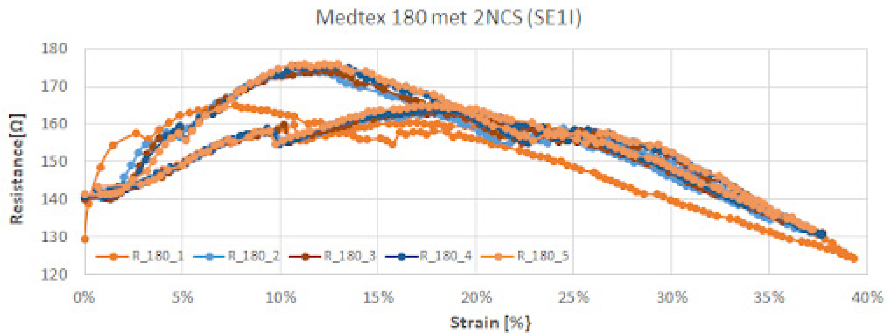


Figure 76. Hysteresis curves of 2NCS integrated lycra strip

4.10 CONCEPT SELECTION

For the selection of the concept, a top 10 of the bill of demands (Appendix 7.1) was selected. After testing all four concepts, the ZigZag stitch produced the best results initially. According to the selection overview(fig. 78), The ZigZag stitch geometry has the best performance of all concepts and will be used to tangibilise the FBMS into an interactive bodysuit.

Conclusion chosen concept

The ZigZag stitch fails to comply with three demands: Sensitivity, Machine washable and Ease to Repair. For the latter two, this failure to comply is inherent to the benchmark of current available materials. Therefore, improving on these demands will not be done within this research. The sensitivity however, can be improved by iteration on the production method and lengthening the stitch.

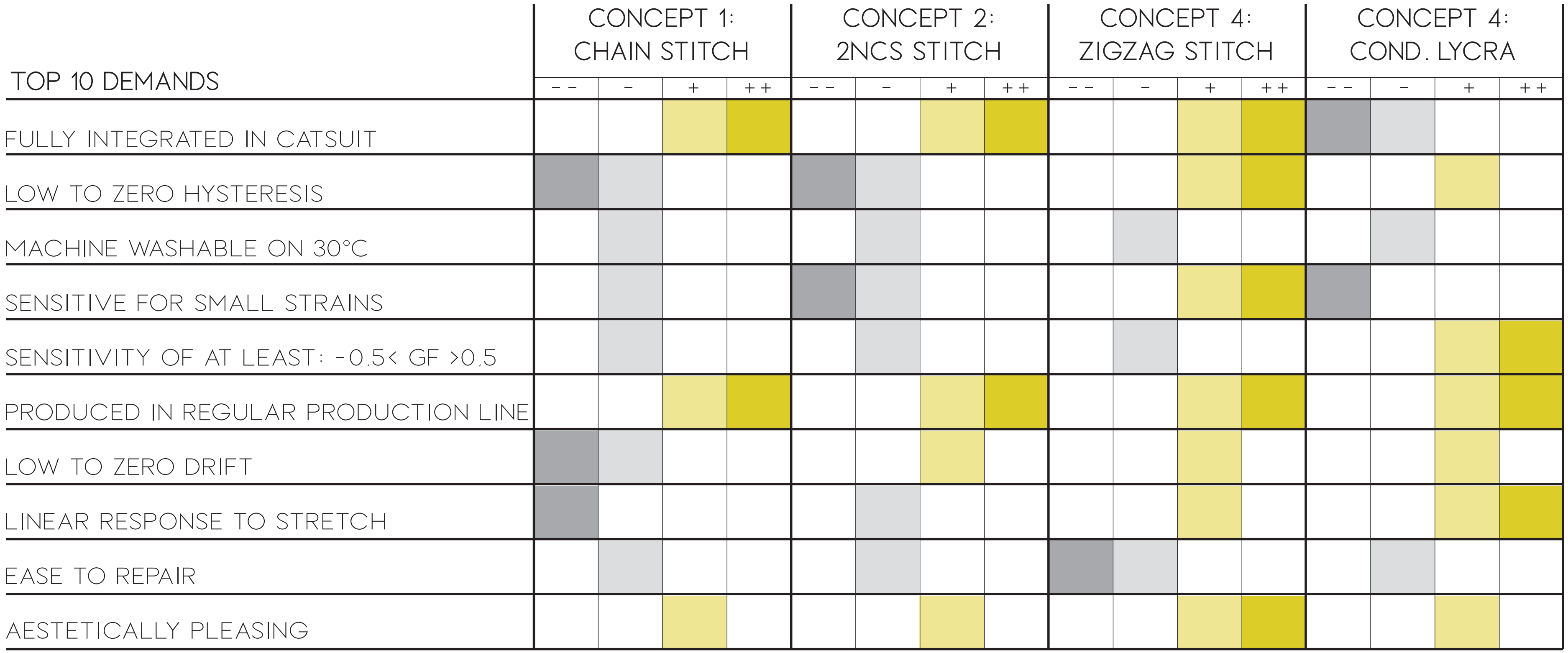


Table 78. Harris profile

4.11 OPTIMISATION

After the selection of the ZigZag stitch as integrated sensor concept on a 85% Nylon substrate, some optimisation is necessary. Five variables were found to impact sensor performance: length, upper thread yarn, stitch dimensions, presser feet and one sided support. An important indication for improvement is the curving of the sensor and fabric of post-LETT stretched patches. The origin of this curving behaviour of the sensor is explained below. This was solved by addressing the stitch dimensions, presser feet and one sided support variables.

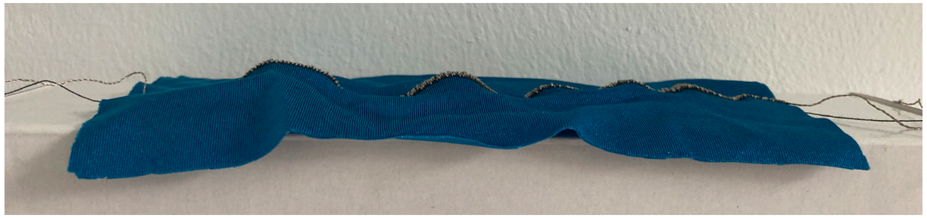


Figure 79. Curving sensor

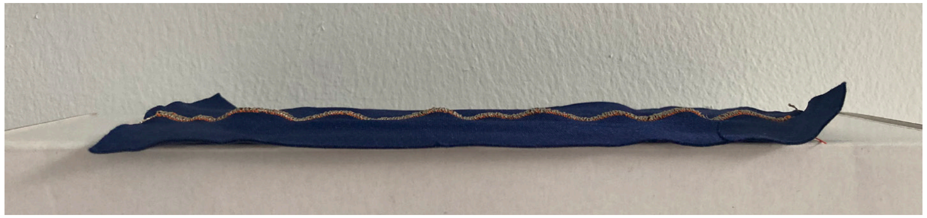


Figure 80. Flat sensor

In Fig. 79, a substrate is shown where the stitching curves after the support material was washed off. In figure 80, the patch stays flat. Initial curving is a red flag for low sensitivity. When the sensor is curved, it means that the material has become longer in relation to the stitching. When the patch is stretched, the sensor will stretch less as there is more fabric to stretch along, resulting in a low ΔR.

This curving occurs both before and after stretching. Prior to stretching, the yarn density differences between the Shieldex and lycra is at cause. Here, high foot pressure and friction forces the fabric forward and gets stretched when stitching, resulting in curving. The need for high thread tension and yarn density difference reinforces this behaviour. Post stretching, when the substrate is stretched, stretch limit differences between the lycra and stitched sensor creates (more) curving: the stitching is not as stretchy as the material. This shows in hysteresis curves as the increase of resistance hits a plateau. Therefore, the elasticity of the stitching needs to be improved.

Iterations
Pre-stretch curving is addressed first. Presser foot pressure is set to 50% of its range and a different presser foot is installed. In total, four feet(Fig. 83) were tested. The jersey sewing foot gave the best results. It uses sharp edges and self-transportation to reduce friction and enhance the passing of fabric.

Next, post-stretching curving is addressed. To make the stitching more stretchy, the top thread is exchanged for Seraflex yarn. This yarn had high elastic properties, creating a higher stretch limit within the sensor. To facilitate this yarn, the thread tension must be reduced from 9 to 6 on the Kayser 69 sewing machine. In turn, the Bobbin Tension (Fig. 82) must be lowered to allow for this combination.

Figure 81. Optimal stitch settings

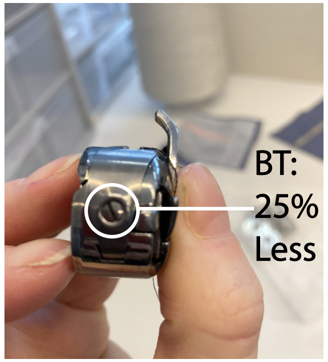


Figure 82. Bobbin Tension

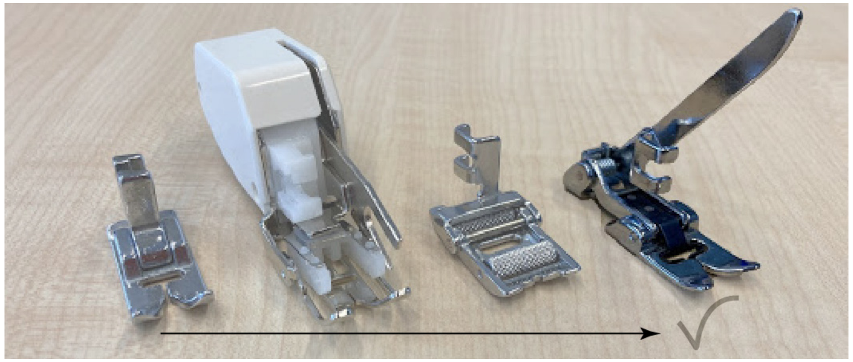


Figure 83. Presser Feet for sewing machine

Finally, the density and precision of the stitching influences the sensitivity. The stitch length was adjusted to the smallest step possible: SL: 0,25 (fig. 81). The precision of a stitch with these dimensions was influenced by two things: manual guidance of the fabric and no support barrier on the fabric bottom. The more fabric needs to be guided through the machine, the more it allows for human errors and consistency. With the self transporting function of the jersey foot(fig. 83), no forced guidance was necessary. By removing the support barrier, the conductive thread is stitched directly on to the fabric, creating less space for the yarn to wiggle thus reducing noise. Before, the gage factor(GF) was (4Ω/57Ω)/0,40 = 0,18. With these iterations, it was possible to produce a sensor response of ΔR(40%) = 10Ω and an average GF of (10Ω/56Ω)/0,40= 0,45 (fig. 84). To reach the minimum of 0,5, the length of the sensor is therefore doubled(fig. 85) to increas the resistive difference between R0 and REmax.

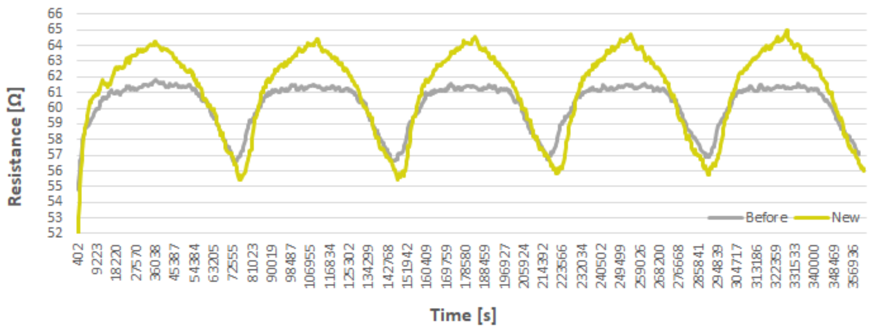


Figure 84. ZigZag stitch sensor performance

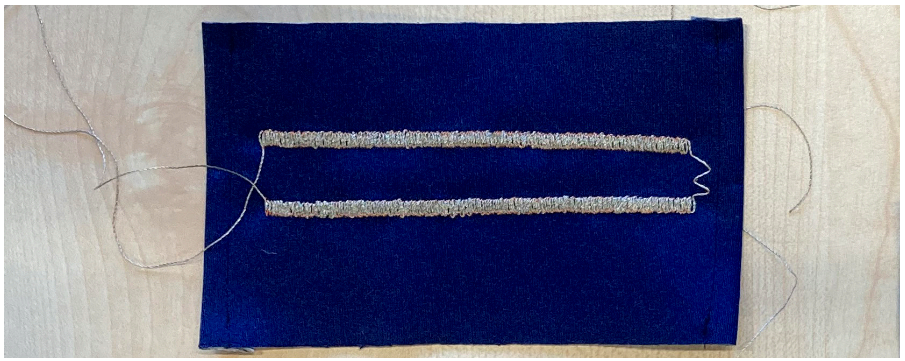


Figure 85. Optimised double row ZigZag sensor design

4.12 CONCLUSION SENSOR DEVELOPMENT

From the context, it was found that exercises users typically are prescribed by their PTs are to establish correct posture and to perform squats to strengthen their core area to maintain that posture. By comparing the correct posture to the direction of the three most common posture deformities in the body of lower back patients, a pattern in the alignment of body parts can be measured along the body by capturing the strain the deformity exudes on the material of the stretch material of the FBMS. This strain can be measured and translated to an electric signal with textile based sensors.

From literature, the most viable textile sensor for the purpose of measuring posture with a lycra catsuit, were strain resistive sensors, due to the ability to be seamlessly integrated in the textile and to measure low strain levels. From assessing 5 types of sensors: Knitted, Single Yarn, Inductive Stitch-Based, Conductive Lycra strips and Resistive Stitch-Based sensors, only the latter two allowed for stand-alone systems and rapid prototyping.

From pre-testing the materials, the variables involved in creating a reproducible, reliable and sensitive sensor were discovered for each sensor. Reproducible means that every produced sensor under the same conditions will perform in equal matter, reliable means that the signal has low hysteresis and sensitive enough to reach a gage factor of at least 0,5. The variables that were found to influence the sensor characteristics are: the substrate material, material orientation, the type of sewing machine, the sewing machine's stitch width(SW), stitch length(SL), needle, presser foot pressure, presser foot type, the upper thread tension(TT) and bobbin tension(BT), the type of yarn, the feeding direction of the yarn, the type of webbing and the placement of the webbing. For pre-testing, 85% Nylon and 15% Elasthane was used as it was found the be the most optimal performing substrate for the stitched sensor types that could provide the desired amount of stretch and user comfort.

After pre-testing, four concepts were developed: Chain stitch, 2NCS, ZigZag stitch and Conductive Lycra. From the tests, the Chain Stitch and 2NCS performed less reliable and sensitive results compared to the ZigZag stitch on equals substrates of 85% Nylon and 15% Elastane. Where the Medtex 180 Conductive Lycra strip initially showed good characteristics: low hysteresis and a sensitivity above GF=0,5, but failed to get appropriately integrated with the current available materials in the lab. Therefore, the ZigZag Stitch was compared on multiple substrates to assess potential for optimisation as it failed on 3 points in the concept selection method: Machine washable, Sensitivity: GF>0,5 and ease to repair. Within the boundaries of this project, the optimisation focussed on optimizing the sensitivity of the sensor.

The problem that had to be overcome to increase the difference in signal between R_0 and R_{Emax} is to avoid curving after removal of the support material and after the first stretch in the tensile tester. This was done by adjusting the sewing machine's setting, changing the webbing material, lower the bobbing tension with 25%, and changing the presser foot type. Notice that for each stitch type, there is an interaction between the sewing machine's settings, the yarn, the substrate and the stitch.

For the final sensor geometry to be sewn on the catsuit are:
Pfaff Kayser Sewing Machine settings: SW: 0,5; SL: 4; TT: 5; Adjusted bobbin tension, 1/2 Presser foot pressure. Furthermore, the amount of rows will be doubled to increase the GF.

5. CONCEPTUALISATION

5.1 SENSOR PLACEMENT

For the conceptualisation of the FBMS, a few prior research prototypes were evaluated, such as the wearable trainer of Soler (2009). To detect upper body postures, Mattman et al. (2007) optimised the amount and placement of textile strain sensors on a catsuit(fig. 86). With their setup, they were able to distinguish 27 postures. The sensor placement was based on reference strain measurements. Cameras measured the position of markers attached to the back of a fitted shirt(fig. 88). By analyzing the distance between the markers, the strain in the clothing could be measured. This resulted in a heatmap(fig. 89a-b), locating the placement of 14 sensors after optimization(fig. 93).

Full body postures
With static positions, sensors in the upper body alone can detect posture changes. A squat however could not be distinguished. Therefore, additional sensors must be added to fully detect this motion and recommended was to measure strains in the lower part of th body.

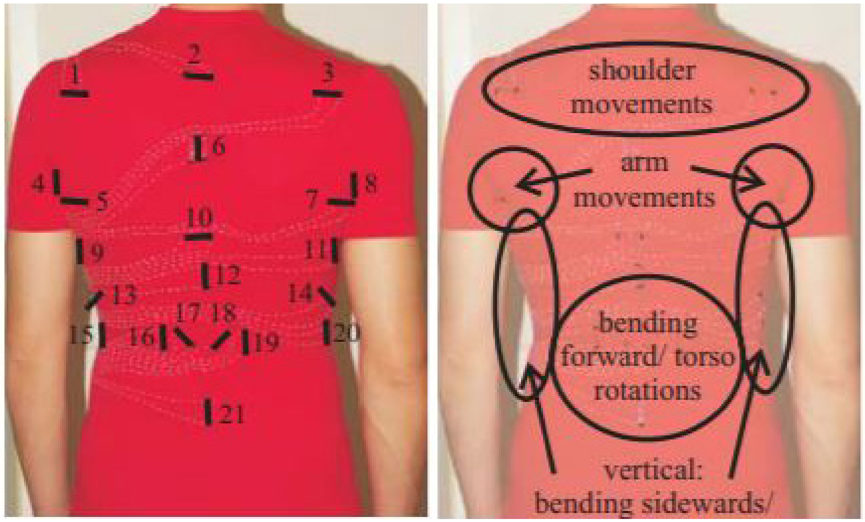


Figure 86. Sensor detection regions

Fig. 87. Wearable Trainer (Soler, 2010)

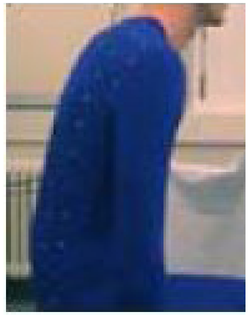


Figure 88. Forward bend

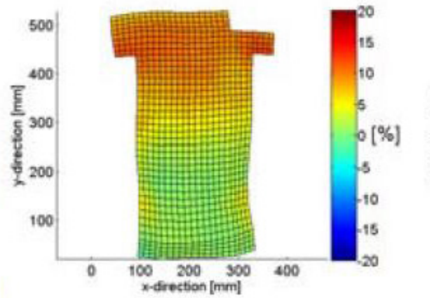


Figure 89a. Horizontal strain bend pattern

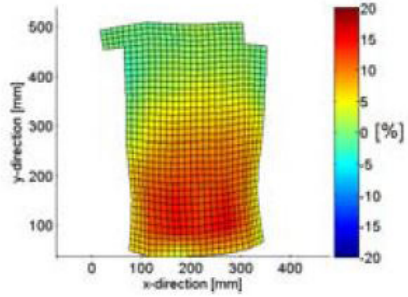


Figure 89b. vertical strain bend pattern

Method

For proof of concept, the reference posture of standing straight(fig. 90a-b) was measured first to detect the amount of natural strain in the catsuit when simply worn. This was then used for reference strain for the wrong squat and proper squat(fig 91-91b). Next, heatmaps were created, displaying the differences in strain. The horizontal strain was measured at the left side of the catsuit and vertical strain on the right side. For proof-of-concept, only the back was measure, as prior research suggests the majority of strain can be sensed in the backside, as well as most of the changes in the body are exerting a force to the back of the body. The goal is to find the spots where the highest strain can be measured, as well as different spots that distinguish a wrong from a proper squat.

Next the generated heatmaps were compared the findings of the existing prototypes from literature to find overlapping areas and minimize the amount of sensors necessary to sensor full body posture with a catsuit.

Figure 90a. leftside catsuit pattern cut out with markers

Figure 90b. Standing for reference

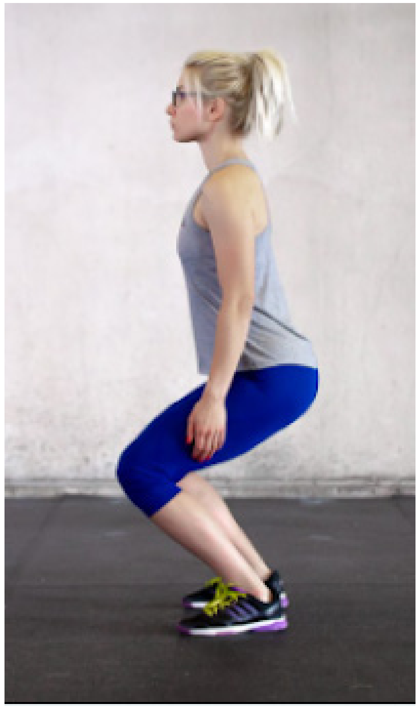


Figure 91a. Wrong squad

Figure 91b. Proper squat

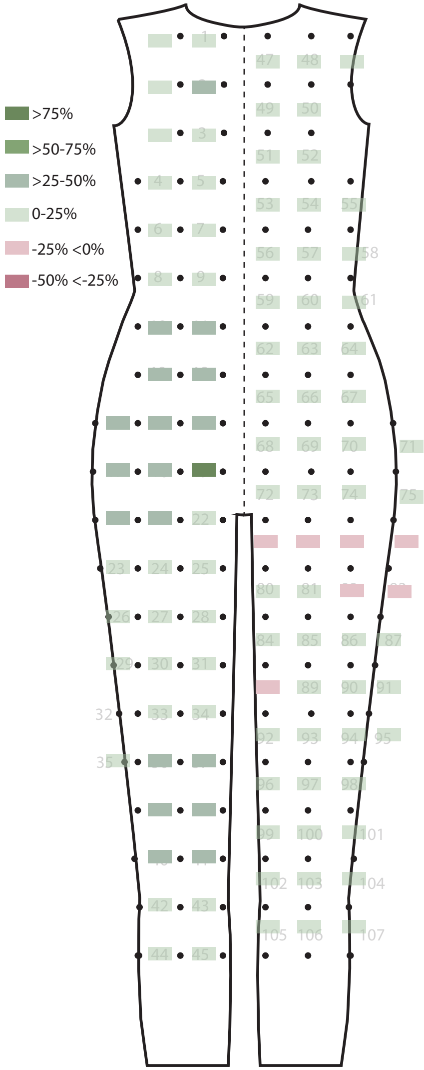


Figure 92a. Back side standing

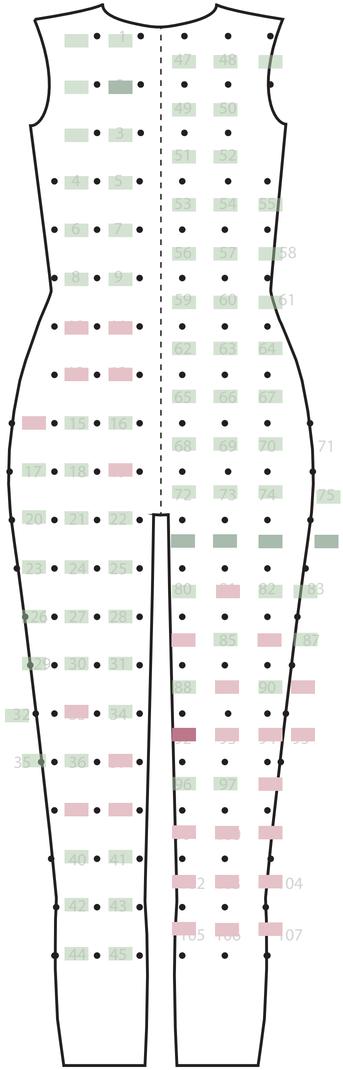


Figure 92b. Backside heatmap poor squat

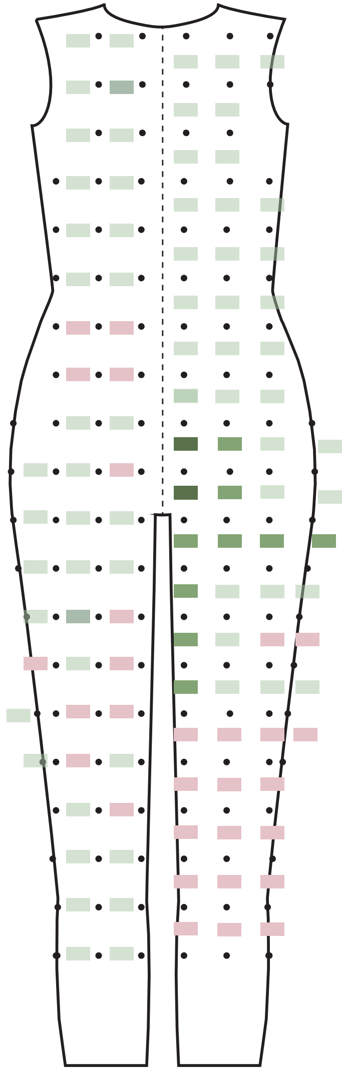


Figure 92c. Backside heatmap good squat

Results

The heatmaps show that there are measurable differences in stretch along the whole body (fig. 92a-c).

In general, the fabric stretched around 15% going from unworn to worn in the neutral position. Below the glutes was a row of vertical stretch points where the fabric bundles up. Furthermore there is one large horizontal stretch on the glutes along the spine.

When executing a poor squats, the fabric bundles up around horizontally under the under the knee, while in a good squat, it bundles above the knee. Vertically, a big stretch appears along and under the glutes. There is also quite some vertical stretch difference along the inner thigh.

Therefore, the placement will happen on the glutes, in vertical and horizontal direction, inner thigh and knees.

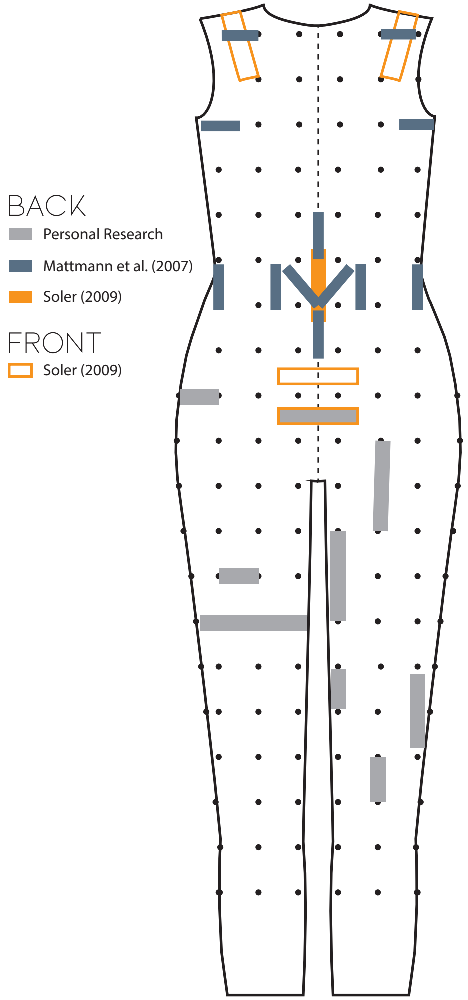


Figure 93. Detailed Placement

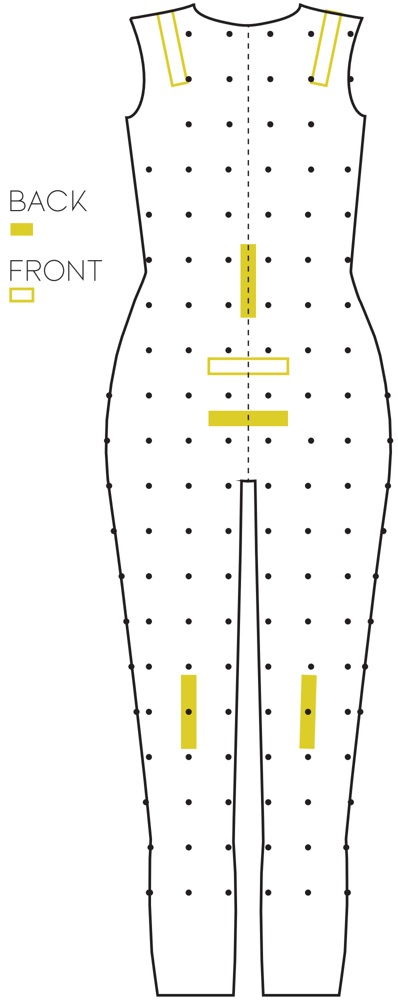


Figure 94. Proof of concept

Conclusion

From the sensor placement research, proof of concept was given that there is a distinct difference in strain measurable in the lower back, glutes and legs between a correct and incorrect execution of a squat. The places with the largest horizontal stretch differences, are shown in the left leg of fig x93. The largest vertical stretch in the right leg.

This research aimed to supplement existing research in textile-based strain sensor placement, as no prior full body strain measurement has been performed in existing literature. The combination of this research with two relevant studies, is shown in figure 93. Mattmann et al. (2007) measured upper body postures and Soler(2009) for the torso.

For proving the capabilities of sensing posture along the whole body, the number of sensors was minimised to seven sensors: front shoulders, lower back, abdomen, glutes, and back of knees. In this concept, the shoulder sensors will sense strain for the right position of the shoulders and upper back and the other sensors for the position of the lower back(fig. 94).

5.2 SENSOR FEEDBACK

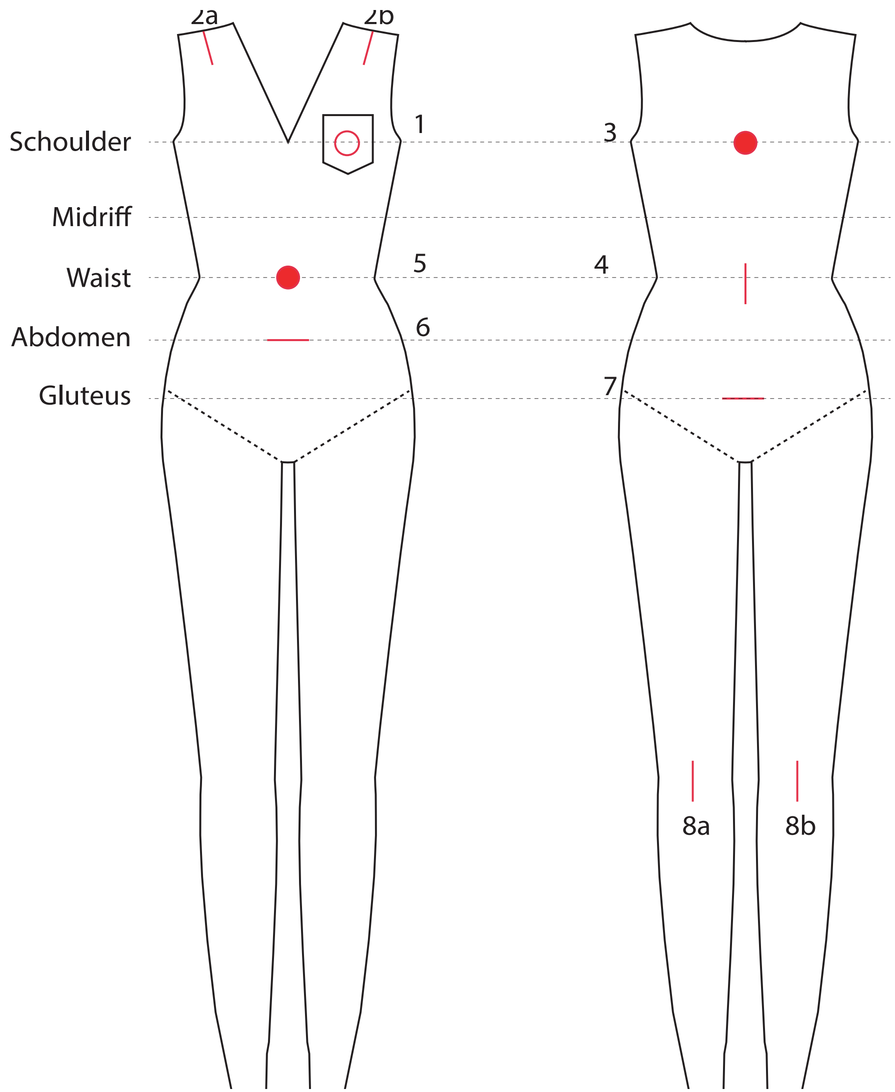


Figure 95. Placement of feedback actuators: vibration motors

Selection of haptic feedback
Communicating feedback can be done through many senses, such as touch, sound, visuals, taste and smell. For the purpose of giving feedback to the user of the FBMS, the sense of touch will be chosen for multiple reasons. Patients should learn to be more conscious of their body from wearing and interacting with the suit. By having to look at a light, users are not being conscious of their own body, but focussed on the light. Further, the light is placed on their body, preventing them from keeping their head straight during exercises. Second, the FBMS is about creating and interaction between the user and the suit, which for some patients could be considered private. When using the FBMS in public spaces, sound might not be functional or reveal their are using a medical tool which they might rather hide. Haptic provides an added bonus that is makes the user feel the area of the body and therefore learns from the feedback, instead of relying on it.

Placement of haptic sensors
From the comparison of the heatmaps to existing prototypes, sensing locations and correction points could be identified. For the correction of forward rotated shoulders and kyphosis, strain can be measured in the shoulder sensors. To counter these spinal deformities, the user must full back their shoulders by moving the shoulder blades together. Therefore, the location haptic feedback should be provided to the user, is between the shoulder blades (fig 93; #3). To correct the hollow back created by the anterior pelvic tilt, which is often connected to overstretching the knees, the core muscles must be activated. This is best imagined as pulling your belly button towards your spine. Therefore, the belly button is the appropriate location to provide haptic feedback to the user (fig. 95; #5). To create haptic feedback, vibration motor were selected for their small size. In the next chapter, electrical components that will enable this feedback system are explored.

5.3 ELECTRONICS

Four components are necessary to make this suit interactive: sensors, actuators, a microcontroller and an electric circuit(fig. 97). The suit contains 7 sensors, 2 vibration motors and a switch for calibration. The sensor's response is an analog signal, therefore seven analog pins are required. To control the input from the sensors to output for the vibration motors, two digital ports with PWM funtions are necessary. The need for PWM is further explained on page 87. Five Arduino boards were compared of which the Arduino Lilypad Plus(fig. 96) was selected for multiple reasons (table 5). For the data infrastructure, 2 colors of electrisola was used for it's insulating properties. To distinguish the + pole and signal line, different colors were used. The shieldex yarn was used as - pole line due to it's high resistivity which should be avoided in the signal line(fig. 98).

Demands	Uno	Micro	LilyTiny	Lilypad	Lilypad plus
Easy integratable in textile	x	+	++	++	++
Machine washable	x	x	++	++	++
Has 7 Analog pins	x	x	x	x	++
Has 2 PWM pins					++

Table 5. Microcontroller selection

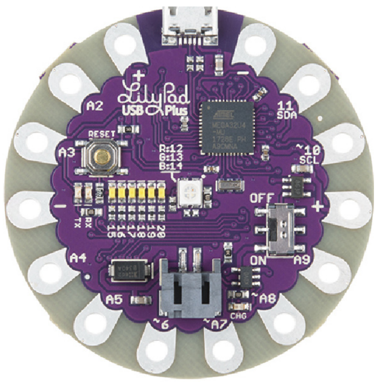


Figure 96. Microcontroller: Arduino lilypad USB Plus

- 14 pins: 7 analog pins, 3 digital pins;
- 2 with PWM(pin 6 and 10), 4 poles
- Connector for 3,7 LiPo Battery
- Built in on/off switch

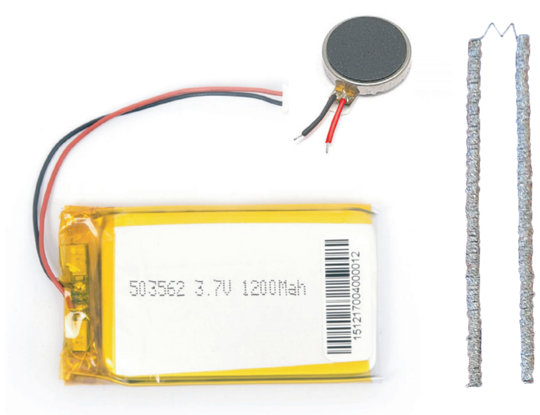


Figure 97. Components

- Vibration Motor d=10mm [2x]
- 1200 mAh 3,7V LiPo Battery
- 7 stitched strain sensors

Figure 98 Infrastructure

- Signal: Elektrisola d=0,09mm [R= 3,5 Ω/m]
- + pole: Elektrisola d=0,08mm [R= 2,7 Ω/m]
- - pole: Schieldex 2-ply [R= 80 Ω/m]
- R2a-R7: Shieldex 2-Ply [varying lengths]

Figure 99 shows how the electronic parts are connected to the Lilypad board. The integration of this system is shown on page 90-93. Calibration is done by resetting the Arduino. Two vibration motors provide haptic feedback: #3 (pin 6) to shoulder sensors (2a & 2b) and #5 (pin 10) to lower back, abdomen, glutes and knees(4, 6, 7 & 8). This is powered by a LiPo battery, lasting up to x hours. An on/off switch is not included as it's integrated in the board. The connections are sewn on the suit with a ZigZag stitch(SL: 4; SW: 3). Because Shieldex has a high resistance, varying lengths are used to create a stitched resistor(SL: 1; SW: 5) as reference resistor. The Resistor stitching length depends on the total thread length between the sensor and pin. The total resistance between the sensor and pin ideally should be 65Ω. Therefore, the knee sensors do not need an additional resistor.

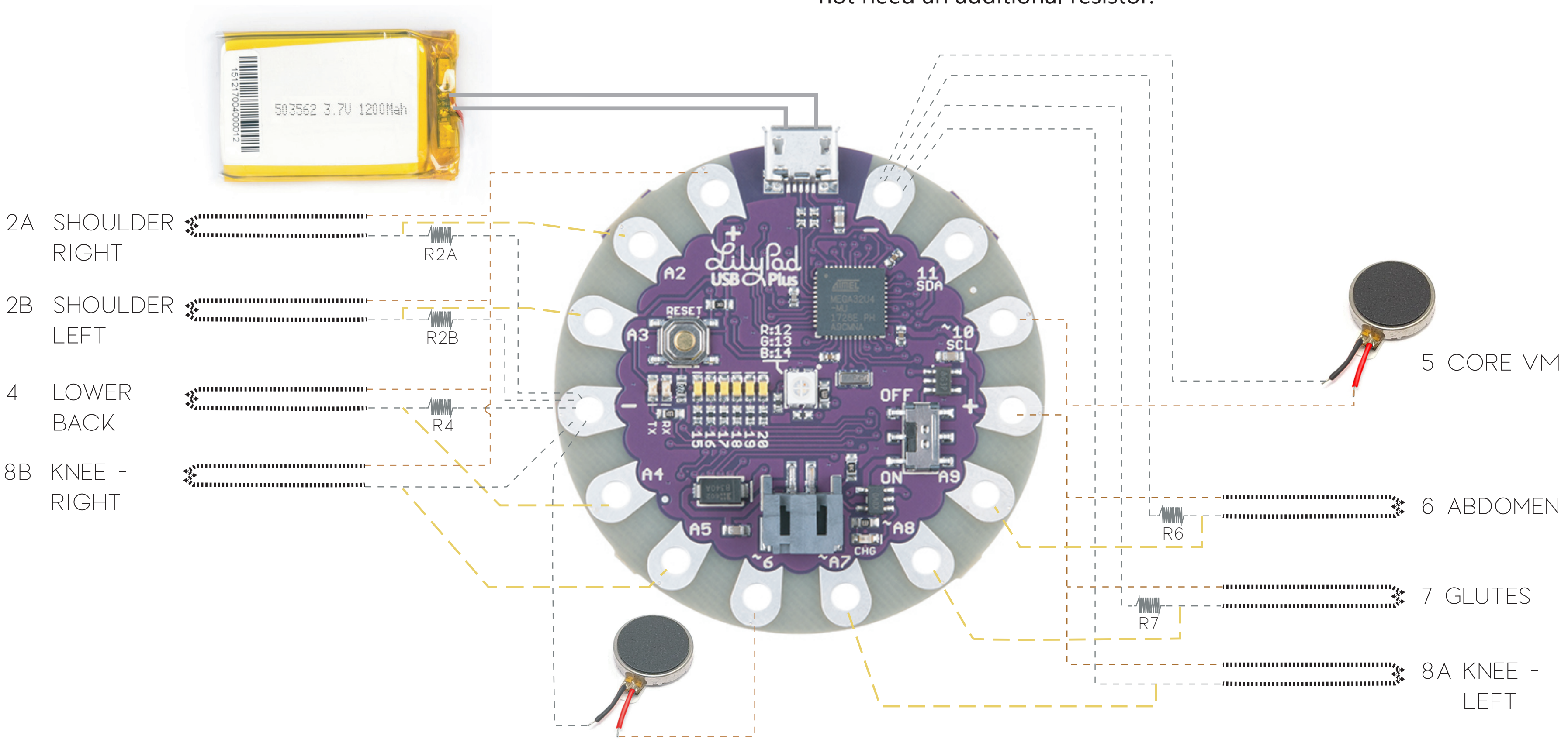


Figure 99. Electronic circuit with components

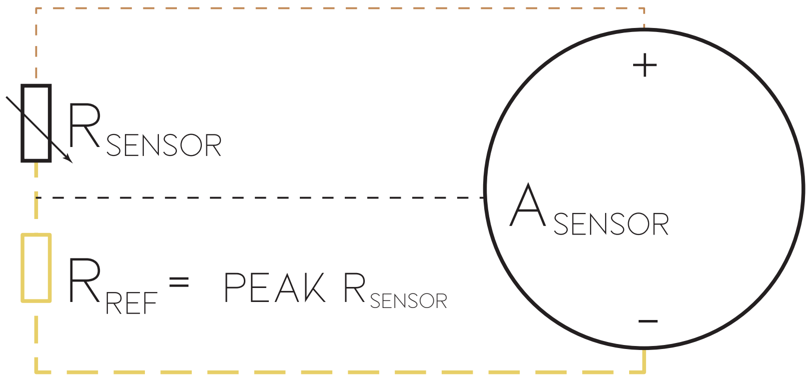


Figure 100. Reference resistance

Controlling the sensors

The stitched sensors are in essence variable resistors. The variation in resistance is linked to the variation in stretch. To determine this difference, a non-varying reference resistance(Rref) is necessary. This difference in resistance is literally measured between the sensor and Rref(fig. 100).

The total Rref value is determined by the peak resistance value of the sensors, which is 65Ω(fig. 84). The resistance in the connection between the sensor and - pole increases with length. The connections of sensors 2-7 are not long enough to reach this value, needing additional stitching. The value of Rref is not important for measuring itself, but will influence the linearity of the signal.

Controlling the vibration motors

The two vibration motors are controlled through two digital pins with PWM function. PWM stands for Pulse Width Modulation and is a technique to create a 'range of voltages' in a digital pin. Unlike analog pins, regular digital pins can only be HIGH(3,3/5V) or LOW(0V). Different voltages create different strengths of vibrations: low voltage input = softer vibrations; high voltage input = strong vibrations. PWM creates the desired voltage by controlling the portion of time the signal is HIGH versus LOW. The duration of "HIGH time" is called the Pulse Width (Hirzel, 2018). By changing the Pulse Width, you 'change the voltage input' and thus the vibration strength(Arduino.cc, 2018).

Controlling the PWM on the Arduino is done by considering the vibration strength range 0 - 3,3V as an analog range (0 - 1023). For the desired range of four vibrations: no vibrations, soft, medium and strong, 0%, 25%, 50% and 75% of the strengths are considered. By writing the corresponding analog values to the PWM pins, the vibration is controlled(fig. 101).

Calibration

In the interaction, the suit must be calibrated in a PT session to establish the norms the sensors should compare input to. This process takes 5 seconds. These values will be used as thresholds in the Arduino for controlling feedback. In the prototype, calibration is done at the initialisation.

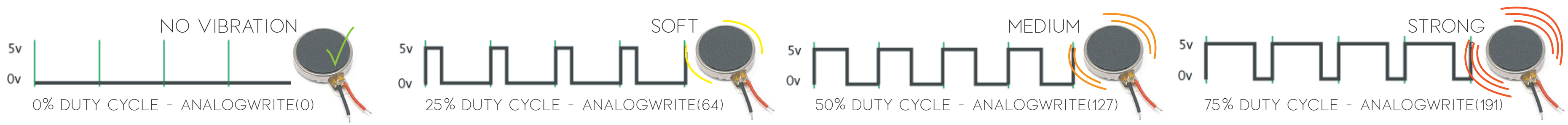


Figure 101. Control of the PWM signal

6. DESIGN OF THE SUIT

6.1 PROTOTYPING

Figure 102. Pattern on Lycra fabric

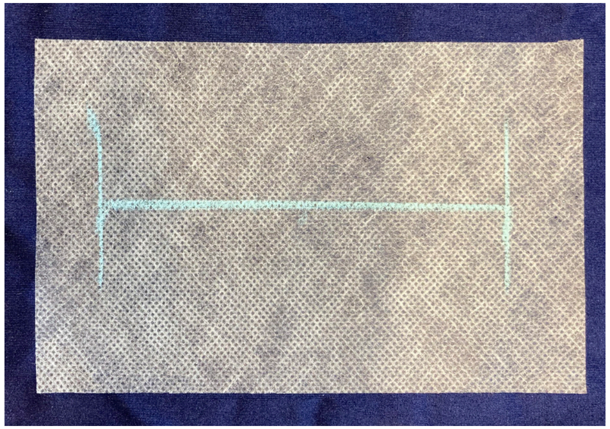


Figure 103. Adding Solufix to lycra

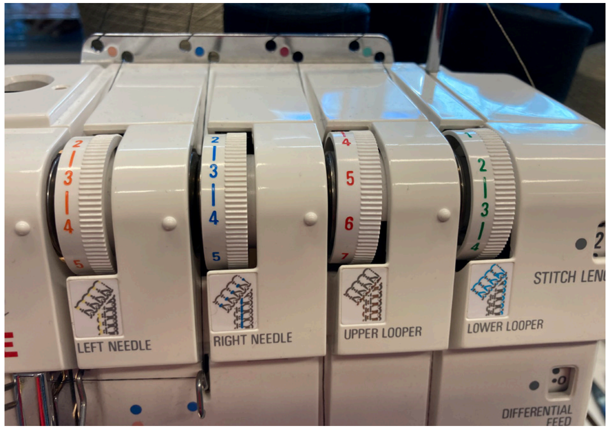


Figure 104. Using the coverlock

Pattern drafting

First a pattern is drafted. In this pattern, the location of the knees and other areas are marked. In figure 102, a short length catsuit was drafted. The pattern is outlined with chalk and cutted with the fabric on fold. In total, there are three pattern pieces to be cut: the body(2x), sleeves(2x) and front pocket(1x).

Stitching the sensor

Preparing for sensor stitching by lining the lycra with self-adhering Solifix(fig. 103). A middle line is drawn, where the ZigZag is sewn half-presser foot apart on both sides of this marking. Stitching is done without fabric manipulation, only keeping the foot parallel to this line. When turning to stitch on the other side of the line, the SL setting changes from 0,5 to 4, for 4 stitches. Switch back and continue to sew the second line.

Assembling the catsuit

Sensor 2A-B and Sensor 8A-B are sewn before assembly. First assemble the legs, side seams and shoulder seams of each part, the center seam second and sleeves third using a coverlock. Now that the suit is assembled, sensor 4, 5 and 7 can be sewn. The End of these sensors can be directly sown to the Arduino, following their path in figure 104.

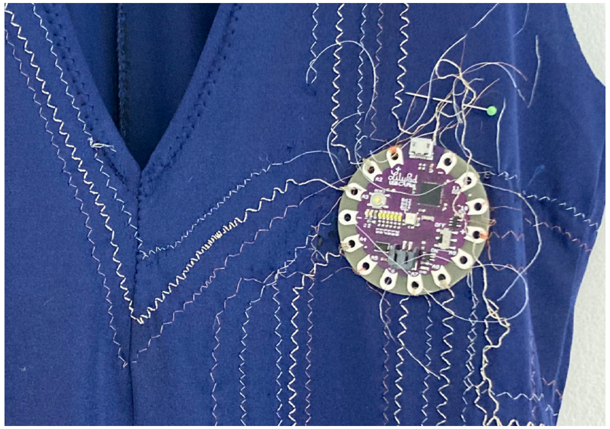


Figure 105. Sewing with Elektrisola

Figure 106. Stripping with soldering iron

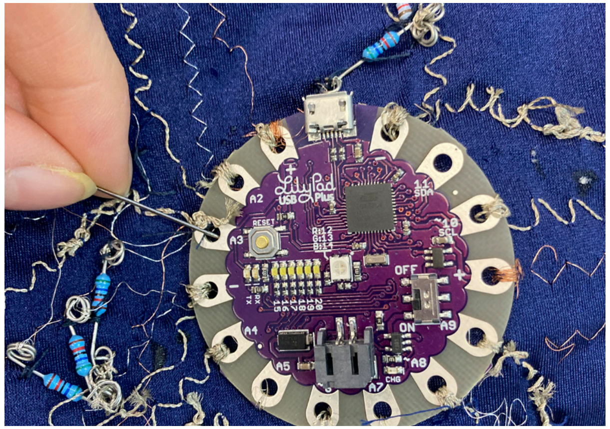


Figure 107. Connecting components

Sewing connective wiring

To power all components, the + and - poles are sewn with Elektrisola after all sensors have been stitched, using a SL: 4 and SW: 3. The wires are not directly connected(fig 105), as they must be stripped from their isolating layer first.

Strip Isolation layer

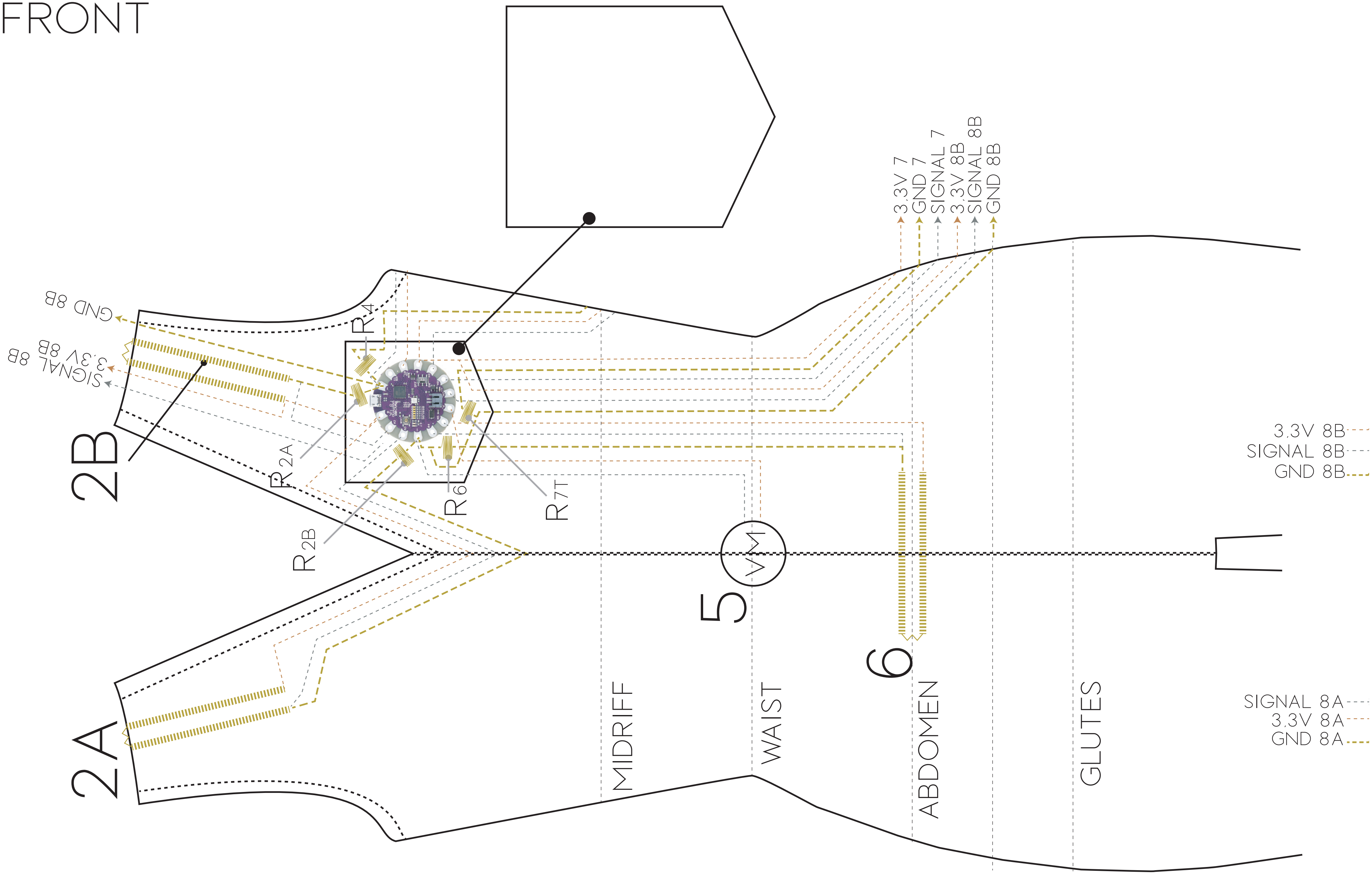
The Elektrisola wires are isolated with a thin layer of TPE. To become conductive, this layer must be stripped back at both ends of the wires(fig. 106). This is done through heat with a soldering iron. A piece of paper is put between the lycra and iron, protecting the fabric.

Connecting wires to components

Using a hand needle, the Elektrisola wires are manually connected to the ends of the sensors and Arduino. The vibration motors are first glued to the lycra using fabric glue. Then, the wires are connected through a small amount of soldering tin(fig. 107).

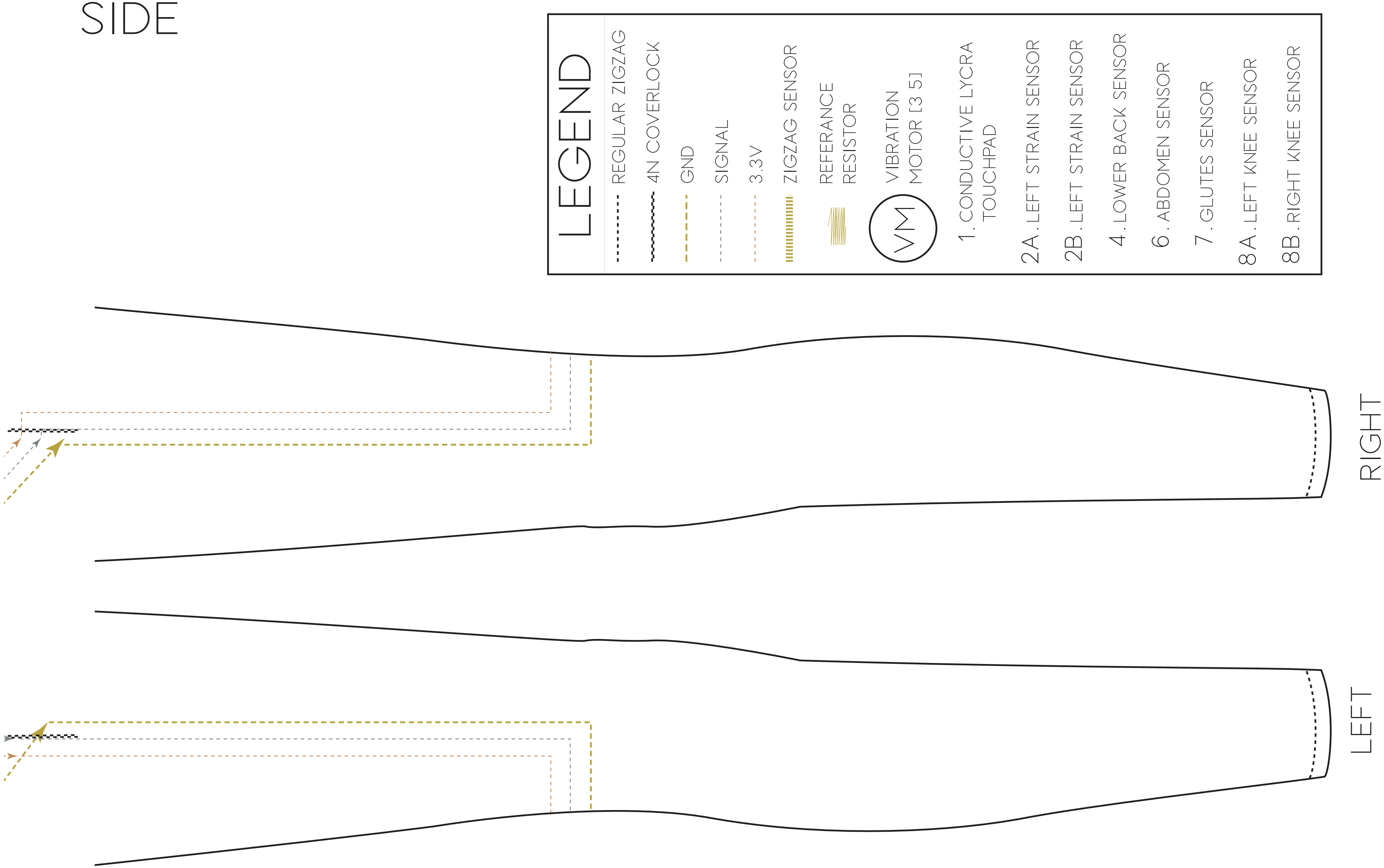
Now that the electric circuit has been created and closed, the Arduino is powered by a 3,7V Lithium-Polymer Battery. For the User test however, it was connected to a 5V adapter. In the Next chapter, the prototype is subjected to a small scale user test for wearability, endurance and overall experience.

FRONT

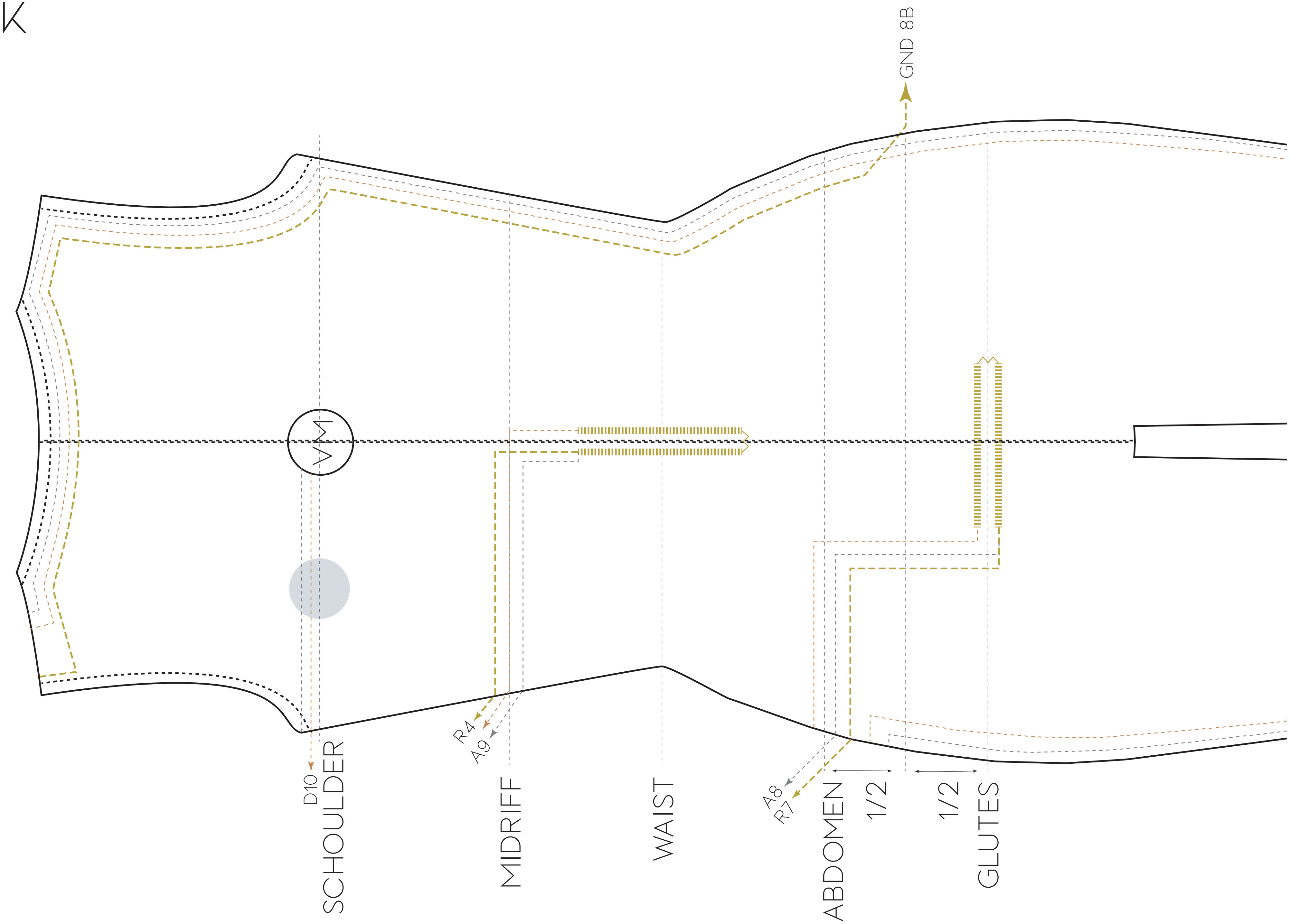


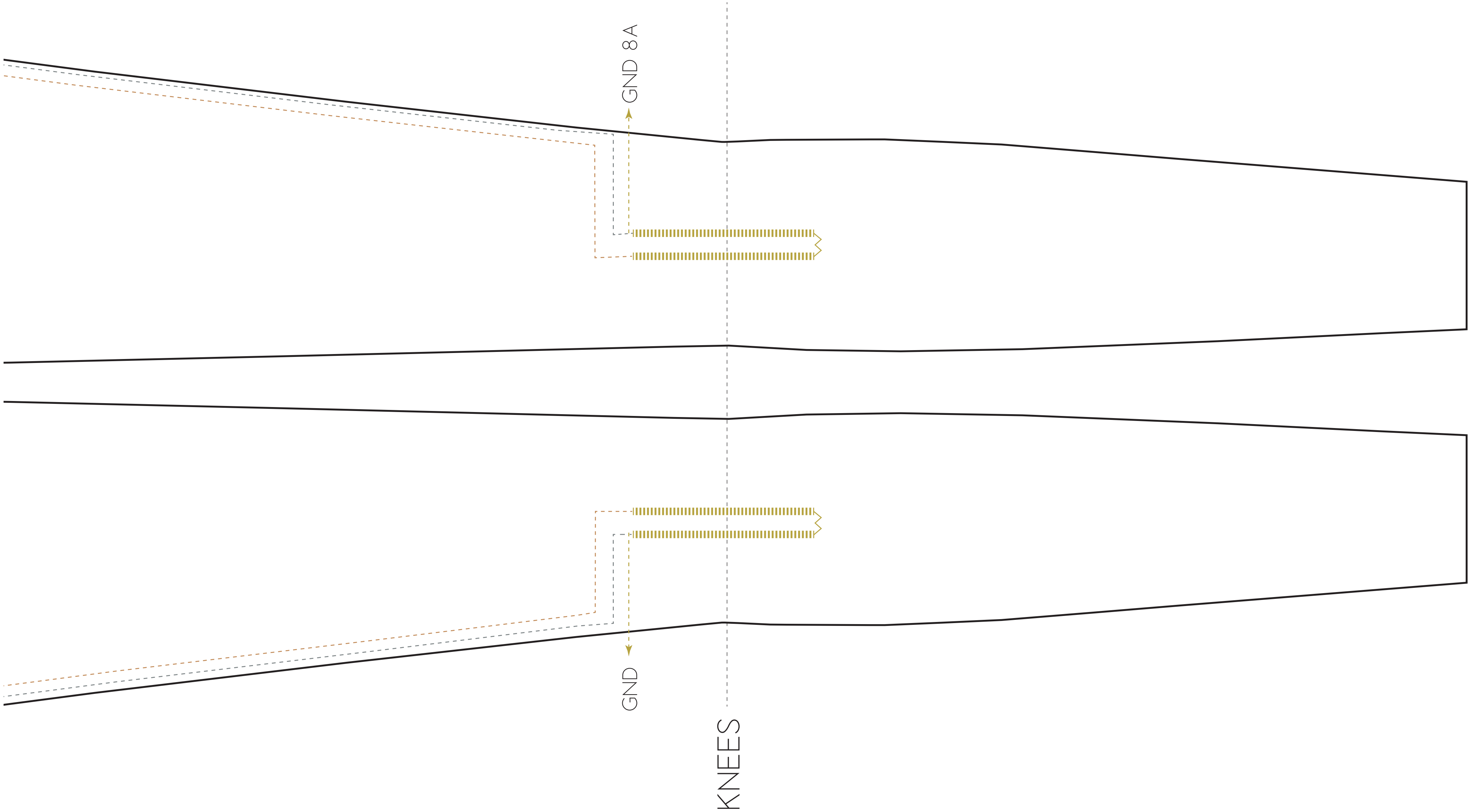
GND 8B
3.3V 8B
SIGNAL 8B
2B
2A
R4
R2A
R2B
R6
R7T
VM
5
6
MIDRIFF
WAIST
ABDOMEN
GLUTES
3.3V 7
GND 7
SIGNAL 7
3.3V 8B
SIGNAL 8B
GND 8B
3.3V 8B
SIGNAL 8B
GND 8B
SIGNAL 8A
3.3V 8A
GND 8A

SIDE


LEGEND
REGULAR ZIGZAG
4N COVERLOCK
GND
SIGNAL
3.3V
ZIGZAG SENSOR
REFERANCE RESISTOR
VM
VIBRATION MOTOR [3 5]
1. CONDUCTIVE LYCRA TOUCHPAD
2A. LEFT STRAIN SENSOR
2B. LEFT STRAIN SENSOR
4. LOWER BACK SENSOR
6. ABDOMEN SENSOR
7. GLUTES SENSOR
8A. LEFT KNEE SENSOR
8B. RIGHT KNEE SENSOR
RIGHT
LEFT

BACK


GND 8B
VM
D10
SCHOULDER
R4
A9
MIDRIFF
WAIST
A8
R7
ABDOMEN
1/2
1/2
GLUTES


GND 8A
GND
KNEES

6.2 TESTING THE PROTOTYPE: USERTEST


Figure 108a. Front view


Figure 108b. Side view


Figure 108c. Back view

Method
For testing the interactive bodysuit, a female subject with lower range height and medium size(M-L), wore the interactive bodysuit prototype whilst changing between a correct, upright posture and faulty kyphosis posture(fig. 108a-c). This was a small scale user test in an informal setting meant to report on wearability and sensor sensitivity (N=1).

Results & Conclusions
The prototype failed on item 1: wearability, as the user had troubles getting into the catsuit without breaking wires. Some of the Elektrisola wires broke at the arduino connection, interfering with the sensing of the lower part of the body. The wires at the connection to the arduino were especially prone to breaking. This was due to the rigid connection to the flexible stitching on the lycra on a location in the suit that is subjected to a large elongation. By wearing the suit, the placement of the sensors and components could also be evaluated: Sensor 2A, 2B, 4 and both vibration motors were placed correctly. The placement of the other sensors need to be adapted to the proportions of the length-size, as the sensors were not fully accurately placed, as is visible in figure 108a: the abdomen sensor (6), is not placed on top of the abdomen curve. Sensor 7 needs to be placed higher on the glutes and sensor 8A and 8B need to be placed higher on the pants of the suit (fig. 108c).

The prototype partially succeeded on item 2: when slouching, creating a kyphosis pose, the sensors on the shoulders activated the vibration motor on the back. This activity is shown in fig. 109b by the red LED lighting up, while it was off in the straight pose in fig. 109a. On item 3, the user was even able to detect a variation in vibrations. The vibration motor adjusting the core did not vibrate at all, due the broken connections prior to the testing. Avoiding breakage around the Arduino is one of the test's main insights which, along others, will be reviewed in the next chapter.

User test research questions

1. **Wearability**
   Is is possible for the user to get into the suit without any part, component of wire in the suit? Second, the user was asked to report the comfort of the suit in their own words
2. **Reactions of the sensors and vibration motor(VM) feedback**
   Are the VMs responding to the sensors when posture changes? Here, the user was asked to stand up straight and to slouch intermittently and asked to report any changes.
3. **Response of the subject to VM feedback**
   How do the user experiences being in the suit and wearing it. The user was asked to report how they felt about the vibration motor feedback and how they interpreted it.

Figure 109a. Straight Posture

Figure 109b. Kyphosis slouched posture

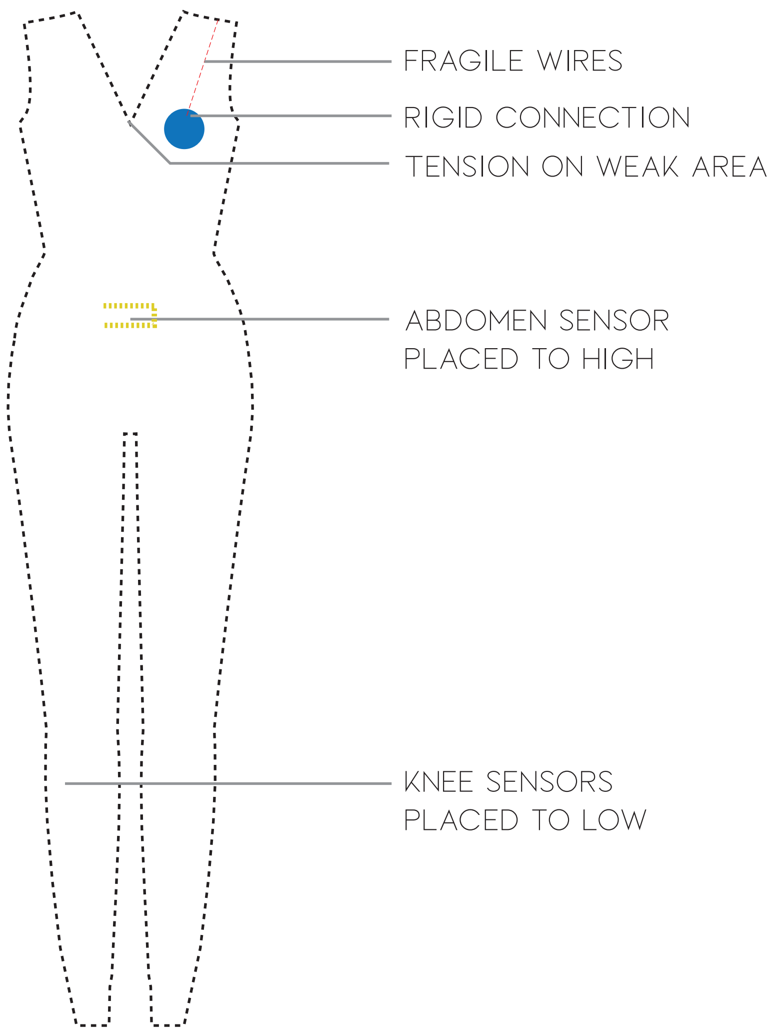


Figure 110. FBMS system interations points

System breaking points

From the user test, a few faults in the design of the suit were found. The prototype failed on 5 points to interact with the user: The fragile Elektrisola wires, the weak point of the Elektrisola wires to the Arduino, The high point of tension created when the users goes in and out the suit and the placement of the abdomen and knee sensors. An overview of all weak points is shown in figure 110.

The small diameter of the Elektrisola wires allow for easy sewing with the Pfaff sewing machine, but are also fragile and prone to breaking. This happened in almost all cases when attempting to strip the insulation layer from the ends of the Elektrisola wire. Both silver and copper wires where prone to breaking. The connection between the wires and Arduino was especially fragile, because here the wires are connected to a rigid object on a flexible base. The zigzag stitch allows for stretch in the wire on the lycra, but not at the pin connection. This problem of breaking at the pin connection was further impacted by the location of the arduino and the opening of the suit. When the user gets into the suit, a high strain is placed on the area around the neckline.

Most sensors were placed correctly from drawing the standardized pattern, but the placement of the abdomen sensors and knee sensors were off. The knee sensors should have been placed higher and the abdomen sensors should have been placed lower at the abdomen curve.

Besides the physical failures, the design could be improved to highlight the stitching even further. On the next page, three iterations to reduce breakage around arduino are illustrated and further described. In the next chapter, The design of the suit will be detailed further.

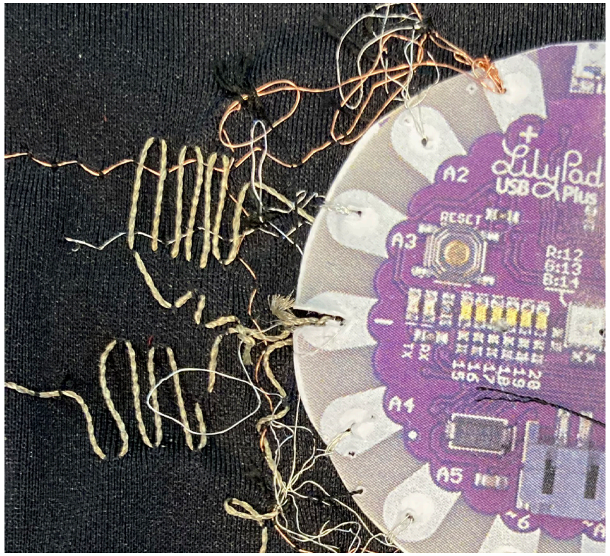


Figure 111. Adding Webbing on pocket area

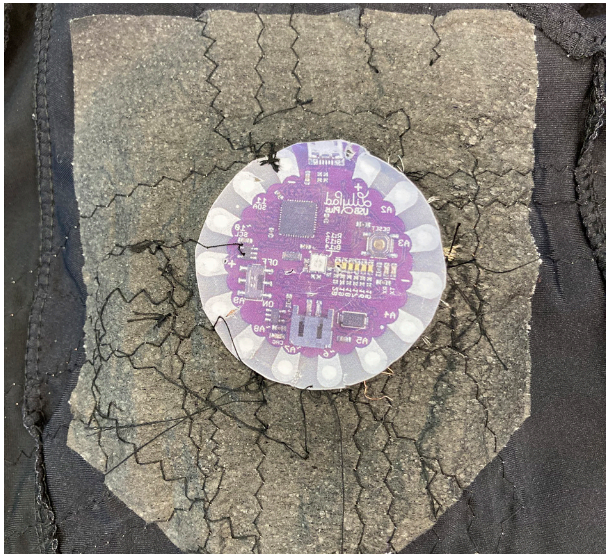


Figure 112. Looping threads at arduino connection

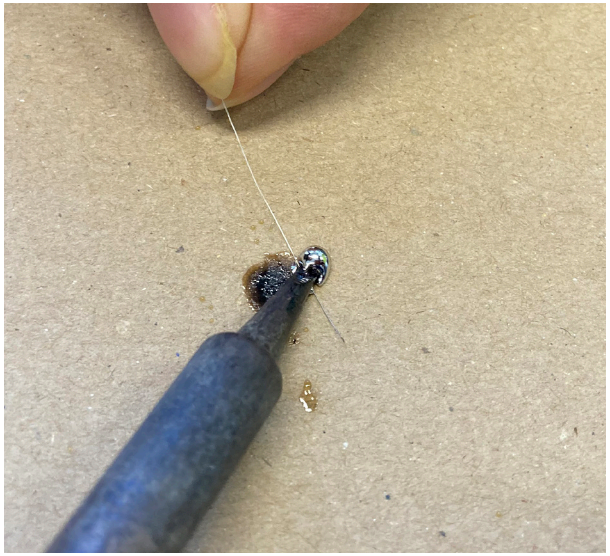


Figure113. Stripping end of Elektrisola with tin

Reinforcement with Webbing

To reinforce the rigid connection of the Elektrisola wires to the Arduino, the base on which the Arduino is stitched, is made rigid by ironing black webbing on the inside of the pocket so the fabric does not stretch around the Arduino (fig. 111).

Loop threads before connecting

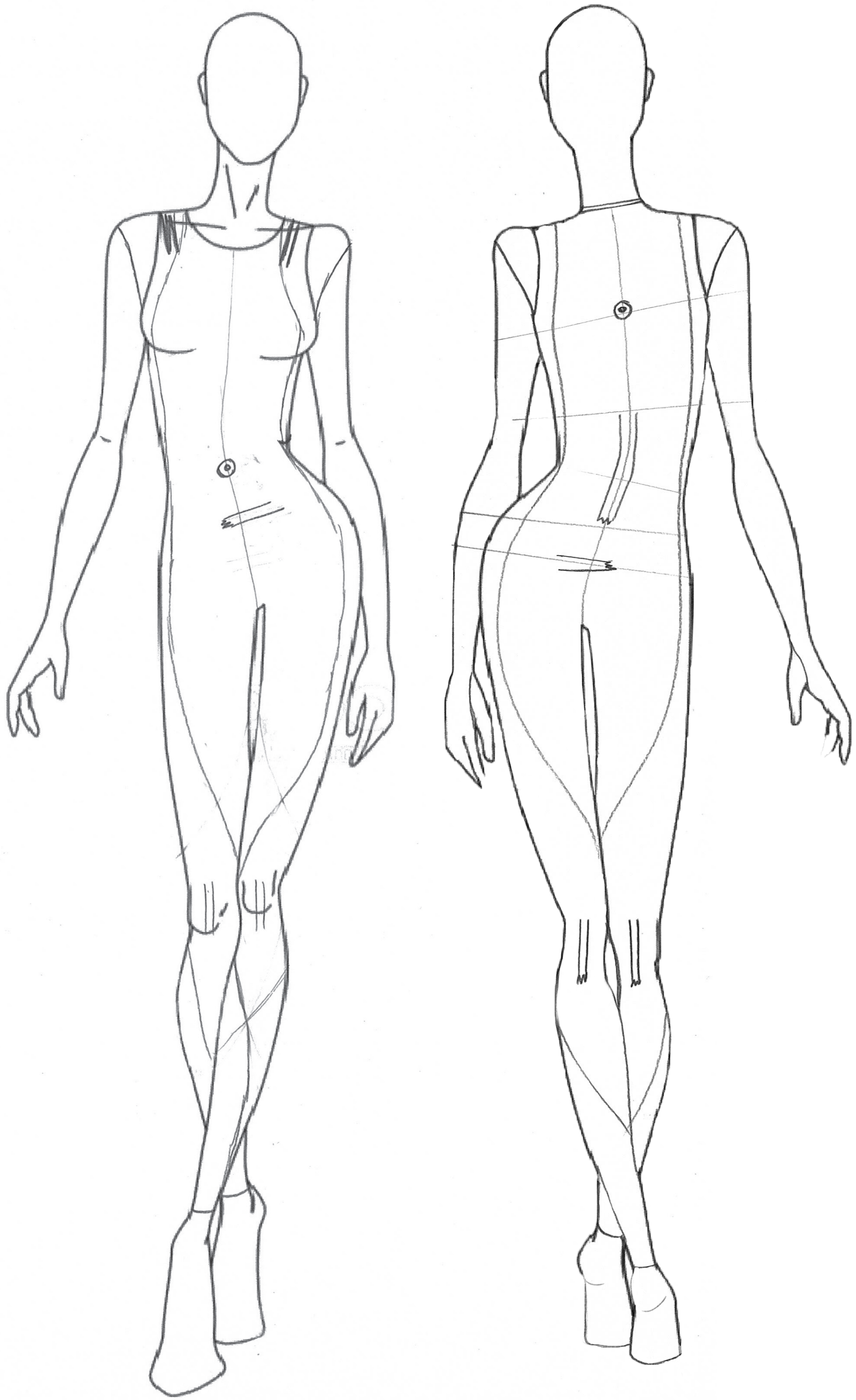
Another reason the wires break at the connection, is because there is not elongation of the wire possible. Therefore, the wires are looped before they are connected to the arduino to allow for stretching in the chest area (fig 112).

Stripping insulation

The stripping of Elektrisola led to many breaking of wire ends when connecting to components. Therefore, the method of stripping must be altered. By pulling the Elektrisola end through a dot of tin, the insulation layers is stripped(fig.

Conclusion

With these concept iterations, the prototype can be improved. The concept currently is executed in a mock-up quality. To improve on the aesthetic and marketable appeal for potential endorsers, the next chapters are detailing the final look of the design and how this will further convey the interaction qualities. The initial small diameter of ≤0,09 mm was beneficial for sewability but highly prone to breakage. From testing, the optimal thickness of the elektrisola wires were found to be 0,15mm as they thin enough to run through the machine and thick enough to break significantly less than the 0,08mm and 0,09mm.



7. FINAL DESIGN DETAILING

7.1 FASHION DESIGN

From the moodboard (fig. 41) concluding the product analysis phase, the aesthetic qualities were determined: the use of dark colors, cool tones and strong lines to create a strong and powerful but elegant aesthetic. The moadboard was set-up to ensure the product qualities were available in the prototype.

To develop the prototype into a mature product, the FBMS must have equal fashion design on the outside to match the novelty of the smart textile wearable technology on the inside. To study desirable fashion design choices featured in the final product, a moadboard was made to create an impression for creating the pattern. In figure 115, catsuits and leggings currently available in the high end segment of the sports apparel and athleasure-lifestyle market are gathered. With the double purpose of both drawing inspiration from and avoiding copying existing brands, a small selection was analysed.

For the final design, I want to celebrate the female body by accentuating the curves in the body. To create visual interest, a combination of multiple fabrics and textures should be used for a high-end finish. What works well in figure 115, is the combination of black and glossy anthracite lycra. Because the use of stitching of electrical components as textiles is the novel aspect, this should be highlighted. The use of two different fabrics should create a design solution where the placement of the smart textile stitching was deliberate act, instead of a forced choice. Because the suit is still a medical product, there should be a sense of relatability and modesty in the expression of character of the suit, making black a safe choice.

With the final design details articulated, the final design was sketched at created. The results of this design research, come together in the next chapter.

Left: Figure 115. Moodboard for fashion design

"BECOMING STRONG
DOESN'T START
IN THE GYM.
IT STARTS
IN YOUR
HEAD."

Left: Figure 116. Final Design

7.2 FINAL DESIGN

For the final design of the FBMS, a catsuit was designed to match the aesthetic objectives as close a possible and give an impression of what the fully developed FBMS product could look like.

In the final design, the sensors are still exposed, the Arduino, battery and wire ends are tucked away behind a elegant pocket. This is done for the protection of the arduino as well as facilitating space for the battery. With the changes in the pattern, the sensors are now placed in the right position according to the sensor placement research to sense postural deformations.

In figure 116-118, the catsuit is worn in size XS-S with medium length. On the next pages, details of the suit are further discussed.

Right: Figure 117. Final Design backside



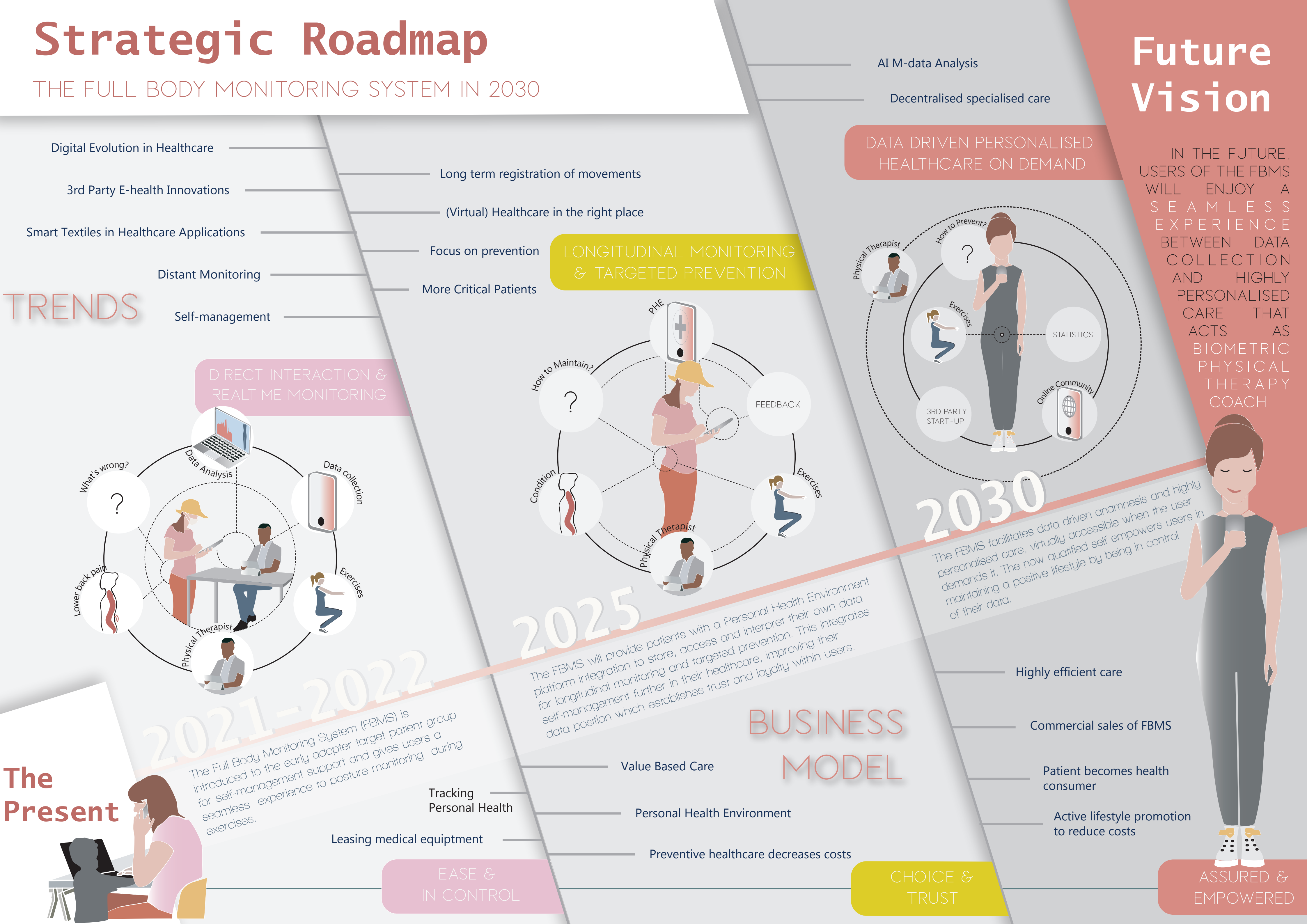

Details
As discussed in the fashion design chapter, the placement of the sensors should be done in a meaningful, deliberate way. These detailed shots provide insight in these design choices.

First, the strong lines discussed in the product quality moodboard are represented by the lines stitched parallel to each other. By placing the stitched conductive threads in the glossy lane of the catsuit pattern, the structure of the connections is highlighted, as well as the symmetry is calm to the eye.

For feedback, haptic vibration motors provide the user with a range of vibrations when performing their home exercises, creating a direct but subtle and personal way of responding to the sensors.

Left: Figure 118a-d. Final Design details

Right: Figure 118e. Final Design details


Strategic Roadmap
THE FULL BODY MONITORING SYSTEM IN 2030
TRENDS
Digital Evolution in Healthcare
3rd Party E-health Innovations
Smart Textiles in Healthcare Applications
Distant Monitoring
Self-management
Long term registration of movements
(Virtual) Healthcare in the right place
Focus on prevention
More Critical Patients
AI M-data Analysis
Decentralised specialised care
Future Vision
IN THE FUTURE, USERS OF THE FBMS WILL ENJOY A SEAMLESS EXPERIENCE BETWEEN DATA COLLECTION AND HIGHLY PERSONALISED CARE THAT ACTS AS BIOMETRIC PHYSICAL THERAPY COACH
DIRECT INTERACTION & REALTIME MONITORING
LONGITUDINAL MONITORING & TARGETED PREVENTION
DATA DRIVEN PERSONALISED HEALTHCARE ON DEMAND
What's wrong?
Data Analysis
Data collection
Exercises
Lower back pain
Physical Therapist
How to Maintain?
PHE
FEEDBACK
Condition
How to Prevent?
STATISTICS
3RD PARTY START-UP
Online Community
2021-2022
The Full Body Monitoring System (FBMS) is introduced to the early adopter target patient group for self-management support and gives users a seamless experience to posture monitoring during exercises.
2025
The FBMS will provide patients with a Personal Health Environment platform integration to store, access and interpret their own data for longitudinal monitoring and targeted prevention. This integrates self-management further in their healthcare, improving their data position which establishes trust and loyalty within users.
2030
The FBMS facilitates data driven anamnesis and highly personalised care, virtually accessible when the user demands it. The now quatified self empowers users in maintaining a positive lifestyle by being in control of their data.
The Present
BUSINESS MODEL
Tracking Personal Health
Leasing medical equiptment
Value Based Care
Personal Health Environment
Preventive healthcare decreases costs
Highly efficient care
Commercial sales of FBMS
Patient becomes health consumer
Active lifestyle promotion to reduce costs
EASE & IN CONTROL
CHOICE & TRUST
ASSURED & EMPOWERED

8 . DESIGN STRATEGY

The method of Design Roadmapping was used to map the future evolution of the FBMS from where it is now. Roadmaps typically map the stages of the product development in four horizons: the first horizon is closest to the present, the second horizon depicts the mid term development and the third horizon the long term development. These three horizons are the necessary stages the product goes through to reach the fourth horizon: the Future Vision. There are two types of roadmaps that are commonly used to create an overview of the vision for the design in the future: the Strategic Roadmap and the Tactical Roadmap. Both types serve their own purpose within a design team and are briefly discussed below.

The Strategic Roadmap
A strategic roadmap offers a quick overview of the design strategy for management purposes. It provides quick insight in context drivers, such as self-management, distant monitoring and preventive healthcare and opportunities for business models to engage in with the new product. In figure 119, the Strategic Roadmap for the FBMS, is shown. A Tactical Roadmap used by the designated design and technology development department for more in depth mapping if product evolutions.

The Tactical Roadmap
The Tactical roadmap is an adaptation of technology roadmapping and assist in planning for new technology components and aligning them with the value drivers of the context. To make optimal use of emerging technologies, and harness new user value opportunities, you can anticipate on these evolutions by mapping four layers: user value, market trends, product system and technology (Simonse, 2017). The trends and technologies that were scouted for the Factor Analysis, the drivers that were found in the Future Context, the values that are meaningful to the user from the Interaction Analysis and product system from the Product Analysis all come together in the tactical roadmap.

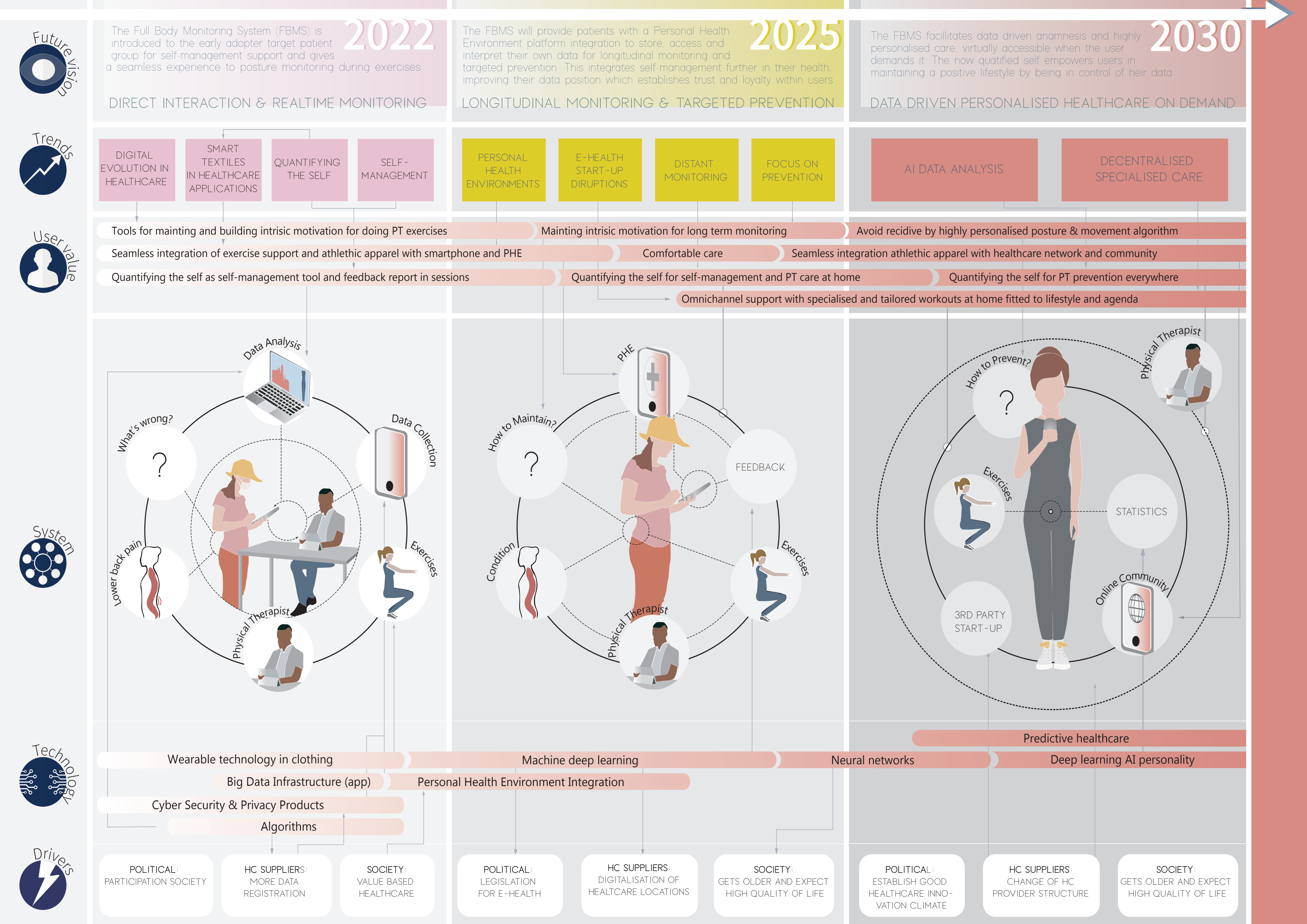
First Horizon
The first horizon is where the current design of the FBMS in this project, is positioned. Here, the system requires the user to still contact their PT. In their session, eligible users receive the interactive bodysuit to take home for home exercises. At home, their are able to receive feedback directly from the sensors and vibration motors, but also track their progress on their phone. This data can also be stored in their PHE and shared with their PT. During session they can use this data as input for feedback and personalising the treatment plan. In this system, the patient and therapist both plays an equal part in the process PT.

Second Horizon
Between 2022-2025, the system of the FBMS will change due to innovations in regards to longitudinal monitoring and targeted prevention. Technology, such as machine deep learning, allows for more intelligent monitoring of posture and movement. By providing the user with such powerful and detailed feedback, they can now take a central position in their health journey.

Third Horizon
Between 2025-2030, technology is expected to progress even further and the FBMS will be intelligent enough to provide the user with predictive healthcare, that can give care from any location the user desires. Here the role of PT becomes more of a distant monitoring coach, that primary care giver in the PT process.

Conclusion: Future Vision
In the final stage of the design strategy, the vision for the FBMS is for users to enjoy a seamless experience between data collection and highly personalised care that acts as biometric physical therapy coach.

Left: Figure 119. Strategic Roadmap; Next page: Figure 120: Tactical Roadmap



Future vision
Trends
User value
System
Technology
Drivers
2022
The Full Body Monitoring System (FBMS) is introduced to the early adopter target patient group for self-management support and gives a seamless experience to posture monitoring during exercises
DIRECT INTERACTION & REALTIME MONITORING
2025
The FBMS will provide patients with a Personal Health Environment platform integration to store, access and interpret their own data for longitudinal monitoring and targeted prevention. This integrates self-management further in their health, improving their data position which establishes trust and loyalty within users
LONGITUDINAL MONITORING & TARGETED PREVENTION
2030
The FBMS facilitates data driven anamnesis and highly personalised care, virtually accessible when the user demands it. The now quatified self empowers users in maintaining a positive lifestyle by being in control of heir data
DATA DRIVEN PERSONALISED HEALTHCARE ON DEMAND
DIGITAL EVOLUTION IN HEALTHCARE
SMART TEXTILES IN HEALTHCARE APPLICATIONS
QUANTIFYING THE SELF
SELF-MANAGEMENT
PERSONAL HEALTH ENVIRONMENTS
E-HEALTH START-UP DIRUPTIONS
DISTANT MONITORING
FOCUS ON PREVENTION
AI DATA ANALYSIS
DECENTRALISED SPECIALISED CARE
Tools for mainting and building intrisic motivation for doing PT exercises
Mainting intrisic motivation for long term monitoring
Avoid recidive by highly personalised posture & movement algorithm
Seamless integration of exercise support and athlethic apparel with smartphone and PHE
Comfortable care
Seamless integration athlethic apparel with healthcare network and community
Quantifying the self as self-management tool and feedback report in sessions
Quantifying the self for self-management and PT care at home
Quantifying the self for PT prevention everywhere
Omnichannel support with specialised and tailored workouts at home fitted to lifestyle and agenda
Data Analysis
What's wrong?
Data Collection
Lower back pain
Exercises
Physical Therapist
PHE
How to Maintain?
FEEDBACK
Condition
Exercises
Physical Therapist
How to Prevent?
Physical Therapist
Exercises
STATISTICS
3RD PARTY START-UP
Online Community
Predictive healthcare
Wearable technology in clothing
Machine deep learning
Neural networks
Deep learning AI personality
Big Data Infrastructure (app)
Personal Health Environment Integration
Cyber Security & Privacy Products
Algorithms
POLITICAL: PARTICIPATION SOCIETY
HC SUPPLIERS: MORE DATA REGISTRATION
SOCIETY: VALUE BASED HEALTHCARE
POLITICAL: LEGISLATION FOR E-HEALTH
HC SUPPLIERS: DIGITALISATION OF HEALTCARE LOCATIONS
SOCIETY: GETS OLDER AND EXPECT HIGH QUALITY OF LIFE
POLITICAL: ESTABLISH GOOD HEALTHCARE INNOVATION CLIMATE
HC SUPPLIERS: CHANGE OF HC PROVIDER STRUCTURE
SOCIETY: GETS OLDER AND EXPECT HIGH QUALITY OF LIFE

DESIGN STRATEGY VISION

IN THE FUTURE, USERS OF THE FBMS WILL ENJOY A **SEAMLESS EXPERIENCE** BETWEEN DATA COLLECTION AND **HIGHLY PERSONALISED CARE** THAT ACTS AS BIOMETRIC PHYSICAL THERAPY COACH

5. CONCLUSIONS

The development of a fully textile based wearable system for monitoring postures is complex but not impossible. In terms of research in the field of wearable textiles, recent developments has shown a surge in possibilities and posture sensing abilities. However, finding the best sensing solutions for the right application is still challenging. Due to the intimate contact With the body that this type of technology enables, wearable smart textiles will play a key role in solving issues with measuring mobility, movement and body posture.

This project focussed on the use of smart textiles for full body posture monitoring and exploring the potential of a tight fitting catsuit to measure close to the body. A full body monitoring system that is wearable and easy to use, was found to be most relevant in the domain of first line care physical therapy(PT). As the form of the product was set in the beginning of the project, the ViP analysis was used to gain insight in the Domain of physical therapy, the context the FBMS is used, the qualities of the interactions users have with the FBMS and the features of the product.

During the duration of this project, a pandemic hit our society, leading to social distancing and social contact that was prior widely accessible, now difficult to reach. Therefore the intentions for this project, investigating a interactive catsuit with design interventions and user testing, proved difficult. With both difficulties in sensor development and connecting to actual patients on a regular basis, the focus from this project made a shift from developing an interactive wearable suit to investigating and optimising the production of stitched sensors. Therefore answering the research questions changed too. With this project, I aimed to make a contribution to the field of textile based stitched sensors and focus on the following items:

Main objectives:

1. **Investigate societal relevance of the application of full body monitoring with wearable technology and to whom it can make a difference.**
2. **Exploring full body monitoring through the means of a catsuit**
3. **Optimise stitched sensors for posture feedback**
4. **Create a strategy for wearables for physical therapy patients between now and 2030.**

The chosen target user are female physical therapy patients with a young family who experience lower back pain. Prevalence of lower back issues are highest among musculoskeletal conditions and issues related to lower back pain have a large influence on the rest of the body. Personal circumstances of the target user, such as feeling responsible for family and friends, working from home and underestimating of bearing physical and mental load, negatively impacts their recovery. According to the interviewed physical therapists, the women from this target group are often regarded as patients who are motivated to quickly regain their health, but somehow fail to adhere to homework exercises. Other choices for this group was their ability to get in a suit and their tolerance towards accepting technology. Choosing this group, does not exclude others as body monitoring is desirable throughout the domain of physical therapy. From the context analysis, it was found that the incorrect execution and lack of motivation to perform home exercises is the biggest challenge in the domain of PT. However, with the tailoring of traditional treatment to value based care, this could be improved. By creating a meaningful interaction for the user, and indirectly the physical therapist, the FBMS positions itself as a means that speaks to the users intrinsic motivation.

During the product analysis phase, both the parameters of what correct posture and execution of the squat were explored. However, due to the complicated nature of measuring both movement and posture across the whole body and the limited amount of time, the focus for proof-of-concept was set to measuring full body posture in a static pose. From the target user validation, it was found that the most common postural deformities were Kyphosis, Forward rotated shoulders, Anterior pelvic tilt and overstretching the knees. From prior research it was found that minimal body posture detection was possible with 7 sensors, monitoring two areas: the shoulders and trunk and knees together as there are two main areas of correcting these deformities. The two sensors on the shoulders provide feedback to in between the shoulder blades while the other sensors are used for feedback on correcting the core. The type of feedback was generated by two small vibration motors that were adhered to the core and shoulder area. Haptic feedback was chosen as this provided the most private and intuitive feedback so user can focus on feeling the body instead of external visual cues. From here, the development of the prototype continued with sensor development. For the application of posture measuring with a catsuit, a strain resistive stitch-based sensor was chosen after thorough examination. From testing with two sensors and an LED, proof of concept was shown by measuring a variety LED light colors when the sensors were stretched in different lengths.

For this project, the most important part was the development of the textile based sensors. Although described in many papers, producing the actual sensors proved to be a difficult and tedious process. Many hours of this project were used to develop a strain resistive sensor that was both reproducible, reliable and sensitive enough to sense the small strains in the lycra material of the catsuit. There are many variables involved in creating a stitched sensor, of which the interaction between the substrate, yarn and sewing machine type and settings determine the outcome of the sensor characteristics. For this project the zigzag stitch was optimized for a 85% Nylon substrate, to give a sensor signal above the minimal desired sensitivity of GF>0,5. Other materials such as scuba knit fabrics and elastic band proved to have far better results but could not be integrated in the suit due to difference in stretch characteristics. However, they could be of great application for other projects.

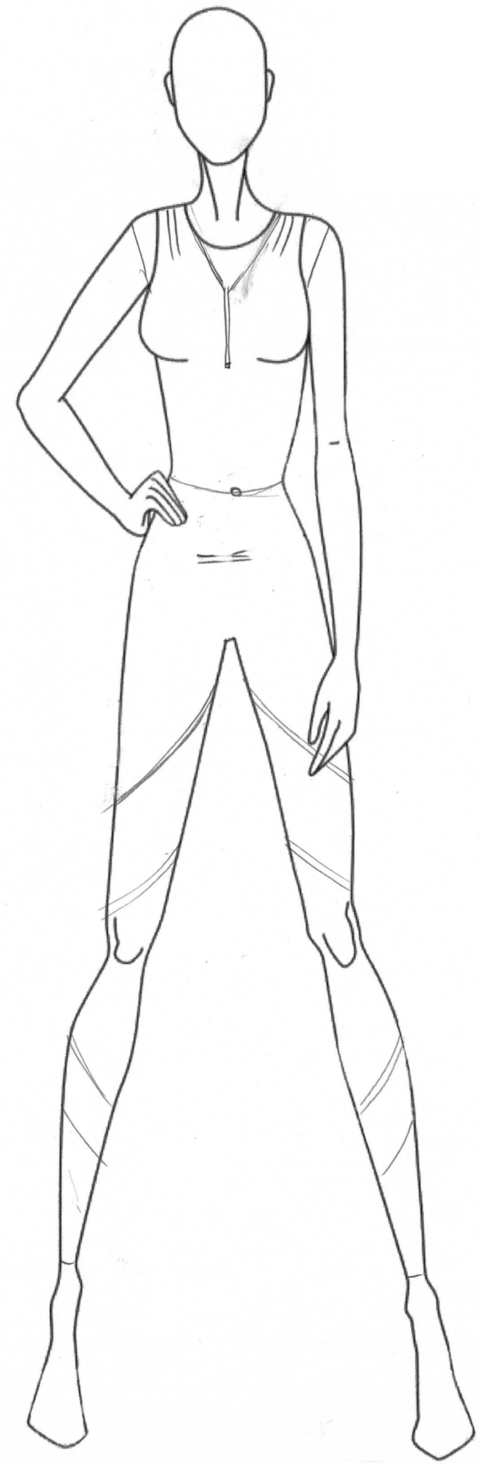
In the development of the prototype, the limitations of the current available materials for fully integrating electronics in soft goods became apparent.

To fully produce the garment with a sewing machine, both insulated and non-insulated yarns are necessary the create the sensing circuit. The insulated yarns are necessary to let the signal travel in a manner that is unaffected by outer influences such as sweat or contact with other conductors. Another reason to choose Elektrisola, is the low resistance in the wires, as opposed to the shieldex yarn, meaning that most of the energy sent to the electronic components from the battery is lost. Even though a wide variety of un-insulated yarns that can be used to produce reliable, reproducible and sensitive sensors with, there are currently no insulated conductive yarns available for smart textile applications. For the purpose of proof-of-concept of a fully textile based interactive catsuit, Elektrisola was used. However, this did not prove to be a viable solution, due to breakage in thin diameter wires or altering the structure of the lycra too much when a wider diameter was used. Therefore, alternatives for Elektrisola should be found. In terms of aesthetics and conveying the product qualities, the Elektrisola was a success.

In a small user test(n=1), the user was able to get into the suit(rq1), experience feedback from the sensors(rq2) and sense a range of vibrations(rq3), based on the degree of their postural deformation. Due to the breakage of wires during the getting in to the suit, proof of concept was only given for sensing a variety in forward rotated shoulders and

Kyphosis. This was the only user test and the answers to the research questions should be interpreted as proof of concept, rather than user validation. Due to the Covid-19 restrictions, the appropriate target user group of lower back patients in PT were not accessible to me. Another reason for minimal prototype testing and only small prototype-to-show-model iterations, are the need for advanced concept and embodiment design engineering skills, including electronics and programming. As the intention of this project focussed more on research, design for interaction and strategy, accepting proof-of-concept from a small scale user test must be acknowledged, but also accepted as a recommendation for further research.

Finally, For the creation of the strategy for creating acceptance and relevance within the domain of physical therapy, the method of design roadmapping was used, to map out user values, trends, the product system and necessary technology to provide meaningful interactions between now and 2030. Giving only a small, suggested glimpse into the future based on trends that were predicted in the past, the design strategy for the FBMS is never set in stone. Is does however offer a starting point for the first horizon and the development of the FBMS in the close future as well as a making future visions more explicit.
In the future, the FBMS has the opportunity to facilitate the transition of traditional healthcare to a more value based care system in the domain of physical therapy, because measuring posture, movement and mobility with textile based wearables, will be just as accessible to the users as measuring heart rate or oxygen levels currently possible with your smartphone. This allows patients to take a more central position in their healthcare system and strengthen their position to take manage their healthcare journey. From here, users will be able to feel assured, empowered and in control of their health. In conclusion, the adaptation of stitched sensors into making an interactive bodysuit, has proved to be a viable concept and offers many opportunities to be explored further.



7. FURTHER RECOMMENDATIONS

From the conclusions, various aspects of the full body monitoring system could be improved for future applications. In this chapter, four topics that could benefit the concept of full body monitoring are: fashion design, smart textile (yarn), user testing and expanding from posture to posture during movement.

Fashion Design recommendations
A major factor in the failure of the prototype, was the breakage of the wires around the Arduino. This happens for two reasons, which is the rigid connection on a flexible substrate as well as the high strain exerted to that area when putting on the suit. Eliminating the strain around the neckline, could be done by widening the neckline with a zipper. In the final model, this iteration is suggested however, it was not implemented due to time constraints on producing the final model.
Second, the connections between the Arduino and the wires should be better protected against impact from when the user is using the suit.

Smart textile recommendations
For the development of the ZigZag sensor concept, Shieldex was used due to it being the best performing off-the-shelve conductive yarn. Shieldex however only produces a resistance of 80Ω/meter, whereas yarns that became available during this project, such as the Amann silver-Tech yarns, which can have up to 0,5kΩ/m resistance. By increasing the resistance in the yarn, a larger ΔR can be achieved, allowing for a higher sensitivity.
Besides the resistive properties, the Amann yarn is thinner, creating less friction in the sewing machine, allowing for better sewability, and therefore more likely, reproducible results.

The Elektrisola wire currently powering the components and connecting the sensor to the Arduino, should be replaced by a textile based alternative for the FBMS to be a viable. This recommendation is difficult to implement, as it requires either material development or waiting for market solutions to catch up.

User testing Recommendations
To validate the design goal and effectiveness of the envisioned interaction qualities, more user research with the target user should be done. To mature this product further real user experience and feedback, as well as feedback to how the FBMS performs in the intended context is necessary.

Expanding from posture to posture during movement.
The initial design goal for this project was for the FBMS to measure posture during movement. To really be of support in guiding and monitoring homework exercises and tracking progress, the interaction between posture and movement is key. From research this was found to be possible by adding more sensors and applying AI algorithms to recognise patterns in sensor feedback. This was beyond the skill level available for this project, but should be explored further for innovating smart textile wearables for measuring mobility.

Left: Figure 121. Recommendation for zipper

8. LITERATURE LIST

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The Interactive Bodysuit
Master Graduation Report
Industiral Design Engineering
TU Delft, April 2021
by Tamara Monster

Chair: Prof. Ir. Kaspar Jansen
Mentor: Ir. Lye Goto

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Figure X. A1.1. Current Products on the Market (Schrevers, 2017)

A.1. MARKET ANALYSIS

Product	Old/New	Prices		Product	Old/New	Prices
Basis B1 Band	November 2012	€175		Leo band	May 2015	€265
Fitbit Flex	May 2013	€85		Heatex textile	August 2012	N/A
Pebble	July 2013	€119		GOW Smart fabric shirt	November 2013	€80
Garmin Forerunner 620	September 2013	€349		Adidas miCoach sports bra	January 2014	€50
Jawbone UP24	November 2013	€129		Adidas miCoach shirt	January 2014	€55
Samsung GEAR FIT	April 2014	€175		MIMO baby sleepshirt	February 2014	€175
Motorola Moto 360	September 2014	€190		Sensoria Ankle sock	March 2014	€175
Misfit Flash	September 2014	€45		OMsignal biometric shirt	March 2014	€100
LG G Watch R	October 2014	€250		Sensoria Fitness bra	April 2014	€70
Sony smartwatch 3	October 2014	€119		Athos	July 2014	€485
Fitbit charge HR	November 2014	€130		Zepp (golf)	October 2014	€130
Apple watch	April 2015	€310		Spree smartcap	January 2015	€175
Pebble Time	May 2015	Not available		Ralph Lauren Bioshirt	N/A	-
BodyMedia Fit armband	Augustus 2011	€96		Lesia trubat's 'E-traces'	N/A	-
NuuboBlendfix e-textile	February 2012	N/A		Cityzen D-shirt	N/A	-
Lumoback	August 2013	€60		Muracci Boditrak's helmet	N/A	-
BSX Insight	March 2014	€265		Xelflex smart fabric	N/A	-
MYO	July 2014	€175		Heddoko	N/A	-
Gymwatch	December 2014	€90		BioStamp	June 2013	€8
Lumo Lift	July 2014	€70		Fitneck	April 2015	€99
Valedo	December 2014	€299		Up Right	December 2015	€129
LumoBack	November 2012	€60		Percko	January 2016	€129
LumoLift	January 2014	€70		TruPosture	May 2016	€175

Table A1.1. Current Products on the Market (Schrevers, 2017)

A.2 INTERVIEW SEMI-STRUCTURED INTERVIEWS

A2.1 CONSENT FORM

Script prior to interview:

I would like to thank you once again for being willing to participate in the interview to deepen my understanding of physical therapy. The aim of this interview is to get an overview of the current aspects of physical therapy and to gain insights in opportunities for my project.

The interview today will last approximately half an hour during which I will be asking you about your profession, different therapies and patients, different kinds of problems and future improvements.

I will process the data anonymously, yet there will be risk that results may be traced back to you as interviewee. When I would like to use your name in my report, I will ask permission for that specifically. The data will be taped, transcribed, summarised and archived on google drive. The data will be kept as long as necessary for writing an article/report and possibly included in a website. Afterwards anonymous data will become available on the TU Delft graduation report repository. The personal background variables will be removed for the repository, unless otherwise consented for.

We would appreciate it if you could sign the accompanying consent form, to make sure the ethical regulations are met.

……
[Name, place, date, signature]

The consent was digitally recorded by consenting through audio over the phone.

A2.2 INTERVIEW GUIDE

Section 1: Introduction questions

1. Wat is uw naam?
2. Wat is uw officiële functie?
3. Heeft u een specialisatie?
4. Hoe komen patiënten bij u terecht?
5. Wat is voor u een motivatie geweest om fysiotherapeut te worden?

Section 2: Broad questions

6. Wat voor interactie heeft u met uw patiënten?
7. Wat probeert u zelf toe te voegen in uw praktijken?
8. Wat voor dingen gaan op dit moment goed?
9. Wat vind u lastig in het begeleiden van uw patiënten?
10. Wat voor dingen ziet u wel eens misgaan bij het begeleiden van uw patiënten?
11. Waar kunnen patiënten zelf wel wat hulp bij gebruiken volgens u?

Section 3: Field specific questions

12. Wat voor verschillende patiënten behandelt u?
13. Zijn deze patiënten onder te verdelen in categorieën?
14. Zijn er verschillen per categorie?
    - Wat zijn deze verschillen?
    - Wat zijn verschillende behoeften per categorie?
    - Hoe uiten deze verschillen zich?
15. Welke patiënten of klachten behelzen therapie voor het hele lichaam?
    - Waarom is het belangrijk dat het hele lichaam (mee)getraind wordt?
    - Hoe dragen benen bij aan deze oefeningen?
    - Hoe dragen voeten bij aan deze oefeningen?
    - Hoe dragen armen bij aan deze oefeningen?
16. Zijn er revalidaties waarbij met het gehele lichaam gewerkt moet worden?
    - Wat voor oefeningen worden hierbij gedaan?
    - Wat zijn bijzonderheden of uitdagingen bij het werken met het hele lichaam?
    - Wat voor dingen zitten hier wel eens tegen of gaan mis?

Section 4: Vision Questions

Stel er is een mogelijkheid om informatie over bewegingen van het lichaam dicht op de huid af te lezen, in de vorm van een pak dat patiënten in de toekomst kunnen krijgen ter ondersteuning van hun oefeningen

17. Hoe zou dit er voor u uitzien?
18. Wat zou u dit willen inzetten tijdens uw fysiotherapie?
19. Hoe zou dat u kunnen helpen?
20. Hoe zou het patiënten kunnen helpen?
21. Wat voor informatie zou u willen hebben?
22. Stel ik wil gaan testen met zo'n pak, ziet u dan samenwerkingsmogelijkheden voor ons?

TITEL HOOFDSTUK

A3 INTERVIEW OUTCOMES

Participant	Method	Main Insights	Main challenges	Vision
General PT (Works with multicultural people)	Phone Call	• Oncological and Post-op patients are very driven • Continuing sport, “under guidance”, outside of PT would be very beneficial for maintaining health • Motivated patients often have a busy lifestyle	• PT works best when people are motivated • People often misinterpret home exercises and perform them wrong • Patients should train more individually to increase therapy success momentum	• Gathering information about muscles and exercises for the whole body, not focussing on a specific area. •Often sees patients with manual labour intensive jobs: wants to track behaviour
Sports PT	F2F	• How to connect trust of people in their own body to learning from a suit?	• People with movement problems are overcompensating in other areas	• How to balance overcompensation and (re)learn healthy movement behaviour
Manual Therapist	Phone Call	• Patients with low body-spatial awareness need help in executing movements in correct posture • Higher educated working women with families want to heal fast	• Insight in what people are doing during the course of the day • Posture is a habit; habits are hard to change	• Patients gaining insight posture and learn how to feel this. • A tool to motivate patients, as lack thereof is detrimental to their recovery process
Anthroposophical vision	F2F	• Arms play less of a role in the vertical MS-chain, but help in exercises. • How do people exercise at home?	• Within healthcare, too less time for making people aware of their body • Hard to keep people motivated	• Stimulating core balance, posture correction and preventing Kyphosis • Feedback on spatial body posture
General PT	Phone Call	• Repeating exercises at home is difficult • Many complications stem from wrong posture • Patients overestimate their performance	• Difference between patients interpretation of an exercise and correct execution. • Patients learn wrong behaviour at home	• Measuring bending of joints • Discover/monitor movement restrictions • Left/right difference in body
General PT/Geriatrics	Phone Call	• Large responsibility on PTs for diagnosis • Seeing improvement is the ‘reward’ for PTs • Analysis of walking pattern is very expensive	• Creating insight in a correct posture • Habit change is difficult to achieve in sessions of 20-30mins	• Show patients how their behaviour influences the pace and extent of their complaint
General PT (works with business owners	Phone Call	• Complaints can arise from other parts in the MS-chain, which at first don’t seem affected • Hernias: regain trust in body	• People don’t know their own limitations • When training the whole body, exercise balance is very important.	• Create awareness how the MS influences all body parts in the vertical MS chain • Gain insight in why recidive occurs
Neurologists	Phone C	• Increased use of personal health environments	• Compliance of patients to therapy	• Need to measure movement behavior
Rehabilitation Therapist(RT)	F2F interview and tour	• Rehabilitation deals with multidisciplinary trauma • with RT, a lot of time is spent training at home • Using digital platforms to prepare exercises	• Low access quantitative measuring devices • Diagnosis with hallway analysis en 6 minute walk test is work-intensive	• Quantify qualitative goals of patients over long period of time • New measurement tool for diagnosis

Figure X. A3.1. Overview of Interview Outcomes

TI

Section 2: Broad Questions				Section 3: Field Specific Questions	
Positives	**Negatives**	**Problematic**	**Use some help with**	**Conditions**	**Different patient needs**
• Communi-cation	• Too few sessions, language barrier	• Skewed expectations, dropping out after few sessions	• Overviewing all body parts at once, behavioral change	Core problems	Legs and arms must get stronger to help the spine, Weak deeper abdominal muscles not supporting the spine properly.
• Coaching	• Low motivation(3x)	• Health insight not increases	• Accessible sports/fitness	Spine problems, MSC conditions"	Abdominal & back muscles, posture related
• Patients are satisfied	• Missing out on (daily) progress(3x)	• "therapy compliance"(3x)	• Execution of exercise(2x)	Pelvic floor, Thorax, Cervical, Lumbar spine	“You have to constantly be aware of it."
• Trust in PTs capabilities	• Patients being erratic/stubborn(2x)	• “Under- estimate complaints"	• Information adapted to patient’s understanding,	Oncological rehab., CVA	**Post-op:** condition and weight training **Hernia**: posture improvement
• People wait less often with a condition	• Not doing homework/exercises(5x)	• "Perform or interpret exercise differently when given(5x)	• Increased self-management in healthcare with apps" and PHE	Sprained ankle, flexible knee, hurt shoulders	**Knee/joint problems**: Train area around injury and full MSC to not overload the area and solve underlying MSC problems against recidive
• Contact(2x)	• Issues with insurance companies (2x)		• Guidance	Parkinson's, MS, "Burnout"	**Neurological disorder**: affect the entire functioning", with Paralysis, core stability is key"

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Section 4: Vision Questions				
Vision	**Utilize**	**How does it help the therapist?**	**Help the patient?**	**Desired information?**
• "Measurement for company doctors", • for people (25-65), • For heavy working conditions” • "Signal for sitting too long in the same position" • "assume a certain position" • "core balance" • "backward balance” • "Posture correction" 2x • "register movements" • "How one exists in space" • "stimulating exercises with registering"	• "How is posture during the day" 2x • "as a feedback mechanism" 2x • "see yourself moving in image" 2x • "difficulty estimating balance" • "activate and stabilize" • "relieve tension by tilting pelvis" • "left / right difference" 3x • "Seeing on toes or heels" • "how many nº joints bend, replace measuring movement with gonio " • "Finding an explanation for injuries/recidive" • "important for motivation to demonstrate things" • "preferably that a patient works with it himself"	• "Help with initial and final measure-ment for insurer" • "use outside treatment" • "that you can compare those results" • "the patient has recovered earlier and is stimulated in his / her recovery."	• "create body awareness in space in patients who are not" (3x) • "Faster recovery through targeted exercises.	• "Do tests": "left / right measurement", "24-hour measurement", posture, legs and torso • "see how someone walks: a step has many phases" • Recidive/ chronic complaints • "feedback on their posture during the day and difference with and without a suit" 3x • "Do...exercises and the.. is in the position we want it" • "whether people stick to what you give them ... or maybe give them too difficult an assignment" • "see body in 3D", "posture and freedom of movement" • “simple info about progress, improving fitness. should be stimulating. Making it clear whether a patient is doing it often enough, improving movement." • "people who are very body unconscious...give feedback through an external tool... and then they can correct themselves" by "getting feedback on their position

Table A3.2. Outcomes per section

A3.2 INTERVIEW RESULTS

	Section 1: Introduction					**Section 2: Broad questions**						**Section 3: Field specific Questions**				
	Officiële functie	Naam	Speciali-satie	Aanvoer	Motivatie	Interactie vorm	Zelf toevoegen	Gaat goed	Lastig	Gaat mis	Hulp	Verschillende patiënten	Verdelen in categorieën	Verschillen per categorie	Patiënten- therapie hele lichaam	Waarom?
1	Fysio therapeut	Inge Blom	Oedeem-therapie	Huisarts, collega's, gezondheidscentrum, online register	-	Bewustwording door aanraken	levenstijlverandering teweegbrengen, activeren, zelf veranderen	Benadering van patiënten: communicatie, motivering, coachen	Te weinig behandelingen, taalbarrière, lage motivatie, vooroordeel: gemasseerd willen worden	Afhaken(3-4x), gezondheidsinzicht niet vergroot, geen tijd/geld(werk)	laagdrempelig sporten, begeleiding	oncologische patienten, postoperatieve patienten, algemene klachten(enkels, knieën, heupen), nek-, rug- en schouderklachten, operatie revalidatie		motivatie: oncologische, post-op patiënten zeer gedreven. onderscheid in culturen	rompklachten, rugklachten, rug-bekken, oncologische revalidatie(hele lijf heeft klap gehad)	rompklachten(benen en armen moeten sterker worden om je rug te helpen) rugklachten(buik en rugspieren trainen, houdingsgerelateerd) oncologische revalidatie(hele lijf heeft klap gehad) Hernia(houding verbetering)
2	Fysio therapeut	Daphne vd Heijden	Sport therapie	bestaande klanten, via sportschool/zwembad, sportvereniging en	Iets met geneeskunde, kon fysio in 3 jaar doen		"Voorwaarde creeëren zodat mensen weer beter kunnen bewegen"	"klanten zijn tevreden, mensen komen terug"	"verzekeraars hebben veel macht" "soms staan mensen er niet voor open dat ze meer moeten bewegen" "niet gemotiveerd om iets te gaan doen"	"als ik een oefening schrijf anders uitvoeren of interpreteren"	"Geen idee"	Veel sporters: amateur, topsport, jong & oud "Veel klachten die van origine uit de rug komen"	"acuut en chronisch" Leeftijdsverschil, intelligentie, internationaal	"Dat is te breed"	"Bijna niet, maar ik kijk wel veel naar de keten"	"Binnen een kader waaronder een knie niet te veel belast mag worden, zul je dus altijd de rest meenemen" "Bij een programma (sportbegeleiding)...zorgen dat hij sterker wordt, beter aansturen minder, blessuregevoelig wordt"
3	Fysio therapeut	Britt Pijls	Manueel Therapeut	website, huisarts, specialist, via-via	Interesse in menselijk lichaam via sportmassage-vak	"heel energiek" "heel eerlijk" "tough love"	"zelfredzaamheid en kennisoverdracht" "leren hoe het lijf werkt"	"contact naar patiënt toe"	Als mensen niet luisteren en hun opdrachten en oefeningen niet (goed) doen. "vind ik het wel lastig om ze daartoe te motiveren en zelf gemotiveerd te blijven"	"Oefening (thuis) verkeerd hebben gedaan" en "zichzelf een verkeerde stap of beweging hebben aangeleerd" voorbeeld: - Rug moet recht blijven bij een squat, sommige mensen voelen dat niet"	"oefening op een bepaalde manier goed uitvoeren" "Je kunt zelf niet alles goed zien",	"Veel hoogopgeleide dames, 25-65 jaar"	"veel schouder-, nek-, spanningsklachten" "ook enkels en voeten"	"willen in 2-3 behandelingen van hun klacht af"" "snappen dat ze thuis ook wat moeten doen" "niet te dure spullen kopen" "kennisoverdracht maken" "bereid er hard voor te werken"	"Dan kijk je voora; naar chronische indicaties of comorbiteiten"	
4	Fysio therapeut	Wander Kriek	Antroposofie	huisarts, in buurt woonachtig	functioneren van menselijk lichaam	"blik breed te houden"		"Veel tijd voor patient ivm de huisarts"	"als motivatie zakt bij de patient...moeilijk om iemand goed te motiveren voor oefenen" Standaardtests vooraf: straight leg raise. richtlijnen via KNGF	"klachten verkeer inschat of onderschat"	"wat met gedragsverandering te maken heeft"	Centraal neurologisch, perifieer neurologisch, spierfasie, revalidatie, post-operatie, standaard gewrichtsklachten	langdurig of korte trajecten		Parkinson, CVA, MS (centraal neurologische aandoeningen)	"het hele lichaam is aangedaan bij dit soort ziektes"
5	Fysio therapeut	Jaron	geen	mond-tot-mond, praktijk	Brede interesse in menselijk lichaam, praktisch ingesteld, mensen helpen	Informeel, didactisch, inzicht geven in klachten origine	Aandacht voor verhaal van mensen. "therapie werkt pas als je vertrouwen hebt"		"dicipline" "moeilijk mensen hun huiswerk te laten doen" "kijken wat mensen thuis doen"	"Dat ze hun huiswerk niet goed doen" "Thuis heel anders doen dan bij jou" "mensen die zich motorisch niet bewust zijn en moeite hebben met uitvoeren wat ze moeten oefenen"	"uitvoering van oefening" Men overschat zichzelf met oefeningen onthouden en van papiertje aflezen "onthouden hoe een oefening ongeveer gaat en hoe een oefening echt gaat is een verschil."	breed publiek, 25-55 jaar, arbeidsgerelateerde klachten	sportgerelateerde klachten, arbeidsgerelateerde klachten, geriatrie	Arbeid: verkeerde houding, lage rugklachten, kans op rsi (houdingsgerelateerde klachten) sport: verstruikingen, spierscheuren. geriatrie: atrose, nieuwe knie, nieuw gewricht	Ouderen, longpatiënten, hartrevalidatie, afvallers	"aanpassen van houding voor heel veel mensen heel moeilijk is. Houding is wel iets wat je voortdurend van bewust moet zijn. Er is veel hulpvraag naar houdingsprobleem omdat je eigenlijk continue feedback op moet krijgen. Ja, dat zou ik voor de werkvloer wel interessant vinden." "Voor sport is het misschien meer om prestaties te meten."
6	Fysio therapeut	Elmar	Geriatrisch	via verpleeghuis	interesse menselijk lichaam, sociale kant, practisch ingesteld	"didactische manier" "boeiend maken"	"gedragsverandering teweegbrengen" "mensen enthousiast maken" mbv "filmpje of uitekenen"	"zonder tussenkomst van arts redeneren wat er aan de hand is"	"mensen erg grillig zijn" "soms gezien als extratje van verzekeraars" "jammer dat ik mensen niet elke dag kan zien" verbetering "moeilijk meetbaar houden"	"therapietrouw" "scheef verwachtingspatroon bij mensen" "proberen gedragsverandering teweeg te brengen in 20 minuten, maar thuis terug in oude patroon"	"Meer laagdrempelig contact met fysio" "duidelijke info die op hen is aangepast"	"kwaliteitsjager" "psychosomatische patiënt, fybromyalgiepatiënt "Patiënt die na 1 behandeling overal vanaf is"	Mannen: klachten rondom schouderblad (krachttraining trend/sportschool) Vrouwen: nek en schouders(kinderzorg) beide: knieklachten door ongetraind hard te gaan lopen	K.J.: "verwachtingen echt torenhoog", "snel resultaat" Fyrbomyalgie: "hogere prevalentie vrouwen", "klagen over klachten",	"Burn-out klachten" "klachten rondom heiligbeen"	B.O.: "het hele lichaam is op" "als knieën niet goed zijn, kan dat weer in je rug uiten, wat zich weer in je nek-schouder uit...relaties met elkaar." "lichaam moet weer op 1 lijn gezet worden"
7	Fysio therapeut	Patty van Eemsbergen	Valpreventie, Sport-blessures	mond-tot-mond, praktijk		bankbehandling en oefentherapie	"verder kijken dat wat ze benoemen. verbanden leggen"	mensen sneller bij fysio terecht	"eigenwijs zijn" "oefeningen meegeeft vaak niet willen doen" "denken dat fysio klacht voor ze oplost"		Info over vergoeding	sportende kinderen, sportende volwassenen	veel ondernemers	"kinderen beïnvloed door hun ouders" "sporters te fanatiek, gaan over grenzen heen" "ondernemers te druk voor eigen lichaam" (sporters en ondernemers) "zitten in de ontkenningsfase"	"ketenproblematiek"	"opeens gekke blessures...het niet alleen een beleidsprobleem is maar een ketenprobleem"
8	Neuroloog	Daan Kamphuis		via huisarts, specialist	klinisch puzzelen	"luisteren naar patiënt"	"meerwaarde voor de patiënt"	"steeds meer kunnen meten met feedback"	"soms niet zo veel kunnen betekenen"	"medicatietrouw en complience" "ouders die medicijnen niet/verkeerd geven"	"steeds meer zelf zaken te laten doen", "apps" "overgang naar PGO"	Kinderen en volwassenen met bewegingsstoornissen,	V: "Parkinson en dystonie, CVA patiënten" Bij kinderen: "ontwikkeling, verlammingen. bewegingsstoornissen in brede zin."	"Te breed" "behandel je heel anders"	"Eigenlijk al mijn patiënten"	"Elke neuro stoornis heeft invloed op het gehele functioneren" "Verlammingsverschijnselen, stabiliteit van de romp is belangrijk" Operaties: "Better in/Better out"
9	Revalidatie therapeut	Nienke	Revali-daties	Revalidatiearts	"Complete plaatje", "multiciciplinaire aanpak", "Veel gecompliceerde klachten"	"Vrij formeel, patiënten willen vaan informeler"	"zoek naar extra dingen, veel bezig met smartlab (innovatielab) binnen basalt"	"Samenwerking binnen verschillende diciplines", "kleine, korte lijntjes"	"vanwege kleine locatie missen we innovaties"	"communicatielijnen" en "wat blijft hangen bij mensen", "afhankelijk van netwerk en mantelzorgers"	"is meer nodig dan één discipline"	"alles van de dwarslaesies, MS, chronische pijn, CVA's", "behalve ALS"			"alles wat je doet doe je met heel je lichaam"	

Section 4: Vision

Oefeningen	Belang benen	Belang voeten	Belang armen	Revalidaties - therapie hele lichaam	Oefeningen	Bijzonderheden/ uitdagingen	Visie	Inzetten	Therapeut helpen	Patiënten helpen	Gewenste informatie	Samenwerkings-mogelijkheden?	Weerstand
romp(ontspanning in bekken, diepere buik- en rugspieren/core stability) Hernia(squat)				Oncologische COPD Hernia dwarslaesie	Gebruik van handen om correcte uitvoering te constateren Sissel kussen om onder rug te leggen, trucjes, seated row, pully, legg press, Cardio voor betere conditie: loopband, cross-trainer, roeien(ok arm), Oncologische patiënten hebben eigen schema	Trainen in een sportschool verliest soms aandacht voor houding("denken bijna niet meer na") Diepe spieren zijn niet "de mooie spieren" Mensen met rompklachten te laten voelen	Meting voor bedrijfsartsen	Voor werkende mensen(25-65), specidieke doelgroep met zwaar werk	Hulp bij begin- en eindmeting voor verzekeraar Vervanging dure apparatuur om te meten		links/rechts meting 24-uursmeting recidieve/chronische klachten Houding Benen en romp		
				"iemand die in een revalidatiecentrum zit wel...daar ga je een heel ander beeld krijgen"			"Meer feedback op kleine aanspanningen uit diepe spieren"			"mensen die heel lichaamsonbewu st zijn ... via een externe tool feedback geven.. en dan kunnen ze misschien corrigeren"	"Gaat het om de alledaagse patiënt..dan gaat het misschien meer om de houding" "Schouderoefeningen doen en staat het schouderblad wel in de positie waar we het willen"		"financiële investering" "liever dat mensen leren voelen dan dat iets ze verteld dat het niet goed is"
"overlappende behoefte is een houdingstukje:goed weten hoe ze moeten zitten" "lage rug is vooral trainen"							"nauwsluitend en wat vooral spierspanning afleest" seintje "te lang in dezelfde houding" en "een bepaalde houding aannemen, bijv. een hele kromme rug"	"als feedback mechanisme" "achteraf kunnen laten zien wat er misgaat door animatie" "leer je veel van: jezelf zien bewegen in beeldvorm"	"buiten de behandeling kunnen gebruiken"	lichaamsbewustz ijn in de ruimte creeëren bij patienten die dat niet zijn	"hoe vaak zitten ze nou" "zit rug bol of recht" "hoe vaak houd iemand zijn houding vast" "wat doet iemand nou met zijn lijf"	Superleuk!	
			armen spelen minder een rol. schouderbladen spelen wel een belangrijke rol in de nek Bij frozen shoulders zijn schouderuitslagen interessant, impingement syndroom, slijmbeursontsteking, hoe hoog iemand zijn arm op kan tillen	CVA, MS en COPD Complexe rugklachten	Bij complexe rugklachten laat ik iemand bijvoorbeeld veel squats maken.	'Het liefst zou ik iedereen wel bewust willen maken van het hele lijf, maar daar is vaak geen tijd voor"	"rompbalans" "voor de achterwaardse balans omdat er vrij veel sway backs zijn" "houdingcorrectie"	"mensen hebben moeite in te schatten waar die balans ligt." "te activeren en stabiliseren" "spanning te verlagen door bekken te kantelen"		"attent willen maken op zijn positie in de ruimte" "feedback krijgen op hun positie"	" of mensen zich houden aan wat je hen opgeeft...of misschien te moeilijke opdracht geeft"		"kosten"
				dwarlaesie, sporters		"interval tussen je trainingen. Je lichaam heeft een bepaalde hersteltijd varieert een beetje tussen 48 en 72 uur... anders geen prgressie maakt"	"ademhaling meten gedurende de dag" "verschil met zonder pak"	"burn out klachten halen slecht adem" "Hoe is houding gedurende de dag" "hoeveel graden kunnen gewrichten buigen" "verschil tussen links en rechts" "gewichtsverschil waarnemen in voeten" "rusthartslag zegt iets over de gezondheid en trainingseffect"	dmv het pak de patiënt sturen		"feedback op hun houding gedurende de dag en verschil met en zonder pak"		"data pricy"
				"Orthopedische revalidaties, zoals hernia's" "knieprotheses", "auto-ongelukken"	"getraind met geïsoleerde kracht-oefeningen: leg press, rug extenties, legg pulls, vooral trek-oefeningen." "eigenlijk gewoon sportschooloefeningen" "(power)yoga dingen worden ook toegepast"	"Dat iemand echt snapt wat je traint. Vooral ook wat je niet moet voelen"	"bewegingen registreren"	" elk gewricht is een as, die zichtbaar is. waarmee je vervolgens oefeningen gaat uitvoeren, je heel visueel hebt wat je nou bijvoorbeeld fout doet of hoe ver je nou bukt. Denk aan een squad bijvoorbeeld, een oefening die je heel makkelijk fout zou kunnen doen. Als dan de computer kan bepalen dat je bijvoorbeeld minder je knieën moet strekken, je ze iets gebogen moet houden en minder je onderrug bollen en je daar ook visuele feedback van geeft van geen last van? Het is vervolgens nog een keer geprobeerd en dat je dan die resultaten kan vergelijken"	"dat je dan die resultaten kan vergelijken" "niet alleen voor fysiotherapeuten, ook voor personal trainers"	"sowieso voor revalidatie" "gang- en loop-analyses"	"zien hoe iemand loopt, want een stap heeft veel fases" "Biofeedback: calorieverbruik, frequentie, diepte, locatie van ademhaling" "myografie" "jouw lichaam in 3D zien" "Testen doen"	"een stapje lager dan de echte zorg maar een stapje hoger dan...zo'n gimmick"	Weerstand door scepsis van dure apparatuur vs een legging
"veel stabiliteitsoefeningen" tests: "op één been staan", "heen en weer laten lopen", "voorover bukken", "qua onderzoek neem ik altijd passief de wervelkolom mee" "Bij schouderklachten letten op: hoe zit iemand, houding	" Zeker rompstabiliteit bereik je via je beenspieren. Hamstrings, de abdotorum. Die zijn van grote invloed"	"in de enkel een bewegingsbeperking, anders gaat lopen en minder stabiliteit heeft. Het lijkt rompinstabiliteit, maar zit in die enkels. Maar ze komen met rugklachten bij je."	"Eigenlijk gebruik je met name de armen."	Pathalogiën: MS, ALS, Guilain -Barré, Burn-Out "Hernia zeker" "Hypermobiliteit(ook zonder syndroom)"	"vertrouwen in het lichaam weer terugkrijgen" "Begin met gesloten oefeningen: legg press, leg pull down" "Daarna losse oefeningen: core stability, spelletjes"	"schakelen: oefeningen te makkelijk/moeilijk" "Balans: benen niet te sterk, armen achterblijven" "draad kwijtraken in progressie in lange trajecten"	"Hoe men bestaat" in de ruimte	"links-rechts balans" "Zien op tenen of hielen staat" "beweging meten met gonio overnemen" "Bij topsporters die niet verder komen" "Verklaring vinden voor blessures en recidieves"			"houding en bewegingsruimte"	"topsportwereld" "binnen de fysiotherapie bij langdurige klachten, hernia of langer geblesseerd zijn"	Kosten en hygiëne
Zie Basalt							"stimuleren van oefeningen als het registreren"	" belangrijk (in) revalidatiefase, buiten het ziekenhuis of in het revalidatiecentrum, thuis of in een poliklinische setting"	"patiënt eerder hersteld is. In zijn hersteld te stimumeerd wordt. Verbetering voor de patient betekent."	beter sneller herstel door gerichte oefeningen.	" liefst dat een patiënt zelf er mee aan de slag gaat" "simpele info over vooruitgang, conditieverbetering. moet stimulerend zijn. Inzichtelijk maken of een patient het vaak genoeg doet, vebetering van movement."	"in de oefenfase gebruiken" "revalidatie richting. Met Basalt" "innovatiecentrum in den Haag. Sander Houdijk is daar een van de innovatie adviseurs"	certificering om te werken in ziekenhuisomgeving
"veel beenspieren oefeningen, squats hier. thuis: opstaan, traplopen. kleine dingen vastpakken, wegzetten, bovenin een kastje zetten. meer praktische oefeningen dan losse. Losse oefeningen zijn gericht op core stability"	"Gebruik benen bij 90-95 procent van wat je doet", "bovenbenen zijn nodig voor rompstabiliteit"	"voeten geven heel veel stabiliteit. Daar zitten heel veel sensoren, dus je zoekt daarmee eigenlijk je stabiliteit op	"aanzetten bewegingen in bovenlichaam", "compenseren van basisstabiliteit"		" met losse materialen werken", "oefenzaal met kleine oefeningen", "circuit met dagelijkse activiteiten", "trap, vastpakken spulletjes"	"ergens anders kan compenseren", "beweging altijd beïnvloedt wordt vanuit het hele lichaam",	Inzetten als alternatief voor handmatige, arbeidsintensieve analyse en als registratie en motivatietool	Door kleine locatie kunnen er geen grote/dure installaties worden geplaatst worden. Daardoor moeten we voor de gangbeeldanalyses of de 6min wandeltest zelf beelden opnemen en handmatig analyseren en dit kost veel tijd. "voor motivatie belangrijk om dingen aan te kunnen tonen"					

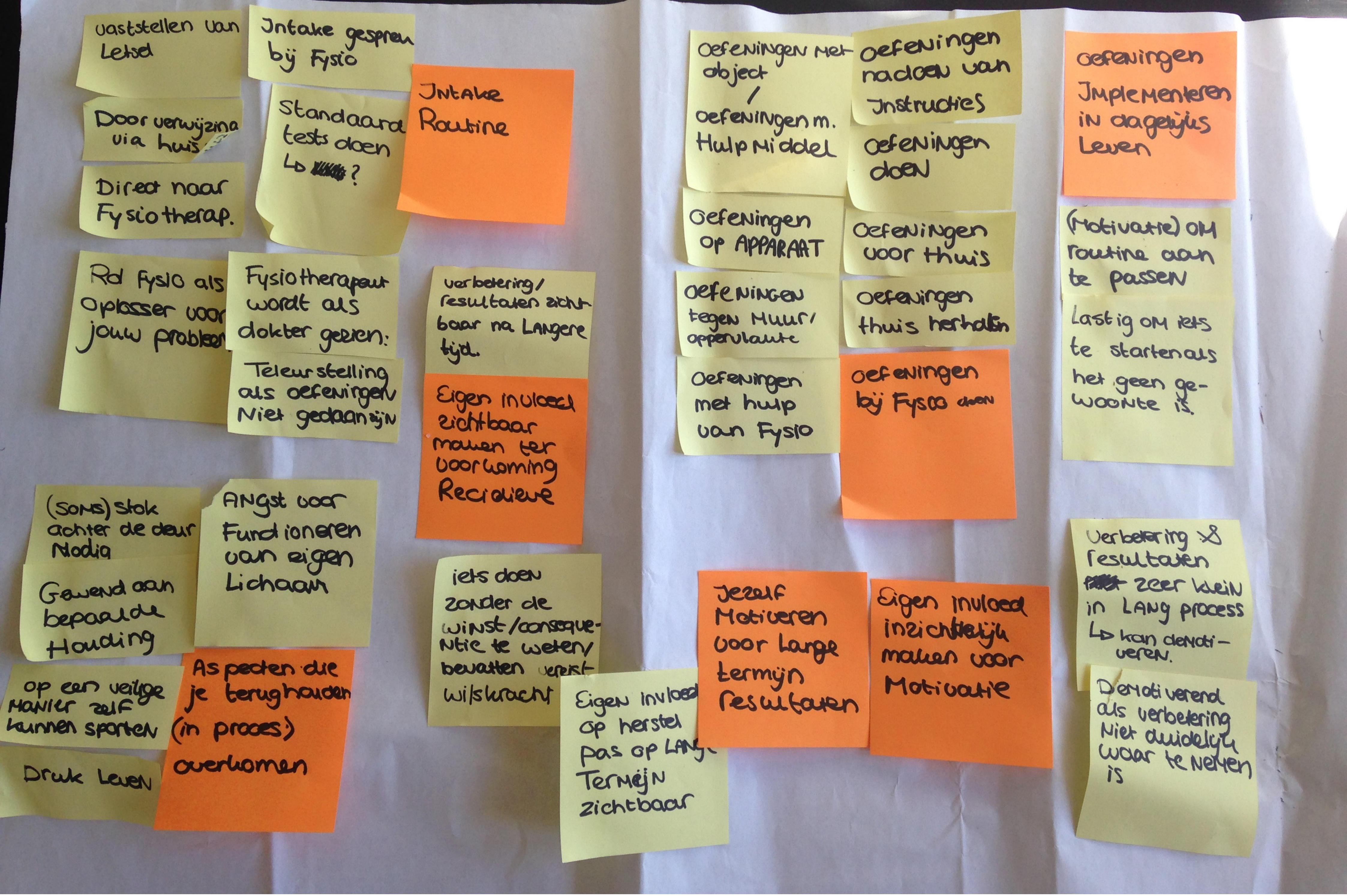


Figure A3.1. Clustering of Interview Results; Yellow: memos, Orange: Memo family name

A.4 PERSONA S

A4.1 NATIONAL AVERAGES

The creation of our persona is divided in two sections: the clinical characteristics and personality traits. From the clinical characteristics, the most suitable conditions for the FBMS are being selected and divided into patient groups. To create relatable personas, the demographic, social environment and personality traits that belong to the patient groups are gathered and verified by conducting user research.

National Averages

The top 10 conditions people seek PT treatment for, are often posture related(Nivel, 2017). 23% of the problems PTs deal with can be attributed to poor posture. The Patient Specific Complaint(PSK) is the most used instrument in 53% of all anamnesis(fig. X). Here, the patient selects three to five complaints that hinder them in their daily or weekly physical activities relevant to them.

Approximately 60% percent of the users of PT are female(fig. X), with an average age of 53. 35,2% are aged 45-64 and 26,8% 18-44(figure X), estimating that approximately half of the PT uses are within the chosen age group of 20-55. On average, people use 10 sessions. Short term usage could apply to 24% of the patients. Another 26% requires 6 months or over(Nivel, 2017)

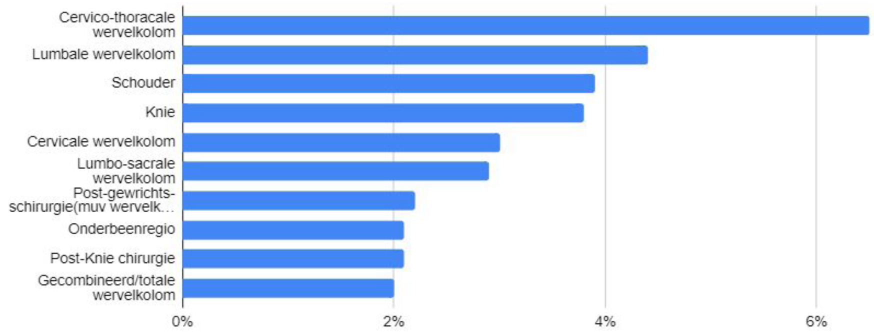


Figure A4.1. Top 10 conditions treated with PT in 2017 (Nivel, 2017

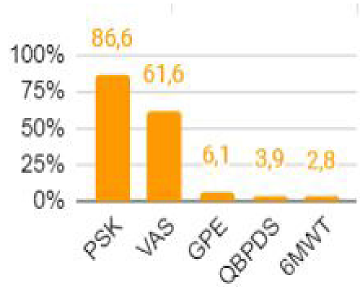


Fig. A4.2. Instruments used

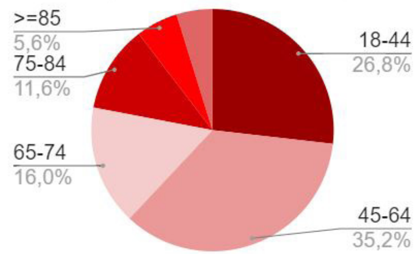


Fig. A4.3. Age groups

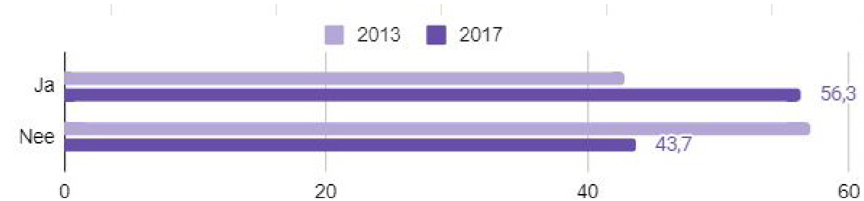
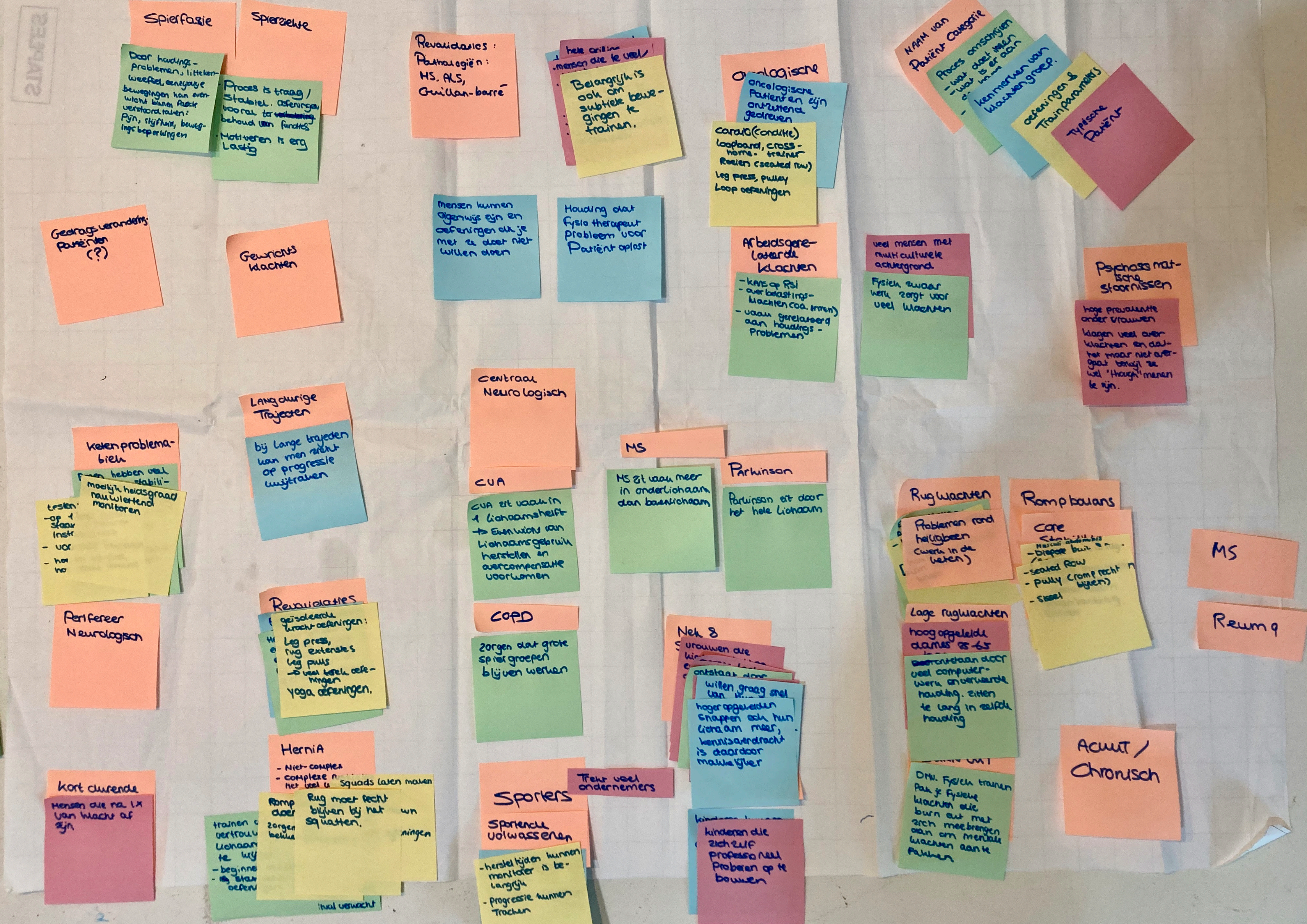


Figure A4.4. Use and amount of measurement instruments in PT


Spierfasie
Spierziekte
Door houdings-problemen, littekenweefsel, eenzijdige bewegingen kan evenwicht binnen fascie verstoord raken: Pijn, stijfheid, bewegingsbeperkingen
Proces is traag / stabiel. oefeningen vooral ter behoud van functies
Motiveren is erg lastig
Revalidaties: Pathalogiën: MS, ALS, Guillan-barré
Belangrijk is ook om subtiele bewegingen te trainen.
Oncologische
oncologische Patiënten zijn ontzettend gedreven
cardio (conditie) loopband, cross-trainer Roeien (seated row) Leg press, pulley Loop oefeningen
Naam van Patiënt Categorie
Proces omschrijven
Kenmerken van klachtengroep.
oefeningen & Trainparameters
Typische Patiënt
Gedragsverandering Patiënten (?)
Gewrichts klachten
mensen kunnen eigenwijs zijn en oefeningen ook je niet ze doet niet willen doen
Houding dat fysio therapeut probleem voor Patiënt oplost
Arbeidsgerelateerde klachten
- kans op RSI
- overbelastings-klachten coa. (armen)
- vaak gerelateerd aan houdings-problemen
veel mensen met multiculturele achtergrond
Fysiek zwaar werk zorgt voor veel klachten
Psychosomatische stoornissen
hoge prevalentie onder vrouwen
klagen veel over klachten en dat het maar niet overgaat terwijl ze wel 'through' menen te zijn.
Centraal Neurologisch
Langdurige Trajecten
bij lange trajecten kan men zicht op progressie uitstralen
Ketenproblematiek
moeilijk heidsgraad nauwlettend monitoren
MS
MS zit vaak meer in onderlichaam dan bovenlichaam
Parkinson
Parkinson zit door het hele lichaam
CVA
CVA zit vaak in 1 lichaamshelft
→ Evenwicht van lichaamsgebruik herstellen en overcompensatie voorkomen
Rugklachten
Problemen rond heupbeen (werk in de benen)
Romp balans
Core
- seated row
- pully (romp recht blijven)
- Steel
MS
Reuma
Perifereer Neurologisch
Revalidaties
geïsoleerde kracht-oefeningen: Leg press, rug extensies Leg pulls → veel kracht oefeningen Yoga oefeningen.
COPD
zorgen dat grote spiergroepen blijven werken
Nek & Schouder
Lage rugklachten
hoog opgeleide dames 35-65
ontstaan door veel computerwerk en verkeerde houding. zitten te lang in zelfde houding
hoger opgeleiden snappen ook hun lichaam meer, kennisoverdracht is daardoor makkelijker
Acuut / Chronisch
Hernia
- Niet-complete
- complete
Squads laten maken
Rug moet recht blijven bij het squatten.
Kort durende
Mensen die na 1x van klacht af zijn
Sporters
Sportende volwassenen
- herstel tijden kunnen monitoren is belangrijk
- Progressie kunnen tracken
Trekt veel ondernemers
kinderen die zichzelf professioneel proberen op te bouwen
Dmv. Fysieke trainen Pak je fysieke klachten die burn out met zich meebrengen aan om mentale klachten aan te pakken

A4.2. CLUSTERING LITERATURE RESEARCH DATA

Method

1. The answers from PTs in section 3 of the interviews were clustered. These answers determined the initial clinical patient clusters

2. The experiences from PTs were compared to national averages, giving insights in the most common ratings.

3. The patients clusters were enriched and verified through a literature study. Prevalence was added to these groups, creating PT profiles (Appendix X).

4a. The Clinical Personas were verified in a small qualitative research session by calling 2 PTs with different clientele to review the clinical personas and give feedback on their accuracy.

4b. Patients are being consulted through a User research survey containing quantitative and qualitative elements. The feedback of potential users serves to assign personality traits and select the target user persona

Left: Figure A4.5. Overview of clustered literature and interview data

A4.3. OVERVIEW OF PATIENT GROUPS

	# 1 Muscle fascia	# 2 Muscular diseases	#3 Oncology
Complaint details	Fascia is a special connective tissue, consisting of fibers from collagen and nerves. In poor condition the tissue can adhere causing pain. This can be caused by bab (work) postures, but also accidents, injuries, stress, overload and too little movement.[1]	Muscular diseases fall under peripheral neurological disorders, including ALS, Guillain-Barré Syndrome (GBS). GBS is a disease that suddenly occurs, leaving patiënts paralyzed within days. ALS and Duchenne are progressive, degenerative diseases slowly attacking muscle functionality.	Cancer survivors can have residual symptoms, such as: fatigue, less strength or poor condition. As a result, they tend to move less, while moving is extra important for them. An active lifestyle contributes to survival and can reduce risk factors for (recurrence of) cancer. [36]
Prevalence	2,44-2,36 per thousand inhabitants, respectively.[2] Plantar fasciitis is most common within the group and often arises during running because people start to work out fanatically without proper preparations and overbalance their foot, ankle and lower leg. [2.4]	**GBS**: 200-330 new patients annually, all ages.[5a] **ALS**: 1500 people, Between 40-60 years old.[6] **Duchenne**: 25 of the annual newborn male population. Life expectancy is not higher than 40.[7]	1 in 3 people will be diagnosed in life. In 2019, approximately 3.5% of the Dutch population was diagnosed: 277,000 men and 301,000 women. [38] Breast cancer prevalence is highest: 119,200 (including men). [37]
Typical patient	Fanatic runner with good intentions after New Years. Femke, 29, studied media & communication. Lives in Amsterdam and likes to jog through the Vondelpark.	GBS: Wesley (53) is the proud father of two children Kevin	Ingrid, 55 Mother of 3 children, administrative worker in a daycare center.
Anamnesis & Treatment	Specific examination of the whole body, treatment of joints, muscles and connective tissue layers. Goals: reduce complaints, improve posture, efficient movement patterns, greater well-being, increased load capacity, increasing resilience to reduce injuries risks.[1]	The diagnosis of muscle diseases is made based on the symptoms and the physical examination.[5] Exercise therapy for maintenance of muscle strength and mobility ensure that this is sustained longer. Focus is on all-day activities. [10]	Using combination of standardized tests.[38] The goals are: pushing/dealing with boundaries, increase pleasure in exercising, developing/regaining an active lifestyle, improving conditional physical functions and anatomical properties and increase/maintain the level of physical functioning. [38]
exercises & Train-parameters	Practically always stretching exercises, with a focus on pain relief [2] Maintaining focus on dexterity and advice for training. [1]	Stretching 4-6 times per week.[11] to keep muscles and joints loose. Breathing exercises to prevent airway inflammation. Training disciplines include: strength training, endurance training (walking, cycling, climbing stairs, swimming) and endurance games [58] to maintain an active lifestyle and avoid underload. Exercises include aerobic exercise and low to medium intensive resistance training.[59]	Training disciplines include: strength training, endurance training (walking, cycling, climbing stairs, swimming) and endurance games [58] to maintain an active lifestyle and avoid underload. Exercises include aerobic exercise.[59] Equipment such as bicycle and ergometer, treadmill, dumbells, barbells, theraband can be used.[38]
Biggest challenges) in treatment	Due to the lack of scientific evidence on the most effective intervention, risk-free and inexpensive treatments such as stretching and posture therapy should be used first. [2]	ALS and Duchenne are degenerative muscle diseases and therefore more and more difficult to perform exercise, while not performing exercises only speeds up the degenerative process: "use it or lose it".	
Therapy	PT; focus on stretching techniques	PT; focus on strength and endurance training	PT; condition training and active lifestyle management

Table A4.3.1. Persona's of patients in the Netherlands

*average age physiotherapist (Nivel, 2017)

Table A4.1. Persona's of PT patients (Dutch Averages)

	# 4 Psychosomatic complaints	**# 5 central neurological disorders (CVA)**	**# 6 Spine problems**
Complaint details	**Fibromyalgia**: chronic pain in muscles and connective tissue. Often pain is accompanied by stiffness, fatigue, bad disturbances and mood swings.[42] **Burnout**: extreme disbalance in mental load and physical capacity disrupt the balance between the stress system and the rest and recovery system. As a result, both mental and physical complaints occur. [40]	In a stroke, something goes wrong in the brain. Part of the brain is no longer receiving oxygen for a shorter or longer period of time. This causes sudden failure symptoms [13]	Spit or lumbago. [22] 95% of all patients have non-specific back pain for which there is no apparent specific cause [23]. In most cases it has to do with the muscles, bands and joints in the back being out of shape.[21] Upper back conditions are often caused by incorrect posture. [56] Cervical complaints often connected to lower back pain. [53]
Prevalence	**Fibromyalgia**: All SOLK group complaints occur in 2.5% of the population [42] It's more common in women than men (3.4% versus 0.5%) and complaints increase with age. [43] **Burn-Out**: 15.1 - 21.4 per 1000 patients, with the male-female ratio being 1: 2. [39]	**CVA**: Appr. 45,000 people/year. Comprise 2.2% of the total cost of health care. [14] **MS**: Occurs in ± 1 in 1000 people, about 17,000 have MS.[60] **Parkinson**: 0.2-0.3/1,000 new patients annually, with 1.8/1000 men, 1.6/1000 women who have it [32]	**Lumbar**: 60-90% of the population will experience nonspecific low back pain at least once in life. The incidence is 40.9/1000 GP patients and is #2 of most common PT complaints, which affects 4.4% of PT patients (Nivel,2017). **Cervical**: 3.0% of all PT patients and 6.5% treated for cervico -thoracic conditions, the #1 PT-condition (Nivel, 2017). **Thoracic**: ±15% op population. ±52-64% of chronic pain is not caused by degeneration of the spine. [54]
Typical patient	**Burn out**: Female law student, 24 with perfectionism and insecurities	CVA: Male 65, works in catering industry, bad health habits.	Lumbago: road worker, aged 48 getting lots or lower back pain. Cervical: office worker who uses wrong posture during her work.
Anamnesis & Treatment	The patient often suspects the diagnosis himself. [39] A PT specialized in the interaction between body and mind and can help to restore balance by, e.g., learn to feel the body better and to recognize signals, building up energy level through exercising.[40] Also exercises for good posture are done. [44]	It is a long trajectory and can take months and years. Remote rehabilitation: consultation, Self- management, lifestyle programs with physical training. Systematic measuring: monitoring, Forecast walking ability six months after the CVA, Forecast basal ADL, Forecast change in walking ability ≥ 6 months , Forecast change ADL skills ≥ 6 months, Systematic feedback on walking speed. Mirror therapy and aerobic system training[14]	With the intake, first ask and provide information about: nature of the condition, degree of activity, imaging diagnostics therapy, employment situation. Expansion of activities: keep moving, even with pain, exercise therapy, behavioral treatment, multidisciplinary rehabilitation[23]. Focus on core stability: Less chance you have of complaints in the lower and upper back.[57]
exercises & Train-parameters	**Fibromyalgia**: Heat up, Exercise of the joints, Shake yourself loose, Stretching, exercises with free weights, Fold hands and push together. [45] **Burnout**: Awareness exercises, massages, posture and movement instructions. [40]	Practicing balance sitting/standing, getting up and sitting down, posture control with visual feedback, Aerobic endurance training, Muscle strength training, combine aerobic endurance with muscle training.[14]	Few exercises: Convex, Rotation and swinging, Rotation position: to mobilize upper bac, Stability thoracic spine: make upper back stronger, squat.[55]
Biggest challenges in treatment	Both conditions suffer from fatigue, poor body strength and a body that tends to resist movement. Exercising is necessary to alleviate complaints but mentality is a big hurdle.	Very long health journey, easy to lose track of progress.	Pain can be experienced, but this is mainly experienced as resistance of the muscles that have become accustomed to the patient's preferred posture. It is important to continue, but alternate enough with rest. (interview wander)
Therapy	Psychosomatic PT; posture and condition	RT+PT: condition and self-management	PT; Cesar-Mensendieck exercise therapy

Table A4.1. Persona's of PT patients (Dutch Averages)

Naam	#7 Hernia	# 8 rheumatism (arthrosis)	#9 COPD
Complaint details	Hernia nuclei pulposi involves damage to the intervertebral discs. These damages most commonly occur in the lower third of the back (the lumbar spine). [46]	Rheumatism is a collective name for more than a hundred different diseases of the joints, which were not caused by an accident. Most people with rheumatic complaints have osteoarthritis (1.1 million)	COPD is a lung disease in which your lungs are damaged. Breathing is more difficult and you have less energy. The acronym COPD stands for Chronic Obstructive Pulmonary Disease (Chronic Obstructive Pulmonary Disease). [17]
Prevalence	36 per 1,000 patients per year and shows [48] The incidence of a true hernia is highest in people between the ages of 30-64 and affects slightly women than men. [47]	**Arthrosis**: Most common musculoskeletal condition, with hip and knee being the most common localizations. An estimated 927,300 patients, half PT every year.[11] **Artritis**: 238,000 people have RA (1.4% of the population). Number is expected to be >300,000 by 2030. Costs: € 51,120,000 for primary care, including PT. [12]	Chance increases with age. 40 to 45 (0.7%) percentage increases to 15% at 80 to 85 (2007). COPD is more common in the lower social class. [16]
Typical patiënt	Vrouw 50, Bus Driver, https://books.google.nl/books?id=JNaam4qWNuwC&pg=PA210&lpg=PA210&dq=buschauffeurs+hernia&source=bl&ots=1yZ6ybracE&sig=ACfU3U1SILisEe91CtZEKJq0uJg9muhxhw&hl=nl&sa=X&ved=2ahUKEwiO7uvzj8rqAhVIyaQKHRFUCDgQ6AEwB3oECAoQAQ#v=onepage&q=buschauffeurs%20hernia&f=false https://chiropractiekes.nl/klachten-chiropractor/hernia	Arthrosis: older lady, 75, pensioned, needs new hip: • old age, at least 45+ • female gender, genetic predisposition, overweight • poorer overall health / vitality - disorder of other joints - heart or lung disease, diabetes, vision or hearing problems • psychosocial functioning (depression, anxiety, coping style, cognition)	
Anamnesis & Treatment	The treatment is tailored to the capacity of the patients back in the recovery period after surgery and therefore has a build-up in load and movement results. Information from the physical therapist about various aspects of recovery is an essential part. [49]	Active physical exam and activation exercise therapy to improve muscle strength, fitness and daily activities, combined with advice / information. PT can be offered individually or in groups, provided that treatment is tailored to the individual patient [12].	Physical exam, including 6 minute walking test. Therapy focuses on reduce short breathness, improve exercise capacity and physical activity, mucus clearance, knowledge, self-management and confidence to do things.[16]
exercises & Train-parameters	Raise knee, back roll, twist back with knees, flex foot with leg on knee, make sitting back hollow and convex, stand on toes (one or 2 legs), stand on heels [50]	Exercises are tailored. Patients during and especially after the treatment period also independently exercise and exercise enough to maintain the treatment effects in the long term. [12]	Endurance training: treadmill, bicycle ergometer Interval training (alternative to endurance training) Resistance training (added component to endurance or interval training).[16]
Biggest challenges) in treatment	Do not blast too much and do not bend too much (always keep your back straight), do not sit too long in a row.	Moving can be very painful due to decrease of cartilage.	Lack of compliance is a known problem. Willingness, motivation, confidence to succeed and barriers to behavioral change determine treatment goals and expectations.[16]
Therapy	PT; core stability training	PT; Geriatric therapy	PT; lifestyle and self-management

Table A4.1. Persona's of PT patients (Dutch Averages)

	#10 KANS	# 11 joint complaints (ankle)
Complaint details	(pain) complaints in the arm (upper or lower arm, elbow, wrist or hand), neck and / or shoulder, or a combination of these. Often disruption between load and resilience: long-term activities, repetitive movements or static posture, whether or not work-related, during work, household, study, sport or hobby. [30]	inversion injury involving examination and treatment 0 to 6 weeks after its onset. [18]
Prevalence	More than a third of Dutch adults report KANS in the past year, with 97 per 1000 patients enrolled per year reporting to the GP. [31] **Neck**: 101.8 per 1,000 men and 137.6 per 1,000 women. 1.6 million visited the physiotherapist for this. [27] **Shoulder**: Annual prevalence with GPs is 3.1%. 40% of patients with shoulder complaints visit their GP for this. The incidence and prevalence increase with age and are higher in women than in men from puberty.	8/1000 patients annually, of which 600,000 are athletes. Highest incidence is in 15-24 years old(males: 17.8/1000, females: 14.2/1000 per year). Above 45 years, more women than men have distortions in joints.[19]
Typical patient	Nek-schouders: Vrouwen 30-40 met stressvolle kantoorbaan Schouder: mannen 30-45 die te actief gaan sporten zonder ervaring en te veel gewicht gaan hebben (interview met PTs)	
Anamnesis & Treatment	Limitations in/reduced range of motion.[30] Advice first: reduce activity level/load, emphasize active lifestyle. After decreasing pain: practice time quota and increase load. Discuss: origins of health problems, recovery factors and influence. Analysis: provocative/ reducing activities, actions/tasks for disorders Instruction:Increase load gradually, Regular evaluation of whether patient understands information and follows advice. [30]	Repetition of an ankle sprain occurs in 3-34% of people and can be significantly reduced by improving the strength, coordination and stability of the ankle. [20]
exercises & Train-parameters	Correct execution movements, Increase mobility of joints; Relaxation exercises, Feeling correct posture and movement, coordination of movements, Work / ADL activity skills	With weak ankles or previous ankle injuries, it is important to perform additional muscle strengthening exercises[20]: One-legged knee flexion, One-legged balance exercise, push up from the toe, rider position, crossed leg swing, toe run.
Biggest challenges in treatment	People vary to what extent they can tune load to their physical and mental abilities (capacity). The extent to which this happens determines the course of the condition.[30]	After 6 weeks you can usually start exercising again. [18] However, many people in the high prevalence target group often overestimate their healing and go beyond their borders, harming full recovery [21]
Therapy	PT; Cesar-Mensendieck exercise therapy	PT; targeted exercise therapy

Table A4.1. Persona's of PT patients (Dutch Averages)

Conclusion

The patient groups from table A4.3.1 are described based on what binds them together by their condition. But what binds them together as a group of people, based on their behaviour, socio-economic demographic and experiences? Five persona's were created. Evaluating these five personas with the selection criteria, their prevalence and expert feedback for application, Lower Back Pain is the condition that will be the focus of the FBMS. Moreover, when the condition is related to the persona, it also becomes very relatable to society's current situation. To relate lower back problems to real world experiences, a small user research was performed(N=3). From this, a day-in-the-life profile was created(figure X).

A4.4 PERSONA VALIDATION RESEARCH

A small usertest was performed to obtain quantitative data about real world experiences. For this, the online tool qualtrics was used. In total, X items were used to obtain data in this study. The list of items can be found in table X.5E.1. Upfront, consent was requested before participation. The survey was distributed among personal Facebook Network and PT connections. Three entries have been deemed valid(N=3).

Item	Section	Item description	Scale
1	Introduction	Survey Introduction	Text
2		Consent	Two point answer
3	Complaints	Segment introduction	Text
4		Voor welke klacht wordt u op dit moment behandeld?	Multiple choice
5		Hoe is de klacht in uw beleving(of na uitleg van fysiotherapeut) ontstaan?	Multiple choice
6		Hoe vaak heeft u al last gehad van deze klacht?	Multiple choice
7		Hoeveel sessies in totaal heeft u voor deze klacht aan fysiotherapie besteed?	Multiple choice
8		Ervaart u verbetering van de klacht doordat u fysiotherapie volgt?	Multiple choice
9		Hoe wordt deze vooruitgang bijgehouden?	Multiple choice
10		Bent u tevreden met de vooruitgang die u boekt? (en kunt u dit wellicht kort toelichten)	Multiple choice
11		Wat is over het gehele proces uw ervaring met fysiotherapie?	Text Entry
12	Exercises	Segment Introduction	Text
13		Heeft u oefeningen meegekregen om thuis, of buiten de fysiotherapie-zittingen om, te doen?	Multiple choice
14		→ If Yes(13: Kunt u deze oefeningen opnoemen en wellicht beschrijven?	Text Entry
15		Hoe vaak moet u deze oefeningen doen? En hoeveel sessies?	Multiple choice + text
16		Hoe gaat het met het beoefenen van deze oefeningen buiten de fysiotherapie-zittingen om?	Multiple choice + text
17		Denkt u dat deze oefeningen, die u tussen de sessies waarbij u de fysiotherapeut ziet, helpen bij het verminderen van uw klachten?	Multiple Choice
18		Hoe zorgt u voor motivatie om de oefeningen te blijven doen?	Text Entry
19		Waardoor kan uw motivatie beïnvloed worden?	Multiple Choice
20		Heeft u ook oefeningen mbt houdings- of bewegingsgewoonten?	Multiple choice
21		Hoe goed gaat het met het veranderen van uw houdings- of bewegingsgewoonten?	Multiple choice
22		Waarom vindt u het lastig dit gedrag aan te passen?	Text Entry
23	Interaction	Segment Introduction	Text
24		Wat is uw ervaring m.b.t. de volgende ervaringen? - Hoe ervaart u de omgang met uw fysiotherapeut? - Hoe ervaart u de begeleiding van uw fysiotherapeut? - Hoe ervaart u de feedback van uw fysiotherapeut? - Hoe goed kunt u vertrouwen op zijn/haar oordeel?	Five point likert scale
25		Hoe groot denkt u dat de invloed van de fysiotherapeut is ten opzichte van uw eigen invloed in het genezingsproces? (Denk aan uw oefeningen doen, adviezen opvolgen)	Five point likert scale
26	Lifestyle	Segment Introduction	Text
27		Hoe vaak sport u per week? (daaronder verstaan we bewust ingedeelde tijd van minstens 1 uur	Multiple Choice

Table A4.2. Items Factor validation survey

		aan een sportieve activiteit)	
28		De volgende vragen gaan over het hebben van een gezonde levensstijl. In welke mate heeft u deze gewoonte? - Roken - Alcohol - Sporten - Lang achter elkaar zitten	Three point likert scale
29	Experience	Segment Introduction	Text
30		Hoe voelt u zich of wat ervaart u wanneer u de gegeven opdrachten van de fysiotherapeut zelf, zonder begeleiding, thuis doet? (fig. A5.1.1)	Heatmap
31		U heeft nu één of meerdere afbeeldingen gekozen. Waarom heeft u deze afbeeldingen gekozen? Wat betekenen deze plaatjes voor u?	Text Entry
32		Hoe ervaart u het contact met de fysiotherapeut? (fig. A5.1.2)	Heatmap
33		U heeft nu één of meerdere afbeeldingen gekozen. Waarom heeft u deze afbeeldingen gekozen? Wat betekenen deze plaatjes voor u?	Text Entry
34		Hoe voelt u zich of wat ervaart u wanneer u de gegeven opdrachten niet doet? (fig.A5.1.3)	Heatmap
35		U heeft nu één of meerdere afbeeldingen gekozen. Waarom heeft u deze afbeeldingen gekozen? Wat betekenen deze plaatjes voor u?	Text Entry
36		Mag ik u hierover terugbellen?	Two point answer
37		U heeft aangegeven dat ik contact met u mag opnemen. U kunt hier uw gegevens achterlaten:	Text Entry
38	Demographic	Wat is uw...? - Leeftijd; Gender; Opleiding; Baan; Nationaliteit; Religie; Familiestatus	Text Entry
39	End	Bedankt voor het invullen van deze survey!	Text

Table A4.1. Persona's of PT patients (Dutch Averages)

Figure A4.6 Context Mapping Heatmap Q30

Figure A4.7 Context Mapping Heatmap Q32

Figure A4.8 Context Mapping Heatmap Q34

Results Target Users validation Questionnaire

#P	item 1	2	3	4	5	6	7	Text	8	9	10	11	12	13	14	15
1	Nek en schouder	Overbe- lasting	1st time	12>	Ja	bijgehouden: Vooruitgang in bewegingen	Ja	meer bewegingen pijnvrij maken	Goed	Ja	Corrigerende oefeningen voor houding schouder	1x/ dag	Het zelf doen van deze oefeningen gaat prima	Ja	Gewoon elke ochtend direct uit bed. Even lekker bewegen	Vergeten
2	Mensen- dieck	Incident	1st time	<12	Ja	bijgehouden: Trainen bovenbeen spieren trainen o.b.v. personal trainer.	Ja	durven te sporten, bijna helemaal vrij in doen(dansen, springen, buitenspelen met kinderen op werk)	Qoute 1*	Ja	Pistol squats, lateral leg raise, Bulgarian split squats, step ups	1x/ dag	Het zelf doen van deze oefeningen gaat prima	Ja	Focussen op resultaat (pijnvrij sporten)	geen zin
3	gewrichts - klachten	Overbe- lasting	2nd time	<12	Ja	?	?		Enigszins tevreden, weet niet zeker of erg effectief is	Ja	Oefenen om enkel sterker te maken	1>/ week	Ik vergeet de oefeningen vaak te doen	?	Wil pijnvrij zijn	Vergeten

# P	16	17	18	19	20	21	22	23* & 24	25* & 26	27* & 28	29	30
1	Ja	Over het algemeen goed	Nvt	Erg goed (4x)	Evenveel als therapeut	>1x /week	Sporten & zitten: (te)veel	plaatjes met tekst gekozen.	Goede communicatie	Oeps	V(25), NL, WO	-
2	Nee	Nvt	Nvt	Erg goed, Goed 2x, erg goed	Relatief groot	>1x /week	Sporten & zitten: (te)veel	De spiegel omdat ik goed in de gaten houd of mijn knie recht blijft.	Fijne tijd gehad.	-	V(25), NL, WO	-
3	Nee	Vergeet 't vaak	Luiheid	Goed, erg goed, goed(2x)	Relatief groot	>1x /week	Sporten & zitten: (te)veel	-	-	-	V(35), NL, WO	-

Table A4.3. Target User research results overview

"De eerste keer was na overleg met het ziekenhuis als revalidatie. Ik moest met krukken lopen en daarna weer kracht en stabiliteit opbouwen. Dit proces heb ik al fijn ervaren. De tweede keer was nadat ik meer klachten kreeg aan mijn knie. Deze arts heb ik als heel meedenkend en deskundig ervaren. Ik was niet ruim verzekerd en hier hield de fysio rekening mee door minder afspraken in de praktijk te doen en meer te vertrouwen op het feit dat ik de oefeningen thuis/in de sportschool deed. "

Quote 1. Item 10, Participant 1

Conclusions Target Users validation Questionnaire

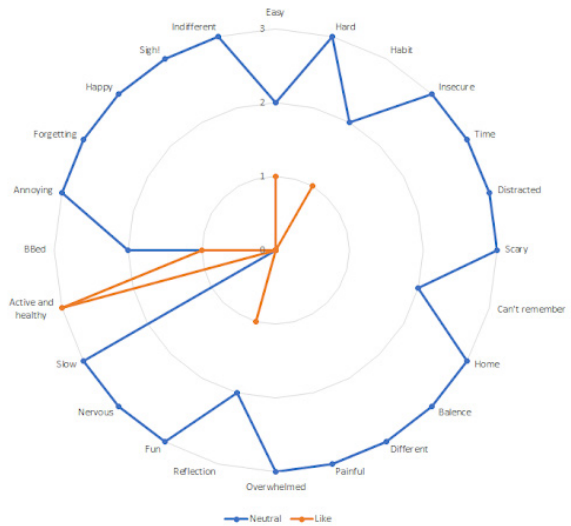


Fig. A4.9 Graph item 23: Exercises

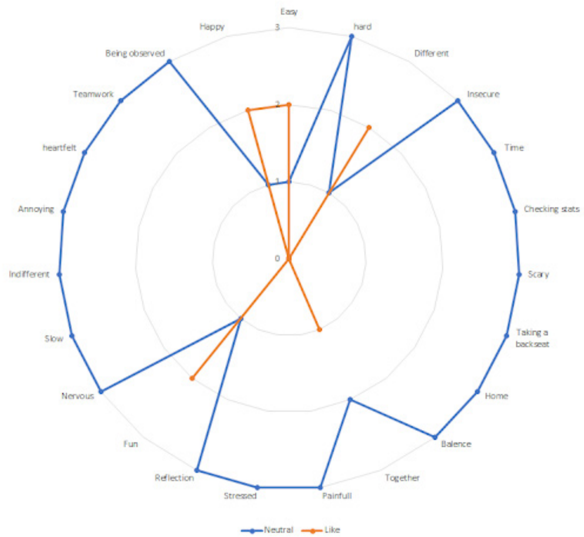


Fig. A4.10 Graph item 25: Contact with PT

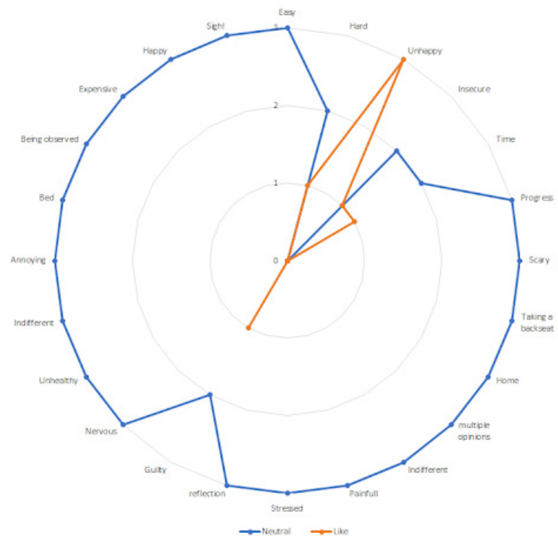


Fig. A4.11 Graph item 27: Not doing Exercises

The survey was filled in completely by three out of six participants. Therefore, this research is considered more explorative than quantitative. Among the participants, neck, shoulder and joint pain were indicated for their PT treatment, stemming from an incident and overloading of the body. And all of them mention sitting too much, which is unhealthy for the body as well. Two participants mentioned they track their progress: either by experiencing their improvement or having their personal trainer be the judge of that. Reasoning behind choosing to participate in PT is getting rid of pain during movement and, more importantly, getting rid of the fear of pain for movement. This is an important factor in perceiving quality of life. Two participants mention they are happy with the results they have achieved, of which one says she was happy the PT trusted her with self management. One participant remains unsure. It is noticeable that this participant does seem to have the most issues with following through on her exercises at home. Although there is too little data to support this claim, it does coincide with previous found arguments and information in this research so far. In general, reasons for not doing exercises is forgetfulness, but this doesn't result in guilt over failure to comply with exercises. This might be because the participants already engage with sports in their spare time.

When it comes to the exercises, the following exercises are done: corrective exercises for shoulder, Pistol squats, lateral leg raise, Bulgarian split squats and step ups. These are done one time a day for both participants. What is noticable is a lot of squats. It is also important to keep the body straight, see figures X.5E.4-7. There is also a mention of using the mirror, to know whether the exercise is done straight. This indicates a need for correct alignment of the whole body above a certain point to make the exercise successful.

The two participants that mention feeling good about their process and see results, have no problem with doing their exercises. However, the person that does not feel like this, answered she has troubles keeping motivation sometimes. Overall, participants feel happy and healthy while doing their exercises, indicating positive feelings towards following up on their homework. The experience with a physical therapist should be Fun, Happy, Easy and Together. Different was confirmed two times, indicating that it would be nice if exercises are changed up. Finally, Participants felt unhappy and somewhat guilty(but not too much) for not doing exercises. Perhaps feeling somewhat insecure. This, the FBMS should counter.

Maintaining a rhythm appears to be important for participants in avoiding the latter does not happen too often. One of the participants does her exercises straight out of bed. Embedding the new exercises in a ritual is a way to get the exercises done, and more importantly not forget about them as this is one of the mentioned reasons for not doing them in the first place. Having something in place, whether tangible or as a service, could be a solution to keep up the work patients need to put in themselves to make the treatment successful.

Figure A4.6 Context Mapping Heatmap Q30

Figure A4.8 Context Mapping

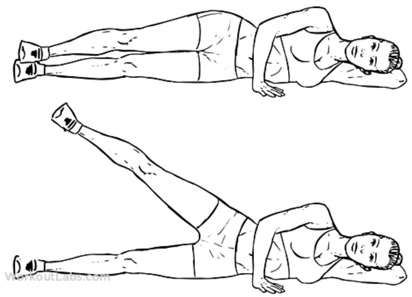


Figure A4.7 Context Mapping Heatmap

Figure A4.8 Context Mapping Heatmap

A5. FACTOR ANALYSIS

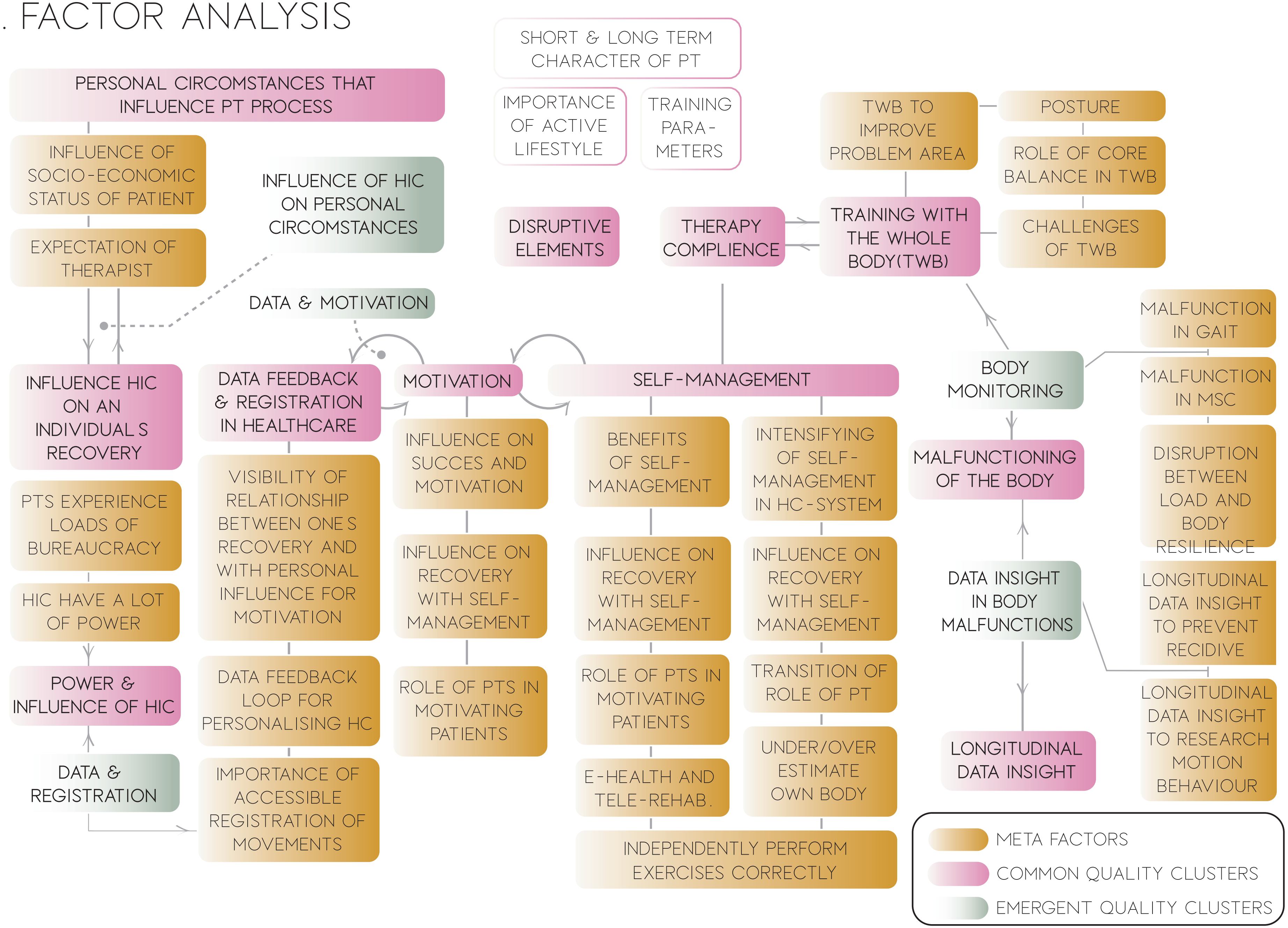


Figure A5.1. Persona's of PT patients (Dutch Averages)


Motivatie
DATA ↔ Motivatie
Rol van Fysiotherapeut in Motiveren
Betekenissen in Motivatie
Invloed van Achtergrond Patiënt bij Fysiotherapie
Persoonlijke omstandigheden die proces beïnvloeden
Korte & Lange termijn van Fysiotherapie
Invloed Succesmomenten & Motivatie
Zelfstandig correct uitvoeren van oefening
Macht & Invloed Zorgverzekeraars
Belang van Actieve Leefstijl ontwikkelen

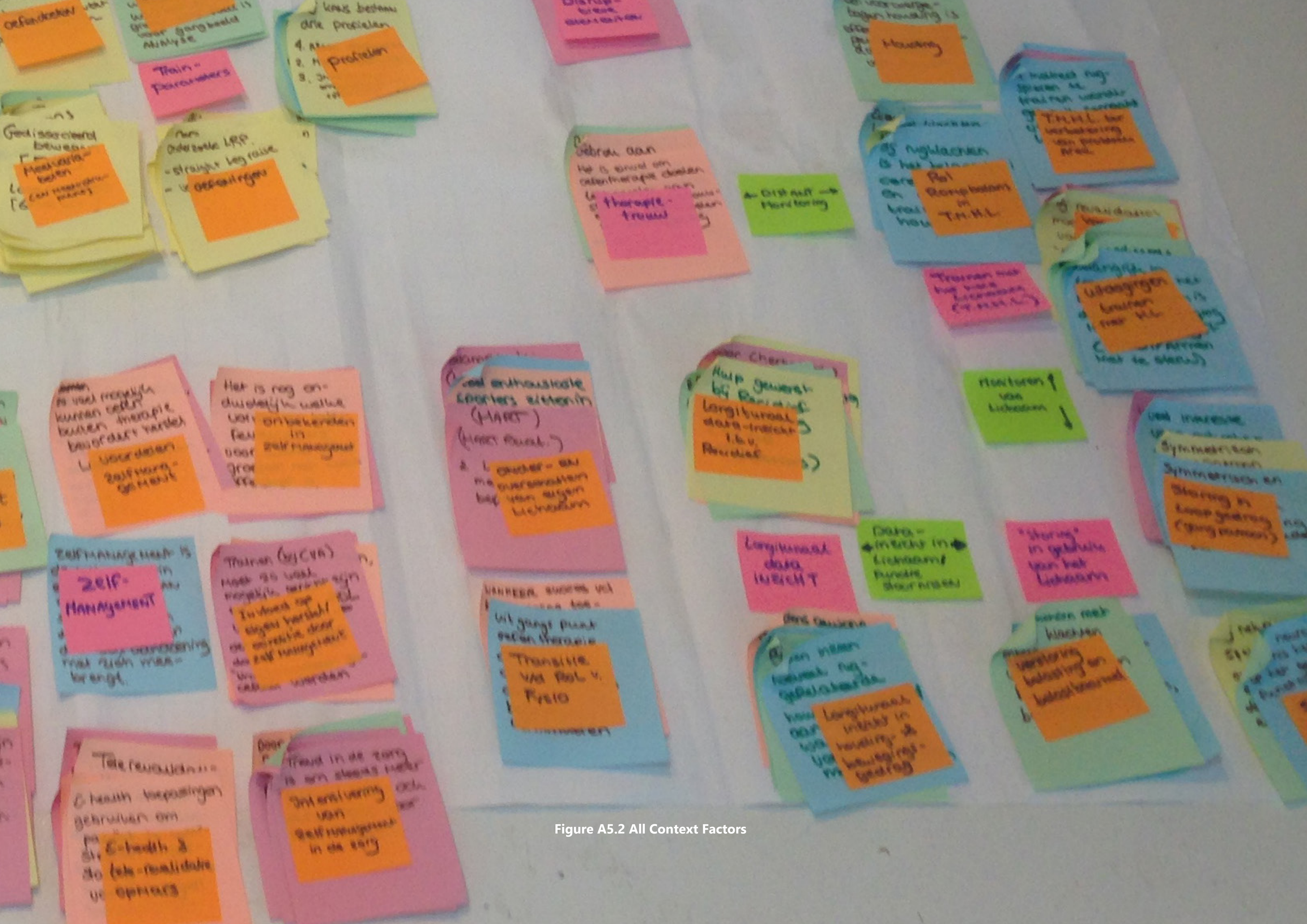


Figure A5.2 All Context Factors

A5.1 FACTOR ANALYSIS VERIFICATION QUESTIONNAIRE ITEMS

#	Section	Item		Item type
1	Introduction	Survey Introduction		Text
2	Consent		Consent text	Two point answer
3	Aspects of the suit	Segment introduction: In mijn onderzoek en uit de interviews zijn een aantal zaken naar voren gekomen die een rol spelen in fysiotherapie. Hieronder kunt u aangeven welke punten u belangrijk vindt binnen uw vakgebied. Dit mogen ook punten zijn waarvan u vindt dat daar meer aandacht aan zou moeten worden besteed. A. Het kunnen inzien van persoonlijke omstandigheden van een patiënt die het fysiotherapeutische proces kunnen beïnvloeden(zoals bijv. werkomstandigheden) B. (Beter) kunnen omgaan met de (toenemende) invloed die zorgverzekeraars uitoefenen op fysiotherapeuten C. (Beter) kunnen omgaan met de (toenemende) invloed die zorgverzekeraars uitoefenen op patiënten D. De mogelijkheid om direct van het lichaam data af te lezen, te registreren en feedback van te ontvangen E. Motivatie onder patiënten verhogen F. Het bevorderen van zelfmanagement G. Longitudinaal data-inzicht verkrijgen in een aandoening of conditie (denk bijvoorbeeld aan chronische indicatie of recidive) H. Storingen in het gebruik van het lichaam kunnen opsporen I. Trainen met het hele lichaam J. Therapietrouw (bevorderen) K. Belang van het onderhouden van een actieve levensstijl L. Korte- en lange termijn interventies onderscheiden in fysiotherapie M. Disruptieve elementen kunnen opvangen (zoals bijv. Covid-19 crisis)		5 point likert scale
4		→ If (3A> Neutral)	In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "kunnen inzien van persoonlijke omstandigheden van een patiënt die het fysiotherapeutische proces kunnen beïnvloeden"? - De invloed van de achtergrond van een patiënt - Verwachtingen die iemand heeft bij fysiotherapie/ de gekozen behandeling	5 point likert scale
5		→ If (3B> Neutral)	In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "(Beter) kunnen omgaan met de (toenemende) invloed die zorgverzekeraars uitoefenen op fysiotherapeuten" en "op patiënten"? - Fysiotherapeuten ondervinden te veel bureaucratie en registratiedruk - Zorgverzekeraars hebben veel macht - Het verschil tussen wat verschillende patiënten aan behandelmogelijkheden hebben wordt steeds groter.	5 point likert scale
6		→ If (3D> Neutral)	In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "De mogelijkheid om, direct van het lichaam, data af te lezen, registreren en feedback van te ontvangen"? - Zichtbaarheid in het eigen herstel en de eigen invloed daarop; deze relatie zichtbaar maken om patiënten te motiveren - Een data-feedback loop kunnen maken voor het optimaliseren van de behandeling voor een patiënt. - Het kunnen registreren van bewegingen	5 point likert scale
7		→ If (3E> Neutral)	A. In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "Motivatie onder patiënten verhogen"? - Behaald succes kunnen meten ter motivering van patiënten - Gevolgen van belemmeringen in motivatie kunnen aankaarten - De rol die fysiotherapeuten spelen in het motiveren van patiënten	5 point likert scale
8		→ If (3F> Neutral)	In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "Het bevorderen van zelfmanagement"? - Het kunnen benadrukken van zelfmanagement - Invloed van zelfmanagement op herstel/ conditie zichtbaar maken - Invloeden van beperkingen in zelfmanagement kunnen inzien - Inzetten van E-health, waaronder tele-revalidatie en consultaties - Het zelfstandig correct kunnen uitoefenen van oefeningen door de patiënt	5 point likert scale

			- De intensivering van zelfmanagement in de zorg - Het kunnen inzien of er sprake is van onder- of overbelasting (voor zowel patiënt als fysiotherapeut) - De veranderende rol van de fysiotherapeut	
9		→ If (3G> Neutral)	In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "Longitudinaal data-inzicht verkrijgen in aandoening of conditie (denk bijvoorbeeld aan chronische indicatie of recidive)"? - Longitudinaal inzicht verkrijgen ten behoeve van recidive - Longitudinaal inzicht verkrijgen ten behoeve van chronische aandoening - Longitudinaal inzicht verkrijgen ten behoeve van houding en bewegingsgedrag	5 point likert scale
10		→ If (3H> Neutral)	In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "Storingen in het gebruik van het lichaam opsporen"? - Storingen in het loopgedrag kunnen opsporen - Storingen in ketens kunnen opsporen - Verstoring tussen balans en belastbaarheid kunnen opsporen	5 point likert scale
11		→ If (3I> Neutral)	In welke mate vindt u de volgende factoren belangrijk binnen het aspect van "Trainen met het hele lichaam"? - Trainen met het hele lichaam ter verbetering van een probleem gebied (bijvoorbeeld planks doen voor core balance) - Houding kunnen meten en monitoren - Rompbalans kunnen meten en monitoren - Risico's van trainen met het hele lichaam verminderen (wanneer patiënten oefeningen zonder supervisie uitvoeren)	5 point likert scale
12		Ontbreken er volgens u nog aspecten of factoren die in de bovenstaande vragen niet vermeld zijn? Vul ze hieronder aan.		
13	Trends	Welke trends gaan volgens u een rol spelen van hoe fysiotherapie er in in de toekomst uit gaat zien? A. De focus gaat verschuiven: van proberen te genezen naar het behouden van een goede gezondheid B. Mensen raken steeds meer geïnteresseerd in hun eigen gezondheid C. De kwaliteit van apps om medische- en gezondheidsdata te tracken, meten en monitoren wordt steeds beter D. De opkomst van E-health(waaronder wearable technology en teleconsultaties) E. Er gaat steeds meer ingezet worden op Zelfmanagement F. De komst van Persoonlijke Gezondheidsomgevingen (PGO's) G. Het personaliseren van zorg door komst van het Value Based Healthcare (VBHC) model H. De informatiepositie van patiënten wordt steeds sterker I. Patiënten worden steeds kritischer op de zorg die zij ontvangen J. Verschuiving van plek waar zorg primair ontvangen wordt: van zorginstelling naar eigen omgeving(thuis/werk) K. Veranderende omstandigheden en structuren waarin zorgaanbieders(o.a. fysiotherapeuten) hun diensten aanbieden L. Technologische ontwikkelingen in het algemeen M. Digitale evolutie in de gezondheidszorg N. Nederlandse socio-politieke invloeden (zoals de verschuiving van verzorgingsstaat naar participatiesamenleving) O. Zorginnovaties door commerciële partijen P. Het kunnen lenen van medische hulpmiddelen Q. Covid-19		5 point likert scale
14		Ontbreken er volgens u nog trends die in de bovenstaande vragen niet vermeld zijn?		Text Entry
15	Vision	Segment Introduction		Text
16		In welke mate bent u het eens met de volgende visie: "Ik wil dat patiënten...waardoor hun motivatie en zelfmanagement worden vergroot"		5 point likert scale
17		Na aanleiding van deze enquête, en met name bovenstaande visie, heeft u nog iets toe te voegen aan uw antwoorden?		Text Entry
18	Samenwerking	Bent u bereid om samen te werken?		Multiple choice
19		→ If Yes:	Name and Email	Text Entry fields
20	End	Outro		Text

Table A5.1. Factor Analysis verification questionnaire items

Items	Answers							
	Sum Average: 4,6≥			**Sum Average: 4,75 - 4,8**				
1	Insight into the patient's personal circumstances	Detect defects in the use of the body	Increase motivation among patients	Directly read data from body, register and receive feedback	Maintaining an active lifestyle			
2			Measure achieved success to motivate	Being able to emphasize self-management	Visualize the influence of self-management on recovery / fitness	Inspection under or overload on body	Being able to detect faults in chains	Being able to register movements
3			More commitment to Self-management	More interested in own health	Patients are increasingly critical			
4	Strongly agree	2						
	Agree	3						
5	Recruiting and guiding	3						
	No	1						
	Other	1	Ja, mits dit ook binnen ons Revalidatie centrum op dat moment ook mogelijk is					

Table A5.2. Factor Analysis verification questionnaire results

A5.2 QUESTIONNAIRE RESULTS OVERVIEW

Items	Answers							
	Sum Average: 4,6≥			**Sum Average: 4,75 - 4,8**				
1	Insight into the patient's personal circumstances	Detect defects in the use of the body	Increase motivation among patients	Directly read data from body, register and receive feedback	Maintaining an active lifestyle			
2			Measure achieved success to motivate	Being able to emphasize self-management	Visualize the influence of self-management on recovery / fitness	Inspection under or overload on body	Being able to detect faults in chains	Being able to register movements
3			More commitment to Self-management	More interested in own health	Patients are increasingly critical			
4	Strongly agree	2						
	Agree	3						
	Recruiting and							

Table A5.2. Factor Analysis verification questionnaire results

Items	Answers							
	Sum Average: 4,6≥			**Sum Average: 4,75 - 4,8**				
1	Insight into the patient's personal circumstances	Detect defects in the use of the body	Increase motivation among patients	Directly read data from body, register and receive feedback	Maintaining an active lifestyle			
2			Measure achieved success to motivate	Being able to emphasize self-management	Visualize the influence of self-management on recovery / fitness	Inspection under or overload on body	Being able to detect faults in chains	Being able to register movements
3			More commitment to Self-management	More interested in own health	Patients are increasingly critical			
4	Strongly agree	2						
	Agree	3						
5	Recruiting and guiding	3						
	No	1						
	Other	1	Ja, mits dit ook binnen ons Revalidatie centrum op dat moment ook mogelijk is					

Table A5.2. Factor Analysis verification questionnaire results

A5.3 QUESTIONNAIRE OUTCOMES

Items	Answers								
	Sum Average: 4,6≥			**Sum Average: 4,75 - 4,8**					
1	Insight into the patient's personal circumstances	Detect defects in the use of the body	Increase motivation among patients	Directly read data from body, register and receive feedback	Maintaining an active lifestyle				
2			Measure achieved success to motivate	Being able to emphasize self-management	Visualize the influence of self-management on recovery / fitness	Inspection under or overload on body	Being able to detect faults in chains	Being able to register movements	
3			More commitment to Self-management	More interested in own health	Patients are increasingly critical				
4	Strongly agree	2							
	Agree	3							
	Recruiting and								

Table A5.3. Summary questionnaire outcomes

A6. TEXTILE STRAIN SENSOR RESEARCH

A6.1 INTRODUCTION

For the creation of a smart textile sensor, the option for a fabric, stitch, knitted and single yarn based sensors was explored. Exploring literature about the latter, it is reported by Mattman, Clemens and Troster(2007) that single yarn based sensors were able to recognise a wide variety of body postures. Second, this sensor type has great properties and proved easy to prototype. However, due to the difference in stiffness between the sensor and the lycra substrate fabric, there was no response below 10% strain levels. This might prove a problem when static posture is measured when a patient's exercise is to stand up straight. Sensors made from conductive fabric displayed large irregularities in resistance after use and being washed, making their measurements unreliable(Schevers, 2016). Having the domain of PT in mind, this is not an option as the suit will be washed frequently. Stitched sensors have a benefit over (integrated) knitted sensors as they can be easily added and altered during the manufacturing process of a garment, while preserving comfort for the user(Gioberto & Dunne, 2016). For the production of the prototype of the FBMS, it is important fast iterations can be made to improve the quality of the concept. With these criteria presented, a stitch sensor shows to be favored for the development of an initial concept prototype.

The response of stitched sensors relies heavily on the physical properties(Jansen, 2020) as well as the anisotropy of the substrate(Dupler & Dunne, 2019) to which it is stitched. Besides the composition of the yarn, the response of the sensor is also influenced by the structure the yarn is stitched(Dupler et al, 2019). For the composition of the yarn, silver plated nylon yarns obtained the best and reproducible results(Jansen, 2020). Greenspan, Hall, Coa, & Lobo(2018) found the zig-zag stitch(304) to show the most stable response to resistance change after multiple cycles. Greenspan et al. produced their results on a substrate of a polyester/lyca(10%) mix. Based on previous findings, at least a 10% lycra substrate will be used and the available silver based conductive yarns will be selected for initial substrate, yarn, stitch type and density tests.

Figure A6.1 Available conductive silver yarns in Applied Labs

A6.2 EQUIPMENT

Figure A6.2. Low quality stitching: Brother prime edition

Figure A6.3. Medium quality stitching

Figure A6.4. Coverstitch Sewing machine

Figure A6.5 Best quality stitching: Pfaff Kayser 69

A6.3 TEST 1: YARN & ORIENTATION

The search for the most optimal stitched sensor starts with the selection of thread, stitch geometry and substrate length. The first test was performed by subsequently varying substrate length, stitch width, length and yarns, see table X. For stitching, the XXXX sewing machine was used. For the development of the first prototype, a lycra substrate is used with 85% nylon/15% Elastane (190 gram/m2). An overview of the samples is presented in figure X. For the initial strain/resistance change testing of the samples, a simple set-up was used. Here, the change in resistance is measured while the fabric is stretched over the full width of the substrate. Using a xx multimeter, the resistance over the stitched sensor can be measured. Using the gauge factor equation(Eq. X), the sensitivity of the sensor can be calculated with the new found resistance changes for each variation.

$$GF = \frac{\Delta R / R0}{\varepsilon}$$

Eq. A6.1

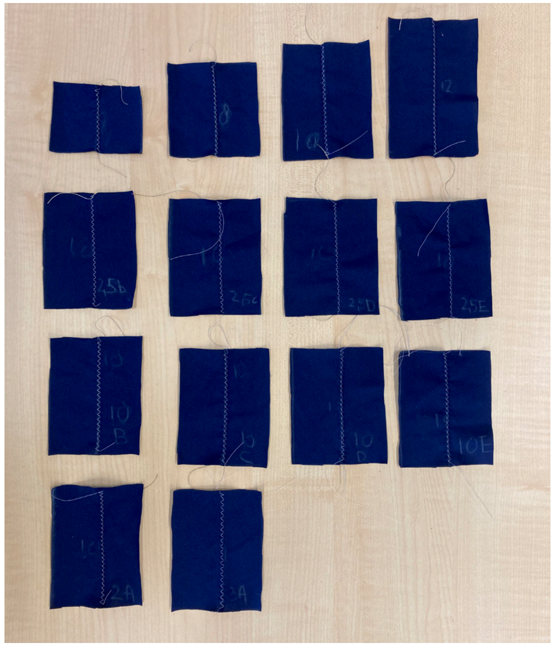


Figure A6.6. First test samples overview

Sample	Yarn	Substrate length (mm)	stitch width (cm)	Stitch length (cm)	Ω_0	$\Omega_{\Delta l = 1}$	$GF_{10\%}$
6	Silver Yarn Dtex 604	60	5	2,5	8,7	8,9	0,023
8	Silver Yarn Dtex 604	80	5	2,5	8,9	8	0
10	Silver Yarn Dtex 604	100	5	2,5	9,2	9,2	0
12	Silver Yarn Dtex 604	120	5	2,5	11,6	11,8	0,017
2,5b	Silver Yarn Dtex 604	100	4,5	2,5	8,1	8,1	0
2,5c	Silver Yarn Dtex 604	100	4	2,5	7,8	7,8	0
2,5d	Silver Yarn Dtex 604	100	3,5	2,5	8,5	8,5	0
2,5e	Silver Yarn Dtex 604	100	3	2,5	8,9	8,9	0
2A	Silver Yarn Dtex 604	100	5	2	9	9,1	0,011
3A	Silver Yarn Dtex 604	100	5	3	10	10,2	0,020
10b	BK 50/2 KS 60/40 PES	100	5	2,5	1,80k	drift	-
10c	BK 50/2 KS 80/20 PES	100	5	2,5	1,81k	drift	-
10d	9052187	100	5	2,5	drift	drift	-
10e	BK 501	100	5	2,5	1,80k	drift	-

Table A6.1. Results first test samples

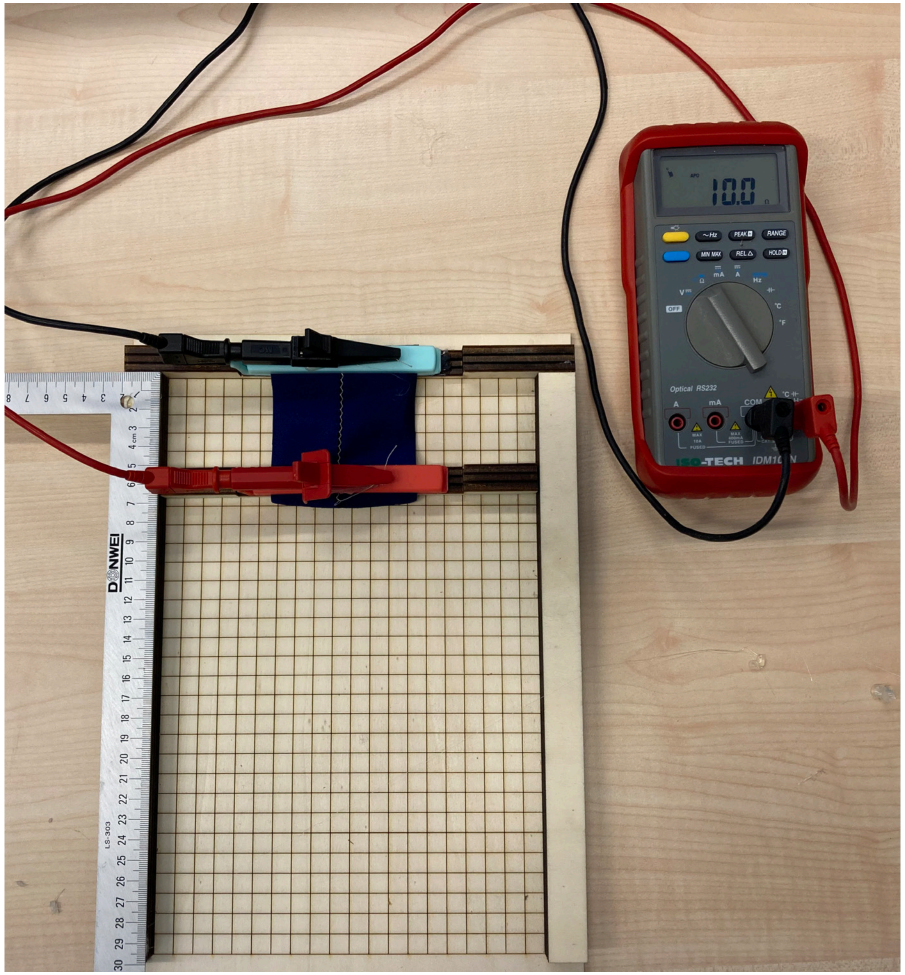


Figure A6.2. Basic strain test setup

From the first test, it was shown that only Silver Yarn Dtex 604 (2-Ply) gave reliable results, therefore this yarn was selected to continue with further experiments. The stitched sensors from Test 1 did not not produce a reliable sensor, with a maximum Gage factor of 0,023. This is below the required GF = (-)0,5. This is in line with the current research on the ZigZag stitch(xxxx,xxxx,xxxx).

For a ZigZag stitch sensor to work as a strain sensor, the threads of each consecutive stitch should be touching each other, and the connective surface should be maximised. This means, the stitch should be as wide as possible, creating a large conductive surface, while being as close stitched as possible.

Test 2 intends to find the optimal settings of the xxx Brother Sewing machine to produce a reliable, reproducible ZigZag stitch with maximum width and minimal length.

A6.4 TEST 2: STITCH GEOMETRY SETTINGS

On the Brother xxxx Sewing machine, different stitch geometries were tested, to see whether these settings were able to reproduce reliable stitches. Due to the tensions on the threads necessary to produce the stitch geometries, the lycra starts tunneling, as the fabric itself is not stiff enough to remain flat. To add stiffness to the fabric, toilet paper was added to the fabric as a stiffness mediator. Toilet paper was chosen based on it's characteristic of dissolving in water. In a previous attempt, removing non-dissolving embroidery paper negatively affected the clean stitch geometry after stitching. Figure X-X shows the results of the different stitch geometries versus the paper placement(figure x). Table x shows the outcomes.

Results

The results were formulated as not-producible(-), producible(+) and reproducible(++). From the stitch swatches in figure X, it was found that a stitch width of 0,6 produced the widest stitch possible on the sewing machine. Hence, this setting was used throughout the rest. The yarn was fed both through bobbin(bottom) and thread(top). The top thread from figure X did produce a neat stitch, but was not reproducible.The best results were obtained using stitch length 0,6, width 6, thread tension 9 and lycra sandwiched between 1 ply of paper. The high thread tension is necessary to pull the thick, stiff and highly frictional yarn in a ZigZag pattern in feeded by the bobbin thread(B0,6.6.9).

Figure A6.3. Paper Thread

Figure A6.4. Paper Bobbin

Figure A6.5. Single ply 2 sides

Figure A6.6. Double ply

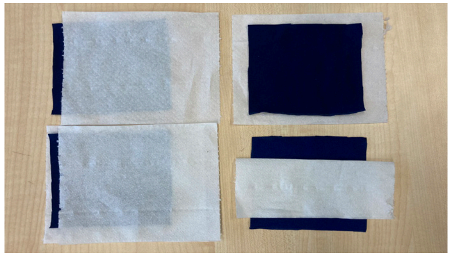


Figure A6.7. Paper orientations

<table>
<tr><th></th><th colspan="3">Paper Thread</th><th colspan="2">Paper Bobbin</th><th colspan="2">Single ply two sides</th><th colspan="2">Double ply</th></tr>
<tr><td>S=0,6</td><td>T=3</td><td>T=5</td><td>T=9</td><td>T=3</td><td>T=9</td><td>T=3</td><td>T=9</td><td>1 side</td><td>2 sides</td></tr>
<tr><td>W=5</td><td>-</td><td>-</td><td>--</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>W=6</td><td>+</td><td></td><td></td><td></td><td>+</td><td>(T) -</td><td>(B) ++</td><td>(T) - | (B) +</td><td>(T) - | (B) +</td></tr>
<tr><td>W=6,5</td><td></td><td></td><td></td><td>-</td><td>+</td><td></td><td>(B) -</td><td></td><td></td></tr>
<tr><td>W=7</td><td>--</td><td></td><td></td><td></td><td>+</td><td></td><td></td><td></td><td></td></tr>
</table>

Table A6.2. Outcomes test 2 (S=Stitch Length, W=Width, T=Tension, (T)=Thread feed, (B)=Bobbin feed)

A6.5 TEST 3: RELIABILITY OF THE B0.6.6.9 ZIGZAG STITCH

In the previous test, the optimal settings for the reproducibility of the stitch geometry was found, but does this also mean the sensor sensitivity of the stitch itself is reproduced? Will the same stitch produce the same stitch, produce equal outcomes? Hence, the reliability of the stitch must be tested.

Method

Four test swatches of 80x100 mm were produced with identical sewing machine settings and substrate. The swatches were elongated to 0%, 20%, 40% and relaxed back to 0%. The resistance was measured on each consecutive 0, 2, 4 minutes using an xx multimeter. These time frames were chosen to measure the relaxation effect during stretching of each sample. The hysteresis was measured when the swatch was stretched back from 40% to 0%. In figure X-X, you can see the outcomes of the reliability test.

Results

Comparing figure X and X to figure X and X, a large difference can be seen in the ---------------. When taking a closer look to the swatches, it shows a ---------------------.

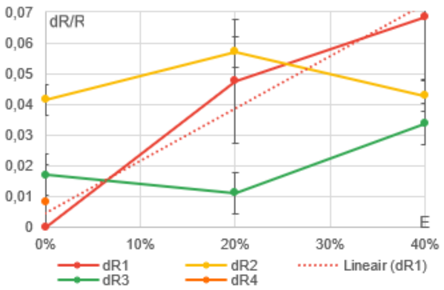


Figure A6.7. Figure X. Swatch 1: 3 cycles of stretching (E= 0%, 20% & 40%)

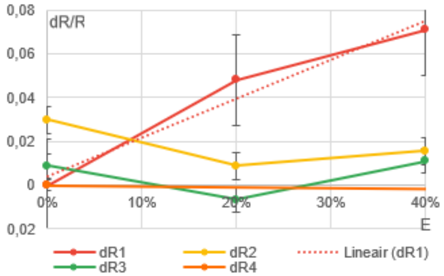


Figure A6.7. Swatch 2: 3 cycles of stretching (E= 0%, 20% & 40%)

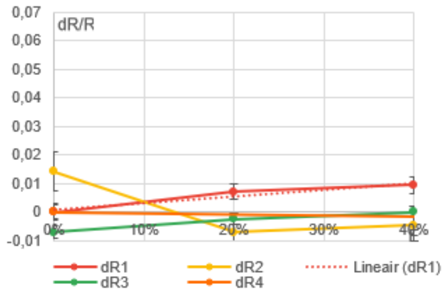


Figure A6.8. Swatch 3: 3 cycles of stretching (E= 0%, 20% & 40%)

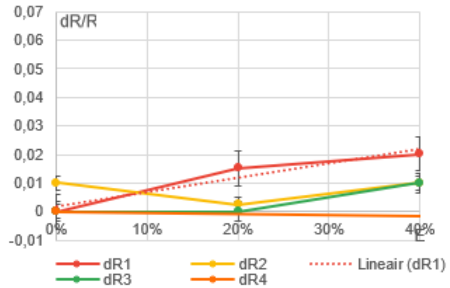


Figure A6.9. 3 cycles of stretching E= 0%, 20% & 40%)

A6.6 TEST 4: ALTERNATIVE STITCHES

Next to the ZigZag stitch, the 2 Needle Coverstitch(2NCS), Bottom Thread (XX, xxxx) and the Chain stitch (XX, xxxx) geometry can be applied to produce a stitched strain sensor. Just like the ZigZag, the Chain stitch increases in resistance, whereas the 2NCS decreases when stretched. To determine whether the Chain stitch and 2NCS outperform the ZigZag stitch, three swatches were made and subjected to cyclic testing.

Method

Three swatches were made from a 4-way stretch lycra, sized 140x80mm. In the middle, a straight line was stitched for each stitch geometry. The xx sewing machine was used for the Zigzag stitch, the Brother xx Coverstitch for the 2NCS and Chainstitch. the swatches were subjected to in plane strain across the full width of the swatch. In compliance with Schevers(xxxx), the conductive behavior was determined through a four point resistivity measurement. A xxx LETT tensile strength tester was used in combination with an Arduino to measure elongation and resistance. For this test, the LETT programme was able to test E1<10%, E2<20% and E3≤40%, for fixed speeds of VE1=10mm/minute, VE2=20mm/minute and VE3=40mm/minute. In total, 5 cycles are measured to obtain the resistive and hysteresis behavior. Prior to these five cycles, each swatch was pre-stretched 20 times, as suggested by (XX, xxxx), for max E≤40% at a rate of 40mm/minute, as to prepare for over stretching.

Results

After pre-stretching, 5 regular cycles were performed. Tests for both 10%, 20% and 40% elongation were performed. The E max≤40% results give the most information about the behaviour of the materials used, whether they reach their stretch limit or not. Hence, only the 40% stretch programme, SE3I, are shown and evaluated. In figures X-X, the change in resistance is displayed during the 5 cycles. Figures X-X show the hysteresis behaviour in the materials. From all the graphs, it shows that none of the stitch geometries is able to withstand 40% stretching, this is visible from

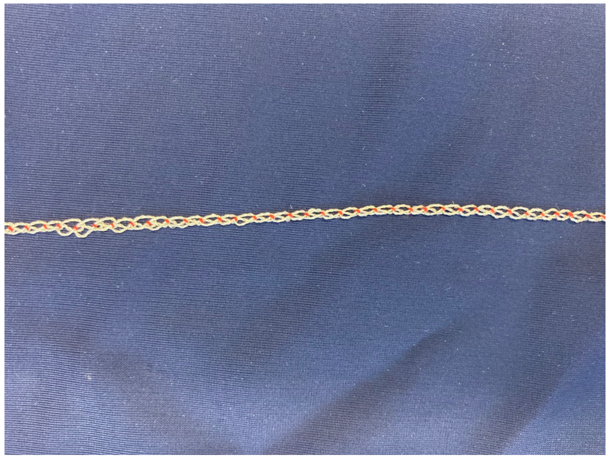


Figure A6.10. Chain Stitch

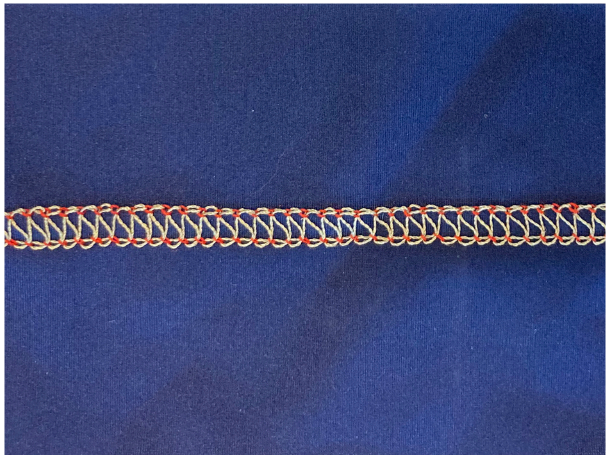


Figure A6.11. 2NCS Bottom threaded

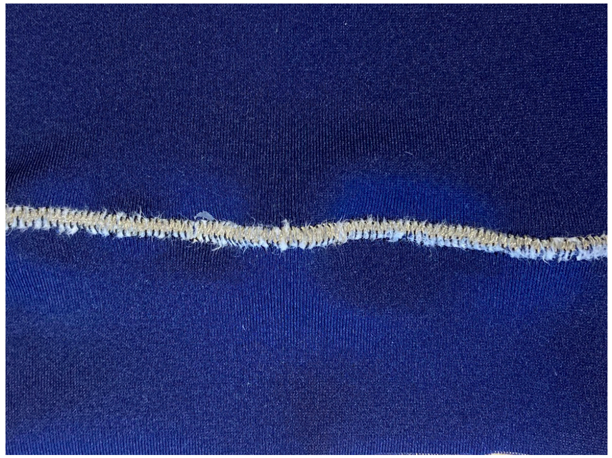


Figure A6.11. Zigzag Stitch

the yellow line in each hysteresis graph, indicating a different first stretch. For the Chain stitch, the resistance decreases when the stitching is stretched and reaches its limits at 25% stretch, with ΔR = 6Ω. However, from all geometries, it also displays the most hysteresis of all 3 tests(fig X). The 2NCS does not display linear or non-linear stretching behaviour, as Emax is reached at 25%(fig. x) for ΔR = 2,75Ω, explaining the small peak in the cycle. The 2NCS displays large hysteresis up to the stretch limit, but past this point gives an equal signal during elongation and retracting. Finally, the Zigzag stitch Emax = 20%, ΔR = 1,75Ω; it hits a plateau in fig. x where resistance no longer increases and slightly decreases.

Discussion

The Zigzag stitch shows the least amount of hysteresis of all geometries, but also the smallest dR. From this test, it is shown that both the Chain stitch and 2NCS are not viable to use in the development of a sensor due to their problematic hysteresis behaviour during the relaxation part of the stretching. These findings are in contradiction with current literature, which pose the chain stitch as the optimal geometry over the 2NCS(Dupler & Dunne, 2019) and the 2NCS over other existing geometries(Greenspan et al., 2014). Going forward, the Zigzag stitch will be the only geometry considered for developing into a sensor.

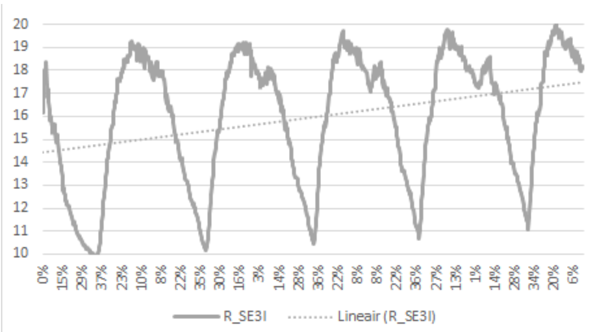


Figure A6.12. Chain Stitch - 5 cycles change in R(Ω)

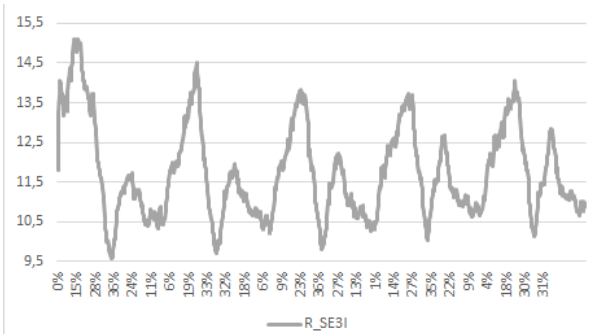


Figure A6.13. 2NCS - 5 cycles change in R(Ω)

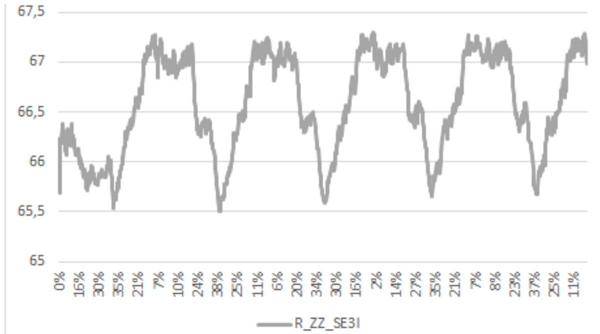


Figure A6.14. 5 cycles change in R(Ω)

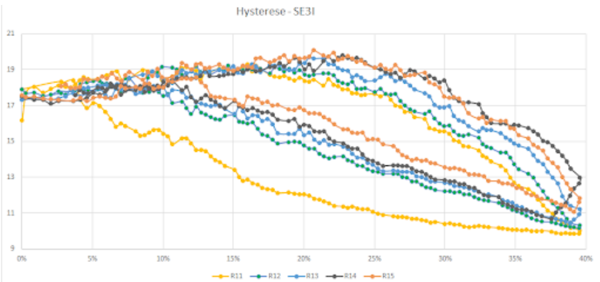


Figure A6.15. Chain Stitch: Hysteresis over 5 cycles

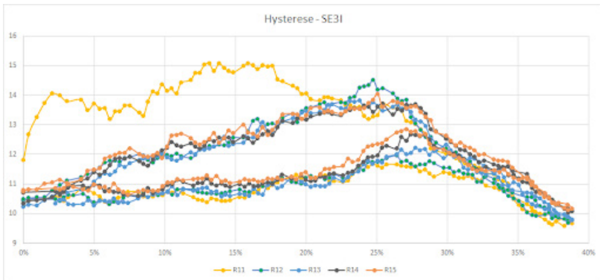


Figure A6.16. 2NCS: Hysteresis over 5 cycles

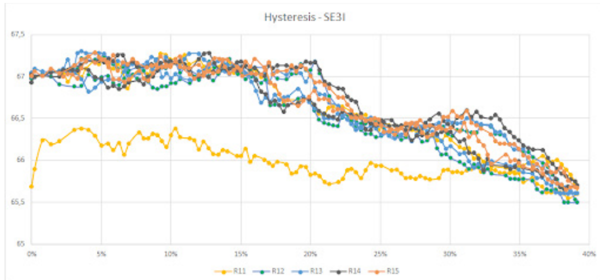


Figure A6.17. Zigzag Stitch: Hysteresis over 5 cycles

A6.7 TEST 5: CONDUCTIVE FABRICS

The three stitch geometries from test 4 did not show promising options on their own. Before trying the route of optimizing the resistive response of the Zigzag stitch, another method of obtaining stretch feedback is investigated. From previous literature, conductive knitted fabrics are not suited due to their lower working range and hysteresis(Jansen, 2020), but could be when laser cutted in small strips and pre-stretched 100-200% (Grassi et al., 2017).

Method

Five types of conductive lycra were laser cut into strips of 1,5x14 cm and pre-stretched to 100%(fig. A6.18). These strips were then subjected to cyclic testing with the LETT Tensile tester setting from fig x. The lycra's were tested to a E<20% limit (SE2I), Stretching it to 20% would be 100% overstretching, whereas 40% would be 300% overstretching, surpassing the limit set by prior research. The lycras used are: MedTex 130, Shieldex 130B, MedTex 180, Shieldex-Silitex en Elektrolycra.

Results & Conclusion

The most notable is that all lycra's show linear or close to linear stretching behaviour in fig X, with no sign of reaching their stretch limit, except for MedTex, 180.. From this figure, it shows that both Shieldex 130B(ΔR = 47Ω) and Medtex 180(ΔR = 44Ω) have the most potential to be used into a sensor, according to their ΔR, which is important for the sensitivity of the sensor. Therefore only these two conductive fabrics will be further investigated. By plotting their cycles over the elongation, their hysteresis behaviour becomes apparent. In both figure X and X, it is shown that after the first stretch, there is some offset in the resistance signal. From these two graphs, MedTex 180 displays the least amount of hysteresis, therefore being the most ideal. Next, it is a challenge of how to attach the Medtex 180 to regular lycra. This will be attempted in Test 6.

Figure A6.18. Lasercutted and 100% pre-stretched MedTex 180 strip

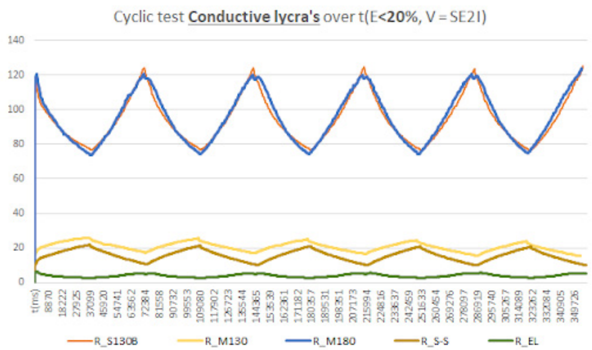


Figure A6.19. Cyclic test: Conductive lycras

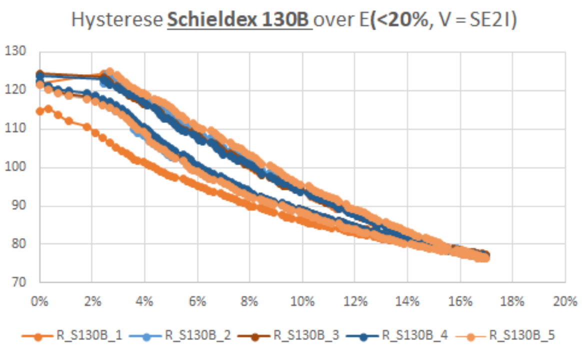


Figure A6.20. Hysteresis: Schieldex 130B

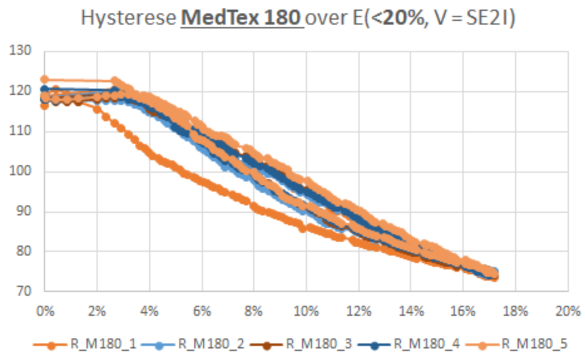


Figure A6.21. Hysterese MedTex 180

A6.8 TEST 6: INTEGRATED CONDUCTIVE FABRICS

For the integration of electrolycra into a regular lycra substrate, two methods were used: gluing and using the 2NCS. In spots and athleisure wear. it is quite common to see different pieces of fabric layered on top of each other and connected, not by seam, but by coverstitch(fig. x).

Method
2 strips of MedTex 180 of 20x160mm are laser cutted, as well als 2 lycra substrates with a 10x140mm hole cut out. Using the xx Industrial Coverstitch machine, a 2NCS is used to connect the MedTex 180 strip to the lycra(85% Nylon, 15% Elastane) substrate. Gütherman Fabric Glue is used to connect the two lycras in the second test. The XX LETT Tensile Strength Tester set-up is used to measure the change of resistance.

Coverstitch Machine Instructions

- Connect Shieldex to bottom thread. The fist connection between the yarn spool and tension rod must be straight to avoid tension.
- Reduce all tension from bottom thread at the lower tension knob. Turn completely to left.
- Remove additional turns for bottom thread in the machine casing
- Remove middle needle and top looper thread for 2N bottom CS

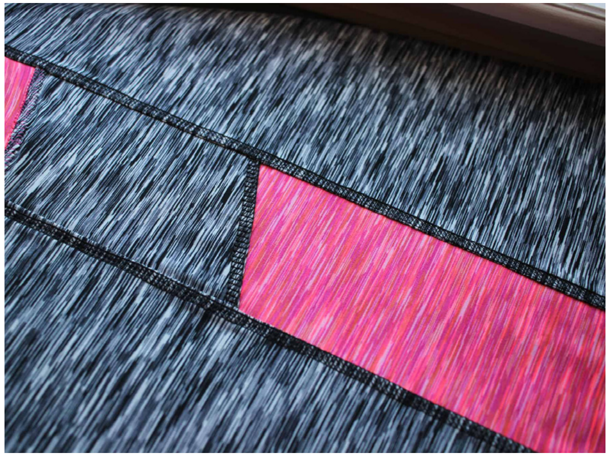


Figure A6.22. Coverstitch fabric connection

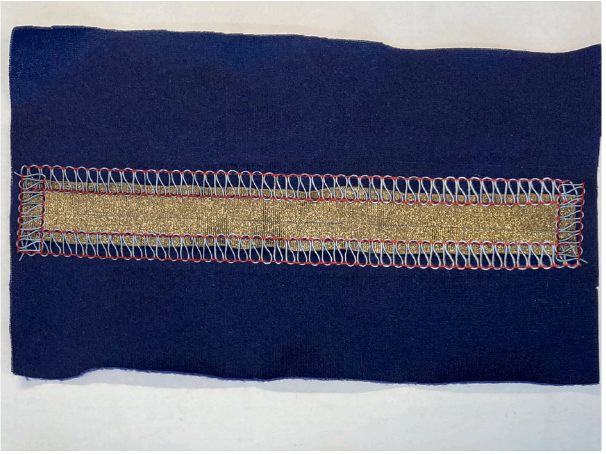


Figure A6.23. 2NCS coverstitch connection

Figure A6.24. Fabric glue connection

Results

The stretch limit was reached within both methods of adhesion(fig x). With the strip connected by the 2NCS, Emax was reached around 15%. This is likely due to the limited stretch behaviour of the 2NCS. The strip that was glued to the nylon lycra strip, caved around 10%, however, the results show very few resistance difference and problematic stretching behaviour(fig.x). This might have been due to errors in the LETT. However, from these results combined, it cleased shows that connecting the strips to regular lycra does not provide a viable solution to create a textile sensor with.

Conclusion

From the results of test 7, it is shown that adhering MedTex 180 to regular lycra, does not provide a reliable sensor. Therefore, the most viable option within this research has thus far proven to be the zigzag stitch geometry. Hence, in the next test, the parameters for turning this stitch into a sensor will be optimized.

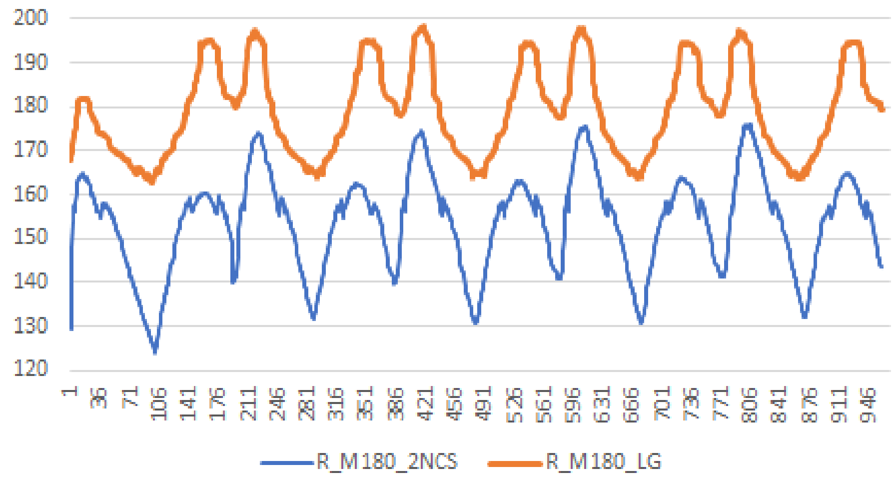


Figure A6.25. Cyclic test: M180 strips on 85%Ny substrate (Emax≤40%, v = SE3I)

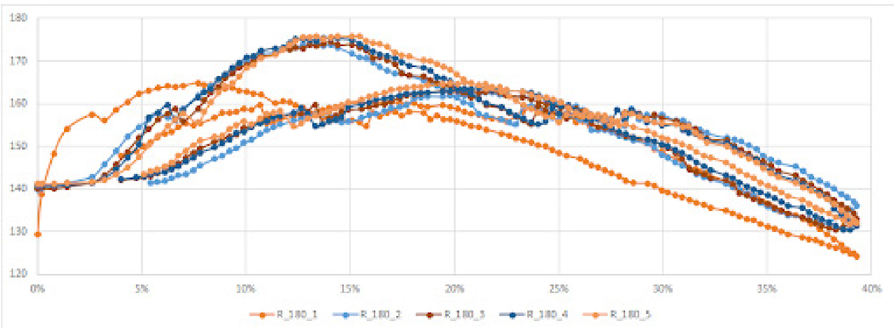


Figure A6.26. Hysteresis: MedTex 180 with 2NCS(Emax ≤40%, v = SE3I)

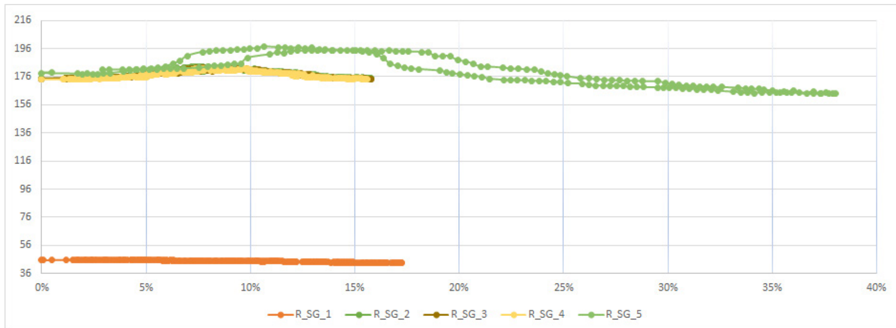


Figure A6.27. Hysteresis: MedTex 180 with Fabric Glue (Emax≤40%, v = SE3I)

A6.9 TEST 7: OPTIMIZATION

The response of a stitched sensor depends on the stitch structure and the anisotropy of the substrate(Jansen, 2020). Currently, the best response(Rhysteresis) and most viable textile sensor was obtained with the Zigzag geometry(test 4). To optimize the signal and suppress hysteresis, the material and its corresponding elastic response to stretching should be further investigated(Dupler & Dunne, 2019). In the latter study, 2-way stretch and 4-way polyester spandex blends were used, therefore these different anisotropies will be investigated too. Looking at lycra compositions, there are many commercial fabrics available with different blends. These blends mainly consist of cotton(CO), polyamide(Nylon) and polyester(PE) with elastane(EA) or Spandex. However, the most promising lycras are 90% PE (Greenspan et al., 2018), 75%Ny (Tansiri et al., 2019) and 93% PE Scuba knit(Dupler & Dunne, 2019). Another material substrate that showed linear stretch signal, low hysteresis and a GF of 4, is self-adhesive kinesio tape (Vergunst, 2021). Therefore an investigation into a material imitating this response is done too.

Method

This test was performed in two sections. First, investigating different lycras and second is exploring alternatives for self-adhesive kinesio tape with equal response to stretch. For part one, the following compositions were tried: 80%, 84%, 85%, 85% (heavy weight) Nylon, 80%, 85%, 90% and 93% Polyester (table X). For section two, Elastic tape, three 2-way stretch thin neoprene fabrics and adhesive-less woven kinesio fabric(97% cotton) were explored(table X). The Zigzag stitch(304) was stitched using the Pfaff Kayser 69 sewing machine with stitch width 5, stitch length 0,5 and thread tension of 6. The lycra substrates were sandwiched between one layer of soluble reinforcement paper: Soluvlies. After stitching, the patches were placed in water to dissolve the Soluvlies and laid to dry. The LETT Tensile testing set-up was used to measure the resistance signal over 5 cycles with an elongation of ≤40% over a speed of 40mm/min(SE3I). The overview can be found in fig X

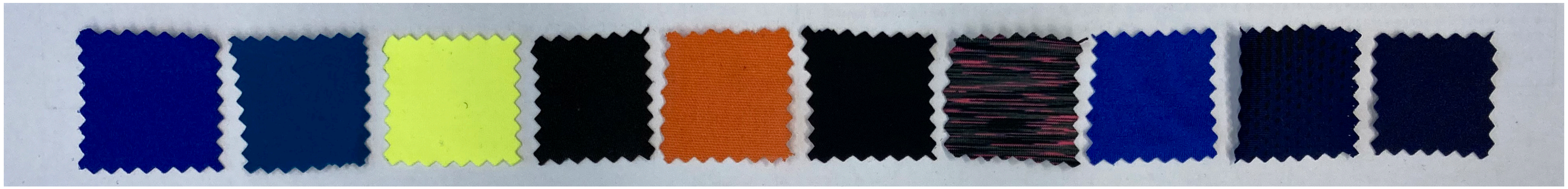


Figure A6.28. Overview of lycra substrates

	Lycra fabrics									Non-lycra's			
Composition	80%Ny, 20% EA	84% Ny, 16% EA	85%Ny, 15% EA	85%Ny, 15% EA	75% PE, 25% EA	80% PE, 20% EA	85% PE, 15% EA	90% PE, 10% EA	92% PE, 8% EA	Scuba black	Scuba grey:	Elastic: ?	97% CO 3% EA
Stretch directions	4-way	4-way	4-way	4-way	4-way	4-way	4-way	4-way	4-way	2-way	2-way	2-way	2-way
Weight	190 g/m^2	186 gr/m^2	190 gr/m^2	495 gr/m^2	270 gr/m^2	240gr/m^2	190 gr/m^2	190 gr/m^2	240 gr/m^2	-	-	-	-

Table A6.3. Substrate compositions

Results

The stretch limit was reached within both methods of adhesion(fig x). With the strip connected by the 2NCS, Emax was reached around 15%. This is likely due to the limited stretch behaviour of the 2NCS. The strip that was glued to the nylon lycra strip, caved around 10%, however, the results show very few resistance difference and problematic stretching behaviour(fig.x). This might have been due to errors in the LETT. However, from these results combined, it cleased shows that connecting the strips to regular lycra does not provide a viable solution to create a textile sensor with.

Conclusion

From the results of test 7, it is shown that adhering MedTex 180 to regular lycra, does not provide a reliable sensor. Therefore, the most viable option within this research has thus far proven to be the zigzag stitch geometry. Hence, in the next test, the parameters for turning this stitch into a sensor will be optimized. From graphs X-X it looks promising to continue experimentation with the non-lycra's and to integrate them into lycras. It looks like lycra alone is, compared to these non-lycras, not thick or stable enough to harbour the dense zigzag stitching. What could be an alternative to this is to make panels of the non-lycra and integrate them in the lycra of the rest of the suit. This was, the stitching could be done in the appropriate fabric, but maintain the stretch necessary from a 4-way stretch lycra necessary for freedom of movement and comfort.

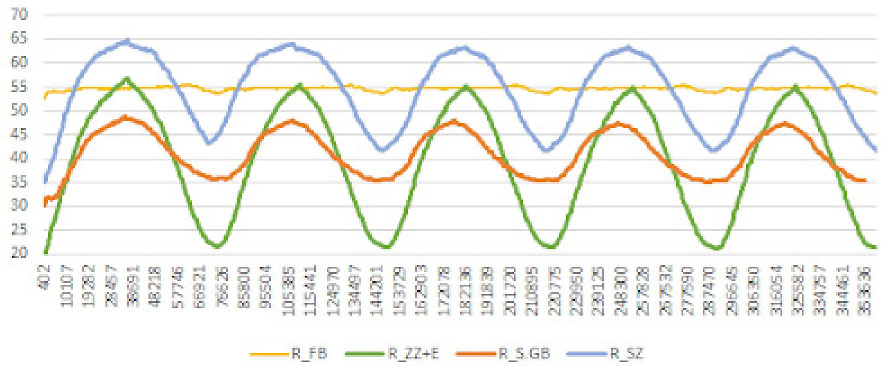


Figure A6.25. Cyclic test: Resistance non-lycras (Emax≤40%, v = SE3I)

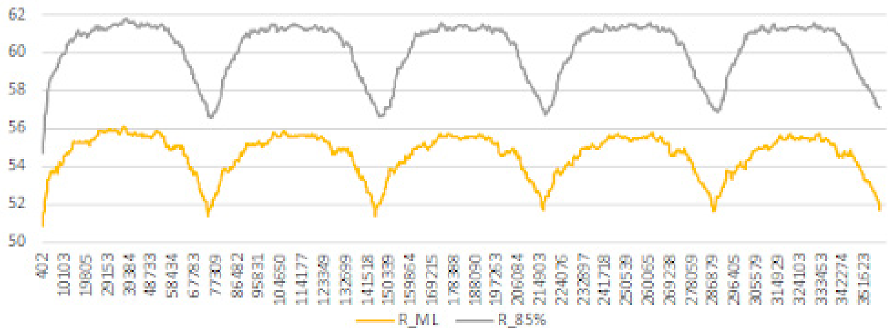


Figure A6.26. Cyclic test: Resistance - PA-lycras (Emax≤40%, v = SE3I)

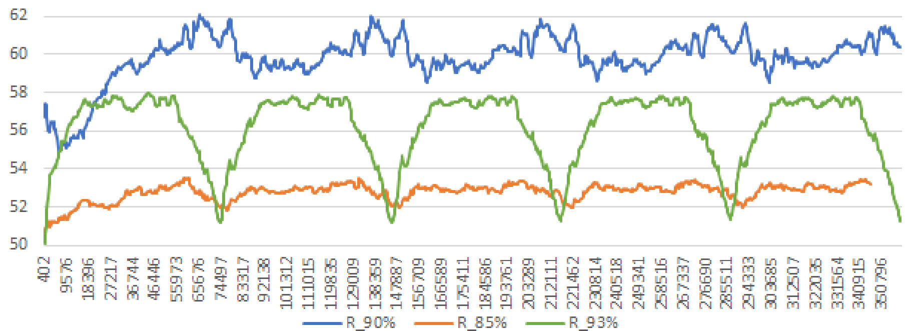


Figure A6.27. Cyclic test: Resistance PE-lycras (Emax≤40%, v = SE3I)

A6.10 TEST 8: OPTIMIZATION OF THE ZIGZAG STITCH: COMBINING LYCRAS AND NON-LYCRAS

From test 7, it appeared that the density of the fabric increased the sensitivity of the sensor signal. However, these dense fabrics do not allow for maximum comfort as they have a higher resistivity to stretch compared to lycras (Alibi et al., 2013). Therefore the same construction is proposed as in test 6, with here with the integration of non-lycras in 85% Nylon lycra.

Method
A Zigzag stitch(304) was stitched on a piece of 40x150 black neoprene and elastic using the Pfaff xxxx sewing machine: SW: 5, SL: 0,5 and TT: 6. The non-lycra substrates were sandwiched between one layer of Soluvlies. Next, they are connected to the center of a nylon lycra substrate of 80x160mm, cut in length orientation, using the 2NCS with the Brother xxx. The top and bottom of each substrate were clamped to the LETT, while the 4-point measuring clamps were placed at the end of the zigzag stitching. and tested with the Lett SE3I programme.

Fig. A6.34. Zigzag on Elastic

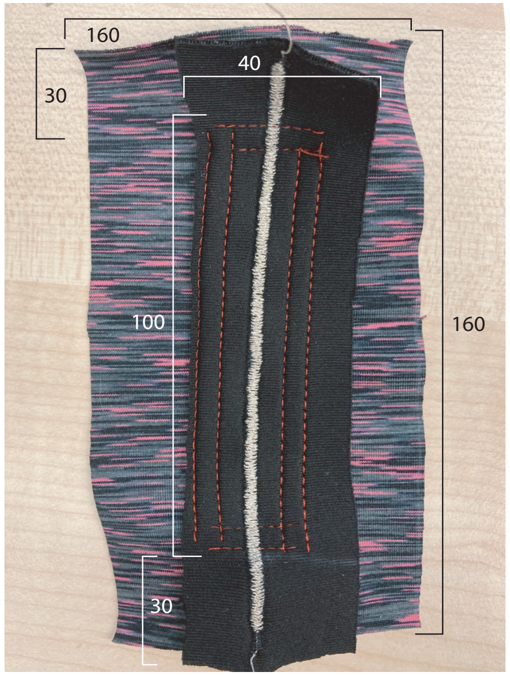


Figure A6.35. 2NCS scuba on 93% PE lycra

Figure A6.36. Method of testing

Results

For the lycra hybrids, there is a considerably smaller signal for the Elastic (ΔR= 35,4Ω), than for the black scuba knit fabric(ΔR,=12Ω) (fig. X). The stretch limit is reached in none of the hybrids. Within the elastic, it deflects into non-linear behaviour at 30%. The scuba black hybrid performs dispalays less hysteresis (Fig x-X), as the stretching and ratraction curves show less overlap in fig x than fig x. When it comes to sensitivity of the hybrids, in its current length, only elastic showed an acceptable GF(>0,5)

Conclusion

Though hybrid designs of a strain resistive sensor proved successful in producing a clean, reliable signal under elongation up to ≤40%, there are doubts this effect can be replicated in the construction of a suit. This due to different resistances to stretch in lycra and non-lycra material. Due to the short amount of lycra between the clampand non-stretch lycras(30mm), the stretch limit of the lycra is reached early on in the stretch cycle, forcing the non-lycra to stretch along. When integrated in the suit, the length of lycra that is pulled is many times larger. Therefore, it could take up all the strain whilst allowing the non-lycras to resist stretching as the stretch limit of the lycra fabric won't be reached. To develop this hybrid design further into a sensor, would require a great deal of time and advanced prototyping. Therefore, this concept, within the boundaries of the design of this research, was successful, it will be discontinued for further development for the FBMS.

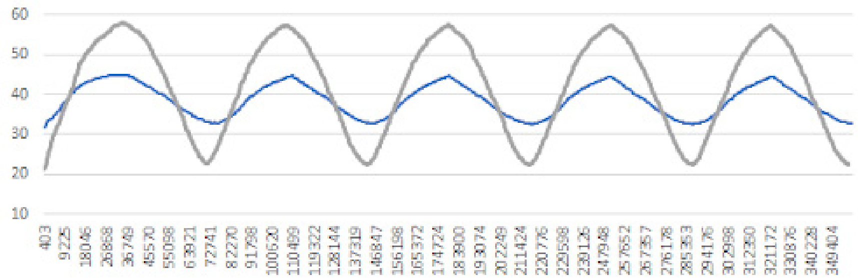


Figure A6.37. Method of testing

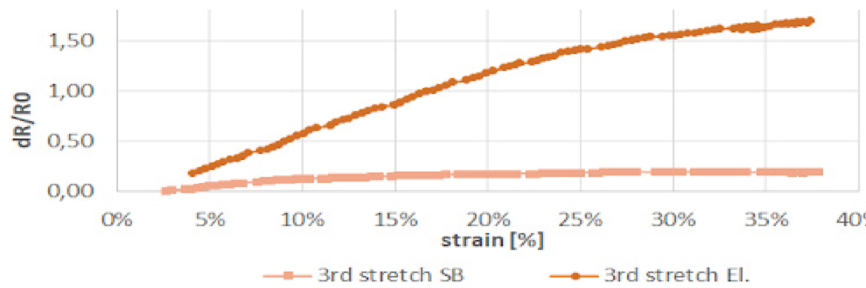


Figure A6.38. Method of testing

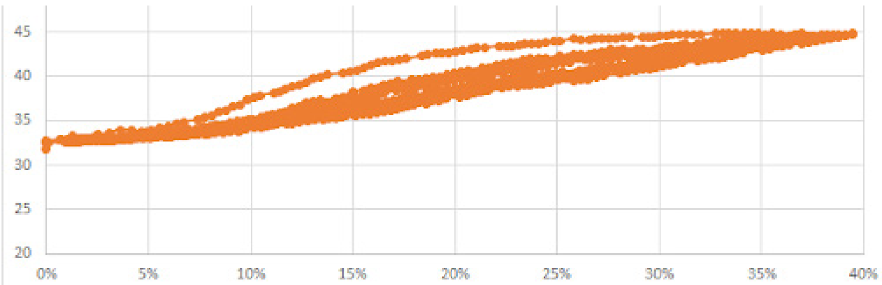


Figure A6.39. Method of testing

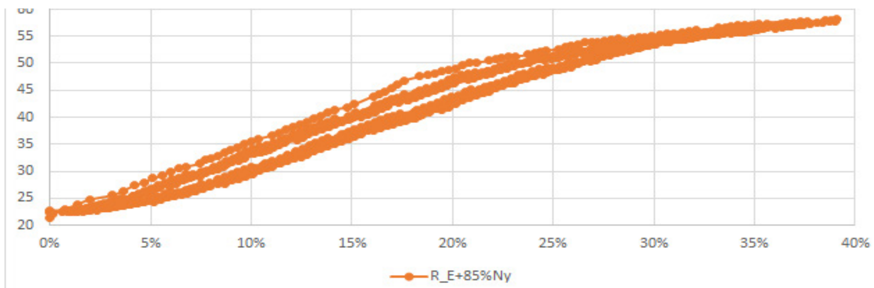


Figure A6.40. Method of testing

A.7 CONSEPTUALISATION

A7.1 PUGH'S CHECKLIST

Performance

1. Be worn
2. Fit snug around the body
3. Have a sensitivity of at least GF = >0,5 v. <-0,5 .
4. Low to zero Hysteresis
5. Low to zero drift
6. Linear response to stretch
7. Start up with one gesture
8. Warn the user when not maintaining correct posture in static situations
9. Warn the user when exercise(movement) is executed in wrong posture
10. Recognise different motion sequences as exercises
11. Only be calibrated once per individual user with a physical therapist
12. Run on an electric stand-alone power circuit, running on maximum 5 V
13. Be connected to a small Li-Ion battery, P: [W] ; I: [mA]
14. Allow a user to fully use the suit two days, twice a day without charging
15. Be washed in a washing machine on 30°C, hand wash function
16. Withstand a stretch of E = 100%
17. Measure with a sensitivity of at least x=1.
18. process data real time without delays
19. Share data wirelessly with a smartphone

Environment

20. Be used in room temperature
21. Be recycled as textiles and electronics without additional separation

Norms

22. comply with stitch standards: ZigZag(304) and Coverlock(514)
23.

Lifespan

24.

Be used once a day, for at least 6 times per week, for 10 weeks, 4 times per year, for five years.
Be washed once a week during that timespan
Will be sold for at least 5 years.
Get repaired when broken during its full expected lifetime
textiles should be restitched
Electronics should be replaced without altering the stitching.

Production and batch size

Be produced in a regular sewing facility fit for the production of commercial athletic wear.
Be produced using market standard production methods
Be produced without altering production processes.
Be produced in batches. First batch: 10 prototypes in horizon 1.

23.
24.
25.

Production Cost

26. Be viable for HIC to invest in. Current examples of resale prices range between $145.95-$399.
27.
For commercial exploits, the resale price should be twice the production costs.
28.

Transport

29.
Transport conditions should be dry.
Electronics must be transported in protective packaging
30.
31.
32.
33.
34.
35.
36.
37.

Packaging

45. For commercial purposes, packaging should entice, seduce and
46. 47. create excitement within users to start using the product
48. The electronics must be packaged separately
49. Includes remote return policies for health care lease

50. **Transport**

51. Transport conditions should be dry.
52. 53. Electronics must be transported in protective packaging

Sizing

54. 55. Be available in size XS-XL, short, regular and tall. This will be
56. achieved in creating 3 width sizes: XS-S, M-L and XL-XXL
57. 58. and three length sizes. In total, 9 different sizes will be available.

59. **Materials, Form, Color and Finish**

60. Consist of a woven lycra material that contains at least 15% Elastane.
61. 62. Stretch at least 200%
63. Feel soft on the skin

Covey a sense of futurism, powerfulness and softness

Dark, minimalist colors to appease the larger consumer group.

Ergonomics

guarantee a perfect fit within each size

Tests

The product must be CE tested to adhere to medical norms

User tests should be executed throughout each horizon of the strategy

Storage

64. Be stored like any other athletic apparel

Societal and political impact

65. 66. contribute to the E-health start-up climate in The Netherlands
67. Contribute to insights in movement research
68. Contribute to self-management of people and their health

Safety 69.

70. Be as safe as regular athletic apparel

31. 71. Product liability

72. The Producer is liable for failures if the source of the failure is
73. not within the user’s fault

74. 75. **Failure**

76. If the product fails, the results of the user should be stored and
77. be accessible when the suit is repaired.

Installation

Instal itself without installation time, other than calibration

The user must instal their app for data tracking

To connect with their desired tracking community app

To connect with tutorials dedicated to work with the FBMS

To connect with their PHE

A7.2 POSTURE AND SQUAT

Exercises: Parameters for correct alignment of posture

The ideal posture with all areas in the right position is presented in fig. X. The center line represents the postural line of gravity of which the center sits in the waist (Trew & Everett, 2005). This posture alignment can be achieved by following the steps in fig x-x (Man Flow Yoga, 2017). A good way to practice this is to stand up against a wall and start the alignment from bottom to the top. As shown in Fig. X, A good posture is the base for any further exercising to battle posture related conditions. Therefore, the recognition of standing up straight in the correct full body position is the minimum qualification for proof of concept.

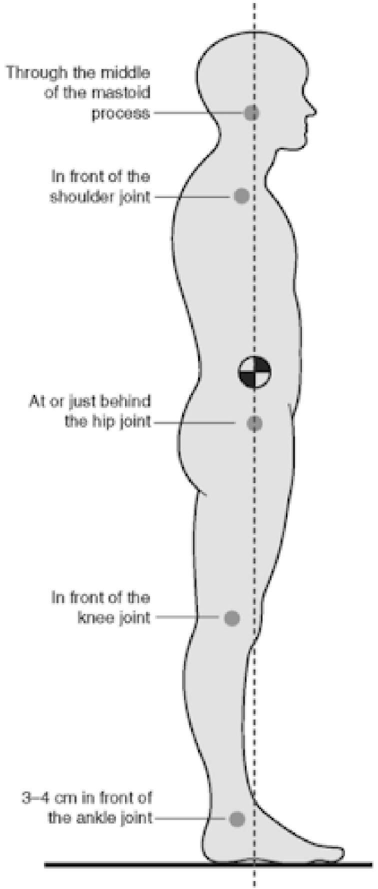


Fig. X. Correct base

•Line up feet straight forward and parallel to each other.
•Spread feet hip width aparts
•Push down through heals and toes, trying to get taller

Fig. X. Activating legs

•Engage thighs by tightening them a little
•Squeeze inner thighs a little towards each other

Fig. X. Activating core

•Bring hips slightly back
•Hips are directly above feet
•Pull belly button to the spine
• Abs must feel engaged after this correction

Fig. X. Elongating spine

•Push head upwards, spine as long as poss
•Look straight forward, not up or down
•Draw neck slightly back
•Turn palms forward to open up chest and put shoulder blades in right position

Left: Fig. X. Correct posture in sagittal plane (Trew & Everett, 2005)

Exercises: Parameters for correct alignment of posture

These four squat posture mistakes often occur when starting with this workout (fig. X- fig. X). A common mistake is starting from the knees(Fig. X). The first thing people do when they want to squat is bend the knees. Not only does that make a proper squat impossible, it also places a lot of unnecessary stress on the knees (Medvesek, 2019). This position also demands focus on multiple areas at once: arched back and knees width. Therefore, this position is chosen for proof of concept for the placement of the sensors.

Fig. X. Mistake 1: Start from knees

Fig. X. Mistake 2: Inward knees

Fig. X. Mistake 3: Hunching back

Fig. X. Mistake 4: Lifting heels

Fig. X. Correction 1

Fig. X. Correction 2

Fig. X. Correction 3

Fig. X. Correction 4

•Stand tall and activate abs
•Move butt backwards when descending
•Weight shifts to heels
•Feet shoulder-width apart; pointed 15 degrees outwards or parallel

•Knees pushed slightly outward
•Knee caps parallel to toes
•Knees are directly above feet

•Look straight ahead, not down
•Open chest and relax shoulders
•Put hands straight to front. If they fall towards knees the back is rounded

•Keep heels on the floor
•"Push" from heels when going up
•Squat as low as possible:
  •Hips go lower than knees
  •When lower back arches excessively, don't go lower

A8. KNGF GUIDELINES LITERATURE REVIEW

A8.1 CURRENT SOLUTIONS AND THERAPIES

Name	Application	Functionalities	Functionalities	Conditions	Link
Pressotherapy suit	lymph flow	A specialist bodysuit with many compartments and a computer which controls them. These moderate compressions promote the body's natural clearing function by helping expel toxins and excess water.	• Increase lymph flow, blood flow, and oxygenation • Relief and comfort for heavy legs • Better kidney, heart, and organ functions	• Thrombosis. • Metabolism • Muscle tension • immune system • Oedema/swelling	https://www.bodycareclinic.ie/_therpis/pressotherapy/
The Sensory Dynamic Orthosis (SDO®)	musculoskeletal support	Dynamic compression Lycra Garment (Class 1) medical device to increase sensory and proprioceptive feedback and musculoskeletal support. To assist and lead to motor learning and neural integration. Through the use of an SDO® providing constant, consistent compression, stretch, support and sensory information the patient is given the effect of therapeutic handling when garment is worn	• Sensory and proprioceptive feedback • Musculo-skeletal support and alignment • Postural control and proximal stability • 17% C, 32% EA and 51% PA	• Cerebral palsy • Spinal Injury • Cerebellar Ataxia • Accident /Stroke • Multiple Sclerosis	https://www.jobskin.co.uk/body-suit-with-sleeves-and-legs-pcp05?cat=2044262
Bodysuit with electrodes	Neurological disorders	An elastic bodysuit covered with electrodes. designed at KTH Royal Institute of Technology. Help those suffering with brain damage or neurological disorder(MS or Parkinson's).			https://tinyurl.com/yzxtmuzv
Intensive suit therapy	Neurological disorders	An orthotic suit consisting of a hat, vest, knee pads, and shoes worn in a therapeutic setting. Multiple adjustable rings and elastic bands provide pressure and support to muscle groups and joints Bungee cords can be adjusted to muscle groups; the suit acts as a soft exoskeleton for proper alignment to correct abnormal muscle tone and re-train movements.			
Wear Ease	post-surgical	To be worn after surgery to redirect pressure in body from affected area			https://tinyurl.com/yfzkqvw6
Arena	post-surgical recovery				https://tinyurl.com/yh3oehgp
Isavela Womens 2nd State Body Suit with Bra	post-surgical recovery	Compression improves circulation, allowing more oxygen and nutrients to reach the muscles. It reduces vibrations coming with dynamic activities. Breathable, anti-microbial, latex-free reduces risks of irritation. The fabric transports moisture to the surface for quick evaporation.	High back compression support, targeted compression in the tummy region, the buttocks, the thighs and the calves		
Active Bodysuits	Adult Degenerative Scoliosis	Body alignment and pain management using special components and active posture training from a biofeedback system. Back pain is often localized along the convexity of the curve.			https://clinicaltrials.gov/ct2/show/NCT03332277
Therapeutic Exercise	Musculoskeletal Injuries				https://tinyurl.com/yejr334e
Review	Neurological disorder	Effects of interventions with therapeutic suits (clothing) on impairments and functional limitations of children with cerebral palsy: A review.			https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5628369/

Table A8.1. Current suits and therapies

A8.2 KWALITEITSREGISTER FYSIOTHERAPIE NL (KNGF) GUIDELINES ANALYSIS

Corona en fysiotherapie
Thuiswerken: hoe voorkom je klachten? - 20 maart 2020
Veel mensen werken door de coronacrisis thuis. Wat kun je het beste doen en wat kun je beter laten? De gemiddelde keukentafel is immers niet geschikt om aan te werken. Heb je een bureaustoel in huis? Zet deze dan aan de keukentafel. In deze podcast geeft fysiotherapeut Jan Pijl van Fysio Holland tips voor een goede werkhouding bij thuiswerken in tijden van corona. "Zet een wekker of het alarm op je telefoon en ga elke 20 minuten even staan. Breng veel meer beweging aan in je ritme als je thuis werkt."

Atrose
Wanneer meerdere zorgverleners bij de behandeling zijn betrokken, is het van belang dat wordt gewerkt met gemeenschappelijke behandeldoelen die zijn afgestemd met de patiënt. De klinische diagnose heup- en/of knieartrose wordt gesteld op basis van een anamnese en lichamelijk onderzoek. Daarbij wordt de 'American College of Rheumatology' (ACR) (tabel 2) classificatie criteria gebruikt.
Bij het lichamelijk onderzoek wordt ook rekening gehouden met contra-indicaties voor oefentherapie, rode vlaggen en het risico van een ongunstig beloop van artrose.

Bied aan:	Overweeg om:
ongeacht leeftijd, ernst van pijnklachten en ernst van de gewrichtsschade.	eHealth-toepassingen te gebruiken om de patiënt te ondersteunen in het zelfstandig (blijven) uitvoeren van oefeningen
in combinatie met voorlichting/advies en een beweegplan (incl. korte- en langetermijndoelen	mate van begeleiding te verminderen
begeleide oefentherapie en zelfstandig uitgevoerde oefentherapie. Bepaal dit samen met de patiënt op basis van zelfstandigheid/motivatie.	oefentherapie in groepsverband aan te bieden

Table A8.2. Algemene aspecten van oefentherapie bij heup- en knieartrose.

A8.3 CVA

De fysiotherapeut heeft een centrale plaats in het team van betrokken disciplines over het te volgen beleid; Taken van de fysiotherapeut zijn oa:
• Het vastleggen van beoogde functionele doelen en rapportage
• Het regelmatig objectiveren van (veranderingen in) het functioneren van de patiënt en deze in maat en getal vastleggen in het patiëntendossier.

Trend: Vroegtijdig ontslag
±50% van de patiënten mag direct naar huis. Van deze groep heeft een belangrijk deel verdere fysiotherapie nodig en wordt er gebruik gemaakt van eerstelijnsgezondheidszorg. Er komt een CVA-team, meestal bestaande uit huisarts, fysiotherapeut, (wijk)verpleegkundige en naastbetrokkenen van de patiënt. Er zal er een steeds groter beroep worden gedaan op het CVA-team. Het functioneren van zo'n team is geen vanzelfsprekende zaak.

Focus behandeling:
Zelfmanagement, secundaire preventie, mobiliteit in en om huis, ADL-vaardigheden en valpreventie, met op gezette tijden een terugkoppeling van de verrichtingen en de vorderingen tussen de verschillende disciplines, alsmede regelmatig onderling overleg. Onderzoeken en behandelen van de lichamelijke gevolgen van een CVA, met inachtneming van onder andere gevolgen. Gezien de complexiteit van mogelijke stoornissen en sterke heterogeniteit van deze patiëntengroep vergt dit specialisatie van de fysiotherapeut. Volgende is belangrijk:

- vraagstellingen die voor de patiënt relevant zijn.
- Vraagstelling bepaalt nadere diagnostiek.
- Na prognose en bepalen van interventie worden meetinstrumenten en meetmomenten geselecteerd om de voortgang te evalueren

De vraagstelling, diagnosestelling, prognose, geselecteerde interventie en evaluatie dienen schriftelijk te zijn vastgelegd zodat het fysiotherapeutisch behandelbeleid kan worden voortgezet bij afwezigheid PT.

Intensiteit
"het aantal uren dat wordt besteed aan oefentherapie". Het voordeel van deze formulering is dat behandeltijd eenvoudig is te meten, het nadeel is dat onduidelijk blijft hoeveel repetities en energie werkelijk is geïnvesteerd. Bij intensivering is er dus sprake van een toename van het aantal uren dat besteed wordt aan het oefenen ten opzichte van het reguliere aantal uren. In de praktijk blijkt echter dat er wordt onderbehandeld.

De intensiteit waarmee patiënten oefenen, uitgedrukt in duur en frequentie van training, hangt positief samen met de snelheid waarmee, en mogelijk de mate waarin, herstel van motorische functies en ADL-vaardigheden optreedt. Het gaat dan om oefenen zonder gebruik te maken van speciale uitrusting of complexe apparatuur. De dosering van oefentherapie heeft geen plafondeffecten. Afhankelijk van de belastbaarheid en leerbaarheid van de patiënt, wordt men bij voorkeur meerdere malen per dag behandeld, ook in het weekend. De behandelsessies dienen uitgevoerd óf gedelegeerd te worden door een fysiotherapeut met expertise op het gebied van neurorevalidatie en CVA.
Patiënten dienen zo veel mogelijk in de gelegenheid te worden gesteld om ook buiten de vastgestelde therapie-tijden te oefenen. Patiënten in zowel de vroegere als chronische fase na een CVA, dienen met hoge intensiteit te worden behandeld. Bij CVA-patiënten dient training zo veel mogelijk gericht te zijn op het (her)leren van vaardigheden die in het dagelijks leven van de patiënt relevant zijn en de omgeving (of 'context') waarin de bewegings wordt uitgevoerd, zoals eigen woon- en werkomgeving. Bij aanvang zal echter op functieniveau moeten worden getraind om activiteiten mogelijk te maken. Vanuit economisch perspectief lijkt vroegtijdig ontslag met zorg in de thuissituatie goedkoper dan de reguliere (poli)klinische zorgverlening. In de meeste gevallen ligt het accent op het aanleren van functionele vaardigheden zelf. Er is echter geen evidentie voor het hanteren van een bepaalde methode.

Binnen de fysiotherapie bestaan verschillende stromingen over de ontwikkeling van het motorisch leren. Geen van de stromingen bieden een afdoende handvaten voor het begrijpen van de motorische problemen.

Parameters
Binnen de fysiotherapie kan gebruik gemaakt worden van bewegingspatronen en controleparameters, zoals snelheid en/of ritme om onder andere de frequentiekoppeling tussen arm- en beenzwaai bepalen om bijvoorbeeld de symmetrie van het gangbeeld te verbeteren.

Diagnostisch proces
Wanneer er geen gegevens beschikbaar zijn is het wenselijk nader uit te vragen en te beoordelen, zoals parese, bewegingsuitslag, coördinatie, somatosensibiliteit, evenals beperkingen in activiteiten als transfers, loop- en arm-handvaardigheid en ADL-vaardigheden.

Teleconsultatie/-revalidatie & zelfmanagement bij CVA
Een recente ontwikkeling is teleconsultatie waarbij patiënten op afstand worden begeleid. Patiënten moeten zelfstandig oefenen en de progressie en uitvoering op gezette met de fysiotherapeut op afstand evalueren. Deze vorm van revalidatie lijkt veelbelovend omdat het inspeelt op zelfmanagement, zelfstandig kunnen oefenen en empowerment van de patiënt (en partner) in de eigen woon- en leefomgeving(tabel 3). Binnen de fysiotherapeutische behandeling kunnen zelfregie en eigen initiatief worden gefaciliteerd door de patiënt actief te betrekken bij het stellen van doelen ('goal setting'). Telerevalidatie is mogelijk kosteneffectief, wegens sneller ontslag en er geen reistijd en -kosten worden gemaakt. Onduidelijk is nog welke vorm van telecommunicatie voor welke subgroepen het meest effectief is. Belangrijke elementen in zelfmanagementprogramma's zijn o.a., informatievoorziening, het stellen van doelen, het oplossen van problemen en het bevorderen van self-efficacy.

Secundaire preventie
De fysiotherapeut speelt een belangrijke rol met het screenen van patiënten en het begeleiden van het CVA preventie door leefstijlprogramma. Elementen binnen een leefstijlprogramma zijn o.a participeren in aerobe training en fysieke activiteit.

Oefentherapie
Bij looptrainingen worden het lopen en aan lopen gerelateerde activiteiten geoefend op een vaste ondergrond. De fysiotherapeut observeert het lopen van de patiënt, zie tabel 9. Een variatie op de looptraining is VR-mobiliteitstraining. De patiënt beweegt zich in een virtuele omgeving en krijgt hierover feedback. Er wordt gesuggereerd dat het gebruik van een virtuele omgeving corticale reorganisatie bewerkstelligt. Deze virtuele omgeving kan bestaan uit typische openbare ruimten zoals een straat of park waarin obstakels moeten worden vermeden, maar ook uit een spelomgeving, waarin de bewegingsuitslag van een gewricht wordt getraind. Het vroegtijdig inzetten van de romp tijdens het grijpen en pakken van voorwerpen, alsmede een proximale sturing vanuit de schouder, zijn kenmerkend binnen dit natuurlijke herstel.

Spiegeltherapie
Geadviseerd als toevoeging op de reguliere behandeling. De patiënt zit in halfzittende houding op bed en kijkt in een langwerpige spiegel die gepositioneerd is tussen de benen in het sagittale vlak, met de spiegelzijde gericht naar het niet-paretische been. Geadviseerd wordt de patiënt te informeren over de geleverde loopprestatie, op basis van de maximale loopsnelheid, gemeten met de Tien-meter looptest. Deze feedback wordt bij elke behandeling herhaald, zodat de patiënt inzicht krijgt in zijn progressie.

A8 .4 COPD

Gebrek aan therapietrouw is een bekend probleem bij therapeutische interventies die het activiteitenniveau en het mucustransport bevorderen. Bovendien moeten persoonlijke behandeldoelen en verwachtingen worden geformuleerd en de bereidheid, de motivatie, het vertrouwen om te slagen en de eventuele barrières die een gedragsverandering in de weg staan worden achterhaald (zie ook bijlage 3). Focuspunten van de fysiotherapeut staan in tabel A8.3.

COPD symptoomdomeinen fysiotherapeuten	behandeldoelstellingen fysiotherapeutische interventies	Nazorg mbt therapietrouw
• kortademigheid • afgenomen inspanningsvermogen • verminderde fysieke activiteit.	1. verminderen kortademigheid; 2. verbeteren inspanningsvermogen en fysieke activiteit; 3. verbeteren mucusklaring; 4. verbeteren kennis, zelfmanagement en vertrouwen om dingen uit te voeren.	• verbeteren door deelname aan groepssessies en fysieke activiteit die men graag doet. • Regelmatige check-ups vergroten motivatie om de gedragsverandering te handhaven.

Tabel A8.3.. COPD domeinen van fysiotherapeut

Figuur 4 is een stappenplan dat dient als leidraad bij het optimaliseren van de inspanningstraining, dat als uitgangspunt de oorzaken van de inspanningsbeperking heeft en als uitkomst de verschillende behandelopties, zoals interval- en duurtraining, weerstandstraining en respiratoire spiertraining, zie tabel A8.4.

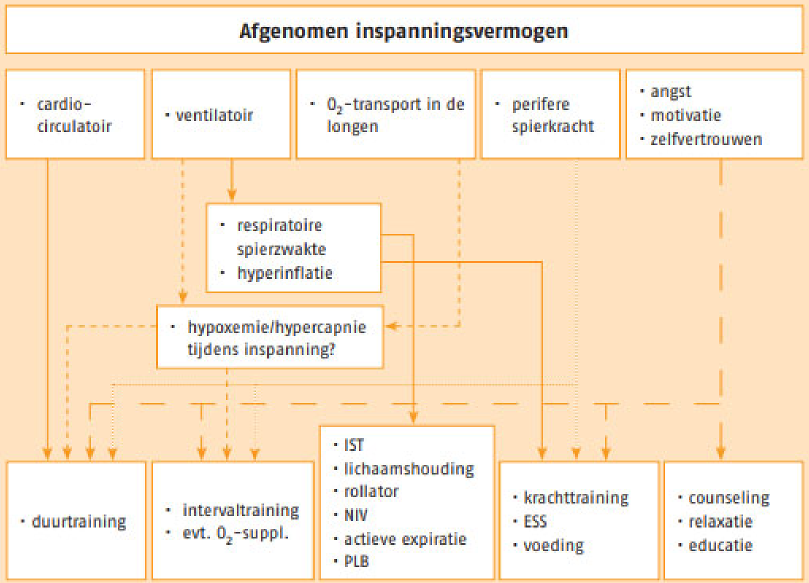
training	beschrijving	aanbevolen	frequentie	Uitvoering
Duurtraining	ter verbetering van de cardiorespiratoire fitheid en aerobe inspanningsvermogen	COPD in alle stadia van de aandoening, die inspanningsgerelateerde beperkingen ervaren	3 tot 5 keer per week	loopband fietsergometer
Intervaltraining		alternatief voor duurtraining bij patiënten die niet in staat zijn om een continue inspanning vol te houden	3 tot 5/week, voor 1w trainingsweken trainingsintensiteit wekelijks beoordelen	loopband fietsergometer
Weerstands- training	toegevoegd component aan duur- of intervaltraining	patiënten met perifere spierzwakte	2 tot 3 sets, 8 tot 12 herhalingen/spier-groep, 2 tot 3/week	

Tabel A8.4.. Aangeboden trainingen voor COPD patiënten.

Tabel 4. Aanbevolen meetinstrumenten om verschillende klinische problemen (relevante parameters) bij patiënten met COPD te objectiveren.

Klinisch probleem	Meetinstrument
Verminderde inspanningstolerantie	• diagnostische maximale inspanningstest (medische informatie) • functionele inspanningstests: 6MWT*, SWT*
Afgenomen skeletspierfunctie	• isometrische spierkrachtmeting: (handheld) dynamometrie*
Terugkerende respiratoire infecties met mucusretentie	• longfunctietest (medische informatie)
Gedaald fysieke activiteitenniveau	• MRC-schaal
Symptomen van vermoeidheid en kortademigheid bij inspanning	• MRC-schaal
Verminderde kwaliteit van leven	• vragenlijsten: – Clinical COPD Questionnaire (CCQ) – Chronic Respiratory Disease Questionnaire (CRQ)* – Saint George respiratory questionnaire (SGRQ)* – Quality of life for respiratory illness questionnaire (QoLRIQ)

** Geschikt voor objectieve follow-upmetingen van behandeleffecten.*
6MWT = 6 minute walking schaal; SWT = Shuttle Walk Test; MRC = Medical Research Counsel.



Figuur 4. Stappenplan uitgaande van de oorzaak(en) van het afgenomen inspanningsvermogen, dat leidt naar de behandelvorm die het inspanningsvermogen optimaal verbetert.
IST = inspiratoire spierkrachttraining; NIV = niet-invasieve ventilatie; ESS = elektrische spierstimulatie; PLB = pursed lips breathing.

Gedurende de eerste trainingsweken wordt aanbevolen om de trainingsintensiteit wekelijks te beoordelen om er zeker van te zijn dat de relatieve trainingsintensiteit constant blijft. Op die manier wordt een optimale prikkel voor perifere spieradaptaties opgelegd. Inspanningstraining moet onder gedeeltelijke of volledige supervisie worden uitgevoerd om optimale fysiologische effecten te verkrijgen. In de toekomst moet worden onderzocht of het nuttig is om gesuperviseerde programma's te combineren met thuisinterventies die door de patiënt worden opgevolgd. Deze aanpak kan mogelijk helpen bij het verhogen van de hoeveelheid fysieke activiteit in het dagelijks leven.

Een voorovergebogen houding is effectief om het gevoel van kortademigheid te verminderen bij patiënten met COPD en is bovendien van nut tijdens het wandelen met gebruik van een rollator.

Educatie en zelfmanagement van de patiënt
Verbetering van therapietrouw en zelfmanagement moet een integraal onderdeel vormen van de fysiotherapeutische behandeling bij COPD. Het promoten van fysieke activiteit in de loop van het trainingsprogramma is belangrijk. Naast therapie moet ook getracht worden een probleemoplossende aanpak en een onafhankelijke actieve levensstijl te ontwikkelen. De doelstelling is dat patiënten de aanbevolen fysieke activiteitsnorm behalen en behouden. Deze interventie is in overeenstemming met de aanbevelingen voor ouderen van het American College of Sports Medicine en de American Heart Association.

Met de Vragenlijst fysieke activiteit kunnen patiënten worden gescreend op inactiviteit. Motiverend interviewen is een consultatiestijl waarbij men niet verstrikt raakt in langdurende adviessessies. De fysiotherapeut moet de patiënt helpen om de ambivalentie van gedragsverandering

A8.5 ENKELLETSEL

Een ‘normaal’ herstelproces leidt binnen 6 tot 8 weken tot functieherstel en genezing zonder restletsels (zoals functionele instabiliteit).Indien dit niet het geval is, dienen belemmerende factoren te worden opgespoord, zie tabel A6.5.

	inversietrauma(acuut enkelletsel)	Functionele instabiliteit
efinitie	inversieletsel waarbij onderzoek en behandeling plaatsvinden 0 tot 6 weken na het ontstaan ervan.	Restklachten houden zoals ‘givingway’, recidiverend zwikken of angst om (voluit) te belasten.
lachte - beeld	Binnen 6 tot 8 weken is er functieherstel en genezing zonder restletsels. Binnen twaalf weken hebben de meeste patiënten het sporten weer hervat op hetzelfde niveau als voor het trauma. Lopen zal in de meeste gevallen weer mogelijk zijn binnen één tot twee weken	pijn, zwelling en gewrichtsstijfheid, feitelijk opnieuw zwikken. Kant kan leiden tot ongewenst aangepast gedrag, een afwijkend gangpatroon, het vermijden van dagelijkse bezigheden, of problemen met activiteiten op het werk of met sporten op het gewenste niveau.
elemm rende ictoren	• relevante nevenpathologie • een sterke ontstekingsreactie • niet te verklaren (oncontroleerbare) pijn • onvoldoende aanpassing van houdings- en bewegingsgedrag van de patiënt (overbelasting) • angst om te belasten • een recidief en/of • een pre-existent instabiele enkel.	• mechanische instabiliteit (laxiteit van het kapsel-bandapparaat) • verstoorde proprioceptie • verminderde spierkracht • vertraagde reactietijd van spieren • chronische synovitis • verminderde dorsaalflexie • inadequaat omgaan met klachten/ angst • onzekerheid over de enkelstabiliteit

Tabel A6.5. Klachtenbeeld enkelletsels

Innameprocedure	Categorisatie	Diagnostische competenties
• aanmelding, • inventarisatie van de hulpvraag • screening op ‘pluis/niet-pluis’ • informeren/adviseren over bevindingen van screeningsproces.	recreatiegerichte sporters	Diagnostiek en behandeling door een algemeen fysiotherapeut volstaat.
	geleidelijk ontstane aandoeningen	Aandoeningen ten gevolge van langdurige sportbeoefening is sportfysiotherapeutische diagnostiek en behandeling relevant.
	prestatiegerichte sporters	Diagnostiek en behandeling door de sportfysiotherapeut worden verzorgd voor zover de sportgezondheidszorg betrokken is bij de betreffende sportbeoefening.
	maximale sporters	competenties van een sportfysiotherapeut vereist voor diagnostiek, behandeling en revalidatie

Tabel A6.6. Screeningsvragen en benodigde competenties

Middels met gerichte vragen, tests of andere diagnostische verrichtingen wordt vastgesteld of er sprake is van een patroon van tekens en symptomen die binnen het competentiegebied van de individuele fysiotherapeut vallen, zie tabel A6.6. Belangrijk aspect van de screening op pluis/ niet-pluis is om ernstige letsels uit te sluiten.

Aanmelding

Patiënten kunnen zich op eigen initiatief melden bij de fysiotherapeut of via een verwijzing door huisarts of medisch specialist. Met ingang van 1 januari 2006 is directe toegankelijkheid van de fysiotherapeut wettelijk mogelijk. Indien een patiënt zich zonder verwijzing aanmeldt, voert de fysiotherapeut, na inventarisatie van de hulpvraag, de screening uit. Aparte screening is niet noodzakelijk indien er wel sprake is van een verwijzing. Wel moet de therapeut gedurende het diagnostisch en therapeutisch proces alert blijven op signalen en symptomen waarvoor eventueel contact met de verwijzer nodig is. Bij de inventarisatie van de hulpvraag is het van belang de belangrijkste klachten, het beloop daarvan en de doelstellingen van de patiënt te achterhalen. Leeftijd, geslacht, incidentie en prevalentie en ontstaanswijze, symptomen en verschijnselen bepalen de inschatting of symptomen pluis of niet-pluis zijn en verder fysiotherapeutisch onderzoek geïndiceerd is. De fysiotherapeut is alert op onbekende patronen, bekende patronen met één of meer afwijkende symptomen en rode vlaggen.

Tabel 1. Typering van sporters volgens het Landelijk Platform Sportgezondheidszorg (LPS).

Recreatiegerichte sporters	Deze sporters zien sport als een ontspannende bezigheid. Zij sporten vanuit de wens om gezond te bewegen en/of de behoefte aan regelmatige sociale contacten. Het leveren van (steeds betere) prestaties is niet hun primaire motivatie.
Prestatiegerichte sporters	Deze sporters zien sport als extra inspanning om (steeds) beter te presteren, zonder uiterste grenzen te zoeken. Zij sporten op presterend niveau in wedstrijden, maar ook ongeorganiseerd.
Maximale sporters	Deze sporters zien sport als uiterste grens van lichamelijke (en geestelijke) prestatie. Zij beoefenen meestal topsport op nationaal en internationaal niveau. Sommige van hen sporten vanuit hun eigen motivatie om 'de beste' te worden.

Acuut enkelletsel	Functionele instabiliteit
• Bevindingen in overeenstemming met het beloop van een 'normaal' herstelproces? • Duur van de klachten (de tijdsperiode na het trauma) in overeenstemming met 'normaal' herstelproces? • Is het verloop van herstel 'normaal', of is er sprake van een afwijking? • Te verwachten hersteltijd; wel of geen specifieke behandeling/ begeleiding? • Is herbeoordeling na noodzakelijk?	• Zijn de factoren fysiotherapeutisch beïnvloedbaar? • Wat zijn bevorderende/belemmerende factoren? Wat zijn de belangrijkste stoornissen/beperkingen in: • functies en anatomische eigenschappen, • activiteiten • participatieproblemen • Hoe hangen dit samen met de persoonlijke en externe factoren?
Indien er sprake is van een afwijkend herstelproces is het volgende van belang: • Kan groei en herstel plaatsvinden? • Voorwaarden voor herstel aanwezig? • belemmerende factoren beïnvloedbaar?	

Tabel A6.7. Analyse van enkelletsel onderverdeeld in acuut en functionele instabiliteit

Doelstellingen zijn een optimaal functioneel herstel, zo volledig mogelijk herstel van functies en activiteiten en een terugkeer naar het hoogst haalbare of gewenste niveau van participatie en het voorkomen van recidiefletsel, exacerbaties en disfunctioneren. De oefeningen en/of de training wordt afgestemd op de specifieke eisen die aan de enkel worden gesteld.

Onderdeel	Functies & Activiteiten
Gangpatroon	Symmetrisch en dynamisch gangpatroon ter voorkoming onderhouden klachten. Oefen dagelijkse activiteiten: opstaan, zitten, traplopen.
Coördinatie en balans	• Statisch evenwicht (balans) met toenemende moeilijkheidsgraad (open/gesloten ogen,groot/klein steunvlak, stabiele/wankele ondergrond, op voldoende hoge (> 30° supinatie) oefentol, zonder/met externe verstoringen, enz.) • dynamisch evenwicht. • opbouw van cyclische bewegingen naar abrupte/onregelmatige bewegingen.
Kracht en uithoudingsvermogen:	• Aandacht voor lokale krachtoefeningen en spieruithoudingsvermogen. • Oefen in functionele situaties. • Voldoende rust- en herstelmomenten in binnen en tussen de trainingen.
Snelheid	Voer snelheid van bewegingen op.
Beweeglijkheid	Oefen, na iedere toename van gewonnen beweeglijkheid (dorsale flexie) direct de proprioceptie en stabiliteit om de stabiliteit te verbeteren.

Tabel A6.8. Te beoefenen functies en activiteiten bij Functionele instabiliteit van de enkel

A8.6 LAGE RUGPIJN

Pijn in de lumbosacrale regio op de voorgrond. Ook kan uitstraling in de bil en het bovenbeen optreden. De pijn kan verergeren door bepaalde houdingen, bewegingen en het tillen of verplaatsen van lasten. Bij iedere patiënt die zich zonder verwijzing aanmeldt bij de fysiotherapeut, zal eerst een screening plaatsvinden, zie tabel A8.9-10. Bij recidiverende lage rugpijn moet speciale aandacht worden besteed aan de oorzaken die aan het recidiveren van de pijn ten grondslag zouden kunnen liggen; verandering in (werk)belasting, werkdruk en/of bewegingsactiviteiten. Gebruikt men ergonomische aanpassingen en wat is de mate van therapietrouw? Volgt de patiënt eerder gegeven adviezen op, en zo niet, wat is de reden daar dan van?

wervelkolom, bekken, heupen	Spieren	Vermoeden uitstraling/ beperkingen	Behandelplan
uitslag richting bewegings weerstand	tonus coördi- natie	Straight leg raising test (teken van Lasègue positief). Vooroverbuigen (vinger- vloerafstand > 25 cm)	• Einddoelen incl. tijdpad • Gekozen verrichtingen • Planning evaluatie momenten/ wijze • Aantal behandelingen (overschrijding van verwachting geeft reden tot evaluatie/bijstelling)

Tabel A8.9. Relevante parameters nekpijn

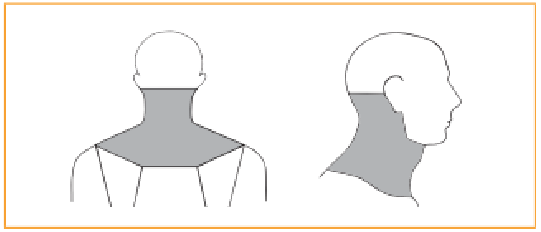
	Profiel 1	profiel 2	Profiel 3
Ken- merken	Aspecifieke lage rugpijn met een normaal beloop van het herstel.	Aspecifieke lage rugpijn met afwijkend beloop zonder dominante aanwezigheid van psychosociale belemmerende factoren.	Aspecifieke lage rugpijn met een afwijkend beloop met dominante aanwezigheid van psychosociale herstelbelemmerende factore
Beleid	• Vermijd passiviteit en stimuleer actieve leefstijl. • Stimulatie van (gedoseerde) beweging, opbouw van activiteiten, hervatten van werkzaamheden (eventueel met tijdelijke aanpassingen). • Max 3 zittingen.	• Vermijd passiviteit en stimuleer actieve leefstijl. • Stimulatie van (gedoseerde) beweging, opbouw van activiteiten, hervat werk (met tijdelijke aanpassingen). •oefenprogramma van patiënt behoefte en expertise therapeut. • Vraag bij werkverzuim langer dan 4 weken naar afspraken met bedrijfs- arts en bespreek beleid	• Bespreek beleid met bedrijfsarts, bedrijfsfysiotherapeut of de arbodienst indie zwaar lichamelijk werk, langer durend ziekteverzuim of een arbeidsconflict herstel belemmeren/bespoedigt • Stimulatie van (gedoseerde) beweging, op van activiteiten, hervatten van werkzaamhe (eventueel met tijdelijke aanpassingen). • tijdcontingent oefenprogramma • Bij werkverzuim doelen van oefenprogram samen laten vallen met werkhervatting

Tabel A9.10. Kenmerken en beleid bij van aspecifieke lage rugpijnklachten

Met het toenemen van de activiteiten tijdens de behandeling, moet de patiënt ook in zijn eigen omgeving stapsgewijs meer activiteiten gaan ontplooien. Hiermee vindt overdracht plaats van de behandeleffecten naar het dagelijks leven van de patiënt. Het verdient aanbeveling een dergelijk tijdgebonden oefenprogramma zo mogelijk in te bedden in een bedrijfsgeneeskundige setting wanneer dit van toepassing is. De oefeningen dienen bij voorkeur te lijken op handelingen die de patiënt op het werk verricht en die deze als problematisch ervaart. De therapeut evalueert de behandeling regelmatig. Indien de behandeling na 3-6 weken geen effect heeft gehad (in de zin van toename van activiteiten en participatie) neemt de therapeut contact op met de huisarts of bedrijfsarts om het verdere beleid te bespreken.

A8.7 NEKPIJN

Tijdens het diagnostisch proces, zie tabel 18, dient er onderscheid te worden gemaakt tussen nekpijn graad I t/m IV oor het behandelbeleid, waarbij graad IV dient te worden uitgesloten. Bij verdenking op graad III, kan de Upper Limb Tension Test (ULTT) (uitsluittest voor graad III) uitgevoerd worden. Het verdere lichamelijk onderzoek richt zich op de aangedane lichaamsregio en de biomechanische, fysiologische en anatomische structuren die daarbij betrokken zijn, zie tabel A8.11.



Figuur 1. Anatomische regio van de nek vanaf de achter- en zijkant.

lichamelijk onderzoek	Vragenlijst tijdens onderzoek
Onderzoek van cervicale en thoracale wervelkolom, schoudergordel en schoudergewrichten: • range of motion (ROM), • richting van de beweging, • weerstand tegen beweging • Spieronderzoek: • elasticiteit, • spiertonus; • spiercoördinatie •nekflexoren testen/craniocervicale flexietest	1. Van welke graad nekpijn is er sprake? 2. Normaal/afwijkend beloop van klachten? 3. Subgroep traumagerelateerde/werkgerelateerd? 4. Psychosociale, persoonlijke en/of omgevingsfactoren ter verklaring afwijkend beloop en zijn deze beïnvloedbaar door fysiotherapie? 5. Verband tussen beperkingen in activiteiten en/of participatieproblemen en nekpijn of andere stoornissen in lichaamsfuncties en anatomische eigenschappen, en is dit verband beïnvloedbaar door fysiotherapie?

Tabel A8.11. Onderdelen lichamelijk onderzoek nekklachten mbt bewegingen en houding

Tabel 4. De behandelprofielen bij patiënten met nekpijn.

Profiel	Kenmerken	Omschrijving
Behandelprofiel A	nekpijn graad I en II met een normaal beloop	nekpijn die (in meer of mindere mate) invloed heeft op activiteiten in het dagelijks leven, die in de eerste zes weken na ontstaan van de klachten verbeteren
Behandelprofiel B	nekpijn graad I en II met een afwijkend beloop, *zonder* dominante aanwezigheid van psychosociale herstelbelemmerende factoren	nekpijn die (in meer of mindere mate) invloed heeft op activiteiten in het dagelijks leven, die in de eerste zes weken van de klachten *niet* verbeteren, of in die periode zelfs verslechteren, en waarbij geen psychosociale herstelbelemmerende factoren dominant aanwezig zijn
Behandelprofiel C	nekpijn graad I en II met een afwijkend beloop, *met* dominante aanwezigheid van psychosociale herstelbelemmerende factoren	nekpijn die (in meer of mindere mate) invloed heeft op activiteiten in het dagelijks leven, die in de eerste zes weken van de klachten *niet* verbeteren, of in die periode zelfs verslechteren, en waarbij psychosociale herstelbelemmerende factoren dominant aanwezig zijn
Behandelprofiel D	nekpijn graad III	nekpijn waarbij neurologische tekenen en symptomen aanwezig zijn.

Het behandelplan wordt in samenspraak met de patiënt opgesteld en is afgestemd op het behandelprofiel van de patiënt. Zie tabel 4 voor de invulling van de behandeling per profiel.

Werk dat bestaat uit repeterende werkzaamheden, werk met een sedentaire werkpositie, werk waarbij regelmatig en langdurig de nek in een voorwaartse flexiehouding is gepositioneerd, werken met een slechte bureau-instelling en in een slechte werkhouding, bij precisiewerk, en de werkomgeving (bijvoorbeeld onprettige omgang met collega's en leidinggevenden, een onprettige werksfeer) mogelijke risicofactoren zijn voor het krijgen van nekpijn.

A8.8 KANS

Centraal staan (pijn)klachten in de arm (boven- of onderarm, elleboog, pols of hand), nek en/of schouder, of een combinatie hiervan. Aan deze klachten ligt steeds een verstoring van de balans tussen belasting en belastbaarheid ten grondslag. Langdurig herhaalde bewegingen of statische houding, al dan niet arbeidsgerelateerd, tijdens werk, huishouden, studie, sport of hobby zijn vaak de oorzaak. Ontstaan en beloop kunnen worden beïnvloed door lichamelijke activiteiten, zowel binnen als buiten de context van waar het probleem is ontstaan.

	Patiëntenprofiel I	**Patiëntenprofiel II**	**Patiëntenprofiel III**
Ken-merken	1.1 Stoornissen in: functies en/of anatomische eigenschappen. 1.2. De patiënt heeft geen beperkingen in activiteiten en geen participatieproblemen	Zie 1.1 2.2. Beperkingen in activiteiten en participatieproblemen. 2.3. Begrijpelijke en herkenbare samenhang tussen stoornissen, beperkingen en/of participatieproblemen.	Zie 1.1 en 2.2 3.3 Sprake van een discrepantie tussen de aanwezige stoornissen enerzijds, en de ervaren beperkingen en/of participatieproblemen anderzijds. 3.4 Inadequate omgang met gezondheidsprobleem door patiënt.
Behan-deling	• Advies dagelijkse routine aanhouden • Bij ziekteverzuim advies: werk hervatten, zo nodig met (tijdelijk) aangepaste werktijden en -taken en eventueel een aangepaste werkplek (Arboarts) • behandeldoelen aanvullen met subdoelen, indien nodig	• **begeleid** zoals profiel I. • activiteitenniveau/belasting verlagen • Benadrukken actieve leefstijl • Na afname pijn, tijdcontingent oefenen • geleidelijk opvoeren van belasting. **bespreek**: • aard/factoren gezondheidsprobleem • herstelfactoren en beïnvloedbaarheid. **Analyse:** • provocerende/ reducerende activiteiten, handelingen **Instructie:** • Belasting geleidelijk opvoeren. • Patiënt begrijpt informatie en volgt adviezen op.	• Oefeningen gericht op geleidelijke toename activiteiten/participatie • tijdcontingent geoefend. • gewoontevorming: volhouden van relevante activiteiten • coördinatie van handelingen en taken. • behandelschema opstellen; uitgangspunt is baselineniveau(gemiddelde activiteitenniveau van de patiënt bij aanvang). In het schema noteert de fysiotherapeut van iedere activiteit de duur, de frequentie en de intensiteit.(patiënt doet niet minder of meer).
Oefen-ingen	• Gewrichtsfuncties • Vergroten beweeglijk- heid gewrichten • Ontspanning • Houdings- en bewegingsgevoel • Vewegingscoördinatie • Vaardigheden uit adl/werksituatie	• Fuiste uitvoering bewegingen. • Vergroting beweeglijkheid van gewrichten; • Ontspanningsoefeningen • Houdings- en bewegingsgevoel • Coördinatie van bewegingen • Werk/adl- activiteiten-vaardigheden	• In praktijk en thuis oefenen • Progressie zelf in grafiek bijhouden (zie C.1.2). • Deelactiviteiten • Laag aanvangsniveau bij bewegingsangst • Aanmoediging toename activiteitenniveau tijdens behandeling • Overdracht behandeleffecten naar dagelijks leven
Algemene behandel-doelen	De patiënt heeft: • Meer kennis over en inzicht in de klachten; • Klachten onder controle; • Kennis over en inzicht in eigen functioneren; • Kennis over en inzicht in de factoren die van invloed zijn op het herstel van het gezondheidsprobleem; • Controle over het dynamische evenwicht tussen belasting en belastbaarheid (zie figuur 1).		

Tabel A8.12. Patiëntenprofielen en (algemene)behandeldoelen

Belasting en belastbaarheid
Er gelden zowel algemene als profielspecifieke behandeldoelen, zie tabel A8.12. Bij profiel I ligt de nadruk op informatie over het gezondheid en advies om belasting tijdelijk te verlagen. Bij profiel II leert men de belasting beter afstemmen op de belastbaarheid en actievere levensstijl. Profiel III richt zich op adequaat leren omgaan met het gezondheidsprobleem maar is intensievere begeleiding nodig. Daarin wordt gewerkt aan het geleidelijk opbouwen van de lichamelijke en mentale belastbaarheid. De patiënt leert de informatie eerst toepassen in de oefensituatie en vervolgens in het dagelijks leven, in het bijzonder op het werk.

Lichaamsbewustheid
Sommige mensen zijn in staat de belasting af te stemmen op hun lichamelijke en mentale vermogens (belastbaarheid). Bij pijn en andere symptomen passen zij de belasting van de arm, nek en/of schouder aan. Anderen kunnen dit echter niet en bij hen ontstaat een langdurig beloop van het gezondheidsprobleem. De samenhang tussen de stoornissen in functies, beperkingen in activiteiten en/of participatieproblemen is dan niet altijd duidelijk. Ook de wijze waarop een patiënt met zijn gezondheidsprobleem omgaat, speelt een rol. Die wordt deels bepaald door iemands opvattingen over zijn gezondheidsprobleem en deels door de betekenis die iemand toekent aan de symptomen ('beliefs'), die op hun beurt weer worden beïnvloed door kenmerken van de persoon zelf, en de interactie tussen de patiënt en zijn omgeving (sociale factoren). Onder deze interactie valt ook de interactie met de fysiotherapeut. De fysiotherapeut brengt de (stoornissen in) functies en anatomische eigenschappen, de (beperkingen in) activiteiten en de (problemen met) de participatie van de patiënt in kaart en inventariseert de factoren. Tevens brengt de fysiotherapeut de opvattingen over het probleem en de verwachtingen van de therapie in kaart voordat daadwerkelijk tot behandeling wordt overgegaan. Vervolgens maakt men expliciete afspraken te maken over behandeldoelen, werkwijze en de tijdstippen waarop deze doelen worden geëvalueerd.

Ketenproblematiek
De hele keten, maar met name die van de nek-schoudermusculatuur wordt middels palpatie beoordeeld op spanning en ontspanning in rust, tijdens (veelgebruikte) handelingen of werkzaamheden met de armen en na afloop van die handelingen. bij werkgerelateerde klachten neemt de fysiotherapeut contact op met de bedrijfsarts wanneer de anamnese daartoe aanleiding geeft. Dit kan ook gebeuren wanneer er onvoldoende informatie over de werksituatie is, bijvoorbeeld het tijdstip van werkhervatting waarnaar de bedrijfsarts streeft of advies over het hervatten/stoppen van werkzaamheden dat strijdig is met dat van de bedrijfsarts.

A8.9 MENISCECTOMIE

Een voorwaarde voor het kunnen toepassen van sportfysiotherapie is een goed geoutilleerde praktijk en een oefenzaal/ruimte die groot genoeg is om loopvorm-analyses te kunnen doen en te oefenen.

Screening
Screeningsproces bestaat uit: aanmelding, inventarisatie van de hulpvraag, screening op pluis/ niet-pluis en informeren en adviseren (Tabel A8.13).
In alle fasen van de behandeling na een meniscectomie staat de oefentherapie centraal. Daarnaast is het begeleiden van de patiënt bij de revalidatie van belang, het informeren over de aandoening, het geven van adviezen en het stimuleren tot participatie. Het einddoel van de fysiotherapeutische behandeling na meniscectomie is een zo volledig mogelijk functieherstel, uitgedrukt in functies, activiteiten (vaardigheden) en participatie. De behandeling bij patiënten uit profiel 1 wordt gekenmerkt door 'begeleiden': patiënten hebben vaak maar een beperkt aantal contacten met de fysiotherapeut en zijn met een aantal adviezen en oefeningen voor thuis in staat het volledig functieherstel zelfstandig te bewerkstelligen. Bij het oefenen ligt de nadruk op bewegen binnen de grenzen van de belastbaarheid. Fase 1a duurt duurt 0 tot 5 dagen tot soms 10 dagen.

Behandelfrequentie
De behandelfrequentie wordt mede bepaald door specifieke behandeldoelen en problemen, en de leerbaarheid en trainbaarheid van de patiënt. Afhankelijk van specifieke behandeldoelen kan de behandelduur over een langere tijd uitstrekken dan bij een normaal herstel. Bij Patiënten met bewegingsangst of overbelasting is begeleiding in de eerste fase intensiever. In fase 2 controleert de fysiotherapeut alleen op gezette tijden de vorderingen die de patiënt maakt met de thuisoefeningen. Aan de hand hiervan wordt het oefenschema bijgesteld.

Actieve levensstijl stimuleren
De fysiotherapeut stimuleert na afloop van de therapie zelf actief te blijven en kan een patiënt gedurende langere of kortere tijd de begeleiden. De patiënt voert dan zelfstandig een trainingsprogramma uit, waarbij de trainingsvoortgang wordt geëvalueerd op niveau en kwaliteit van functioneren. Vooral patiënten met patiëntenprofiel 2 en inactieve patiënten dient de fysiotherapeut te wijzen op bewegingsactiviteiten. Het is van belang het bereikte niveau van functioneren en de kwaliteit van het bewegen te beoordelen door na te gaan of het functieherstel optimaal is geworden (evaluatie op lange termijn).

Anamnese	Bewegingsonderzoek	**Analyse**
• het gezondheidsprobleem • beloop: oorzaak, duur en aard klachten; • stoornissen in anatomische eigenschappen, functies, beperkingen • belastbaarheid • prognostische factoren • wijze van omgaan met de klachten, inzicht, indrukken, angsten, 'illness beliefs' (Wat heb ik? Waar komt het door? Hoe lang gaat het duren? Wat heeft het voor gevolgen? Gaat het over en wie kan er wat aan doen?); • informatiebehoefte van de patiënt; • zelfstandigheid; • steun van de omgeving; • werksituatie • Activiteiten belangrijk zijn voor de patiënt	• actief bewegingsonderzoek: - actieve stabiliteit in stand, op twee benen, op één been, met afnemende knieflexie / naar extensie(staan) • (in)stabiliteit, bewegingsangst en 'giving way' bij opstaan en lopen • mobiliteitsonderzoek: onderzoek kniegewricht en patella: • gangpatroon-observatie, optie: GALN • kwaliteit van bewegen • belastbaarheid bij flexie naar extensie (zwaaifase) • bewegingsonderzoek/functieonderzoek op de bank: - spierfunctie musculus quadriceps femoris • spierkracht bovenbeenspieren (hinkelen/hoptest) • pijnvrije bewegingsrange• onderzoek van de mechanische stabiliteit: • algemene indruk 'active straight leg raising' • gestrekt heffen van aangedane been:'extension lag test' • bepalen van kracht en belastbaarheid(geen afwijkend resultaat) • Squat-test (op één of twee benen)	1 Belangrijkste gezondheidsproblemen (zie figuur 1) van de patiënt (met de nadruk op stabiliteit/beweeglijkheid? Zijn er rode vlaggen? 2 verbanden tussen stoornissen in anatomische eigenschappen/functies en beperkingen? Welke? 3 Factoren die invloed hebben op herstel? Welke? 4 herstelfase: normaal/vertraagd herstelproces? 5 Instroom in het therapeutisch proces **Aansluitend:** 6 zijn problemen door fysiotherapie te beïnvloeden? 7 behandeling volgens richtlijn Meniscectomie?

Tabel A8.13. Anamnese en bewegingsonderzoek meniscectomie

A8 .10 PARIKINSON

Het ziekteproces bij de ziekte van Parkinson is niet te beïnvloeden, alleen de symptomen van de ziekte zijn te beïnvloeden, met o.a. fysiotherapie. De ziekteprogressie wordt afremt doordat fysieke activiteit het neurodegeneratieve proces beïnvloedt.

Zelfmanagement

Zelfmanagement is de mate waarin een patiënt kan omgaan met de symptomen, de behandeling, de lichamelijke, psychosociale en sociale gevolgen van een chronische aandoening, en de veranderingen die het hebben van een chronische aandoening in het met zich meebrengt. Met gerichte coaching op het gebied van zelfmanagement bevordert de fysiotherapeut het gevoel van autonomie van de patiënt t.o.v. van de behandeling. De fysiotherapeut kan 4 methoden inzetten: educatie, functie-, vaardigheids- en strategietraining.

Educatie: gedragsverandering

Voor een goed resultaat van de fysiotherapeutische behandeling is vaak gedragsverandering nodig. Om een bepaald gedrag te veranderen, is motivatie nodig. Naast intrinsieke motivatie die vanuit een patiënt zelf komt, kan een fysiotherapeut helpen bij het veranderen van gedrag met coaching. Bijvoorbeeld met het 5A's-Model(tabel A8.14). Het veranderen van inactief gedrag maar ook het komen tot een meer actieve rol in het zorgproces (zelfmanagement) zijn voorbeelden van gedragsverandering. Het informeren en adviseren van patiënten (en mantelzorgers) geeft hen meer inzicht in en een gevoel van controle over de aandoening, waardoor de betrokkenen zelf een actievere rol kunnen spelen bij de behandeling. Om de gedragsverandering vol te houden, is het belangrijk dit voordelen oplevert (gezondheidswinst) en dat iemand plezier krijgt in het bewegen.

Tabel 2. WHO-aanbevelingen ten aanzien van fysieke activiteit.

Voor volwassenen (18 t/m 64 jaar)	• Aerobe fysieke activiteit: – ≥ 150 min/week matig-intensief; – of ≥ 75 min/week intensief; – of een combinatie daarvan die in totaal op hetzelfde neerkomt.
	• Deze aerobe activiteit dient te zijn opgebouwd uit perioden van minstens 10 minuten onafgebroken bewegen.
	• ≥ 2 dagen/week spierversterkende activiteiten gericht op grote spiergroepen.
	• Voor extra gezondheidsvoordelen: – 300 min/week matig-intensieve aerobe fysieke activiteit; – of 150 min/week intensieve aerobe fysieke activiteit; – of een combinatie daarvan die in totaal op hetzelfde neerkomt.
Voor ouderen (≥ 65 jaar), vergelijkbaar aan volwassenen, plus:	• Bij mensen met beperkte mobiliteit: ≥ 3 dagen/week fysieke activiteit gericht op verbetering van de balans en preventie van valincidenten.

zelfmanagement moet bevorderen/stimuleren:	Factoren die zelfmanagement beïnvloeden:
• gevoel van autonomie • vertrouwen in het eigen kunnen • parkinsonspecifieke kennis • therapietrouw • Fysieke activiteit • gedragsverandering	• complexere problemen • cognitieve problemen • communicatieproblemen • een laag opleidingsniveau • weinig sociale steun uit omgeving • achtergrond beslissingen door zorgverleners • sociaal-economische achtergrond • toegang tot informatietechnologie

Betrekken van mantelzorger bij zelfmanagement:
• waardevolle informatie over beperkingen in dagelijks leven • aanleren van bewegingsstrategieën • specifieke informatie, zoals instructies en uitvoering van (dubbeltaken. Informatie voor mantelzorgers zou is opgenomen in Addendum Praktijk, H4.

Educatie focus zelfmanagement	**gedragsverandering(5A's -Model)**	**Motivatiebevordering**
• informatie over de ziekte van Parkinson • zelfmanagement en de rol die de patiënt daarbij speelt (Addendum Praktijk, hoofdstuk 8) • onderbouwing van de therapievorm(en) • het belang van therapietrouw	• achterhalen actuele activiteiten/belangrijkste problemen • adviseren over belang van verandering • afspreken welke doelen nagestreefd gaan worden • assisteren om barrières vast te stellen • arrangeren ondersteuning/nazorg om het vol te houden.	• doelen • voordelen interventie uitleggen • gezamenlijk nadenken over wegnemen barrières • Voldoende steun uit omgeving • Therapietrouw op lange termijn • hulp bij bepalen lichaamsbeweging • hulp bij bepalen intensiteit/frequentie • Patiënt hierin laten meebeslissen

Tabel A8.14. Educatie focus ter bewerkstelliging van zelfmanagement van Parkinson

A8.11 ONCOLOGISCHE REVALIDATIE

Patiënten die fysiek actief zijn na een grote buikoperatie, zoals bij eierstok- of baar-moederhalskanker, lopen minder kans op complicaties, verblijven korter in het ziekenhuis en worden minder vaak opnieuw opgenomen. En patiënten die preoperatief trainen laten zowel lichamelijke als geestelijke verbeteringen zien ten opzichte van patiënten die niet oefenen.

Empowerment
Voor het stimuleren van deelnemen aan revalidatie door patiënten, die daarvoor in aanmerking komen of die zeggen daar behoefte aan te hebben (intern gerichte interventies), is het aan te bevelen om de ervaren gedragscontrole (eigeneffectiviteit) ten aanzien van deelnemen door de patiënt, te versterken bijvoorbeeld door middel van de positieve effecten en het plezier in het deelnemen te benadrukken (attitudeversterking). Bij het adviseren om aan een revalidatieprogramma deel te nemen, is het aan te bevelen dat zeker ook bij oudere patiënten (>65 jaar) de motivatie voor deelnemen wordt besproken en duidelijk wordt gemaakt dat revalidatie ook voor hen effectief en dus belangrijk kan zijn.

Therapietrouw
Om therapietrouw te bevorderen, moet er aandacht worden besteed aan het versterken van de gedragscontrole (eigeneffectiviteit). Dit kan bijvoorbeeld gebeuren door:

- Te demonstreren hoe vergelijkbare patiënten fysieke training correct en volledig uitvoeren en daar de positieve effecten van ervaren.
- specifiek voor patiënten met kanker ontwikkeld revalidatieprogramma deel te nemen.
- Persoonlijke doelen en grenzen van de patiënt.
- Op diverse belangrijke (keuze)momenten in het proces, naaste(n) van de patiënt te betrekken.

Het beweegprogramma oncologie kan als eerste keuze worden ingezet als reguliere oncologische revalidatie. Het programma heeft een generiek, op bewegen gericht karakter.

De fysiotherapeut kan ook een meer gedragsmatige aanpak hanteren om cliënten te ondersteunen bij het ontwikkelen van een meer autonoom en intrinsiek gemotiveerd beweeggedrag. Regelmatige lichaamsbeweging bij kankersurvivors is positief geassocieerd met kwaliteit van leven. Verschillende studies laten zien dat survivors die de richtlijnen voor gezond bewegen volgen een hogere kwaliteit van leven ervaren dan overlevenden die niet aan deze normen voldoen. Opvallend hierbij is dat beweeginterventies weliswaar de kwaliteit van leven verbeteren, maar dat dit effect in veel gevallen verdwijnt na het staken van de interventie. Het beweegprogramma oncologie is daarnaast in meer algemene zin gericht op het hernemen of ontwikkelen van een actieve levensstijl en het wegnemen van barrières.

Succesmomenten benoemen
Wanneer de intentie tot meer bewegen bestaat, leidt dit niet automatisch tot het uitvoeren van het gewenste gedrag. De cliënt kan worden ondersteund bij het vertalen van het algemene voornemen om meer te gaan bewegen in concrete plannen. Om de eigeneffectiviteit te versterken, is het belangrijk om concrete, haalbare doelen te stellen. Het ervaren van succesmomenten is een belangrijke bekrachtigende prikkel die de eigeneffectiviteitsbeleving vergroot. Het expliciet maken van bereikte resultaten kan doorlopend plaatsvinden binnen het trainingsverloop en door gemaakte vorderingen grafisch weer te geven, of door de cliënt een

activiteitendagboek bij te laten houden voor activiteiten thuis en daar op positieve manier feedback op te geven. Ook moet expliciet worden stilgestaan bij het behalen van de gestelde doelen en de positieve effecten die dat heeft op het denken, voelen en doen van de cliënt. Negatieve ervaringen kunnen gemakkelijk leiden tot terugval in minder actief gedrag en ook daaraan moet op een opbouwende manier aandacht worden besteed. Wanneer zich (nieuwe) barrières voordoen die het nieuwe gedrag bemoeilijken, kan samen met de cliënt worden gezocht naar een passende manier om deze te slechten. Hierbij wordt in toenemende mate een beroep gedaan op het zelfoplossend vermogen van de cliënt. De rol van de fysiotherapeut verschuift in dit gehele proces steeds meer van trainer naar coach. Hierbij past ook een verschuiving binnen een beweegprogramma oncologie van hoogfrequente (3x/week) naar laagfrequente (1x/week of minder) begeleiding.

Sport, spel en grenzen van belasting

De fietsergometer is het meest gebruikte trainingsmiddel binnen de revalidatie. De belasting is zeer goed doseerbaar en in kleine stappen op te voeren vanuit lage instapniveaus. Als referentiewaarde voor de training geldt de waarde die is behaald met de (maximale) fietstest. Een ander voordeel van fietsen is dat het een efficiënte vorm van bewegen is. Bovendien vinden veel cliënten fietsen leuk en is het ook voor mensen met evenwichtsstoornissen een veilige manier van trainen. Het gebruik van fitnessapparatuur ter verbetering van grondmotorische eigenschappen moet daarom worden aangevuld met het oefenen van de functionele beweging(handeling) waarvoor die eigenschap gewenst is. Oefeningen met gebruik van vrije gewichten zoals dumbells en barbells benaderen functionele bewegingen vaak beter dan bij krachtapparatuur het geval is. Mogelijk nadeel is dat er hogere eisen worden gesteld aan zowel de coördinatie van de beweging als aan het handhaven van de houding.

Sport- en spel activiteiten vragen een positieve attitude, en leveren, bij een juiste keuze van de activiteit, een hoge eigeneffectiviteitsbeleving op, en geven een succeservaring en plezier in het bewegen, allemaal belangrijke factoren bij het vertonen en volhouden van een actieve levensstijl na behandeling voor kanker. Patiënten die moeite hebben met het inschatten van hun fysieke grenzen kunnen door het competitieve element van sport en spel worden uitgedaagd hun grenzen op te zoeken of op te rekken ('onderbelasters') of juist te bewaken ('overbelasters') in een dynamische, minder gecontroleerde situatie. Spelvormen kunnen zo worden ingericht dat de deelnemers worden gestimuleerd om hun eigen grenzen expliciet te bewaken dan wel op te zoeken. Wenselijk is de activiteit zo aan te passen dat deze met de voor hen juiste intensiteit kan worden uitgevoerd. De aandacht moet vooral bewaakt worden voor het opstellen van (haalbare) doelen, het bewaken van de veiligheid in de trainingssituatie en het voorkomen en vroegtijdig signaleren van overbelastingklachten. Bij het trainen met kankersurvivors is de mogelijkheid van het optreden van een