Paediatric physiotherapist´s perspective on the upcoming implementation of the Wearable Breathing Trainer for children with dysfunctional breathing

Master of Health Sciences

2024

Nina Schreuder

Supervisors

Dr. J.A. van Til

Dr. G.D.S. Ludden

External partner

M. van Schaik

UNIVERSITY OF TWENTE.

SAXION HOGESCHOOL

Title	Paediatric physiotherapist's perspective on the upcoming implementation of the Wearable Breathing Trainer for children with dysfunctional breathing
Author	Nina Schreuder
University	University of Twente Drienerlolaan 5 7522 NB Enschede
Study program	Health Sciences
Track	Innovation in Public Health
Supervisors	Dr. J.A. van Til (1st supervisor) Dr. G.D.S. Ludden (2nd supervisor) M. van Schaik (external partner)
Research defense	November 6th, 2024

Acknowledgements

This report describes the master's thesis titled "Paediatric physiotherapist´s perspective on the upcoming implementation of the Wearable Breathing Trainer for children with dysfunctional breathing". This thesis is written as the final part for the master of Health Sciences at the University of Twente.

The assignment at the department of sustainable and functional textiles at Saxion was a great experience, which gave me the opportunity to address a practical issue. I, therefore, hope that the findings of this research help this department, and its associated partners, in making informed choices regarding the implementation of the Wearable Breathing Trainer and that ultimately a large group of children with dysfunctional breathing will receive the benefits of using this wearable in their treatment.

I would like to express my sincere gratitude to everyone who has supported me throughout the process of writing this thesis. First, I would like to thank my two supervisors at the University of Twente, Janine van Til en Geke Ludden for their guidance and support. Their expertise and feedback has helped me to not only complete the thesis, but to also elevate the quality of the thesis. I am also very grateful to all the physiotherapists whom I got to interview, especially knowing most of them had to give up their free time for this. There willingness to participate in this research and to share their thoughts and opinions on this subject was of significant value to this research. Lastly, I want to thank my family and friends for their unwavering support and encouragement throughout this process.

I wish you much enjoyment in reading.

Nina Schreuder

Enschede, 31th of October, 2024

Abstract

Dysfunctional breathing is a respiratory disorder for which an optimal treatment approach is needed to prevent long-term health problems. The Wearable Breathing Trainer is a wearable that could support the current treatment of dysfunctional breathing, as it is developed to support the self-management of children with dysfunctional breathing. However, the actual implementation of wearables into the healthcare system has been relatively slow. The support from healthcare professionals is essential to integrate wearables into the healthcare system. Therefore, the aim of this research is to explore the perspective of paediatric physiotherapists on the barriers and facilitators for the upcoming implementation of the Wearable Breathing Trainer.

A qualitative cross-sectional study is carried out, using semi-structured interviews to identify the barriers and facilitators for the upcoming implementation of the Wearable Breathing Trainer. The interviews were conducted with paediatric physiotherapists in the Netherlands. The framework that has been used to give structure to these interviews is the MIDI instrument. The interviews were held on the work location of the paediatric physiotherapists and online. For the data analysis, an inductive thematic analysis was applied.

This study demonstrates that the implementation is primarily impeded by the time required to learn the technical functioning of this wearable, not having the financial resources to purchase or rent the wearable, or having the financial capacity but being reluctant to spend it if the wearable is not cost-effective, empirically validated as effective, will not be frequently utilised, or is not user friendly. Facilitators that support the implementation of the Wearable Breathing Trainer are the logical structure of the treatment plan, the treatment being more objective, more fun and beneficial for patients, and having reliable support from colleagues. Moreover, the availability of a clear instruction for physiotherapists, as well as patients and their parents, supports the implementation. These facilitators either compensate for the time one has to invest in this wearable or reduce the learning curve and thus potentially minimise the time physiotherapists have to invest in the learning process and implementation of the Wearable Breathing Trainer.

To conclude, physiotherapists are enthusiastic about the use of the Wearable Breathing Trainer in their physiotherapy practice and there are quite a number of facilitators identified that support the implementation of this wearable. However, there is also an equal amount of barriers identified that would hinder this implementation and that would need to be addressed before the wearable is implemented. It is also evident that physiotherapists hold the opinion of their patients in high regard. In particular, physiotherapists place great importance on ensuring that patients are satisfied with using the wearable, encounter no difficulties in its use, and derive clear benefits from its implementation. The findings of this research assist the department of sustainable and functional textiles at Saxion and its associated partners in making informed choices to ensure that the Wearable Breathing Trainer aligns with the preferences of physiotherapists. Understanding their perspective, will contribute to a more seamless implementation process with minimal obstacles for physiotherapists. Including physiotherapists in the decision-making process is crucial to secure broad adoption, so that ultimately a large group of children with dysfunctional breathing can benefit from a wearable device that enhances their treatment.

Inhoud

List of figures

List of tables

Chapter 1: Introduction

Dysfunctional breathing is a respiratory disorder that affects both adults as well as children, but it is considered to be a significant health issue among children (Trompenaars et al., 2020). Dysfunctional breathing occurs when an individual has an abnormal and irregular breathing pattern, such as breath holding, deep sighing, or hyperventilation (Vidotto et al., 2019).

With dysfunctional breathing a person can experience various symptoms, such as shortness of breath, throat tightness, chest pain, and difficulty breathing in (Barker & Everard, 2015). Furthermore, experiencing these symptoms can make underlying conditions, such as asthma and anxiety even worse (Vidotto et al., 2019). Therefore, an optimal treatment approach of this respiratory disorder is essential to prevent long-term health problems and improve the quality of life (Connett & Thomas, 2018).

The prevalence of dysfunctional breathing is imprecise, but it is estimated to affect more than 5% of the children in the Netherlands (*Project Wearable Breathing Trainer | NWO-SIA ProjectenBank*, z.d.). Since the associated symptoms are similar to other cardiopulmonary diseases, such as COPD and asthma, dysfunctional breathing is often underdiagnosed or misdiagnosed (Vidotto et al., 2019). High rates of misdiagnosis of dysfunctional breathing suggest that this disorder is not fully understood yet and may therefore fail to provide patients with the right treatment (Vidotto et al., 2019). This emphasises how important it is to understand dysfunctional breathing among children including its causes, the symptoms, and the possible treatment options (Connett & Thomas, 2018).

The current treatment of dysfunctional breathing consists of breathing exercises coordinated by a paediatric physiotherapist (Vidotto et al., 2019). Additionally, children have to do daily breathing exercises at home. However, most children lack support and motivation to do these exercises for a long time. Next to this, the paediatric physiotherapist does not know what progress patients make at home and how often they perform these exercises. Therefore, physiotherapists are dependent on the information they get from the children and parents during a consultation. This makes it more difficult to give the correct advice, causing treatment to take longer than necessary (*Project Wearable Breathing Trainer | NWO-SIA ProjectenBank*, z.d.). These limitations in the current treatment, require an innovative solution.

Since 2017, the department of sustainable and functional textiles at Saxion started having conversations about the development of medical wearables as an innovative solution for children with dysfunctional breathing. Medical wearables are technologies that can be worn on the body, where the technology interacts with a patient (Lee et al., 2016). They can be used to collect patient data, provide exercise guidance or drug administration reminders, and so on. The goal of wearables is to get real-time and accurate information that can be used for self-diagnosis and self-monitoring (Lu et al., 2020). Integrating such technologies into the clinical care pathway might support patient self-management, and lead to improvements in symptoms and quality of life, while also reducing the burden on healthcare professionals (Nagase et al., 2022).

The wearable that the department of sustainable and functional textiles and their consortium partners are currently doing research on, is the Wearable Breathing Trainer (*Project Wearable Breathing Trainer | NWO-SIA ProjectenBank*, z.d.). The Wearable Breathing Trainer is developed to support self-management and practice breathing exercises daily at home (Siering et al., 2019). It is a smart textile vest with electronics that can sense and give feedback to the body. Through sensor-based monitoring in combination with vibrotactile stimulation, the wearable is able to provide feedback and motivate children to do their exercises by giving rewards through gaming time.

Therefore, it could help these children to gain the skills to support solving their dysfunctional breathing (Siering et al., 2019).

While there are many benefits with the use of wearables, such as achieving high quality, real-time measurement of personal health, especially in connected healthcare and precision medicine, the adoption of wearables in the healthcare system has been relatively slow (Lu et al., 2020).

This relatively slow adoption of wearables is caused by many challenges, such as issues with the accuracy of data and the privacy of the user (Lu et al., 2020), and the integration with clinical workflows (Lewy 2015). Smuck et al. (2021) elaborate on this by stating that knowledge is limited regarding the factors that foster the implementation of wearables into the healthcare system, making the clinical implementation of wearables a challenge (Smuck et al., 2021). Nonetheless, strategic change is possible, but the support from healthcare professionals is critical to integrate wearables into the healthcare system (Kang & Exworthy, 2022).o

Therefore, in this research paediatric physiotherapists who treat patients with dysfunctional breathing in the Netherlands, will be interviewed. The objective is to explore their perspective on the barriers and facilitators for the upcoming implementation of the Wearable Breathing Trainer.

1.1 Research question

The research question of this study is: “What are the barriers and facilitators for the upcoming implementation of the Wearable Breathing Trainer from the perspective of paediatric physiotherapists?”

1.2 Sub questions

1. What is the perception of paediatric physiotherapists regarding the use of the Wearable Breathing Trainer in their treatment plan?
2. How do paediatric physiotherapists perceive the impact of the Wearable Breathing Trainer on their own work?
3. What is the capacity in terms of budget and time of paediatric physiotherapists to implement the Wearable Breathing Trainer?

1.3 Scientific relevance

In scientific literature, extensive research has been carried out on the advantages and possibilities of medical wearables. According to Lu et al. (2020) wearables minimise the disruption in a patient´s daily routine that is typically associated with healthcare (Lu et al., 2020). Patients can also easily monitor their health with wearables, enabling better diagnosis and treatment (Kang & Exworthy, 2022) (Lee et al., 2016). Another example is that wearables support the quality of life and the independence of an individual (Volpato et al., 2021). Watt et al. (2019) confirm that wearables are increasingly recognised as a technology that can transform the healthcare system due to its many benefits (Watt et al., 2019).

However, according to Lewy (2015), there are limitations in the implementation of wearables into clinical medicine. More specifically, the developments in wearables drive a change in the healthcare system, which raises challenges in the way these wearables should be implemented into the clinical workflows of healthcare professionals (Lewy, 2015). According to Smuck et al. (2021), knowledge is limited regarding the factors that foster the implementation of wearables into the healthcare system, making the clinical implementation of wearables a challenge (Smuck et al., 2021). Kang and Exworthy (2022) state that it is critical to have the support of healthcare professionals to successfully integrate wearables into the healthcare system (Kang & Exworthy, 2022). However, little research has been

done on the perspective of physiotherapists regarding the use of wearables in their current practice (Blumenthal et al., 2018).

With this lack of research about the implementation process of wearables and the perspective of healthcare professionals, it is of scientific relevance to study the perspective of paediatric physiotherapists about the upcoming implementation of the Wearable Breathing Trainer and identify the barriers and facilitators that hinder or facilitate the implementation of this wearable.

1.4 Practical relevance

Next to the scientific relevance of this research, it is also important to consider the practical relevance. The Wearable Breathing Trainer needs to be implemented in a physiotherapy practice. However, there is little known about the perspective of paediatric physiotherapists who are involved in the implementation process. Therefore, it is still unclear how the Wearable Breathing Trainer should be implemented. With the results of this research, the department of sustainable & functional textiles at Saxion might be able to paint a better picture of the perspective of these physiotherapists regarding the implementation of the Wearable Breathing Trainer. This could guide them into making more informed choices regarding the implementation of this wearable.

Next to this, the paediatric physiotherapists benefit from the results of this research. Through this research they could reflect on what they deem to be important when implementing and using a new wearable in their treatment. Therefore, the implementation of other personalised medical wearables into a physiotherapy practice, might be relatively easier in the future as physiotherapists are more aware of what their wishes are for a wearable and what facilitators could foster an implementation.

1.5 Conclusion

To conclude, an optimal treatment approach for dysfunctional breathing is essential to prevent long-term health problems and improve the quality of life (Connett & Thomas, 2018). The Wearable Breathing Trainer is developed to support the self-management of children with dysfunctional breathing. This could help them to gain the skills to support solving their dysfunctional breathing (Siering et al., 2019). While there are many benefits with the use of wearables, the adoption of wearables in the healthcare system has been relatively slow (Lu et al., 2020. Strategic change is possible, but the support from healthcare professionals is critical to integrate wearables into the healthcare system (Kang & Exworthy, 2022). The aim of this research is to explore the perspective of paediatric physiotherapists on the barriers and facilitators for the upcoming implementation of the Wearable Breathing Trainer.

Chapter 2: Theoretical framework

In this chapter several topics are discussed to create a better understanding of dysfunctional breathing, wearables, and the MIDI instrument, which will be used as a framework to discover the barriers and facilitators of the upcoming implementation of the Wearable Breathing Trainer.

2.1 Dysfunctional breathing

Dysfunctional breathing is a respiratory disorder that is characterised by an abnormal and irregular breathing pattern, such as breath holding, a deep sigh, or hyperventilation (Vidotto et al., 2019). This abnormal breathing pattern is displayed in Figure 1.

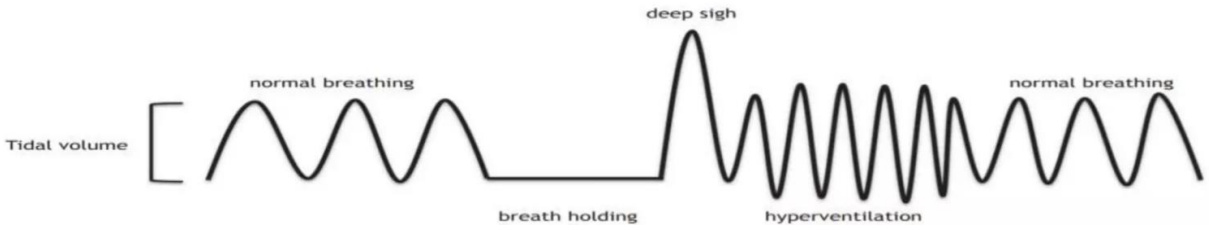

Figure 1. A normal breathing pattern and a dysfunctional breathing pattern (Vidotto et al., 2019).

An incorrect breathing pattern occurs whenever a patient's abdomen draws in during inhalation and out during exhalation. This results in an inadequate tidal volume and over activation of the breathing muscles of the upper chest. Meanwhile, a normal breath is referred to as an abdominal breath, where breathing from the chest is minimal (Chapman et al., 2016)

2.1.1 Prevalence

The prevalence of dysfunctional breathing is imprecise, due to an underdiagnosis in clinical practice (Vidotto et al., 2019). However, it is estimated to affect 9.5% of the population (Vidotto et al., 2019). It is more common in women and in people with asthma, whereas 29% of the people with asthma have dysfunctional breathing (Thomas et al., 2005).

2.1.2 Symptoms

With dysfunctional breathing a person can experience a variety of symptoms, such as breathlessness, chest tightness, chest pain, fatigue and light headedness (Thomas et al., 2005). These symptoms are often provoked and get worse during exercising, singing, playing a music instrument or during a panic attack, but it could also start when someone is resting (Barker et al., 2020). Experiencing these symptoms can make underlying conditions, such as asthma and anxiety even worse (Vidotto et al., 2019).

2.1.3 Diagnostic methods

For the diagnosis of dysfunctional breathing the gold standard diagnostic criteria are absent. Therefore, accurately determining the prevalence of dysfunctional breathing is not possible (Boulding et al., 2016). Due to high rates of underdiagnosis, a healthcare professional may fail to provide patients with the right treatment (Vidotto et al., 2019).

According to Barker et al. (2020) the current diagnosis of dysfunctional breathing starts with a general practitioner. He or she does an anamnesis, which is essential in reaching a diagnosis, and afterwards the patient is being referred to the physiotherapist. Then a physiotherapist is required to do an examination of the patient's breathing pattern, which at first happens during rest and then once more during a provoked attack. This breathing pattern assessment is done through observation, palpation and the use of scanning techniques. Within the assessment of children, it is typical that they present a thoracic dominant pattern, increased respiratory rate, sigh rate and mouth breathing.

Questionnaires could also be useful for the assessment of dysfunctional breathing, but can also be used to measure the efficacy of the treatment (Barker et al., 2020). The Nijmegen questionnaire is the most used questionnaire for this and can be used as a method of diagnosis or evaluation of treatment, but might not be valid in some circumstances. The Nijmegen questionnaire has, for example, not been validated for children. Also, the symptoms specific to children have not been included in the questionnaire (Boulding et al., 2016). Besides questionnaires they also use a VAS scale to assess the condition of a patient. The VAS scale helps evaluating the breathing effort and distress of a patient (Meek et al., 2003).

2.1.4 Current treatment

The current treatment of this respiratory disorder usually starts with body awareness. This is an approach that is often used within physiotherapy to make patients aware of how their body is functioning (Gard et al., 2019). In the case, patients become aware of how they are breathing. After this, the physiotherapist starts coordinating the breathing exercises of the patient (Vidotto et al., 2019). These exercises are personalised to align with the goals of each patient (Barker et al., 2020). The physiotherapist's breathing techniques can alleviate the patient's symptoms and assist them in gaining quicker control over future attacks (Boulding et al., 2016). Patients are asked to perform the breathing exercises daily at home.

2.2 Wearables

Wearables are electronic devices that are integrated into gadgets or clothes and can be worn on the body (Ometov et al., 2021). In recent years wearables have developed rapidly due to the rapid development of information and communication technology (Lee et al., 2016). An abundance of wearables is being sold to the general population (Canali et al., 2022). Approximately 440 million units are expected to be sold globally in 2024 (Izu et al., 2024). Examples of such consumer products are wellness gadgets or fitness trackers (Kang & Exworthy, 2022).

2.2.1 Benefits of wearables within the healthcare field

Wearables have become a valuable resource for individuals to manage and monitor their own health and well-being (Izu et al., 2024). Due to this growth in personalised health monitoring, wearables have developed rapidly in specifically the healthcare field. Medical wearables are seen as a promising tool to consider in modern medicine, as they are designed to collect and analyse health-related data (Lu et al., 2020). This given data provides a more digital, personalised and preventative approach to healthcare (Canali et al., 2022) (Powell & Godfrey, 2023). Patients monitoring their health multiple times a day over a span of months, also provides healthcare professionals with a dataset that could potentially help them with making a diagnosis or treating a patient (Kang & Exworthy, 2022). Wearables also provide health coaching. Health coaching is a continuous loop of feedback between the wearable and the user to support the user reaching a certain goal (Sqalli & Al-Thani, 2020).

2.2.3 Challenges in the use of wearables

There are also some issues and risks that slow the use of medical wearables. For example, it is essential to have high quality data to guarantee reliable results for the patient as well as the healthcare professional. Due to a variety of sensors and a lack of consistency in the collection of data it is difficult to assess this quality (Canali et al., 2022). The further development of the sensors of wearables is very important, so that the data analysis is more likely to be reliable (Lee et al., 2016).

Another example is the risk regarding the security and privacy of a patient's data (Canali et al., 2022). Wearables collect, store and share a considerable amount of personal data, to which third parties sometimes have access to. This data could also be exposed by hackers or through data breaches, caused by human errors. Therefore, it is important personnel is adequately educated. One of the key

regulations a wearable must comply with is the General Data Protection Regulation to decrease the risk of personal information being leaked (Bouderhem, 2023) (Lee et al., 2016).

2.2.4 Classification of wearables

Wearables can be categorised into three primary groups, which are displayed in Figure 2. The wearable in this research falls under the group of Skin Based Healthcare Wearable Devices (HWDs), and more specifically in the category of Textile based HWDs. This category includes wearables that have sensors embedded into clothes (Iqbal et al., 2021). Johansson et al., describe that the goal of Skin Based HWDs is to monitor health-related data of patients to facilitate a treatment (Johansson et al., 2018), in this case the treatment of dysfunctional breathing.

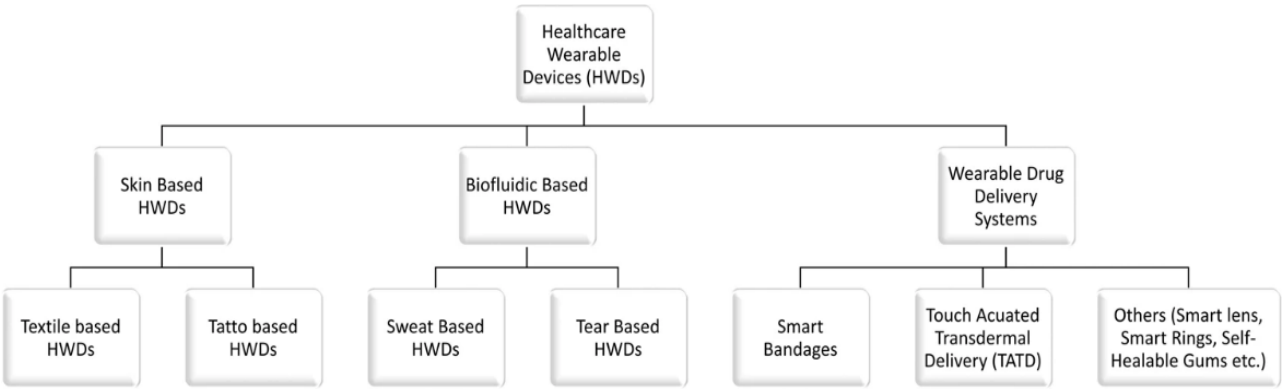

Figure 2. The classification of wearables in the healthcare industry (Iqbal et al., 2021).

2.2.5 Regulatory aspects of medical wearables

All products and devices, including medical wearables, must adhere to European regulations before they can be successfully implemented into any country in the European union (De Jong et al., 2023). The first step in getting market access, is through a certification process, such as the European CE-marking. Furthermore, compliance with the European Medical Device Regulation (MDR) is necessary when a wearable qualifies as a medical device with a medical purpose (Brönneke et al., 2021).

Besides regulatory requirements, remuneration is another important aspect for manufacturers when they want to bring medical wearables to the market. In order for wearables with a medical purpose to be either reimbursed or compensated, they often need to fulfil additional requirements. Even with having a CE-marking and complying to the MDR, it does not guarantee a direct claim to remuneration (Brönneke et al., 2021).

Getting reimbursement within the healthcare industry depends on various factors including the type of technology, the structure of the healthcare system (e.g. public or private insurance companies), insurers and regulatory authorities assessing the device, and the medical contexts of use (e.g. diagnosis or treatment). Additionally, the decision for remuneration on new medical wearables is based on the evaluation of the Health technology Assessment (HTA). The clinical effectiveness and the economic effectiveness can be respectively proven with randomised controlled trials (RCTs) and health economic evaluations (Brönneke et al., 2021).

Apart from regulatory requirements, there are also privacy and data security regulations that are crucial in the process of bringing wearables to the market. Therefore, the GDPR was established by the European Union. The GDPR is a framework that protects the personal data of any individual in the EU by any processor within the EU (Brönneke et al., 2021).

2.3 The Wearable Breathing Trainer

The Wearable Breathing Trainer is a smart textile vest and falls under the category of textile based HWDs (Iqbal et al., 2021). Smart textile is a relatively novel direction in the field of wearable devices. Smart textile could be defined as an integration of electronic systems with intelligent functions in clothing (Siering et al., 2019).

The Wearable Breathing Trainer is developed to enhance the engagement of patients by adding game elements integrated into an app, and to support the self-management for patients in the home environment through health coaching. The continuous loop of feedback between the wearable and the patient is in this case via vibrotactile feedback. Additionally, the wearable collects and analyses data, which gives physiotherapists more objective information about the progress or regression their patient has made.

The textile vest of the Wearable Breathing Trainer consists of different components, which is shown in Figure 3. The vest itself is made of Nylon and it has sensors and vibration motors embedded in the garment. These sensors and vibration motors are connected to a central circuit (Siering et al., 2019).

The sensors monitor the breathing pattern of a patient by measuring the change in the size of the chest and abdomen. The vibration motors provide vibrotactile feedback, which are vibrations to make patients more aware of when they are breathing through their abdomen. The aim is to return to a normal breath, which is an abdominal breath (Chapman et al., 2016). In the current treatment a physiotherapist places their hand or a book on the abdomen of a patient (Chapman et al., 2016), but with this wearable a patient is also able to mimic this at home during their breathing exercises.

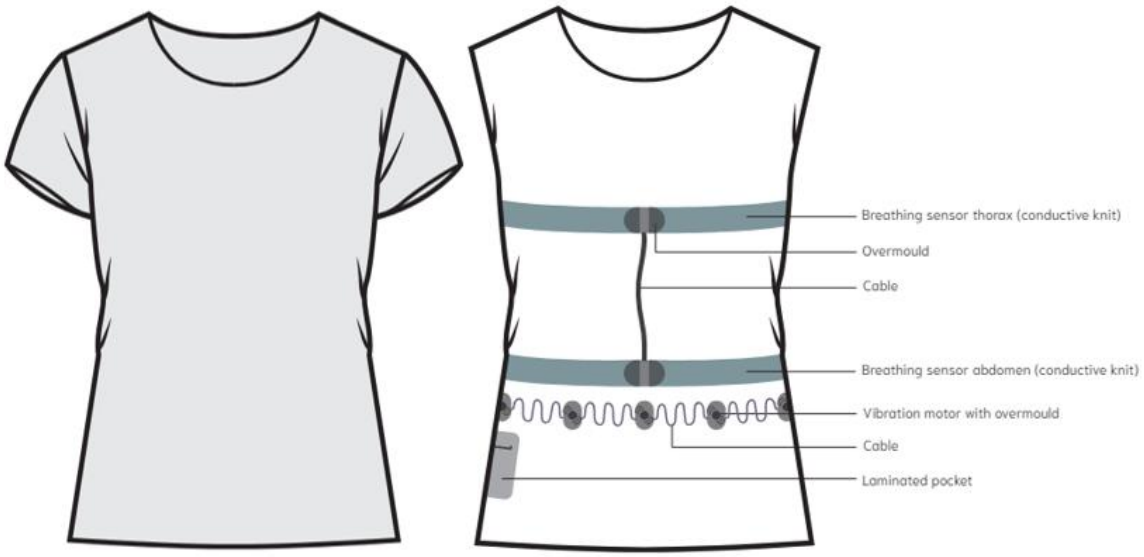

Figure 3. The prototype of the Wearable Breathing Trainer.

2.4 The introduction of innovations in the healthcare system

To study what the barriers and facilitators are of the Wearable Breathing Trainer, from the perspective of paediatric physiotherapists, the Measurement Instrument for Determinants of Innovation (MIDI) is used. Barriers can be defined as factors that hinder individuals from behaving in a certain way. Facilitators can be defined as factors that factors that facilitate and support individuals to behave in a certain way (Garcia et al., 2022).

Since 1999 the framework shown in Figure 4 has been used in the Netherlands to introduce and evaluate innovations in the healthcare system. An innovation process begins with the dissemination phase, where information about the innovation is spread. In the adoption phase, potential end users learn how the innovation works and decide on whether they would want to use the innovation. This adoption phase is followed by the implementation phase, where end users actually use the innovation. Whenever the implementation is a success, the use of the innovation is continued (Fleuren et al., 2014).

The transition of one phase to another can either be positively or negatively affected by a variety of innovation determinants. These innovation determinants are either associated with the innovation, the adopting person, the organisation or the socio-political context (Fleuren et al., 2014).

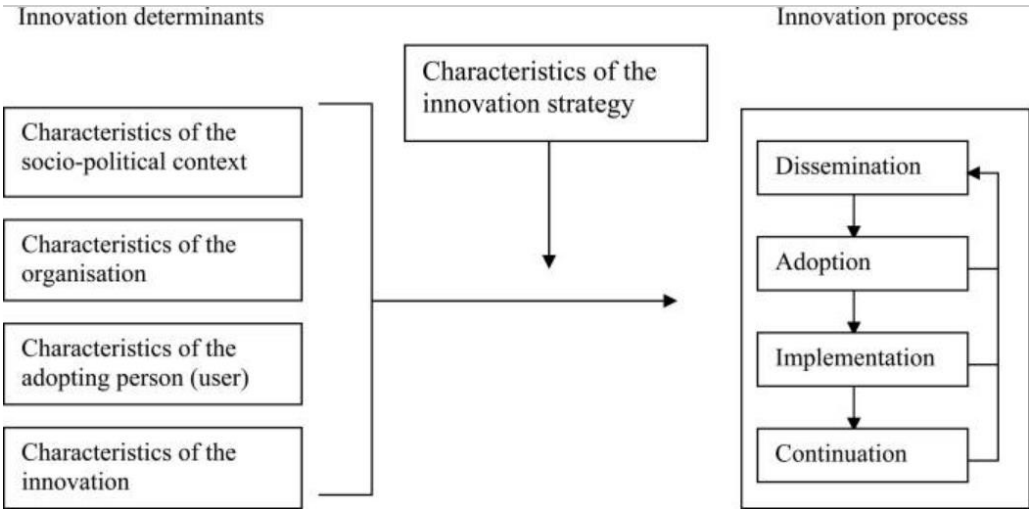

Figure 4. A framework to introduce and evaluate innovations (Fleuren et al., 2014).

2.4.1 Measurement Instrument for Determinants of Innovation (MIDI)

According to the study of Fleuren et al. (2013), there are 29 innovation determinants that can predict the implementation of a new innovation. An overview of these determinants is visualised in Figure 5. It is up to the researcher, to decide which of these 29 determinants deem to be relevant to include in their study. These 29 determinants can be found in the Measurement Instrument for Determinants of Innovation (MIDI). This instrument is developed to study the perception of intermediary users relating to the innovation. Intermediary users are people whose actions determine whether a patient gets treated with the innovation (Fleuren et al., 2013). In this research, these are the paediatric physiotherapists.

The MIDI instrument can be used before or after the implementation of an innovation. With this instrument the critical determinants that predict the implementation process of an innovation, in this case the Wearable Breathing Trainer, can be better understood (Fleuren et al., 2013).

Determinants associated with the innovation	
1 Procedural clarity (e)	5 Compatibility (e)
2 Correctness (e)	6 Observability (e)
3 Completeness (e)	7 Relevance for client (e)
4 Complexity (e)	
Determinants associated with the adopting person (user)	
8 Personal benefits/drawbacks (e)	14 Descriptive norm (e)
9 Outcome expectations (e)	15 Subjective norm (e)
10 Professional obligation (t)	16 Self-efficacy (e)
11 Client/patient satisfaction (e)	17 Knowledge (t)
12 Client/patient cooperation (t)	18 Awareness of content of innovation (e)
13 Social support (e)	
Determinants associated with the organisation	
19 Formal ratification by management (e)	24 Material resources and facilities (t)
20 Replacement when staff leave (e)	25 Coordinator (e)
21 Staff capacity (t)	26 Unsettled organisation (p)
22 Financial resources (t)	27 Information accessible about use of the innovation (e)
23 Time available (e)	28 Performance feedback (e)
Determinants associated with the socio-political context	
29 Legislation and regulations (t)	

(e) based on the meta-analyses of the *empirical* data

(t) based on *theoretical* expectations of implementation experts

(p) based on *practical* experience of implementation experts

Figure 5. Overview of the determinants in the MIDI instrument (Fleuren et al., 2013).

2.5 Conclusion

To conclude, dysfunctional breathing is a respiratory disorder that is characterised by an abnormal and irregular breathing pattern. The treatment consists of daily breathing exercises that patients are required to do at home (Vidotto et al., 2019). To support the treatment of dysfunctional breathing, a wearable, specifically the Wearable Breathing Trainer, is developed. Wearables are electronic devices integrated into clothing (Ometov et al., 2021). Wearables have become a valuable tool to manage and monitor an individual's health (Izu et al., 2024). However, there are also some challenges that slow the implementation of medical wearables. To discover what barriers would either hinder the implementation of the Wearable Breathing Trainer and what facilitators support this implementation the MIDI instrument has been used.

Chapter 3: Methods

In this chapter the methodology of the research is described according to several paragraphs: research design, data collection, measuring method, study population, recruitments of respondents, data analysis and finally the ethical considerations.

3.1 Research design

This research is a cross-sectional study and is carried out for the department of sustainable & functional textiles at Saxion in Enschede. A qualitative design has been chosen, because this research aims to explore new insights and opinions. In this research interviews were held with paediatric physiotherapists about the upcoming implementation of the Wearable Breathing Trainer to discover their perspective on this topic. The framework that has been used to give structure to these interviews is the MIDI instrument, which is explained in Section 2.4.

3.2 Data collection

In this research primary data was collected through qualitative research, in which semi-structured interviews have been conducted. These interviews have been conducted in May and June of 2023.

3.3 Measuring method

The interviews have been conducted through a semi-structured interview schedule (appendix B). Having a semi-structured interview schedule with topics and questions, keeps the structure of all the interviews quite the same. By following these topics and questions, it is possible to measure what one intended to measure during the interviews without deviating from the topic as much. This will strengthen the validity of the research. In addition, the design of the interview is semi-structured, so that there is still room to ask further questions about the respondent's answers.

The topics for the interview were determined based on the dimensions of the MIDI instrument. An operationalisation table has been made, which explains the concept of innovation determinants through different dimensions and indicators (appendix A). The topics of the interview are: determinants associated with the innovation, determinants associated with the adopting person and determinants associated with the organisation. The questions for the interview were subsequently drawn up and based on the indicators. The interview consists of some closed questions to rule out situations, but it mainly consists of open questions to obtain an explanation from paediatric physiotherapists.

3.4 Study population

The study population, which is displayed in Table 1, consists of paediatric physiotherapists. These health professionals are the ones who have to implement the Wearable Breathing Trainer in their work and treatment method and are therefore a relevant group to study. The study population was distributed across various regions of the Netherlands. Other relevant characteristics of the respondents are whether they work in a primary care setting or secondary care setting, how big the team is they are working in, and whether they are employed or self-employed. There has been chosen for these characteristics to create a study population that is representative for the whole country. A total of 12 interviews have been conducted, since at that point theoretical saturation had been reached.

Respondent number	Profession	Work location	Primary care or secondary care provider	Total number of physiotherapists	Employment
1	Paediatric physiotherapist	Doetinchem	Primary care	10	Employed
2	Paediatric physiotherapist	Eindhoven	Primary care	6	Self-employed
3	Paediatric physiotherapist	Enschede	Secondary care	17	Employed
4	Paediatric physiotherapist	Enschede	Primary care	11	Employed
5	Paediatric physiotherapist	Gorinchem	Secondary care	48	Employed
6	Paediatric physiotherapist	Hardinxveld-Giessendam	Primary care	1	Self-employed
7	Paediatric physiotherapist	Heukelum	Primary care	6	Employed
8	Paediatric physiotherapist	Houten	Primary care	3	Self-employed
9	Paediatric physiotherapist	Nijkerk	Primary care	15	Employed
10	Paediatric physiotherapist	Roosendaal	Primary care	16	Employed
11	Paediatric physiotherapist	Sliedrecht	Primary care	12	Employed
12	Paediatric physiotherapist	Wervershoof	Primary care	2	Self-employed

Table 1. Study population

3.4.1 Inclusion criteria

With the recruitments of the respondents, several inclusion criteria have been taken into account that each of the respondents must comply with. First of all, the profession of the respondent has to be a paediatric physiotherapist. Furthermore, he or she should be specialised in treating children with respiratory problems. Some physiotherapists for example, only treat patients with injuries. Lastly, these paediatric physiotherapists should work in the Netherlands.

3.5 Recruitment of respondents

The respondents of the study population have been recruited by sending different paediatric physiotherapists an email in which the research topic is described and in which they are asked whether they would want to participate in the research. Another recruitment technique that has been used, is snowball sampling. Snowball sampling is a technique in which participants are asked if they know other individuals who might be willing to participate in the research. With this technique, two respondents have been recruited.

The interviews have been, where possible, held on the work location of the paediatric physiotherapist. Eventually one of the 12 interviews has been held online and the others were all held at a work location. With the interview that was online, it was more difficult to capture non-verbal signals, which may have affected the validity of this interview.

3.6 Data analysis

The interviews have been transcribed using the program Amberscript. Because of the privacy of the respondents the transcripts are anonymous and not shared with third parties. The interviews have been analysed with the program ATLAS.ti. Then an inductive thematic analysis was applied, which is a process of coding data without the use of a predetermined coding scheme. This inductive analysis allows findings to emerge from the data organically without being restricted by the predetermined coding scheme. The following steps were done to analyse the data: (1) open coding, where codes were labelled; (2) axial coding, where the codes were categorised in groups and linked to determinants from the MIDI instrument; and (3) selective coding, in which relationships between themes were established and themes were compared with each other. A final list of the codes from this research, is displayed in a codebook (appendix C).

3.7 Ethical considerations

Prior to conducting this research, this research has been ethically approved by the ethics committee at the University of Twente. In addition, as has been noted in the ethical approval, respondents have given verbal consent that their answers are allowed to be recorded and analysed in this study. This was asked prior to an audio recording and was repeated at the beginning of an audio recording.

Chapter 4: Results

This chapter describes the results derived from the 12 interviews with paediatric physiotherapists. These results include several innovation determinants, which are thoroughly discussed and substantiated with quotes that are derived from the interviews. The innovation determinants are subdivided into three themes. Respectively these are determinants associated with the innovation, determinants associated with the adopting person and determinants associated with the organisation.

4.1 Determinants associated with the innovation

The first part of the results focusses on the perspective of physiotherapists regarding the Wearable Breathing Trainer. This part discusses how well the wearable would fit into their treatment, how complex they expect it to be, and how relevant it could be for their patients.

4.1.1 Procedural clarity

The treatment plan for the Wearable Breathing Trainer is clear to all of the respondents. According to them, it has a logical structure and fits well with the current treatment, as it follows the same steps. A respondent said the following words about this:

"That is clear. Certainly. It is actually the same order as we already apply, only without the vest." (R5)

4.1.2 Completeness

The completeness determinant determines whether further changes, in terms of activities or functions in the design of the Wearable Breathing Trainer, are necessary. At the moment the Wearable Breathing Trainer is not developed to wear during fitness exercises, as the sensor cannot measure the breathing pattern correctly when a patient is moving. The thoughts about whether or not this part of the wearable should be further developed, differ under the respondents. One the one hand several physiotherapists hope it will be further developed as they view this step of the treatment the most difficult step and they think the vibration motors could support patients in this step. On the other hand, there are also several physiotherapists who do not mind that this wearable is not developed to wear during fitness exercises. They think it is more important to find the reason as to why they do not breathe correctly and then work on that problem. A respondent said the following about this:

"It also has a lot to do with your physical condition. When someone is in bad shape, they will of course use their breathing muscles much sooner and they will quickly adopt a different type of breathing to allow them to breathe more deeply. Patients often have dysfunctional breathing based on what has gone wrong in someone's history. That problem needs to be addressed and then, once breathing has been learned correctly again, I think you can apply it very well during exercise." (R4)

Another point of improvement that was made by some of the physiotherapists is that they would like to see a variety of games to be integrated in the app attached to the Wearable Breathing Trainer. A respondent described this as follows:

"I think it is good to include games that are fun and performance-oriented, but perhaps it can also be good to incorporate soothing breathing exercises. I think it would be interesting to take this into account, so that these games do not always have to be a distraction that is motivating, but it can also be a distraction that provides peace." (R10)

4.1.3 Complexity

The respondents assume that the wearable is not that difficult to use, because they are used to working with technology and apps. In working with wearables, not just technology, there are big

differences between physiotherapy practices. Despite there being big differences in the use of wearables, the respondents talk quite positive and enthusiastic about it. Some respondents who have not worked with wearables before think it might take some time to get used to, but are confident they can work with them. A respondent described this by saying:

"From what I hear, it seems easy to use. I may spend some time figuring out exactly how it works with the first patients, but it does not seem very difficult to me. Once I know how it works, it seems very easy to use." (R8)

Nonetheless, the physiotherapists state that they would like the interface and use of the wearable to be as simple as possible, because the physiotherapists, the parents, and the children must understand it. That being said, the physiotherapists are quite satisfied with how well parents and children can use technology these days.

4.1.4 Compatibility

According to the respondents the current treatment matches well with the Wearable Breathing Trainer. because it follows the same treatment steps. The physiotherapists state that an important first step of the current treatment is making sure patients are aware of their breathing. This also aligns with the first step of the treatment with the Wearable Breathing Trainer. Moreover, physiotherapists think the games from the Wearable Breathing Trainer matches well with the current treatment, as some of them also use games to make the treatment more fun.

Additionally, physiotherapists can monitor the progress that children make at home with this wearable, which provides them with more objective information and about what should be learned during the next appointment. The following is said about this:

"I can then see exactly what went well and what the challenges still are. I can also see when things went less well and perhaps those are times when the patient experienced more stress or whatever. I think it can give a lot of shape to how you construct your treatment plan." (R9)

The only slightly negative comments that was made a few times, is that physiotherapists do not want this wearable to totally take over a treatment method. They still want to rely on their own observations, and that of patients too, and not blindly and solely look at the results from this wearable.

4.1.5 Relevance for client

It is up to the physiotherapist to decide whether a patient is suitable to use the Wearable Breathing Trainer. When asked which children they think the wearable would be suitable for, they stated it depends on the child and multiple other factors.

The treatment duration for a patient with dysfunctional breathing complaints differs per child. If children solely suffer from only these complaints, they will be free of complaints in about six weeks. Several physiotherapists mention that they think this wearable might be less relevant for those children who either are free of complaints in six weeks. This wearable is perhaps also less relevant for patients who are too young to understand it, or parents who are resistant towards using this technology.

The respondents indicate that most of their patients have a disturbed breathing pattern due to other underlying problems, such as a bad shape, anxiety, performance anxiety, stress, chronic pain complaints or trauma. These patients also need to visit their physiotherapist more often over a longer period of time. There are also children, often times children with autism, who have trouble

understanding how their breathing pattern is. Physiotherapists therefore think it might be quite relevant for the patients described in this paragraph. A respondent said the following about this:

"I think it is suitable for all patients, but the question is also whether you want to use it for all patients. You might be able to achieve it in a different way without using this wearable. I think this wearable, specifically, could be useful for children with autism or anxiety. This allows them to fall back on something that is a certainty." (R4)

4.1.6 Other purposes

Some of the physiotherapists did also have other ideas for which the Wearable Breathing Trainer could be used. They thought it might be interesting to use as a tool for the diagnosis of dysfunctional breathing, for pelvic floor therapy, patients with COPD, for people who have trouble sleeping, children who are overstimulated quickly, adults with dysfunctional breathing. One respondent had said the following about this:

"You often see that when children have problems with sleeping, they also work on breathing exercises to create peace and quiet to fall asleep, so this might be a tool for that." (R12)

4.2 Determinants associated with the adopting person

In this part, the focus lies on the view of paediatric physiotherapist about the Wearable Breathing Trainer regarding the changes in their own work. This part discusses therefore the personal benefits and drawbacks, the expected outcomes, the influence of others, and it discusses the required knowledge they assume is necessary to use this wearable.

4.2.1 Personal benefits

According to the respondents there are several benefits to implementing the Wearable Breathing Trainer into their treatment plan. First of all, they mention that it can monitor the data of the patient's breathing exercises. This makes the treatment more objective, since the results are based on facts. These results show physiotherapists whether, and to what degree, a patient has made progress or degression. With this information they can get a better understanding of their patient and target the treatment to the patient's needs.

With the integrated games, these healthcare providers also have less trouble to make the treatment fun. Furthermore, health insurers demand the results and effects of a treatment. With this wearable, physiotherapists are able to show scientific results to a health insurer. A respondent describes the benefits in the following manner:

"With this I can treat my patients in a more targeted way, as I can see it in the data when something is not going great during the exercises. In the current treatment, the patients or its parents have to tell me information about the progress they are making, but with this technology I will have more objective information." (R7)

4.2.2 Personal drawbacks

The respondents have described different drawbacks. Some physiotherapists fear their patients will use the wearable irresponsibly by either not returning it, breaking a component, making it dirty, or it getting lost. Another concern is that the lifespan is not very long, because it has electronics and is often worn. They would also dislike it when it is not clear who is responsible to request a vest and then later return it, in case it is being rented.

Another drawback is that physiotherapists get more responsibilities, as they have to keep track on how many wearables they want present in their practice, depending on the number of patients and their sizes. They also need to invest time in learning how to use this wearable and only employees with a fixed-hour contract get paid for this. Others would have to do this in their own time.

Furthermore, health insurance companies give a relatively low amount of money per patient. Therefore, some respondents think it is too expensive to purchase it themselves, especially if they do not see the added value. Some of these drawbacks are described by a respondent, who said:

"I think the time you have to invest in it is a disadvantage. I, but also the patient, must understand how it works. I would then look if I have seen added value to decide whether I want to invest my time in it." (R3)

4.2.3 Outcome expectations

In terms of expected outcomes, the respondents envisioned several scenarios. They first of all, expect that adding games to the wearable, will result in patients having more fun during breathing exercises. Most of the physiotherapists assume patients will therefore have a higher motivation to practice with this wearable and thus practice more. Since the majority of the respondents have trouble motivating their patients, they are quite enthusiastic about the integrated games. A small proportion of the respondents believe their patients do the exercises at home, because most of their patients have intrinsic motivation to get rid of their complaints. Those physiotherapists do not expect that the integrated games will lead to very different outcomes for their patients.

Another effect physiotherapists expect are that the vibration motors, that are integrated into the vest, will support patients in being more aware of when they successfully breathe from their abdomen instead of their chest. They expect that this higher awareness in breathing correctly together with a higher motivation, result in a more effective treatment where a patient would need less appointments.

The physiotherapists described that they would not mind if it would result in less appointments, even though an insurance company gives them money based on how many appointments a patient will have. Helping their patients is more important to them than having more appointments. Next to this, all respondents have said their agenda is very busy, so the time they could save with treating these patients, they could use to treat other patients.

A less beneficial effect of the Wearable Breathing Trainer, however, could be that some patients may start panicking when they see they are failing in these games and thus create a reversed effect. One of these envisioned outcomes is described by a respondent as follows:

"I expect that patients will be more motivated and will practice more often. Therefore, I think their breathing pattern is more quickly back to normal, because they get feedback every time they practice. Normally, when I practice with them, they do not get feedback at home. So, with that in mind, I think it could help the patient to learn faster how they should breathe correctly." (R7)

4.2.4 Client satisfaction

In terms of patient satisfaction, physiotherapists assume that patients will enjoy the exercises more due to the integrated games, and thus practice more. They believe that the complaints of their patients will then diminish more quickly. Nonetheless, they fear a low patient satisfaction when patients are either embarrassed to wear the wearable, when they are not wearing the right size, or when it is uncomfortable to wear. A respondent said the following:

"I think that, especially among young people, there is a lot more fun. If there is something of a game involved, young people soon find it very fun. That is much more fun than when I tell them to lie on their back and I place a stuffed animal or book on them and then they have to feel how it moves. I think that therapy compliance will also increase." (R9)

4.2.5 Client cooperation

Client cooperation means in this case how well the children and parents cooperate with the Wearable Breathing Trainer. Some of the respondents could think of parents, who would not want their child to use this technology, because they do not think it would work. In that case, the wearable will most likely not be used.

In order to cooperate well, the physiotherapists emphasise that is should be user friendly for the children as well as the parents. Besides, they should get a clear explanation of how this wearable should be used. Lastly, in case the wearable is rented, it should not create fuss for parents. It should be clear who is responsible for requesting and returning the wearable. A respondent has said the following:

"I think it is important that parents are informed about how the wearable works and what they should do if something does not work." (R11)

4.2.6 Social support

In terms of social support, all of the respondents in this study mentioned that they get support from their colleagues when they introduce a new technology that they are enthusiastic about. These physiotherapists add that often times their colleagues get curious about it and also want to know how it works and whether they could apply it to some of their patients too. A respondent described this as follows:

"We are with six and have an open-minded attitude towards each other. I think that they too will be very curious to use this wearable. We have a nice collaboration and if one of use introduces something new, everybody is open-minded to it. I do not see a problem there at all." (R7)

4.2.7 Knowledge

There are certain things that one must know, according to the physiotherapists, before they could apply this wearable in their treatment. They think it is convenient to have knowledge of breathing and a dysfunctional breathing pattern to properly understand the progress made with this wearable. They also think one should have some affinity with children, since this wearable is used in a treatment plan for children.

Besides this, a physiotherapist should know how to use the app, how to select the right breathing exercises, how to charge the wearable, know where they could find the monitored data, and how to read the data in order to correctly apply the wearable to their patient. This is described as follows:

"I think I should now how it works, so I can explain it to my patients. I, specifically, also think I should know how the app works and how I could see the monitored data." (R4)

4.3 Determinants associated with the organisation

This part of the results lay out what the capacity of paediatric physiotherapists is in terms of budget and time to implement this wearable into a physiotherapy practice. It specifically outlines the approval of the management, budget, available time and coordination of the implementation.

4.3.1 Formal ratification by management

This determinant discusses the approval process of the Wearable Breathing Trainer before it is purchased and implemented into a physiotherapy practice by either management or the practice owners of the physiotherapy practice. According to the respondents, it is either a manager in secondary care or a practice owner in a primary care setting who decides how money will be spend. Such a person makes these decisions, while also taking the long-term goals of the physiotherapy practice into consideration. Nonetheless, these respondents vocalised that they do have some input in this decision. If they are enthusiastic about something and it adds value to the treatment, they can go to their employer and ask whether it could be purchased.

The physiotherapists mention that several factors will determine whether or not management will invest in a new product. The most important factor is whether it adds value to the current treatment. To prove this, the respondents would want a cost-benefit analysis to show there are more benefits than costs and also see results from research about the effectivity of this wearable. In addition, the respondents think it is also important that there are a lot of patients in their practice who could use this wearable. Otherwise, they would think it is a shame if it would not be used often. Besides this, the patient's interest is also very important. They should also indicate that they would love to use this wearable. The respondents also state that they would first want to try the wearable. If they come to the conclusion that it helps them and their patient during the treatments, they would be interested to either buy or lease the wearable. A respondent had to say the following about this topic:

"Suppose I would like to have this. I would first talk to him. Then we will see together whether it is something to invest in. It obviously depends on the costs, but it also depends on how often I think I will use this wearable. It would also be nice if sufficient research has been done to prove its effectiveness. If it is proven effective, we are more likely to purchase it. We can then also inform the doctors in the area that we have this product, so that doctors are more likely to refer these patients to us." (R11)

4.3.2 Financial resources

In order for physiotherapy practices to use the Wearable Breathing Trainer in their treatment they should have the financial resources to purchase or rent it. Therefore, the price of the wearable itself is also an important factor in the decision about spending money on this product.

Since there will be three different sizes, a physiotherapist would most likely need to purchase more than one product. Additionally, patients bring the wearable to their home, meaning that more than one wearable is needed to treat all patients with a dysfunctional breathing in their practice. Therefore, as mentioned by some of the respondents, it depends on the financial state of the physiotherapy practice if it is financially responsible to purchase this product.

More than half of the respondents either know or assume their physiotherapy practice has enough budget to be able to invest in the Wearable Breathing Trainer if the wearable meets their previous mentioned requirements, such as it being effective. Less than half of the respondents mention they either know or assume their physiotherapy practice's budget is not that high and would therefore have to cut back on some expenses to purchase it and would therefore only purchase it if it met all their requirements, or not purchase it at all. They would more so prefer to rent it whenever they felt it would make the treatment of a patient better. The following is said about this topic:

"I think there is a budget for this. Within our practice we also have an online brace store, and our practice offers fitness subscriptions, so there is more income than just the money from the health insurance." (R7)

4.3.3 Purchasing and leasing possibilities

It is not clear yet whether the Wearable Breathing Trainer would have to be bought or rented. Physiotherapists could be the ones who would have to buy the wearable or a rental company could buy these products from the production company and then rent it to physiotherapists or patients. Another option would be that an insurance company covers the costs of the Wearable Breathing Trainer, but it is not known yet if such a company would want to do this.

Respondents who think they will treat a lot of patients with dysfunctional breathing, would prefer to buy the wearable instead of renting it. They think it would be more convenient this way instead of requesting the product from a rental company, renting it, and then later returning it.

A few other respondents would prefer to rent the Wearable Breathing Trainer, because then they can rent it whenever they would need it for a patient. When asked whether they would want the parents or themselves to be responsible for renting the wearable, respondents were not quite sure what they would prefer as they saw advantages and disadvantages in both. In general, they do think renting this wearable would be more efficient if it was done by themselves, but they prefer to not spend time on this or be responsible for the wearable if a patient damages it. In case they would let parents rent the wearable, they worry this would be a burden on some of the parents too, which could result in them not renting the wearable at all. The following was said about this topic:

"It really depends on how often it is going to be used. If this becomes the first practice to use it, more patients will probably be referred to here and I will therefore need to have the wearable more often. In that case, it would be nice to always have a vest here available. But if I do not use it often, it would be more practical to borrow it." (R3)

4.3.4 Time available

Physiotherapists only get paid by an insurance company whenever they see a patient. Therefore, the time spend on searching for new technologies and figuring out how they work all happen outside working hours. They state that at the moment almost every course or business meeting is in the evening or during the weekend. Despite having less free time, they would still invest time in it if they think it would improve the treatment of their patients. Only physiotherapists with a fixed-hour contract are allowed to schedule time during working hours to invest in a new technology. They would have to schedule a moment for this in advance, as they state that their agenda is very busy.

Most physiotherapists mention that they would prefer it if information about new wearables would be sent to them instead of them searching for it, as they do not have time for this or might overlook some technologies. Someone said the following about this:

"It is more pleasant if information comes to me. Just because part of it is in my blind spot. If you had not emailed me, I would never have known this was in development. The moment I know about things like this, I can tell my employer I like it and would want to have it in this physiotherapy practice." (R9)

4.3.5 Coordinator

In order to implement the Wearable Breathing Trainer, or any other technologies, someone must be responsible in a physiotherapy practice to make sure it all goes smoothly and in the right direction. According to most of these respondents, the physiotherapists who is going to use this wearable in their treatments, will be the one who has to coordinate it. In case more employees in one practice will use it, they will discuss who wants to be responsible for this. One respondent, who works in a secondary care practice, is also working in the department of Care and Innovation and would therefore be made responsible. About this topic the following has been said:

"It is not that we specifically have one person who takes responsibility for steering everything that comes into the practice in the right direction. The moment this wearable enters this practice and is also intended for children, then I am ultimately responsible for it." (R10)

When asked how they would approach the coordination of the Wearable Breathing Trainer, these physiotherapists would either schedule a business meeting or clinical lesson with colleagues who are also interested in using the wearable. During such a meeting, they would discuss the technical functioning of the Wearable Breathing Trainer. Apart from this, they would also have to coordinate is making sure parents understand how the wearable can be used at home, how it can be rented in case the physiotherapists do not buy it, who is responsible to pay for repairment in case it gets damaged, and how it can be washed after the wearable has been worn by a patient.

4.3.6 Information accessible about use of the innovation

When these respondents were asked what kind of information they would want for the Wearable Breathing Trainer the answers were varied. While half of the respondents would be content with only a manual or information via mail, the others would like to also have a small course where someone explains it to them in an online meeting. A few respondents also said it depends on the complexity of the wearable. If the producer of this wearable expects a manual to be clear enough, they would want that, otherwise these respondents would be interested in an online course. Besides information about how the wearable works, physiotherapists mention that they would also want to know what information they should give to their patients and their parents. A respondent has said the following about this topic:

"Basically, what is necessary. If you can figure it out with just a manual, that would be great. Otherwise, a course would be fine too." (R2)

4.3.7 Preconditions

There are a few preconditions where de Wearable Breathing Trainer must comply with before these respondents would want to use it in their treatment. First of all, after a patient has used the wearable for a certain period of time, it must be cleaned before another patient will use it. Moreover, many of the physiotherapists emphasise that they would want a free trial, where they can try the wearable before they purchase it. The wearable must also be durable, meaning the technology inside must remain in place and not damage quickly. Furthermore, they would like to know the results from the user study to see whether it is effective. Lastly, the wearable itself should be user friendly and not be a burden to use for the physiotherapist as well as the patient. A respondent has said the following about the preconditions:

"I would prefer it if there was a trial period first, and I would not have to purchase it right away." (R1)

4.4 Barriers and facilitators per (sub)category

Table 2 presents the identified barriers and facilitators on the upcoming implementation of the Wearable Breathing Trainer from the perspective of paediatric physiotherapists.

Category	Subcategory	Barriers	Facilitators
Determinants associated with the innovation	Procedural clarity		The logical structure of the treatment plan of the Wearable Breathing Trainer
	Completeness	The wearable is not yet developed to use during fitness exercises.	The wearable being able to provide a wide range of games
	Complexity	The fear of the Wearable Breathing Trainer not being user-friendly for patients and their parents	Most physiotherapists are familiar with using technology in their work
	Compatibility		The logical structure, game elements and monitored data support the current treatment
	Relevance for client	The wearable being less relevant for patients who are free of complaints in less than six weeks or patients who are too young	The wearable being relevant for patients who have trouble understanding their breathing pattern, patients with autism or with underlying problems, such as anxiety and panic attacks
	Other purposes		The wearable being suitable to use in other healthcare settings
Determinants associated with the adopting person	Personal benefits		The treatment becoming more objective by getting more data from the wearable, and the treatment being more fun due to the integrated games
	Personal drawbacks	The fear of having more responsibilities, patients being irresponsible with it, and fear of how much time and money it will cost them	
	Outcome expectations	The chance of patients panicking when failing the integrated games, creating a reversed effect	Patients having a higher motivation, better awareness of their breathing, needing less appointments
	Client satisfaction	Patients being embarrassed or uncomfortable, or not wearing the right size	Patients experiencing more joy in doing their breathing exercises

	Client cooperation	Parents who are sceptical about the efficacy or have trouble understanding technology	Clients receiving a manual and a clear instruction from the physiotherapists
	Social support		The support of other colleagues
	Knowledge	Not having knowledge about dysfunctional breathing, the technical functioning of the wearable, and having no affinity with children	
Determinants associated with the organisation	Formal ratification by management	The wearable not meeting the management's wishes.	Physiotherapists having influence on the purchase decisions
	Financial resources	Not having the financial resources to either buy or rent the wearable and fear of having to pay for any damage	A willing insurance company covering the costs of this wearable
	Purchasing and leasing possibilities	Having more responsibilities by renting the wearable themselves or putting the burden on the parents	Being able to rent the wearable when needed
		The fear of buying the wearable and then not using it often	The convenience of buying it and not having to deal with rental companies
	Time available	Having to give up free time outside working hours, being too busy to make time, worry it takes too much time	Having to spend less time in the future on understanding the technical functioning of wearables
	Coordinator	The coordination of implementing the wearable being another added responsibility.	
	Information accessible about use of the innovation	The information provided about the wearable not aligning with the complexity of the wearable	The availability of a manual and (online) training if necessary
	Preconditions	The wearable not being durable or cleaned sufficiently, not having access to efficacy results or a free trial	

Table 2. The barriers and facilitators of the Wearable Breathing Trainer

Chapter 5: Discussion

The primary aim of this thesis is to investigate the barriers and facilitators for the upcoming implementation of the Wearable Breathing Trainer from the perspective of paediatric physiotherapists. This chapter discusses the key findings, the theoretical and practical implications, acknowledges any limitations within this research, and recommends areas for future research.

5.1 Key findings

Facilitators that support the implementation of the Wearable Breathing Trainer are the logical structure of the treatment plan, the treatment being more objective, more fun and beneficial for patients, and having reliable support from colleagues. Moreover, the availability of a clear instruction for physiotherapists, as well as patients and their parents, support the implementation. Barriers that hinder the implementation of this wearable are primarily, not having the financial resources to purchase or rent the wearable, or having the financial capacity but being reluctant to spend it if the wearable is not cost-effective, empirically validated as effective, will not be frequently utilised, or is not user friendly. Another main barrier is the time required to learn the technical functioning of this wearable. It was unexpected to discover that physiotherapists are often too occupied to invest time in learning the technical functioning of a new technology or to participate in any interview and that most physiotherapists have to plan this outside working hours. Another unexpected outcome was that physiotherapists answer questions sometimes from a patient's point of view even though the questions are about the physiotherapist's perspective. Therefore, it becomes evident that the opinions of their patients carry significant weights in their decision-making process regarding the implementation of the Wearable Breathing Trainer. In particular, they place great importance on ensuring that patients are satisfied with using the wearable, encounter no difficulties in its use, and derive clear benefits from its implementation.

The findings reveal that needing to learn the technical functioning of new wearables outside working hours, creates a burden for physiotherapists. This could potentially reduce the willingness of them to learn how this wearable works. Existing literature on applying the best practices in treatment, confirm that the lack of time physiotherapists have, contributes to them not applying the most effective care in their practice (Stander et al., 2020)(Dannapfel et al., 2013).

The collection of objective data shows that the wearable does not only support the patient, but also gives the physiotherapist a tool to enhance the credibility of their treatment, which makes the treatment more objective. Moreover, physiotherapists are then able to tailor a treatment to an individual's needs. Since physiotherapists are willing to invest more of their time if it will improve the current treatment, the aforementioned benefits might compensate for the time required to successfully implement this wearable. The findings also reveal that a clear and logical treatment plan, that also aligns with the current treatment, facilitates the willingness to implement this wearable into a physiotherapy practice. It highlights that the treatment plan of the Wearable Breathing Trainer, which is already similar to the current treatment, reduces the learning curves. Thus, potentially saving some time for the physiotherapist during the learning process. Lastly, physiotherapist can count on the support of their colleagues, meaning physiotherapists generally have a work environment where innovation is supported, which could save them some time implementing the wearable. Dannapfel et al. (2013) elaborate on this by describing how physiotherapists indeed easily exchange knowledge with each other and have no problem helping each other (Dannapfel et al., 2013).

Moreover, them being reluctant to purchase or rent this wearable, limits the ability to integrate this wearable into a physiotherapy's practice. As described before this reluctancy stems from questioning

the wearable's efficacy, how frequent it will be used, and its user-friendliness. Existing literature on the efficacy and user-friendliness of healthcare technologies emphasise that these aspects significantly impact the use of a technology (Mattison et al., 2022) (Smuck et al., 2021).

Physiotherapists being sceptical about the efficacy, indicates that they want to avoid risk, as they hesitate to spend money on a wearable that is not empirically proven to be effective yet. They are also hesitant to spend money if it appears to not be user-friendly for themselves and for the patients and their parents. It shows they want to prevent adding a complex tool in their own workflow. They also emphasise that they want patients and their parents to perceive the wearable as user-friendly, as they not want them to have trouble using this wearable. These findings signify as to why physiotherapists have requested a free trial period. With a free trial they are able to see if it is user-friendly and see whether the wearable is indeed effective, and thus be more certain of their decision when they choose to buy the wearable. Whilst physiotherapists do express concerns regarding the user-friendliness of this wearable, they have experience in working with technologies and they believe that patients and their parents are also familiar with technology and using apps on their smartphone.

Furthermore, them being reluctant to purchase the wearable if it will not be frequently used, indicates that physiotherapists doubt whether the financial costs are worth it if the wearable is only relevant for a small proportion of their patients. Furthermore, the findings demonstrate that physiotherapists are cautious implementing the wearable when they would be responsible to pay in case the wearable becomes damaged, as they fear patients can be irresponsible with it.

As described before the findings demonstrate that physiotherapists place great importance on the opinions and well-being of their patients. Since physiotherapists think that the Wearable Breathing Trainer could accelerate the progress of their patients, if proven effective, the Wearable Breathing could be beneficial for the patient, which facilitates the implementation. These findings align with existing literature that describes when healthcare professionals think a patient would benefit from a technology, it facilitates the implementation of a technology (De Veer et al., 2011).

Moreover, one characteristic of the study population is that the physiotherapists are either employed or self-employed. It seems that self-employed physiotherapists are more worried about whether they can afford buying the Wearable Breathing Trainer and perceive it as a more significant barrier than employed physiotherapists. Employed physiotherapists also consider the costs as a barrier, but consider other main barriers, such as the time they would have to invest in the wearable, equally important. This difference might stem from the fact that self-employed physiotherapists are also responsible for the financial state of their practice, and are therefore more cautious when evaluating the costs of a new technology. Lastly, there are respondents who have already experienced working with wearables. Whilst they mostly have a positive attitude towards working with wearables, some of them have also experienced some struggles using wearables and have raised more concerns regarding the Wearable Breathing Trainer. Therefore, one could argue that their general outlook on wearables may potentially shape their perception of this technology.

5.2 Practical implications

The barriers and facilitators discovered in this study can give guidance to implementation researchers and developers in making choices regarding the implementation of the Wearable Breathing Trainer.

From the findings it has become evident that the user-friendliness of a wearable is quite important in whether a physiotherapist would want to implement a wearable. Therefore, developers should focus on whether the wearable is user-friendly for not only the physiotherapists, but also for the patients

and their parents as they must understand the technical functioning of the wearable as well. Focusing on this during the development of a new wearable, enhances the likelihood of physiotherapists wanting to implement the wearable in their treatment. This can be accomplished via usability testing, where a group of potential end-users carries out a series of tasks using a prototype of the technology, so that experts can then detect whether there are any usability issues (Almasi et al., 2023).

This study also highlights the importance of empirically proving the effectiveness of a technology before a physiotherapist would want to implement it and apply it in their treatment. Not only is the efficacy of this wearable wanted by physiotherapists, it is also required. Conducting a clinical trial is one of the prerequisites for the approval of medical devices under the MDR in the European Union (Brönneke et al., 2021). Therefore, clinical user trials should be conducted to gather data before the wearable is introduced to physiotherapists and brought on the market.

Another important finding was that physiotherapy practices are reluctant to purchase the Wearable Breathing Trainer if it is not cost-effective. Therefore a business plan with a cost-effective analysis should be made before this product is brought to the market. Moreover, not every physiotherapy practice is able to afford buying or renting this wearable. As described in Section 2.2.5, getting reimbursement within the healthcare industry depends on various factors. In the Netherlands specifically, 'Zorginstituut Nederland' (ZIN) is an important stakeholder in the decision regarding the composition of the basic health insurance. This institution publishes every year a document that goes into detail about the criteria and processes around the reimbursement of, for example, new innovations. The minimum criteria for care to qualify for reimbursement include the proven effectiveness, the cost effectiveness, the necessity, and feasibility (Ministerie van Volksgezondheid, Welzijn en Sport, 2024). Therefore, developers and stakeholders involved in the development and implementation of the Wearable Breathing Trainer must read this document to have knowledge on the whole process and make sure that this wearable fully complies with the criteria before it is brought to the market.

This study also shines light on that physiotherapists would not want to purchase a wearable if they will not frequently use it. Some physiotherapists either do not treat that many patients with dysfunctional breathing and some consider the wearable irrelevant to use on patients who quickly recover. With any new product it would be wise to forecast the demand to make decisions in the supply chain (Abolghasemi et al., 2020). If there is a low demand, however, one could explore other purposes this wearable could be suitable for, such as adults with dysfunctional breathing, to have a higher demand.

Next to this, the findings revealed physiotherapists only get paid per treated patient. Therefore, physiotherapists have to learn new knowledge or skills outside working hours, which inhibits the willingness to learn new technologies. In a context where healthcare professionals have limited time to learn the technical functioning of a new technology, good strategies for training and having IT support are a must for a successful implementation (Gagnon et al., 2010).

Lastly, in this study it was also evident that physiotherapists do not have much time to search for new wearables to apply in their treatments or discuss their opinion on wearables. Therefore it can be quite a challenge for implementation researchers and developers of wearables to discuss matters with them.

5.3 Theoretical implications

Beforehand, a list of determinants from the MIDI instrument was chosen to be included in this study. Four determinants that were initially not included, deemed to be quite relevant during the analysis of the results, and were therefore included in the results. These are: completeness, relevance for client, client satisfaction, and client cooperation. In this study three determinants have been added that are originally not in the MIDI instrument. These are: other purposes, purchasing and leasing possibilities, and preconditions. This does not necessarily mean they should be added to the MIDI instrument in general, since these determinants specifically relate to the Wearable Breathing Trainer.

5.4 Strengths and limitations

In this study the MIDI instrument has been used as a framework to study the perspective of physiotherapists on the upcoming implementation of the Wearable Breathing Trainer. A strength of this study is that a list of determinants is created based on a systematic review of empirical studies and a Delphi study involving implementation researchers. This list was then used in eight empirical studies. Data from these eight studies were then combined to a single set of data. The results from this meta-analysis in combination with comments from implementation experts resulted in the list of determinants from the MIDI instrument (Fleuren et al., 2013).

The MIDI instrument does only include the perspective of intermediary users, which are in this case paediatric physiotherapists. However, when answering the interview questions that are based on this framework, they answered some of the questions on behalf of their patients and what they would think about this wearable. Therefore, one could argue that the MIDI instrument is slightly less suitable to use as a framework when the innovation impacts the patient a lot too. The UTAUT model, for example, is a framework that helps understanding what factors influence the acceptance and use of a technology. One of the components in this model is subjective norm. This component dives into whether and why people that are important to the user or influence the user, in this case the patient, think that he or she should use the technology (Venkatesh et al., 2003). In this study the patient is important to the physiotherapists and influences their behaviour. Therefore, one could argue that this model is suitable to apply in this research. Nonetheless, the aim of the UTAUT model is to assess the likelihood of success for new technologies and to help understand what the drivers of acceptance are (Venkatesh et al., 2003). It is not specifically developed for a healthcare technology. The MIDI instrument, in contrast, is developed to study the perspective of intermediary users in a healthcare setting (Fleuren et al., 2013), which is also the aim of this research.

A limitation of this research is that the interviews have been conducted by only one researcher. Therefore, there was not another researcher present who could check during the interview whether the interview script was followed correctly, and all questions were asked, which could impact the internal validity. Also, only one researcher has coded the data of the interviews, meaning it was not possible to review and study the differences and similarities between multiple coding schemes with another researcher. This could also influence the internal validity of this research, because it can lead to missed patterns or an overemphasised focus on certain themes that one researcher deems important.

Prior and during the selection of the participants for this research, various demographic factors were taken into account to ensure that the findings represent the entire population of paediatric physiotherapists in the Netherlands. Nonetheless, physiotherapists who have an interest in new healthcare technologies were naturally more willing to participate in this study than physiotherapists who have no interest in using healthcare technologies in their treatment. Therefore, this study population might not accurately reflect the target population and thus impact the external validity of

this research. This limitation, however, was unavoidable since some physiotherapists do not prioritise looking into healthcare innovations and would thus not make time for an interview.

Another limitation is that one respondent had already heard from the Wearable Breathing Trainer before. Nonetheless, the other respondents received comprehensive background information about the Wearable Breathing Trainer before the interviews started and were thus well informed. The interview did therefore not lead to different answers and thus did not affect the results.

Lastly, while the aim of this research was to study the perspective of physiotherapists, they did speculate a lot on behalf of the patients and their parents. Such answers may give a distorted picture, and thus influence the internal validity, because the patients and their parents were not given the opportunity to speak for themselves in this study.

5.5 Future research

Upon reflection on the results of this study, there are several promising directions for future research. In this study the barriers and facilitators are studied before the actual implementation of the Wearable Breathing Trainer. It would be interesting to evaluate the use of the Wearable Breathing Trainer once it has been implemented, as there may be different barriers and facilitators once physiotherapists actually experience the use of this wearable and have applied it in their treatment.

Moreover, the Wearable Breathing Trainer might be suitable to use for other purposes, such as a tool for the diagnosis of dysfunctional breathing or COPD patients. Therefore, it would be interesting to investigate the perceived suitability and potential impact of this wearable across different healthcare settings.

Chapter 6: Conclusion

This research offers an overview of the barriers and facilitators for the upcoming implementation of the Wearable Breathing Trainer from the perspective of paediatric physiotherapists.

Overall, physiotherapists are enthusiastic about the use of the Wearable Breathing Trainer in their physiotherapy practice and there are quite a number of facilitators identified that support the implementation of this wearable. Main facilitators are the logical structure of the treatment plan, the treatment being more objective, more fun and beneficial for patients, and having reliable support from colleagues. Moreover, the availability of a clear instruction for physiotherapists, as well as patients and their parents, support the implementation. However, there is also an equal amount of barriers identified that would hinder this implementation. The main barriers are not having the financial resources to purchase or rent the wearable, or having the financial capacity but being reluctant to spend it if the wearable is not cost-effective, empirically validated as effective, will not be frequently utilised, or is not user friendly. Another significant barrier is the time physiotherapists would have to invest in this wearable. Nonetheless, the aforementioned facilitators either compensate for the time one has to invest in this wearable or reduce the learning curve and thus potentially minimise the time physiotherapists have to invest in the learning process and implementation of the Wearable Breathing Trainer.

It has also become quite evident that the opinion of a patient carries significant weights in the decision-making process. In particular, physiotherapists place great importance on ensuring that patients are satisfied with using the wearable, encounter no difficulties in its use, and derive clear benefits from its implementation.

The findings of this research assist the department of sustainable and functional textiles at Saxion and its associated partners in making informed choices to ensure that the Wearable Breathing Trainer aligns with the preferences of physiotherapists. Understanding their perspective, will contribute to a more seamless implementation process with minimal obstacles for physiotherapists. Including physiotherapists in this decision-making process is crucial to secure broad adoption, so that ultimately a large group of children with dysfunctional breathing can benefit from a wearable device that enhances their treatment.

Summed up, the Wearable Breathing Trainer could be a valuable tool to support the current treatment of patients with dysfunctional breathing. However, it is essential to address the identified barriers and enhance the facilitators from this research, as that can contribute to a more seamless implementation of the Wearable Breathing Trainer.

References

Abolghasemi, M., Beh, E., Tarr, G., & Gerlach, R. (2020). Demand forecasting in supply chain: The impact of demand volatility in the presence of promotion. Computers & Industrial Engineering, 142, 106380. https://doi.org/10.1016/j.cie.2020.106380

Almasi, S., Bahaadinbeigy, K., Ahmadi, H., Sohrabei, S., & Rabiei, R. (2023). Usability Evaluation of Dashboards: A Systematic Literature Review of Tools. BioMed Research International, 2023, 1–11. https://doi.org/10.1155/2023/9990933

Barker, N., & Everard, M. L. (2015). Getting to grips with 'dysfunctional breathing'. *Paediatric Respiratory Reviews*, *16*(1), 53–61. https://doi.org/10.1016/j.prrv.2014.10.001

Barker, N., Thevasagayam, R., Ugonna, K., & Kirkby, J. (2020). Pediatric Dysfunctional Breathing: Proposed Components, Mechanisms, Diagnosis, and Management. *Frontiers in Pediatrics*, *8*. https://doi.org/10.3389/fped.2020.00379

Blumenthal, J., Wilkinson, A., & Chignell, M. (2018). Physiotherapists' and Physiotherapy Students' Perspectives on the Use of Mobile or Wearable Technology in Their Practice. *Physiotherapy Canada*, *70*(3), 251–261. https://doi.org/10.3138/ptc.2016-100.e

Bouderhem, R. (2023). Privacy and Regulatory Issues in Wearable Health Technology. *Engineering Proceedings*, *58*(1), 87. https://doi.org/10.3390/ecsa-10-16206

Boulding, R., Stacey, R., Niven, R., & Fowler, S. J. (2016). Dysfunctional breathing: a review of the literature and proposal for classification. *European Respiratory Review*, *25*(141), 287–294. https://doi.org/10.1183/16000617.0088-2015

Brönneke, J. B., Müller, J., Mouratis, K., Hagen, J., & Stern, A. D. (2021). Regulatory, Legal, and Market Aspects of Smart Wearables for Cardiac Monitoring. *Sensors*, *21*(14), 4937. https://doi.org/10.3390/s21144937

Canali, S., Schiaffonati, V., & Aliverti, A. (2022). Challenges and recommendations for wearable devices in digital health: Data quality, interoperability, health equity, fairness. *PLOS Digital Health*, *1*(10), e0000104. https://doi.org/10.1371/journal.pdig.0000104

Chapman, E. B., Hansen-Honeycutt, J., Nasypany, A., Baker, R. T., & May, J. (2016). *A CLINICAL GUIDE TO THE ASSESSMENT AND TREATMENT OF BREATHING PATTERN DISORDERS IN THE PHYSICALLY ACTIVE: PART 1*. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5046973/

Connett, G., & Thomas, M. (2018). Dysfunctional Breathing in Children and Adults With Asthma. *Frontiers in Pediatrics*, *6*. https://doi.org/10.3389/fped.2018.00406

Dannapfel, P., Peolsson, A., & Nilsen, P. (2013). What supports physiotherapists' use of research in clinical practice? A qualitative study in Sweden. *Implementation Science*, *8*(1). https://doi.org/10.1186/1748-5908-8-31

De Jong, I. J., Lexis, M. A. S., Slegers, K., & Tuijthof, G. J. M. (2023). Medical device regulation: requirements for occupational therapists in The Netherlands who prescribe and manufacture custom-made devices. *Disability And Rehabilitation Assistive Technology*, *19*(4), 1415–1423. https://doi.org/10.1080/17483107.2023.2187889

De Veer, A. J., Fleuren, M. A., Bekkema, N., & Francke, A. L. (2011). Successful implementation of new technologies in nursing care: a questionnaire survey of nurse-users. BMC Medical Informatics And Decision Making, 11(1). https://doi.org/10.1186/1472-6947-11-67

Fleuren, M., Paulussen, T., Van Dommelen, P., & Van Buuren, S. (2013). Measurement Instrument for Determinants of Innovations (MIDI). *BMJ Quality & Safety*, *22*(Suppl 1), A42.2-A42. https://doi.org/10.1136/bmjqs-2013-002293.124

Fleuren, M., Paulussen, T., Van Dommelen, P., & Van Buuren, S. (2014). Towards a measurement instrument for determinants of innovations. *International Journal For Quality in Health Care*, *26*(5), 501–510. https://doi.org/10.1093/intqhc/mzu060

Gagnon, M., Desmartis, M., Labrecque, M., Car, J., Pagliari, C., Pluye, P., Frémont, P., Gagnon, J., Tremblay, N., & Légaré, F. (2010). Systematic Review of Factors Influencing the Adoption of Information and Communication Technologies by Healthcare Professionals. Journal Of Medical Systems, 36(1), 241–277. https://doi.org/10.1007/s10916-010-9473-4

Garcia, L. M. T., Mendonça, G., Benedetti, T. R. B., Borges, L. J., Streit, I. A., Christofoletti, M., Silva-Júnior, F. L. E., Papini, C. B., & Binotto, M. A. (2022). Barriers and facilitators of domain-specific physical activity: a systematic review of reviews. *BMC Public Health*, *22*(1). https://doi.org/10.1186/s12889-022-14385-1

Gard, G., Nyboe, L., & Gyllensten, A. L. (2019). Clinical reasoning and clinical use of basic body awareness therapy in physiotherapy – a qualitative study? *European Journal Of Physiotherapy*, *22*(1), 29–35. https://doi.org/10.1080/21679169.2018.1549592

Iqbal, S. M., Mahgoub, I., Du, E., Leavitt, M. A., & Asghar, W. (2021). Advances in healthcare wearable devices. *Npj Flexible Electronics*, *5*(1). https://doi.org/10.1038/s41528-021-00107-x

Izu, L., Scholtz, B., & Fashoro, I. (2024). Wearables and Their Potential to Transform Health Management: A Step towards Sustainable Development Goal 3. *Sustainability*, *16*(5), 1850. https://doi.org/10.3390/su16051850

Johansson, D., Malmgren, K., & Murphy, M. A. (2018). Wearable sensors for clinical applications in epilepsy, Parkinson's disease, and stroke: a mixed-methods systematic review. *Journal Of Neurology*, *265*(8), 1740–1752. https://doi.org/10.1007/s00415-018-8786-y

Kang, H. S., & Exworthy, M. (2022). Wearing the Future—Wearables to Empower Users to Take Greater Responsibility for Their Health and Care: Scoping Review. *Jmir Mhealth And Uhealth*, *10*(7), e35684. https://doi.org/10.2196/35684

Lee, J., Kim, D., Ryoo, H. Y., & Shin, B. S. (2016). Sustainable Wearables: Wearable Technology for Enhancing the Quality of Human Life. *Sustainability*, *8*(5), 466. https://doi.org/10.3390/su8050466

Lewy, H. (2015). Wearable technologies – future challenges for implementation in healthcare services. *Healthcare Technology Letters*, *2*(1), 2–5. https://doi.org/10.1049/htl.2014.0104

Lu, L., Zhang, J., Xie, Y., Gao, F., Song, X., Wu, X., & Ye, Z. (2020b). Wearable Health Devices in Health Care: Narrative Systematic Review. *Jmir Mhealth And Uhealth*, *8*(11), e18907. https://doi.org/10.2196/18907

Mattison, G., Canfell, O., Forrester, D., Dobbins, C., Smith, D., Töyräs, J., & Sullivan, C. (2022). The Influence of Wearables on Health Care Outcomes in Chronic Disease: Systematic Review. Journal Of Medical Internet Research, 24(7), e36690. https://doi.org/10.2196/36690

Meek, P. M., Lareau, S. C., & Hu, J. (2003). Are self-reports of breathing effort and breathing distress stable and valid measures among persons with asthma, persons with COPD, and healthy persons? *Heart & Lung*, *32*(5), 335–346. https://doi.org/10.1016/s0147-9563(03)00100-6

Ministerie van Volksgezondheid, Welzijn en Sport. (2024, 20 augustus). *Beoordeling stand van de wetenschap en praktijk 2023*. Publicatie | Zorginstituut Nederland.

https://www.zorginstituutnederland.nl/over-ons/publicaties/publicatie/2023/04/11/beoordeling-swp-2023

Nagase, F. I., Stafinski, T., Avdagovska, M., Stickland, M. K., Etruw, E., & Menon, D. (2022). Effectiveness of remote home monitoring for patients with Chronic Obstructive Pulmonary Disease (COPD): systematic review. *BMC Health Services Research*, *22*(1). https://doi.org/10.1186/s12913-022-07938-y

Ometov, A., Shubina, V., Klus, L., Skibińska, J., Saafi, S., Pascacio, P., Flueratoru, L., Gaibor, D. Q., Chukhno, N., Chukhno, O., Ali, A., Channa, A., Svertoka, E., Qaim, W. B., Casanova-Marqués, R., Holcer, S., Torres-Sospedra, J., Casteleyn, S., Ruggeri, G., Lohan, E. S. (2021). A Survey on Wearable Technology: History, State-of-the-Art and Current Challenges. *Computer Networks*, *193*, 108074. https://doi.org/10.1016/j.comnet.2021.108074

Powell, D., & Godfrey, A. (2023). Considerations for integrating wearables into the everyday healthcare practice. *Npj Digital Medicine*, *6*(1). https://doi.org/10.1038/s41746-023-00820-z

Project Wearable Breathing Trainer | NWO-SIA ProjectenBank. (z.d.). https://www.sia-projecten.nl/project/wearable-breathing-trainer

Sqalli, M. T., & Al-Thani, D. (2020). Evolution of Wearable Devices in Health Coaching: Challenges and Opportunities. *Frontiers in Digital Health*, *2*. https://doi.org/10.3389/fdgth.2020.545646

Siering, L., Ludden, G., Mader, A., & Van Rees, H. (2019). A Theoretical Framework and Conceptual Design for Engaging Children in Therapy at Home—The Design of a Wearable Breathing Trainer. *Journal Of Personalized Medicine*, *9*(2), 27. https://doi.org/10.3390/jpm9020027

Smuck, M., Odonkor, C. A., Wilt, J. K., Schmidt, N., & Swiernik, M. A. (2021). The emerging clinical role of wearables: factors for successful implementation in healthcare. *Npj Digital Medicine*, *4*(1). https://doi.org/10.1038/s41746-021-00418-3

Stander, J., Grimmer, K., & Brink, Y. (2020). Time as a barrier to evidence uptake—A qualitative exploration of the concept of time for clinical practice guideline uptake by physiotherapists. *Journal Of Evaluation in Clinical Practice*, *27*(2), 280–290. https://doi.org/10.1111/jep.13397

Thomas, M., McKinley, R. K., Freeman, E. E., Foy, C., & Price, D. (2005). The prevalence of dysfunctional breathing in adults in the community with and without asthma. *Primary Care Respiratory Journal*, *14*(2), 78–82. https://doi.org/10.1016/j.pcrj.2004.10.007

Trompenaars, A. M., Van Roest, A. P., & Vaessen-Verberne, A. (2020). Dysfunctional breathing in children. *Journal Of Pulmonology And Respiratory Research*, *4*(1), 001–005. https://doi.org/10.29328/journal.jprr.1001013

Venkatesh, N., Morris, N., Davis, N., & Davis, N. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27*(3), 425. https://doi.org/10.2307/30036540

Vidotto, L. S., Carvalho, C. R. F., Harvey, A., & Jones, M. (2019). Dysfunctional breathing: what do we know? *Jornal Brasileiro de Pneumologia*, *45*(1). https://doi.org/10.1590/1806-3713/e20170347

Volpato, L., Del Río Carral, M., Senn, N., & Santiago-Delefosse, M. (2021). General Practitioners' Perceptions of the Use of Wearable Electronic Health Monitoring Devices: Qualitative Analysis of Risks and Benefits. *Jmir Mhealth And Uhealth*, *9*(8), e23896. https://doi.org/10.2196/23896

Watt, A., Swainston, K., & Wilson, G. (2019). Health professionals' attitudes to patients' use of wearable technology. *DIGITAL HEALTH*, *5*, 205520761984554. https://doi.org/10.1177/2055207619845544

Appendix A: Operationalisation table

Concept	Category	Sub-category	Indicators
Innovation determinants	Characteristics of the innovation	Procedural clarity	The clarity of the procedures regarding the treatment of the Wearable Breathing Trainer
		Complexity	The complexity regarding the use of the Wearable Breathing Trainer
		Compatibility	The compatibility of the Wearable Breathing Trainer and the current treatment
	Characteristics of the adopting person (user)	Personal benefits/drawbacks	The benefits and drawbacks of adopting and applying the Wearable Breathing Trainer
		Outcome expectations	The expected outcome of using the Wearable Breathing Trainer
		Social support	The amount of support physiotherapists get from their colleagues
		Knowledge	The required knowledge physiotherapists need to use the Wearable Breathing Trainer
	Characteristics of the organisation	Formal ratification by management	The formal approval regarding the Wearable Breathing Trainer
		Financial resources	The availability of financial resources to implement the Wearable Breathing Trainer
		Time available	The availability of time to implement the Wearable Breathing Trainer
		Coordinator	The responsibilities in terms of coordination are assigned
		Information accessible about use of innovation	The access to the correct and required information to use the Wearable Breathing Trainer

Table A 1. Operationalisation table

Appendix B: Interview schedule

Goedendag,

Allereerst bedankt dat u wilt deelnemen aan dit onderzoek. Mijn naam is Nina Schreuder en ik studeer Gezondheidswetenschappen aan de Universiteit Twente. Ik zit nu in mijn vijfde jaar en ben momenteel bezig met mijn afstudeeropdracht. Hierbij doe ik onderzoek naar de perceptie van fysiotherapeuten omtrent de implementatie van de Wearable Breathing Trainer. De hierop aansluitende onderzoeksvraag is: “Wat zijn de factoren die de implementatie van de Wearable Breathing Trainer in het werkproces van fysiotherapeuten bevorderen of juist belemmeren?

In dit onderzoek wil ik fysiotherapeuten, verspreid door heel Nederland, interviewen om zo meer inzicht te krijgen in de mening van fysiotherapeuten over het gebruik en de implementatie van de Wearable Breathing Trainer.

U zal binnen dit onderzoek anoniem blijven en ook de antwoorden die u geeft, zullen vertrouwelijk behandeld worden en niet worden gedeeld met derden. Verder heeft u het recht om op elk moment dat u wilt te stoppen met dit interview. Het interview dat ik bij u zal afnemen, duurt ongeveer 45 minuten. Mocht u naderhand nog vragen hebben over het onderzoek of eventueel geïnteresseerd zijn in de resultaten, kunt u contact met mij opnemen via het volgende mailadres: n.schreuder@student.utwente.nl

Gaat u ermee akkoord dat dit interview wordt opgenomen?

Start opname

Het is vandaag *datum*. Het doel van het onderzoek en de verwerking van de resultaten zijn aan u uitgelegd. Gaat u hiermee akkoord en vind u het goed als dit interview opgenomen wordt?

Ik zal dan eerst even informatie geven over dit onderwerp. Wearables zijn technologieën die gedragen kunnen worden op het lichaam. Hierbij kunt u denken aan bijvoorbeeld horloges die uw gezondheid kunnen meten. Een wearable waar dit onderzoek dus over gaat is de Wearable Breathing Trainer. Vanuit fysiotherapeuten is de vraag ontstaan naar een hulpmiddel voor oefeningen die thuis worden gedaan. De huidige behandeling voor kinderen omvat nu, onder andere, het thuis uitvoeren van ademhalingsoefeningen. Alleen door veel kinderen worden deze oefeningen als saai ervaren en daarnaast kunnen fysiotherapeuten ook de progressie van een kind thuis niet monitoren.

De Wearable Breathing Trainer is een vest met een sensor en vibratie motoren. Tijdens het oefenen meet dit vest de ademhaling van de borst en buik. De sensoren zijn verbonden aan de vibratie motoren die door vibratie patronen een buikademhaling stimuleren en het kind bewust maken van de ademhaling. Verschillende patronen zijn hiervoor ontworpen en getest om te voldoen aan de verschillende behoeften. Daarnaast zijn er ook spelelementen ontworpen in de bijbehorende app, waardoor kinderen op een leuke manier thuis hun ademhalingsoefeningen kunnen doen. De gegevens die verzameld worden kunt u als fysiotherapeut dan ook aflezen, zodat u de progressie die een kind thuis maakt ook zou kunnen zien.

Het vest van de Wearable Breathing Trainer heeft 2 banden, een daarvan zit rondom de borst en de ander zit rondom de buik. Elke band bevat een sensorsysteem en deze sensors kunnen de ademhaling monitoren doordat zij de verandering in omvang van de borst- en buikhoogte kunnen meten.

Naast sensors heeft de Wearable Breathing Trainer ook vibratiemotoren die zorgen voor haptische feedback. Haptische feedback is aanrakingstechnologie bijvoorbeeld via trillingen. Deze motoren kunnen aan de binnenkant van het vest worden geplaatst rond de plek van de buik. Het shirt bestaat

uit twee lagen waardoor er geen direct huidcontact is maar dat de vibratiepatronen en sensoren aan de buitenkant ook niet te zien zijn. Deze plaatsing is gekozen met co-design sessies met fysiotherapeuten om inzicht te krijgen in geschikte ademhalingsoefeningen. Want waar normaal gesproken de fysiotherapeut of patiënt zelf bijvoorbeeld een boek of zijn of haar handen plaats op de buik, om de ademhaling te voelen, kunnen de motoren door trillingen een buikademhaling stimuleren.

Daarnaast is er ook een behandelplan gemaakt voor de Wearable Breathing Trainer. Die had ik u per mail ook gestuurd, maar deze zal ik alsnog kort met u doornemen. Het pad van een begint bij de diagnose en doorverwijzing naar een fysiotherapeut. Daaropvolgend kijkt een fysiotherapeut naar de klachten van een kind en voert de fysiotherapeut eventueel enkele testen uit. Tijdens de 2e afspraak kan bepaald worden of een fysiotherapeut de Wearable Breathing Trainer wil inzetten.

Vervolgens start de eerste behandelfase, waarbij de fysiotherapeut op de bijbehorende app het juiste programma selecteert. De fysiotherapeut legt dan aan de patiënt de buikademhaling uit, die de patiënt voor de eerste fase liggend zal uitvoeren. De patiënt voert dit uit en krijgt dan feedback daarop van de Wearable Breathing Trainer. Daarna neemt de patiënt de Wearable Breathing Trainer mee naar huis en kan daar de aangeleerde oefeningen thuis uitvoeren. Dit doet de patiënt 1 keer per dag voor zo'n 10 minuten. Hierbij is de keus vanuit de fysiotherapeut welke oefeningen geschikt zijn en ook hoelang de oefeningen moeten duren. Na een evaluatie terug bij de fysiotherapeut kan overgegaan worden naar behandelfase 2.

In behandelfase 2 wordt weer het juiste programma geselecteerd. Dit betreft de buikademhaling en ademhalingstechniek in rust, maar dit keer terwijl de patiënt zit. Na de uitleg van de fysiotherapeut kan de patiënt thuis, met behulp van de Wearable Breathing Trainer, de ademhalingsoefeningen uitvoeren. Na deze oefeningen te hebben geëvalueerd kan de fysiotherapeut besluiten of de patiënt door kan naar behandelfase 3.

Behandelfase 3 verloopt precies hetzelfde, maar dan voert de patiënt de oefeningen niet meer liggend of zittend uit, maar staand. Na evaluatie hiervan kan de patiënt door naar de volgende fase.

Behandelfase 4 is het uitvoeren van de juiste ademhalingstechniek bij inspanning. De start van fase 4 begint met de fysiotherapeut die de patiënt helpt met het oefenen van de ademhalingstechniek bij inspanning. De patiënt voert thuis met de Wearable Breathing Trainer oefeningen uit in rust en voert pas daarna ook de inspanningsoefeningen uit thuis zonder de Wearable Breathing Trainer. Na het uitvoeren van deze inspanningsoefeningen past de patiënt de aangeleerde ademhalingstechnieken toe. Met het huidige ontwerp is het nog niet mogelijk om het vest tijdens inspanning te dragen, want de metingen kunnen dan verstoord worden. Vervolgens evalueert de fysiotherapeut de ademhaling van de patiënt weer tijdens het consult en bepaalt dan of de patiënt klaar is om de behandeling af te ronden. De Wearable Breathing Trainer wordt dan weer ingeleverd bij de fysiotherapeut.

Het is nog even de vraag wie de Wearable Breathing Trainer aan zal moeten schaffen, omdat er meerdere opties mogelijk zijn. Het kan zijn dat de verzekering het zal vergoeden, maar als dat niet zo is zal de fysiotherapeut het zelf aan moeten schaffen. Wat ook een optie kan zijn, is dat ouders het ophalen bij een servicepunt en dan de wearable lenen totdat hun kind de wearable niet meer nodig heeft.

Heeft u op dit moment verder nog vragen?

Introductie

1. Wat is uw werkervaring en huidige functie?

2. Hoe vaak behandelt u gemiddeld een kind met disfunctionele ademhalingsklachten?
3. Bij hoeveel van de patiënten die u ziet merkt u dat ze wellicht ongemotiveerd zijn om thuis hun ademhalingsoefeningen te doen?
4. Wat vindt u van het gebruik van wearables binnen uw werk?

Determinanten geassocieerd aan de Wearable Breathing Trainer

5. Wat vindt u van het behandelplan van de Wearable Breathing Trainer?
6. Op welke manier denkt u dat de Wearable Breathing Trainer zou kunnen bijdragen aan de huidige behandeling?
7. In hoeverre denkt u dat de Wearable Breathing Trainer toepasbaar is in uw behandeling?

Determinanten geassocieerd aan de fysiotherapeut

8. Wat denkt u dat voor u persoonlijk de voordelen zijn van het werken met de Wearable Breathing Trainer?
9. Wat denkt u dat voor u persoonlijk de nadelen zijn van het werken met de Wearable Breathing Trainer?
10. Wat verwacht u dat de effecten zijn als u de Wearable Breathing Trainer gaat gebruiken in uw werk?
11. In welke zin voelt u zich gesteund door uw collega's, op het moment dat u zou besluiten de Wearable Breathing Trainer te gaan implementeren en gebruiken?
12. Wat voor vaardigheden of kennis denkt u dat u nodig heeft voordat u de Wearable Breathing Trainer kan toepassen in de behandeling?

Determinanten geassocieerd aan een fysiotherapiepraktijk

13. Wie beslist er over invoering van zorgtechnologie, zoals de Wearable Breathing Trainer, in uw praktijk?
14. Wat zijn de overwegingen die gemaakt worden tijdens de beslissing of de Wearable Breathing Trainer wel of niet aangeschaft zal worden?
15. Wie is verantwoordelijk om de implementatie van de Wearable Breathing Trainer in goede banen te leiden, in uw praktijk?
16. Welk budget is er in uw praktijk voor het aanschaffen van de Wearable Breathing Trainer?
17. Hoeveel tijd heeft u voor het implementeren en leren omgaan met zorgtechnologieën, zoals de Wearable Breathing Trainer, in uw werkproces?
18. Op welke manier zou u geïnformeerd willen worden over de gebruikswijze van een Wearable Breathing Trainer?

Heeft u verder nog een vraag aan mij of een opmerking over de wearable of over iets anders? Zo niet, dan zal ik de opname stoppen.

Appendix C: Codebook

Concept	Category	Sub-category	Quote
Innovation determinants	Determinants associated with the innovation	Procedural clarity	*That is clear. Certainly. It is actually the same order as we already apply, only without the vest.*
		Completeness	*I think it is good to include games that are fun and performance-oriented, but perhaps it can also be good to incorporate soothing breathing exercises. I think it would be interesting to take this into account, so that these games do not always have to be a distraction that is motivating, but it can also be a distraction that provides peace.*
		Complexity	*From what I hear, it seems easy to use. I may spend some time figuring out exactly how it works with the first patients, but it does not seem very difficult to me. Once I know how it works, it seems very easy to use.*
		Compatibility	*I can then see exactly what went well and what the challenges still are. I can also see when things went less well and perhaps those are times when the patient experienced more stress or whatever. I think it can give a lot of shape to how you construct your treatment plan.*
		Relevance for client	*I think it is suitable for all patients, but the question is also whether you want to use it for all patients. You might be able to achieve it in a different way without using this wearable. I think this wearable, specifically, could be useful for children with autism or anxiety. This allows them to fall back on something that is a certainty.*
		Other purposes	*You often see that when children have problems with sleeping, they also work on breathing exercises to create peace and quiet to fall asleep, so this might be a tool for that.*

	Determinants associated with the adopting person	Personal benefits	*With this I can treat my patients in a more targeted way, as I can see it in the data when something is not going great during the exercises. In the current treatment, the patients or its parents have to tell me information about the progress they are making, but with this technology I will have more information.*
		Personal drawbacks	*I think the time you have to invest in it is a disadvantage. I, but also the patient, must understand how it works. I would then see if I have seen added value to decide whether I want to invest my time in it. But once you know how it works, I do not think I will have to spend any extra time on it.*
		Outcome expectations	*I expect that patients will be more motivated and will practice more often. Therefore, I think their breathing pattern is more quickly back to normal, because they get feedback every time they practice. Normally, when I practice with them, they do not get feedback at home. So, with that in mind, I think it could help the patient to learn faster how they should breathe correctly.*
		Client satisfaction	*I think that, especially among young people, there is a lot more fun. If there is something of a game involved, young people soon find it very fun. That is much more fun than when I tell them to lie on their back and I place a stuffed animal or book on them and then they have to feel how it moves. I think that therapy compliance will also increase.*
		Client cooperation	*I think it is important that parents are informed about how the wearable works and what they should do if something does not work.*

		Social support	*We are with six and have an open-minded attitude towards each other. I think that they too will be very curious to use this wearable. We have a nice collaboration and if one of use introduces something new, everybody is open-minded to it. I do not see a problem there at all.*
		Knowledge	*I think I should now how it works, so I can explain it to my patients. I, specifically, also think I should know how the app works and how I could see the monitored data.*
	Determinants associated with the organisation	Formal ratification by management	*Suppose I would like to have this, I would first talk to him. Then we will see together whether it is something to invest in. It obviously depends on the costs, but it also depends on how often I think I will use this wearable. It would also be nice if sufficient research has been done to prove its effectiveness. If it is proven effective, we are more likely to purchase it. We can then also inform the youth doctors in the area that we have this product, so that doctors are more likely to refer these patients to us.*
		Financial resources	*I think there is a budget for this. Within our practice we also have an online brace store, and our practice offers fitness subscriptions, so there is more income than just the money from the health insurance.*
		Purchasing and leasing possibilities	*It really depends on how often it is going to be used. If this becomes the first practice to use it, more patients will probably be referred to here and I will therefore need to have the wearable more often. In that case, it would be nice to always have a vest here available. But if I do not use it often, it would be more practical to borrow it.*

		Time available	*It is more pleasant if information comes to me. Just because part of it is in my blind spot. If you had not emailed me, I would never have known this was in development. The moment I know about things like this, I can tell my employer I like it and would want to have it in this physiotherapy practice.*
		Coordinator	*It is not that we specifically have one person who takes responsibility for steering everything that comes into the practice in the right direction. The moment this wearable enters this practice and is also intended for children, then I am ultimately responsible for it.*
		Information accessible about use of the innovation	*Basically, what is necessary. If you can figure it out with just a manual, that would be great. Otherwise, a course would be fine too.*
		Preconditions	*I would prefer it if there was a trial period first, and I would not have to purchase it right away.*

Table C 1. Codebook