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HANDBOOK II

Guidelines on the use of wearable sensor systems in-home rehabilitation combined with remote connections

Flowchart and Practice guideline

Publications of Karelia University of Applied Sciences
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HANDBOOK II

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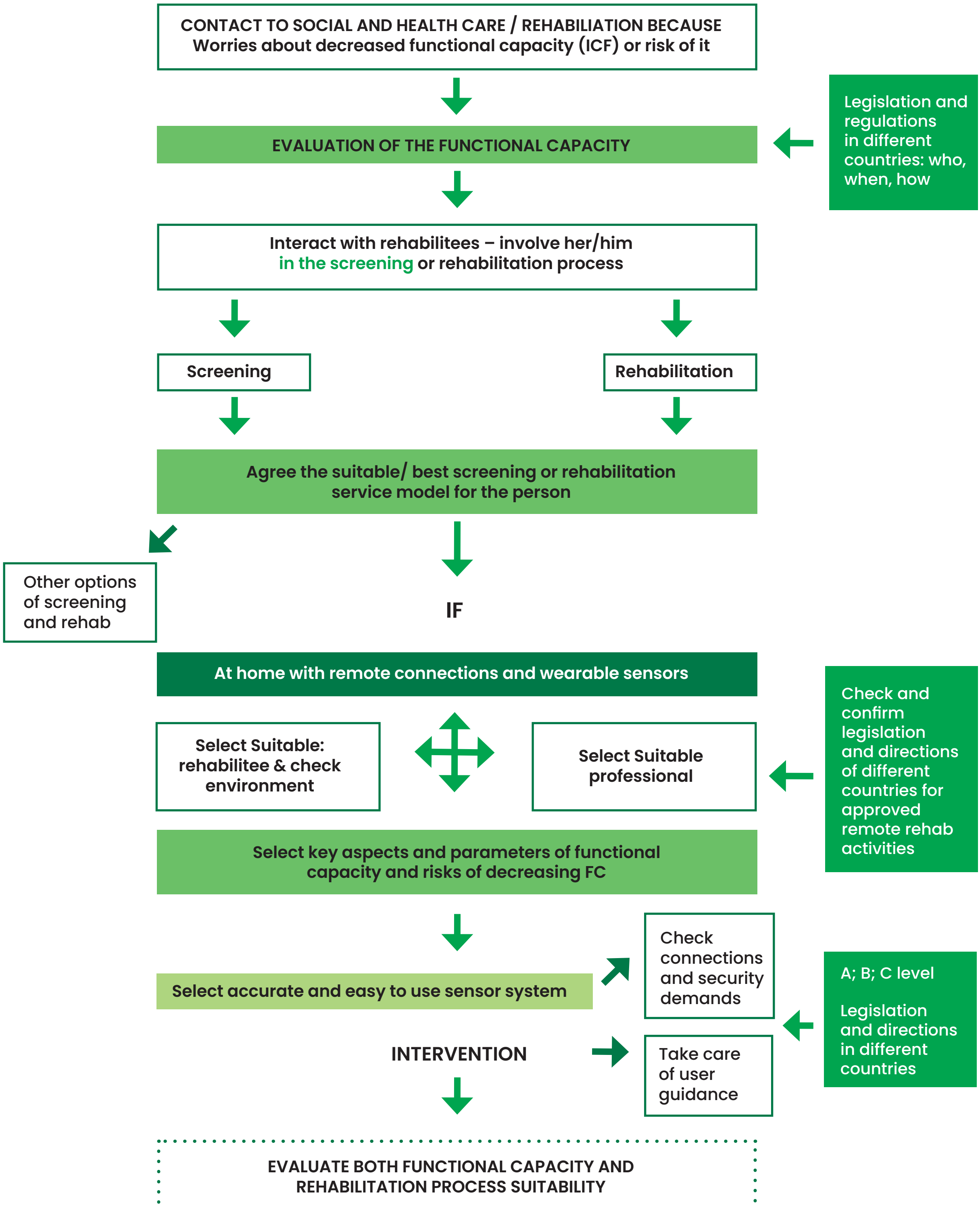
WEARABLE SENSOR TECHNOLOGIES SENDoc

Contents

FLOWCHART depicting the use of wearable sensor systems in-home rehabilitation with remote connections



1 Introduction

This Handbook Part II was developed to assist and orientate rehabilitation staff and organisations who are planning to start remote home rehabilitation activities, particularly with the older persons. The ideas and suggestions for the remote rehabilitation process in this document can be easily adopted to any kind of functional capacity problem in rehabilitation. The Handbook Part II focuses on the attributes and aspects that you must consider when you start a remote rehabilitation process with remote connections and wearable sensor systems.

This Handbook Part II is a continuation from the HANDBOOK of Wearable Technology Supported Home Rehabilitation Services in Rural Areas – Emphasis on Monitoring Structures and Activities of Functional Capacity, launched in 2019.

2 Background

Finland's Social and Health Care Ministry have estimated that at least half of the health care services will be transferred to homes by 2025. The ministry has agreed that remote (tele) technology services are considered as an effective alternative to face to face rehabilitation. Home organised rehabilitation with remote connections is one viable option to enable a versatile and effective class of rehabilitation services and is an especially desirable solution for those in the sparsely populated areas of Europe and the World.

The SENDoc project (Smart Sensor Devices fOr rehabilitation and Connected health, https://sendoc.interreg-npa.eu) has assessed and evaluated the technical, clinical and social acceptability aspects of wearable sensors and their impact on patients, on health and care delivery, and in rural communities (SENDoc 2018). It´s an international project, where Karelia UAS is one of the partners, the lead partner is Ulster University (UK) and the other partners are Tyndall Institute/ University College Cork (Ireland) and Västerbotten County Council (VLL)/ Umeå University (Sweden). This project was funded by the Northern Periphery and Arctic Programme (NPA 2018, http://www.interreg-npa.eu/).

The Sendoc partners have developed this guideline based on a descriptive review of research literature, trials organised and conducted by the SENDoc team throughout the project including the demonstrator projects, and research and clinical experience. We have collected reflections from rehabilitation staff's clinical experiences from partner countries who have used and tested different sensor systems. We have also launched a "Virtual Guide from this Handbook II" on both the Sendoc and every partner's webpages (https://sendoc.interreg-npa.eu).

The Sendoc project's focus has been on the key physical functional capacity factors that are crucial for continuing independent living at home or homelike circumstances. These aspects belong mainly in the ICF (International Classification of Function) class Structure and Activities. Special individual social, psychological and environmental factors play a huge role in functional capacity, but the analysis / monitoring of them with sensors has so far been overlooked. These guidelines are particularly focused on older people, whose ability to continue independent living is endangered by decreased functional capacity or the risk of this happening.

A large variety of different sensor types have been developed in the last 15 years. Some of them are available for purchase off the shelf, but many of them are still under the development process to reach the clinical standard demands (usability, accuracy and reliability). Many of the sensor systems are developed mainly for research purposes. Wang et al. (2017) published a taxonomy of sensor dimensions: sensing technology, feedback modalities and system measures. The typology of sensors, examples of manufacturers, and their technologies can be found in the previously mentioned Handbook I. In that document you can find more details about the published research concerning wearable sensors used in the monitoring and analyzing ICF sub-areas of usual medical diagnosis.

3 Updated models, terminology, regulations and instructions for remote rehabilitation

In this document, remote rehabilitation is considered to be synonymous with, and a parallel expression to, tele-rehabilitation, meaning that rehabilitation activities are conducted with telecommunication and other electronic equipment. There are different concepts about remote rehabilitation or therapies, and the use of them can be mixed. In these guidelines, remote monitoring refers to physiological monitoring which may be prescribed or recommended by a healthcare professional. The rehabilitee may use monitoring for self-management, or monitored patient data in the home environment can be used by a healthcare professional for reviewing the functional capacity.

Table 1. Terminology in remote rehabilitation (modified Salminen et al. 2019)

TERMINOLOGY	DEFINITION
Video-call, video conferencing	Via webcam or smartphone among two or more users
Real-time remote rehabilitation or synchronous remote rehabilitation	Individual or group. Real-time connection between rehabilitee and rehabilitation professional by using applications using remote technology
Remote rehabilitation in addition to usual rehabilitation or "hybrid model"	A combination of remote rehabilitation / therapies and normal face to face activities
Time-independent remote rehabilitation or asynchronous rehabilitation	A form where rehabilitation is designed by professional, but rehabilitee carries out therehabilitation activities on their own with the assistance of technology. This remote rehabilitation form is time and place independent.
Online rehabilitation	Independent time and place rehabilitation where additional support from the professional who provides the service is available, for example, via online chat. Rehabilitation is carried out using an online program featuring videos, images, text or audio

Examples of remote rehabilitation in the field of physiotherapy

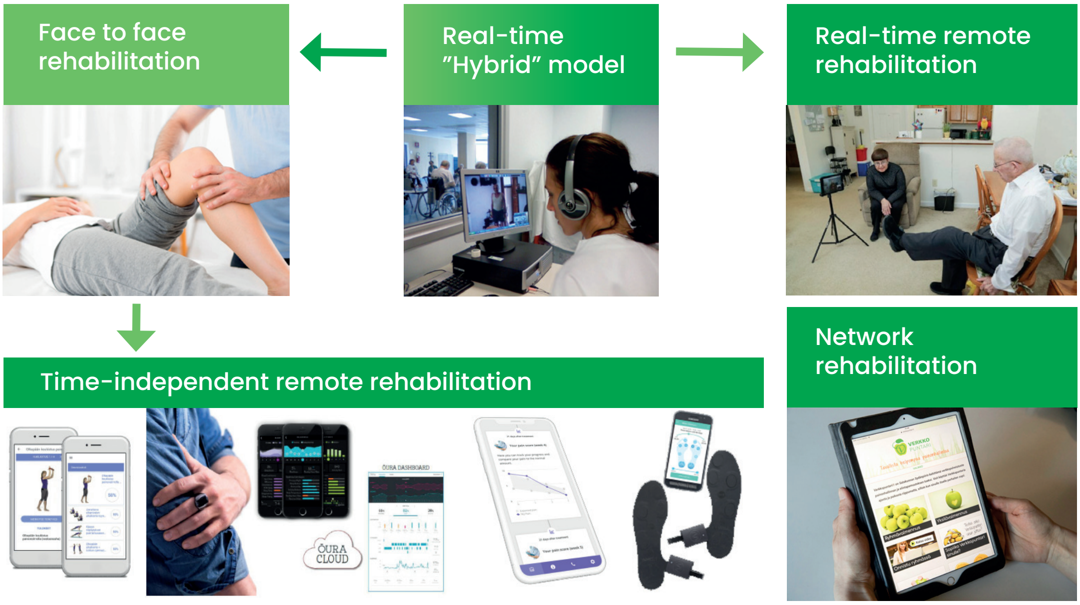


Figure 1. Example of remote therapies conducted

3.1 Regulations and instructions regarding the use of remote rehabilitation in SENDoc countries

The general regulations and requirements for remote rehabilitation seem to vary in different countries. The situation can change quite rapidly for a variety of reasons, such as COVID-19. Some of the EU-countries have more loose 'recommendations' rather than precise, strict regulations. In this report, we focus on the situation and regulations in Finland and include some links to the regulations and instructions for Ireland, UK and Sweden for further reading.

FINLAND

In Finland, the key organisations that provide instructions and set the regulations for organising remote rehabilitation are Ministry of Social and Health Care (STM), The Finnish Institute for Health and Welfare (THL), National Supervisory Authority for Welfare and Health (Valvira) and National Social Insurance Institute of Finland (Kela). Kela's role in rehabilitation is written in law. The responsibility concerns several different rehabilitation services. For example, if a private healthcare provider is registered for rehabilitation and reception activities, the permit license issued by the licensing authority also covers remote rehabilitation and remote reception.

In all cases, conducting remote rehabilitation must:

- Be goal-oriented
- Be led and followed by a rehabilitation professional
- Have a clear goal, start and endpoint
- Include examination, functional capacity diagnosis, diagnosis, monitoring, the follow-up, and treatment.
- Allow for the treatment decisions or recommendations of the patient to be based on the information and documents transmitted via video online or on a smartphone.

Valvira regulations for remote rehabilitation:

- The patient identification must be based on a reliable method, ie. strong identification (Suomi.fi, bank ID, mobile certificate). If the rehabilitee is already familiar with the therapist, strong electronic identification is not considered a requirement.
- The identification method must be verifiable afterwards (e.g. log information, mention of the event).
- The client can send documents to the therapist remotely using secure electronic communication

Kela instructions and requirements for a remote rehabilitation system:

- Must enable goal-oriented, both real-time and asynchronous, remote rehabilitation.
- Before using the electronic rehabilitation service, the rehabilitee must be identified by online banking IDs or by strong authentication using a mobile certificate (also when electronic transaction).
- The client must be able to send documents to the therapist remotely during the rehabilitation process using secure electronic communication
- The rehabilitee must be able to communicate with the therapist and other rehabilitees (e.g. discussion, chat, e-mail, announcements, giving feedback).
- The rehabilitee must participate in various activities (e.g. open questions, multiple choice questions) and practice and training.
- The system should allow for tracking goals and the use of multiple measures for monitoring changes of functional capacity.
- The system should provide the option to add and use text, pictures, videos, and links by both the rehabilitee and rehabilitation professionals.
- The rehabilitation team should be able to modify contents according to the individual needs of the rehabilitee.
- Participation of multi-professional rehabilitation team.
- (www.kela.fi)

Data security demands

The starting point for data security is the confidentiality, integrity and usability of the data. Data security must cover everything related to the availability, accuracy and confidentiality of data during processing, storage and transmission. Enabling and securing the use of information are the most important requirements for information security. The self-monitoring plan shall describe the procedures to ensure that data protection is implemented in practice.

Appropriate patient records must be made of the remote service, and the patient record must be maintained under the provisions and regulations issued. In the future, the goal is that all remote rehabilitation connections and patient reporting systems must fulfil Level A data security demands.

- Laki vahvasta sähköisestä tunnistamisesta ja sähköisistä luottamuspalveluista. https://finlex.fi/fi/laki/ajantasa/2009/20090617
- Valvira. Potilaille annettavat terveydenhuollon etäpalvelut. https://www.valvira.fi/terveydenhuolto/yksityisen_terveydenhuollon_luvat/potilaille-annettavat-terveydenhuollon-etapalvelut
- Tietoturva ja tietosuoja. Tietoturva ja tietosuoja Dnro 7018/00.01.00/2012

Table 2. General regulations of patient reporting systems

Regulation demands for social and health care *information and patient reporting systems*
Must meet the requirements for electronic processing of social and health care customer data (159/2007)
The organisation must update the self-monitoring plan (2/2015) in accordance with the The Finnish Institute for Health and Welfare (THL) regulation, taking into account the content of remote services
According to the Act (159/2007), a service provider who processes personal data electronically must have a data protection officer for the monitoring and control task. E.g. the organisation must name a person responsible for surveillance and data protection.

There are three different data security levels in Finland related to remote rehabilitation. Level A is that you have to pass a joint test organized by KELA. The information security of Class A information system must be assessed by an information security assessment body. Level B does not require external assessment. The service provider must have a written report that the data security requirements are fulfilled. If the purpose is processing of the rehabilitee data, then minimum Level B data security system must be informed in the Valvira register.

IRELAND

In Ireland, the instructions and goals for remote (tele) rehabilitation can be found in the following links. The use of telehealth systems should comply with the HSE IT policy and standards, and any users of telehealth systems are directed to documents about Secure Video and Audio Clinical Consultations. Specific references were made to requesting patient consent as well.

Governance documents and Standard Operating procedures have been developed and they are gathered on the website for ease of access, including a Procedure for the Management of Virtual Outpatient Clinics.

- Effective implementation and monitoring of telehealth and telecare in Ireland: learning from international best practice. http://nda.ie/Publications/Disability-Supports/Assistive-Technology/Effective-implementation-and-monitoring-of-telehealth-and-telecare-in-Ireland-learning-from-international-best-practice.pdf
- eHealth Ireland. https://www.ehealthireland.ie/Our-Team/Chief-Technology-Officer/CTO%20Technology%20Strategy%20.pdf
- Sláintecare Action Plan 2019. Https://www.gov.ie/en/publication/109e2b-slaintecare-action-plan-2019/

- Telehealth resource document. Https://www.aoti.ie/covid/telehealth-resource-document
- Irish society of chartered physiotherapists. Https://www.iscp.ie/news
- Fox rehabilitation. An enigma for years, it's time for telerehabilitation. Here's how. https://www.foxrehab.org/telehealth-regulations-therapy-clinical-codes/
- ehealth ireland. Procedure for the management of virtual outpatient clinics. Https://www.ehealthireland.ie/national-virtual-health-team/resources-and-documents/procedure-for-the-management-of-virtual-outpatient-clinics-scheduled-care-transformation-programme-august-2020.pdf

UNITED KINGDOM

In the UK, the NHS (National Health Service) and Chartered Society of Physiotherapists (CSP) have given instructions and information regarding conducting telehealth services and video consultations, and the tools required for this. In the guide for rapid implementation of remote consultations, there are key tips for launching such services such as consent, security, and circumstances, especially during Covid-19. However, it is thought that these guidelines are likely to continue after the pandemic.

- General medical counsil. Regulatory approaches to telemedicine. https://www.gmc-uk.org/about/what-we-do-and-why/data-and-research/research-and-insight-archive/regulatory-approaches-to-telemedicine
- NHS. Key information and tools. Https://www.nhsx.nhs.uk/information-governance/
- Chartered society of physiotherapy. Covid-19: guide for rapid implementation of remote consultations. Https://www.csp.org.uk/system/files/publication_files/remote%20consultations%20top%20tips%20v9.pdf

SWEDEN

You can find instructions regarding remote rehabilitation under the topic "digital physiotherapy" from the Swedish physiotherapy associations web pages. There are also links to the authorities web pages concerning the topic in question.

- Fysioterapeuterna. Guide – för att du ska känna dig trygg med och komma igång med digital fysioterapi. https://www.fysioterapeuterna.se/globalassets/professionsutveckling/guide-for-digital-fysioterapi.pdf
- Swedish Authority for Privacy Protection (IMY). https://www.datainspektionen.se/other-lang/
- Socialstylersen. Digitala vårdtjänster. Övergripande principer för vård och behandling. https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/ovrigt/2018-11-2.pdf
- Socialstylersen. Patientjournal – Innehåll i en patientjournal. https://div.socialstyrelsen.se/juridiskt-stod/patientjournal-innehall-i-en-patientjournal
- Socialstylersen. Juridiskt stöd för documentation. https://div.socialstyrelsen.se/juridiskt-stod
- Vårdanalys. Tre perspektiv på digitala vårdbesök. https://www.vardanalys.se/rapporter/tre-perspektiv-pa-digitala-vardbesok/

- Sveriges Kommuner och Regioner. Ersättningar för digitala vårdtjänster i primärvården. https://skr.se/halsasjukvard/ehalsa/digitalavardtjansteriprimarvarden/ersattningardigitalavardtjansteriprimarvarden.28836.html https://skr.se/download/18.1509f18f17059700521f0222/1582650823232/avgifter_%C3%B6ppen_slutenvard_2020_uppdaterad.pdf
- 1177 vårguiden. Patientavgifte och högkostnadsskydd. https://www.1177.se/Stockholm/sa-fungerar-varden/kostnader-och-ersattningar/patientavgifter/

4 Motives for using wearable sensors and remote connections

4.1 Cost-effectiveness, impact on functional capacity and rehabilitees' experiences

There is little research evidence on the cost effectiveness of the remote rehabilitation/therapy processes. Direct cost savings incurred by reduced travel, reduced overall appointment time per rehabilitee, and therefore a theoretical reduction in required rehabilitation staff can be calculated and counted. However, the actual comparison of costs together with the more intangible assets of changes of functional capacity, the need of assistance, quality of life, and so on, compared to the traditional rehabilitation processes are difficult research questions yet to be answered.

Comparisons of experiences and changes in certain physiological, psychological variables are reported from different forms of rehabilitation processes. According to research conducted on remote rehabilitation used in physiotherapy, it appears that the results are at least similar, or in some cases better, than in conventional physiotherapy. However, more good quality research is needed.

Tousignant et al. (2015) made a cost-analysis and comparison of in-home telerehabilitation versus face to face in-home rehabilitation, calculating the direct expenses of post knee arthroplasty therapies. Their results showed that in-home telerehabilitation's direct total expenses were significantly cheaper than the usual face-to-face therapy (both single session and total expenses) when the rehabilitee´s home was located more than a 30 km round trip distance from the health care center. In a systematic literature overview (Hewitt at al. 2020) it was reported that digital health interventions can be clinically beneficial in musculoskeletal condition pain and functional capacity. Digital health interventions have the potential to reduce the costs of the impacts of the condition for both the individual and society. In the Pedro (Physiotherapy evidence database) web pages there are a collection of reviews focused on the evidence towards telehealth physiotherapy. These reviews cover a variety of health problems including cardiac, stroke, COPD, musculoskeletal, diabetes, pain, and asthma.

Physiotherapy Evidence Database. Evidence to guide telehealth physiotherapy.
https://pedro.org.au/english/evidence-to-guide-telehealth-physiotherapy/

Research examples:

- Lever et al. (2020) Telerehabilitation services for stroke. Cochrane database of systematic reviews.
- Adamse et al. (2018) The effectiveness of exercise-based telemedicine on pain, physical activity and quality of life in the treatment of chronic pain: A systematic review.
- Shield et al. (2018) Cost-effectiveness of cardiac rehabilitation: a systematic review.
- Rush et al. (2018) The efficacy of telehealth delivered educational approaches for patients with chronic diseases: A systematic review.
- Tousignant et al. (2015).Cost Analysis of In-Home Telerehabilitation for Post-Knee Arthroplasty.
- Hewitt et al. (2020). The Effectiveness of Digital Health Interventions in the Management of Musculoskeletal Conditions: Systematic Literature Review.
- Tarnanen et al. (2020). High-quality pain rehabilitation with remote physiotherapy.
- Cottrell et al. (2017). Real-time telerehabilitation for the treatment of musculoskeletal condition is effective and comparable to standard practise: a systematic meta-analysis.
- van Egmond et al. (2018). Effectiveness of physiotherapy with telerehabilitation in surgical patients: a systematic review and meta-analysis.
- Pastora-Bernal et al. (2017). Evidence of benefit of telerehabilitation after orthopaedic surgery: a systematic review.
- Rintala et al. (2017). Etäteknologian vaikuttavuus liikunnallisessa kuntoutuksessa. Järjestelmällinen kirjallisuuskatsaus ja meta-analyysi.
- Benell et al. 2019. Does a web-based exercise programming system improve home exercise adherence for people with musculoskeletal conditions? Randomized controlled trial.
- Schließmann et al. 2018 Trainer in a pocket - proof-of-concept of mobile, real-time, foot kinematics feedback for gait pattern normalization in individuals after stroke, incomplete spinal cord injury and elderly patients.

Monitoring walking quality factors using remote technology

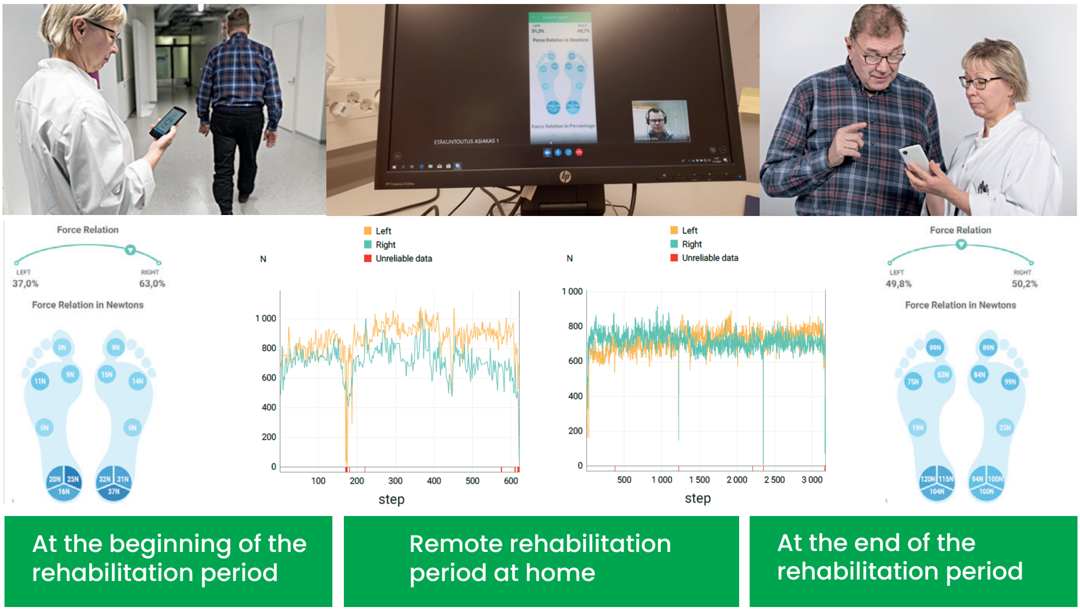


Figure 2. Example of using technology in remote rehabilitation.

Experienced benefits and challenges of remote rehabilitation

An example provided by the Cork Early Supported Discharge (ESD) for Stroke Team who implemented a Telerehabilitation strategy is discussed below. The pros and cons from the team are summarized in the following table.

Table 3. Feedback from Cork Early Supported Discharge (ESD) for Stroke Team

Patient benefits of remote rehabilitation	Challenges to remote rehabilitation
• Early discharge home • Continued rehabilitation in the clients own home enabling goal-focused functional therapy • Family involved in therapy sessions • Reduced anxiety regarding COVID-19 transmission • Clearer communication as no face mask required • Offers an alternative service delivery model for patients who have difficulty accessing therapists	• Difficult for hands-on assessment or treatment • Reliant on family/carers to assist with physical demands • Technology – It may fail! Cameras freeze and internet connections can be unreliable • Lack of equipment/internet availability

The 2nd example is from the Care of the Elderly Day Hospital, Beaumont Hospital, Dublin with benefits/challenges shown in the table.

Table 4. Feedback from Care of the Elderly Day Hospital, Beaumont Hospital

Patient benefits of remote rehabilitation	Challenges to remote rehabilitation
• Positive feedback from all patients • Reduced anxiety for patients and caregivers regarding COVID-19 transmission • Clearer communication as no face mask required • Offers an alternative service delivery model for patients who have difficulty with travelling to attend appointments • Ease of carer burden in terms of a person's dedicated carer having to organise to travel to the appointment and added pressures of Covid pandemic restrictions e.g. also caring for children at home • In the majority of cases, although family involved in the initial set-up, sessions were completed on a one-to-one basis to respect confidentiality and independence	• Access to technology for older people – most participants required some level of assistance from family members • Reliant on family/carers to assist with physical demands i.e. is the movement of a camera required to assess physical components • Technology – sound quality could be compromised intermittently • Need for good internet connection and equipment for completing teleconferencing • Considerations of confidentiality i.e. contacting the house landline and not immediately speaking with the person you are calling • The organisation is key, with the need for posting out information and availability if the patient runs into technical difficulty so reassurance and instruction can be provided as needed

Table 5. Acquired Brain Injury Ireland (https://www.abiireland.ie/) organisation's experienced benefits and drawbacks of remote rehabilitation

Benefits of remote rehabilitation for brain injury (found during COVID-19):	Drawbacks of remote rehabilitation for brain injury (found during COVID-19):
Continuity of rehabilitation and goals for brain injury survivors	Lack of broadband is a barrier for many
Maintaining keyworker/client relationships remotely	Not suitable for all client abilities
Structured online sessions for clients with follow-up	Unable to assess client environment and supports at home

Limerick Post. Acquired Brain Injury Ireland Turning to Telerehab during COVID-19. https://www.limerickpost.ie/2020/04/21/acquired-brain-injury-ireland-turning-to-telerehab-during-covid-19/

Experienced benefits and challenges of remote combined with wearable sensors

In Karelia UAS demonstrator projects, from the rehabilitation staff point of view, the use of sensors alongside online communication using video brings considerable benefits to the rehabilitation activity.

- By using an online wearable sensor, the therapist can gain instant insights and feedback on, for example, ground reaction forces during gait or exercise, muscle activity, cardiovascular level, accurate knowledge of ROM (range of movement), velocity and acceleration of movement. Providing insights such as these increase the therapist's ability to instruct, correct and give feedback to rehabilitee, compared to only a visual inspection of a moving picture. Camera techniques (e.g. Pan tilt zoom, picture capture programs) can also contribute this aspect.
- By using sensors, a more accurate picture of the rehabilitees´ functional capacity is captured as the normal or increased daily living activities are reported compared to the limited measures that can be made in a time-bound laboratory or clinic session.
- From the private practitioner's or company's point of view, one open question is the economical impact of this kind of activity. For example, how are productisation of rehabilitation services and business logics considered and calculated.

Tarnanen et al. (2020) demonstrated that with remote physiotherapy, it is possible to achieve high quality pain rehabilitation. They noted the benefits of remote physiotherapy and digitalisation as the following:

- Benefits of digitalisation and automation of data collection.
- Benefits of communication between therapist and rehabilitee:
  - One data secure communication channel where it is addressed
  - Controlling of communication and intensified use of time
  - Low contact threshold increases the intensity and efficiency of therapy
  - Can be both synchronous or a-synchronous
  - Timetables are more suitable for both parties
  - Opportunity to use digital material to support the instructions and advice. The rehabilitee can transfer data from every-day activities – sensor or measuring and monitoring data
  - fast answers to rehabilitees questions which promotes the increase of understanding and decreases the arousal of misunderstandings
  - Digital data collection allows for the monitoring of the rehabilitees situation
  - The actual therapy process can proceed with web-coaching when there is no further need for physical visits, thus maintaining the motivation of the rehabilitee and increasing the efficiency of the therapy.
  - Diversification in mode of operations can make the quality, effectiveness and satisfaction of therapy more intense. Therapy begins to be one part of the rehabilitees everyday life. (Fysioterapia 02/2020, 26-32.).

4.2 Accuracy, validity and reliability

The demands of accuracy, validity and reliability can easily be forgotten while developing wearable sensor systems for actual clinical or remote rehabilitation processes. The accuracy is often compared with "golden standard or reference measures" (construct validity). However, the expressions from the statistical analysis of accuracy and validity might give slightly misleading information for therapy purposes. For example, when the research results express a moderate (r. = 0.5) or strong (r.= 0.8) correlation, the actual situation in some cases may be a risk to clinical work. In a situation, when you're given the limitation of ground loading the foot after surgical operation is 15 kg, and the measuring equipment shows loading of 15 kg and the real is 20 kg, malpractice can be apparent. Also measuring sleep time and phases can have differences to reality, depending on various reasons.

Another example can be seen in counting steps (pedometer) as activity analysis without knowing the step length or walking speed (e.g. the power), can be misleading. The real activity in MET:s and distance walked can be very different. General physical activity is a concept that is considered to have an impact on many health and quality of life related aspects (10.000 steps for your health?). Age, health issues, functional capacity, psychological and social factors and work, leisure time and environmental factors all have an effect on it. Evaluating the correlation between those measures can be argued, and is dependent on what parameter is considered to be the golden standard. Commonly, physical activity and it's levels are considered to be in direct correlation to a person's energy expenditure (kcal, J, metabolic eqvivalent MET). Evaluations have been calculated from heartrate, etc. physiological changes. The number of steps (pedometers) and the relationship between moving and resting times (accelometers), combined with measures of distance moved with GPS, have been used to analyze and measure physical activity and intensity levels of it. Special groups like older people, adolescents, children, patient groups etc. cause challenges to those measures for various reasons. From the ICF (Inetrnational Classification of Functioning, Disability and Health) point of view, in rehabilitation and research, it is best to use the terms of real measures.

The user has to be aware of the validity properties of the equipment in different situations. Another aspect that the therapist must identify is the accuracy in every (or needed) parameter that the systems reports, because it can be different from parameter to parameter. In the literature the reliability level needed in clinical work, is expressed as having to be more than 0.9 (Atkinson, De Vet). Accuracy, validity and reliability studies are important to follow by clinicians and researchers currently – and is especially relevant when new equipment is being launched to the market.

Research examples:

- Hegde et al. (2019). Automatic Recognition of Activities of Daily Living Utilizing Insole-Based and Wrist-Worn Wearable Sensors.
- Rantalainen et al. (2019). Reliability and concurrent validity of spatiotemporal stride characteristics measured with an ankle-worn sensor among older individuals.
- Arvidsson et al. (2019) Re-examination of Accelerometer Calibration With Energy Expenditure as Criterion: VO 2net Instead of MET for Age-Equivalent Physical Activity Intensity.

- Ridder et al. (2019) Concurrent Validity of a Commercial Wireless Trunk Triaxial Accelerometer System for Gait Analysis.
- Faria et al. (2018) Validity of the accelerometer and smartphone application in estimating energy expenditure in individuals with chronic stroke.
- Serra et al. (2017) Validating Accelerometry as a Measure of Physical Activity and Energy Expenditure in Chronic Stroke.
- Innerd et al. (2015) A comparison of subjective and objective measures of physical activity from the Newcastle 85+ study.
- Leirós-Rodríguez et al. (2019/2020) Percentiles and Reference Values for the Accelerometric Assessment of Static Balance in Women Aged 50–80 Years (2019/2020).
- Trumpf et al.(2020) Quantifying Habitual Physical Activity and Sedentariness in Older Adults—Different Outcomes of Two Simultaneously Body-Worn Motion Sensor Approaches and a Self-Estimation .
- Renggli et al. (2020) Wearable Inertial Measurement Units for Assessing Gait in Real-World Environments.
- Kerdjidj et al. (2020) Fall detection and human activity classification using wearable sensors and compressed sensing.
- O'Brien et al. (2019) Augmenting Clinical Outcome Measures of Gait and Balance With a Single Inertial Sensor in Age-Ranged Healthy Adults.
- Razjouyan et al. (2018) Wearable Sensors and the Assessment of Frailty among Vulnerable Older Adults: An Observational Cohort Study.
- Soangra et al. (2018) Inertial Sensor-Based Variables Are Indicators of Frailty and Adverse Post-Operative Outcomes in Cardiovascular Disease Patients.
- Muñoz et al. (2018) Smart Tracking and Wearables: Techniques in Gait Analysis and Movement in Pathological Aging.
- Immonen. (2020) Risk factors for falls and technologies for fall risk assessment in older adults.
- Buisseret et al. (2020). Timed up and go and 6 minutes walking tests with wearable inertial sensor: One step further for the prediction of the risk of fall in elderly nursing home people.

4.3 Usability

Usability of both remote technology and wearable sensor systems are crucial demands for wider use in real working life rehabilitation situations and processes. Usability is a versatile concept like Nielsen defined in 1993. This model can be added with one important concept, which is the context where the system is used. In our case "the usability context" is real rehabilitation situations and processes, by older persons and at home or homelike circumstances.

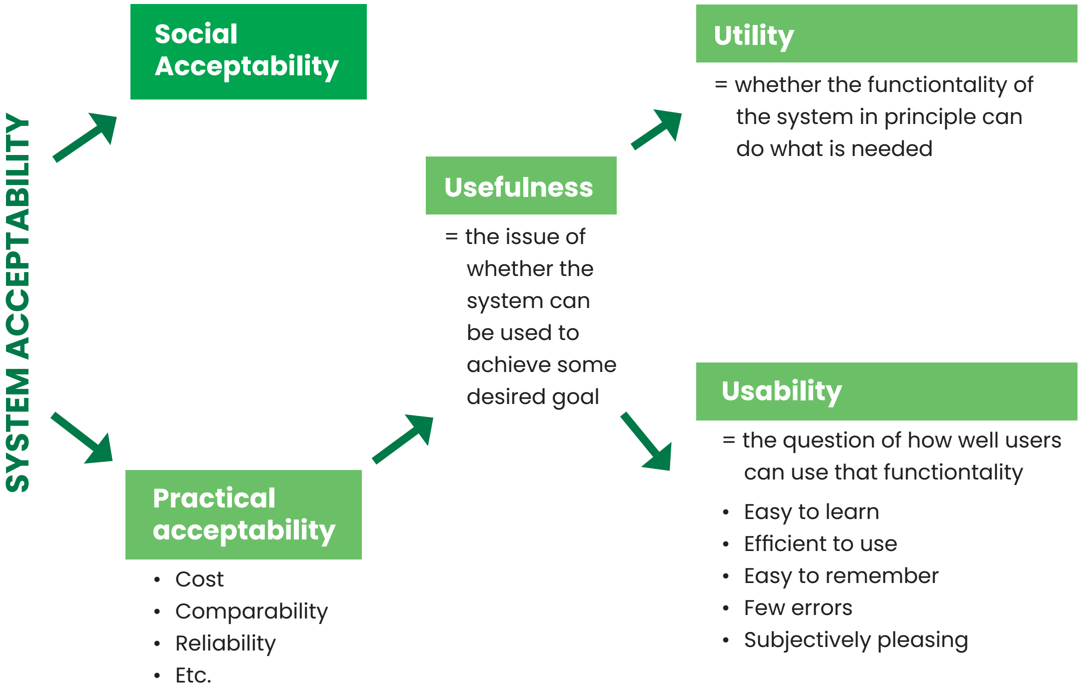


Figure 3. System acceptability modified from Nielsen´s system acceptability (1993).

In practice, we have found that a couple of simple usability aspects are worthwhile defining before implementing the equipment into the rehabilitation situation. For example,

- Is the equipment extremely easy to use, so you can implement it in "a relatively normal" timeline in therapy sessions?
- Is the system valid/accurate?
- Are the data and report directly beneficial to your therapy and the progress of rehabilitation?
- Or you can modify the Cochrane ladders
  - Efficacy: can it work?
  - Effectiveness: does it work in practice?
  - Cost-effectiveness: is it worth it? (Cochrane 1971)

Sendoc partners have tested several wearable sensor systems (23), both engineering staff and health care staff. The experiences and aspects of utility, usability, and usefulness of the wearable sensor systems were collected (Table 5.)

Table 5: Lessons learned of utility, usability and usefulness during SENDoc activities.

UTILITY	USABILITY	USEFULNESS
Accuracy - accurate, relevant and verifiable results	**Hardware** - barriers to usability: Too cumbersome to wear, too complicated - the number of sensors needed **Software** - too complicated (e.g. data is not organized according to what is needed) - Interfaces have to be user-friendly and - flexible managing of rehabilitee data (security, documentation, and storage, transferring data) - need for education/training and ability to troubleshooting - raw data possibilities - installation of software/application must be easy	**Monitoring** - opportunity to monitor in real-life situations and for longer periods - integration to a person´s everyday routines
Report - data needs to be presented in a way that the results can be directly usable in rehabilitation - assists decision making of clinical work	**Support** - easy access to technical support - clear user manual (language options) - clear instructions - organisational support for their use	**Individualize** - opportunity to individualise processes and instructional exercises
Benefits - there has to be some added value using a sensor system in the rehabilitation process - It should be beneficial compared to other methods (time-consuming, accuracy, novel aspects of functional capacity)		**Sensor design** - must be discrete - comfortable to wear - not labelling the user for illness
Hardware & Software - long battery life, easy/ reliable connectivity and working data storage		
Context - the user should consider the context actual environments (e.g. indoors, outdoors, home, clinic, everyday life) enable connection to several age groups (e.g. children, and older people) it should be connected with the cognitive and functional levels of a person		

5 Remote home rehabilitation with wearable sensor systems – process guide

5.1 Step 1: First contact

Seeking rehabilitation services, in case of worries of decreasing functional capacity of an older person, is instructed in different ways in EU-countries. We use here examples from the UK, Ireland and Finland.

The regulations, how every citizen of **Finland** can contact the rehabilitation services, depends on what area of the rehabilitation or therapy (vocational, psychological, social, medical, speech, physio, occupational etc.) is the one involved. In cases, that are held accountable for the responsibility of Kela, or are allowed compensations for expenses of therapies/rehabilitation from Kela, you must visit a doctor first.

In most of the regions of Finland, in the case of musculoskeletal based problems of functional capacity, a person can contact services directly (self-referral) to get physiotherapist evaluation, instructions and therapy. This is possible without contacting the General Practitioner (GP) first to be admitted for evaluation. Self-referral is possible both in public and private health care organizations.

The older person's rehabilitative services are a wide concept. There are available various "service packages" and different forms of rehabilitation, in the different regions of Finland. Typically those services include first some rehabilitation professional – or specific team (physiotherapists, occupational or ergo therapists, speech therapists, psychotherapists, rehabilitation medicine etc.) – who will carry on the evaluation of the persons functional capacity problems, the available resources for managing it, and the services needed. After that, the rehabilitee agrees with the plan and involved in a suitable package of services, maybe consisting from some special services (food, transportation, or home modifications), to intensive rehabilitation periods in institution or activities of so-called open-day-rehabilitation. Variations of rehabilitation services or service packages also occur in services offered by private rehabilitation service providers.

- Suomen fysioterapeutit. Fysioterapeuttien suoravastaanotto. https://www.suomenfysioterapeutit.fi/fysioterapia/ammatin-kehittaminen/fysioterapeuttien-suoravastaanotto/
- Kangas, H. (2017). Asiantuntijoiden välinen luottamus ja sosiaalinen työnjako julkisen terveydenhuollon organisaatioissa : fenomenografinen tapaustutkimus fysioterapeuttien ja lääkäreiden luottamus- ja työnjakokäsityksistä kahdessa kuntaorganisaatiossa. Väitöskirja. Itä-Suomen yliopisto Yhteiskuntatieteiden ja kauppatieteiden tiedekunta, Sosiaali- ja terveysjohtamisen laitos. http://urn.fi/URN:ISBN:978-952-61-2470-4
- Karppinen, J., Kangas, H., Paukkunen, M., Remes, J., Partanen, K. (2020). Fysioterapeutin suoravastaanotto tuki- ja liikuntaelinpotilaiden hoidossa. Työnjako ja kokemuksia. Lääkärilehti 5/2020. https://www.laakarilehti.fi/pdf/2020/SLL52020-263.pdf
- Helsingin kaupunki. Ikääntyneiden arviointi ja kuntoutus. https://www.hel.fi/helsinki/fi/kaupunki-ja-hallinto/hallinto/palvelut/palvelukuvaus?id=7369
- Kela. Quick guide to rehabilitation. https://www.kela.fi/web/en/rehabilitation-quick-guide

In **Ireland** and the **UK**, a person goes to his/her GP first with concerns. The GP can refer to the Primary Care rehab services in the community (Primary Care Team- OT, physio, nurse, etc) or "Staying fit" group. Or the GP can refer to secondary care- for an Older Person Service to be seen in a clinic or ambulatory care hub – from there the person can access day-care, in-patient or community rehab- this last one includes specialist rehab teams e.g. stroke, falls etc. Or GP can refer to private rehab services- paid by the health insurance. The person can also directly access an individual private therapist if there is a limited issue (e.g. frozen shoulder). The public service is fine- there can be waiting lists in certain areas, but an urgent issue is usually seen promptly. A person can also access "fitness" classes provided by Health and Wellbeing services- in the local community at a discounted cost.

In Ireland initially, if a person is at home and stable, as per above. GPs are often the "gatekeeper" to the next level. Disciplines who have the professional competence to assess function are Physios, OTs, Nurses and Doctors

Acute hospital staff if the person had presented to the Emergency Department (ED) or admitted to the hospital. every hospital has an Older Persons Liaison service who can arrange rehab based on the need. Includes dedicated MDT staff in ED (Frailty team; "Home First Team" etc.) with direct pathways to community teams. Community MDT- see earlier section on access. Most teams and services have referral criteria (need/geographical region), and the service MDT can refuse a referral if it feels to be inappropriate.

Probably soon the remote rehabilitation will be included in every rehabilitation organizations service repertoire as one possibility. Our guess – at least in Finland – is that some kind of hybrid model, which combines face to face and remote rehabilitation activities, is the advisable model. The health information security levels and especially transferring remote rehabilitation data to local organization's e-health reporting and archive system and national health report archive must be previously mentioned in A-level.

The first connection can happen in various ways (phone, visit, email etc.) and the first meeting can take place at the rehabilitees home, clinic etc.

5.2 Step 2: Evaluation and agreement of suitable rehabilitation model for rehabilitee

After the contact with the rehabilitation services, the first step is to evaluate rehabilitee functional capacity and resources to manage it. In the case of remote rehabilitation, according to instructions of Valvira, the first evaluation must be in person. During this step, in addition to the evaluation of functional capacity and rehabilitees resources, they must be involved in the rehabilitation process. The correct rehabilitation professional and organization (public, private and basic or specialized) must be considered. An agreement must be formed about the suitable / best rehabilitation service model for the person. The next concrete action is to build and write a rehabilitation plan.

A few attributes for older people who can operate with sensors and remote connections manifested in our demonstrator projects are: First the rehabilitee must have motivation for remote rehabilitation model activities. Second, the rehabilitee must have enough cognitive capacity to understand the use of the equipment and key results. Third, the rehabilitee must have good enough sight to operate the system and read the screen/report. Fourth obviously rehabilitees functional capacity has to be good enough to operate with the equipment independently or with little assistance.

5.3 Step 3: Selection of staff, sensor, remote connection equipment

Operating rehabilitation organisation have to choose the right rehabilitation professional, who can take care of the process with wearable devices and remote rehabilitation with the rehabilitee. Rehabilitation staff should be educated to interact through remote connections because there are some different demands compared to normal face to face activities. Rehabilitation staff must be aware of the large portion of video-based action concerns and technical issues e.g. quality of the picture, or quality of sound. The technical support staff has to be defined for both rehabilitee and therapist.

Video-based interaction in a remote rehabilitation

The health IT-infrastructure, organisational routines and workflows, interactional work of a video consultation must be considered while implementing remote healthcare services. The healthcare professional must evaluate if the rehabilitee is appropriate for remote connection consultations. Typically, the interaction might meet challenges like opening the video connection, managing possible disruptions to the conversation by typically audio and/or video connections. The physical examination is difficult to conduct because it requires good interaction with the rehabilitee, and the use of certain measuring equipment. Physical safety must be also secured.

Video consultation talks in healthcare can be divided into the following types: setting up, social talk, clinical talk, repair talk, operational talk. A setting up talk is to instruct to the technical use of the equipment for the rehabilitee (e.g. microphone, camera). A social talk is to build up a relationship with rehabilitee. A clinical talk is used to handling the rehabilitee´s situation, results, functional capacity and other key information. A repair talk is used to teach how to manage technical difficulties. An operational talk is utilized to instructing and guiding the rehabilitee about setting up specific things (e.g. quality of sound and picture and positions of the camera).

- Shaw et al. (2020). Video Consultations Between Patients and Clinicians in Diabetes, Cancer, and Heart Failure Services: Linguistic Ethnographic Study of Video-Mediated Interaction
- Wherton et al. (2020). Guidance on the introduction and use of video consultations during COVID-19: important lessons from qualitative research

Table 6. Attributes of a wearable sensor system and remote connections

Attributes of a wearable sensor system suitable for remote use in-home	Attributes of remote connections and the equipment for organising remote rehabilitation
Easy to wear independently or with minimum assistance	A-level data security
Easy connection to application/program	Possibility to link online for example sensor data
Comfortable to wear (e.g. do not interfere with normal activities)	Possibility to link instructions, literature, picture videos, text, tasks
At least some monitoring parameters are also descriptive to the rehabilitee	Possibility to link a group of people

Table 7: Lessons learned from different remote connection systems

Systems & combination of equipment used in a remote rehabilitation	Findings & observations
• A tablet computer with a touch screen is delivered for the rehabilitee´s home • Service provider organises both connections and equipment • Physiotherapist connects through a secure connection to the rehabilitee´s tablet/ computer and they share an external monitor • External monitoring/measuring devices can be attached with USB-C	• A direct and secure connection between the therapist and the client • Easy to use (one tap in touch screen to connect) • The rehabilitee can share the wearable sensor data (online or collected) with the therapist by connecting the application view to the tablet computer • Costs for the rehabilitee and the organization? Is it cost-effective?
• The therapist uses licensed remote application that secures the connection to rehabilitee´s tablet computer • Preselected and specially build safety connection for monitoring device can be connected to the application interface	• A direct and secure connection between therapist and rehabilitee • Easy to use for rehabilitee • Ability to collect data from selected applications • Only selected applications can be used to share secure information between rehabilitee and therapist • Cost-effectiveness depending situation
• An electronic health care platform with a possibility for a video call between rehabilitee and therapist • Transmission of files with a secure connection	• Data security is guaranteed by strong identification: rehabilitee identification (bank -id etc.) build a password in the system • Easy video call connection for rehabilitee • Possibility to send files (excel, pdf), no online data monitoring possibility • Building the files from the report can be difficult for some rehabilitees
• Patient report system with an integrated video phone application • Rehabilitee receives a link for a video call via SMS or E-mail	• The therapist must be sure that the email is used by the correct rehabilitee e.g. strong identification must be done before • Easy video call connection for the rehabilitee • Only video calling, no possibility to share sensor data

Following service providers and solutions have been found from web-based information:

EXAMPLES OF REMOTE SERVICE PROVIDERS IN FINLAND 2020

- Sencom www.sencom.fi
- Movendos www.Movendos.com
- Navicre https://health.navisec.fi/
- Mumo Care www.mumo.care
- HealthFox https://www.healthfox.fi/rehabilitation/
- CSAM health www.csamhealth.com
- VideoVisit www.Videovisit.fi
- Medixine www.medixine.fi
- Arcturia www.artic-connect.com

The solutions mentioned in the preceding section are those recommended by eHealth Ireland and the HSE.

EXAMPLES OF SERVICE PROVIDERS IN IRELAND 2020

- Doxy.me – Virtual Clinic https://doxy.me/
- NuaSolutions NuaHealth App – Telemedicine solutions https://www.nuasolutions.com/#start
- Wellola Patient Portal Software Solutions – video consultation and patient portal - https://www.wellola.com/
- MyClinic365 – patient engagement platform https://myclinic365.com/
- Salaso Health Solutions - Mobile Physiotherapy App https://salaso.com/
- VideoDoc https://videodoc.ie/
- Human Centred Movement https://humancentredmovement.ie/movement-clinic/
- Spectrum Health, previously the Physio Company - https://www.spectrumhealth.ie/digital-services
- PhysioCare https://physio.ie/contact-us/physiocare-online-consultations/

SERVICE PROVIDERS IN UK 2020

- Remote service delivery options https://www.csp.org.uk/news/coronavirus/remote-service-delivery-options/digital-tools-support-service-delivery
- Health Care Providers who are disrupting the Industry Telemedicine Providers who are Disrupting the Industry (ringcentral.co.uk)
- Sun Rehab Sun Rehab - leading national provider of occupational health physiotherapy (sunrehabilitation.co.uk)
- PHYSIOTOOLS Telehealth service for remote rehabilitation | Physiotools
- Hobbs Rehabilitation Home | Hobbs Neurological Rehabilitation (hobbsrehabilitation.co.uk)

- Physio Med Physio Med - Experts in Physiotherapy Care | Physio Med - Physiomed
- Physitrack Physitrack® - The world leader in remote patient engagement and Telehealth.

SERVICE PROVIDERS IN SWEDEN 2020

Swedish physiotherapy associations web pages there are tips for five different companies that offer tele physiotherapy services. (Unfortunately, you have to be a member and have a password)

- Fysioterapeuterna. Digital fysioterapi. https://www.fysioterapeuterna.se/utbildningar/digital-fysioterapi/

5.4 Step 4: Selecting measuring parameters to describe the change on the functional capacity

Select the measuring parameters to describe the change on the rehabilitee's functional capacity. Worldwide and nationally there are suggestions and consensus papers of reliable and validated means of analyzing and monitoring different components of functional capacity. Some of those means are generic, some are for specific age cohorts or health condition /diagnosis based. Different rehabilitation and health care professionals have their favourites and guides for use. Links for recommendation examples can be found below (ICF based, non-diagnosis based, Frailty, Stroke, Arthrosis, Preventing fall, Parkinson, Rheumatic arthrosis etc):

- Ottawa panel evidence-based clinical practice guidelines for post-stroke rehabilitation. https://europepmc.org/article/med/16939981
- Terveysportti. TOIMIA-tietokanta. (ICF based measures). https://www.terveysportti.fi/dtk/tmi/koti
- Terveysportti. Kaatumisten ja kaatumisvammojen ehkäisyn fysioterapiasuositus. (Fall). https://www.terveysportti.fi/dtk/sfs/avaa?p_artikkeli=sfs00003
- Evidence-Based Practice Guideline: Fall Prevention for Older Adults. https://pubmed.ncbi.nlm.nih.gov/29065212/
- RNAO. Preventing Falls and Reducing Injury from Falls. https://rnao.ca/sites/rnao-ca/files/bpg/FALL_PREVENTION_WEB_1207-17.pdf (Fall)
- Terveysportti. Sepelvaltimotautipotilaan liikunnallinen kuntoutus. (Cardiac). https://www.terveysportti.fi/dtk/sfs/avaa?p_artikkeli=sfs00002
- Terveysportti. Polven ja lonkan nivelrikon fysioterapiasuositus. (Arthrosis of hip and knee). https://www.terveysportti.fi/dtk/sfs/avaa?p_artikkeli=sfs00001
- Physical Frailty: ICFSR International Clinical Practice Guidelines for Identification and Management. https://link.springer.com/article/10.1007/s12603-019-1273-z

- An Immersive Motor Protocol for Frailty Rehabilitation. https://www.frontiersin.org/articles/10.3389/fneur.2019.01078/full
- European Physiotherapy Guideline for Parkinson's Disease. https://www.parkinsonnet.nl/app/uploads/sites/3/2019/11/eu_guideline_parkinson_guideline_for_pt_s1.pdf
- Canadian Guideline for Parkinsons disease. https://www.cmaj.ca/content/cmaj/suppl/2019/09/04/191.36.E989.DC1/Parkinson-final-E-online-LR.pdf

From the wider perspective of monitoring/measuring parameters, select those most important ones to your rehabilitee. In this document, we use the hip arthrosis-based situation as an example of possible selections.

Case hip arthrosis: Check if the selected parameters – or which of them – are possible to measure/monitor (Handbook I) with sensors and remote connections. Check from your organization's sensor equipment repertoire?

ARTHROSIS

STRUCTURES & FUNCTIONS

Examples:

- Pain
- Limitation of ROM
- Joint deformity
- Posture
- Swelling
- Walking
- Limping
- Stability
- Soreness
- Muscle strength
- Muscle tension
- Aerobic capacity

ACTIVITIES AND PARTICIPATION

- Changes of posture (squating, standing etc.)
- Dressing
- Walking speed
- Balance
- Lifting and carrying
- Use of vehicles
- Activity
- Hobbies
- Social relationships
- Working capacity
- Home care activities

ENVIRONMENTAL FACTORS

- Medication
- Assistive device
- Need of assistance
- Working environment

INDIVIDUAL FACTORS

- Age
- BMI
- Education
- Health

QUALITY OF LIFE

Figure 4. Modified ICF-based evaluations of functional capacity in case of hip arthrosis (KNFG).

Table 8. ICF Structure & Activities component measures of the functional capacity.

- WHOQOL
- WOMAC
- Muscle strength and strength balance of lower limb (concentric/ isometric/ isokinetic)
- ROM (range of motion) of hip (especially extension and extrarotation)
- Cardiovascular capacity (6MWT, Polar test)
- Gait analysis (e.g. ground reaction forces, kinematic analysis, muscle activity analysis
- Balance
- BMI

Table 9. The parameters possible to be measured with wearable sensors, for example.

- ROM of hip and other lower limb joints
- Cardiovascular capacity
- Spatiotemporal and ground reaction forces of gait – asymmetry, speed etc.
- Balance
- Web-based WHOQOL, WOMAC, VAS etc.

5.5 Step 5: Usage guidance, support, and timetable

Consider rehabilitee and/or next of kin and/or assistive persons will have usage guidance – especially:

1. Positioning and dressing/wearing of sensor
2. Connecting sensor to phone/tablet/computer
3. Usage of program/application
4. Usage of remote connection equipment
5. Connecting previous to the online activity or for reporting data to connection equipment.
6. Ensure that all the equipment is available.
7. Confirm that remote (telemedicine) connections to rehabilitees home are available and good enough and working: bandwidth and speed etc.
8. Confirm that data transfer to patient reports is working and according to safety instructions and legislation.

9. Confirm that support is easy to reach.
10. Agree with the rehabilitee about the possible timetable and the need to support the rehabilitation goals.
11. You have to consider the location(s) where virtual clinics will take place, taking into consideration:
    - A private, well-lit area where you will not be disturbed during the consultation
    - Ensure the background of the video call is appropriate, no visibility of sensitive information e.g. whiteboard with personal data, X-rays, personal items etc.

5.6 Step 6: Ensuring connections, interaction in process steps and the actual therapy activities

Agree and take care of the process – contact times and dates, different options, actions - according to the rehabilitation plan. The rehabilitee and physiotherapist agree on the time for their virtual therapy session. In the comfort of their own home, the rehabilitee uses, for example, the touchpad remote rehabilitation technology equipment to connect to smart measuring insoles which provide data about gait asymmetry, weight distribution during walking, ground reaction forces during step and time. The touchpad equipment connects online allowing remote monitoring by the physiotherapist during exercises such as walking together while they observe the ability to do exercises. Another possible use of this equipment is to collect the data during normal daily activities (such as gardening/going for a longer walk/ going to the market, shopping etc), providing a better insight into the rehabilitees progress. A report is then generated and sent to both the rehabilitee and the physiotherapist, allowing for a discussion about the current real-life situation and, for example, if required, updating the set of exercises. The online data increases the real knowledge about the performance of the rehabilitee considerably and helps individualize the therapy process.

The physiotherapist uses the same service providers as the rehabilitee for the equipment on their end, which is installed in the "remote connection therapy room". The therapist observes, monitors and analyses the data seen on the screen, and gives reflections about the situation and development to the rehabilitee. When necessary, the therapist updates the exercises and progress.

Record up and document according to the laws of the activities of every therapy session in the patient reporting system used in your organisation.

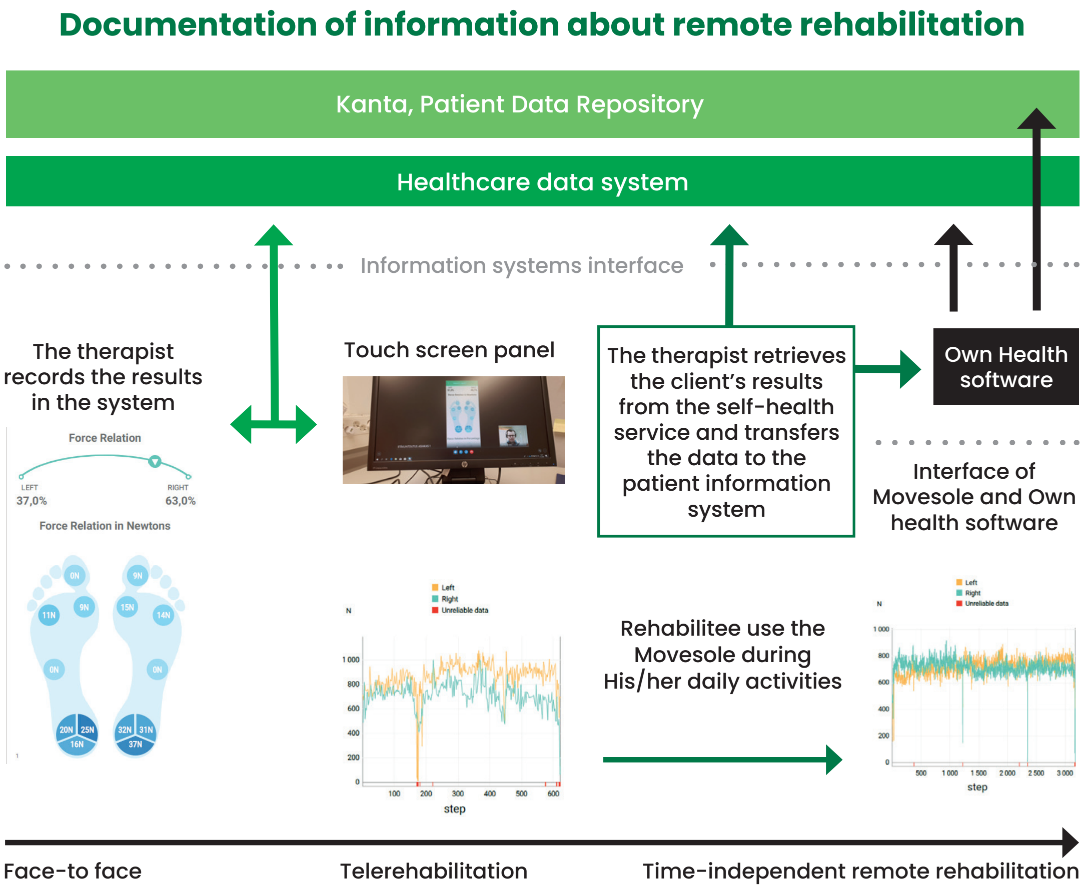


Figure 5. Documentation of information about remote rehabilitation.

5.7 Step 7: Evaluation

Of course in a way every remote therapy session includes evaluation and feedback in both directions about both changes of functional capacity and used remote systems. At the end of the whole therapy period, the whole rehabilitation process and services included are evaluated to plan the future: Are more or other kinds of therapies and services needed? etc. Decisions and plan are documented in organisations patient reporting system.

An example of remote-rehabilitation and wearable sensors: Change of the difference of weight distribution- Movesole Smart Insole

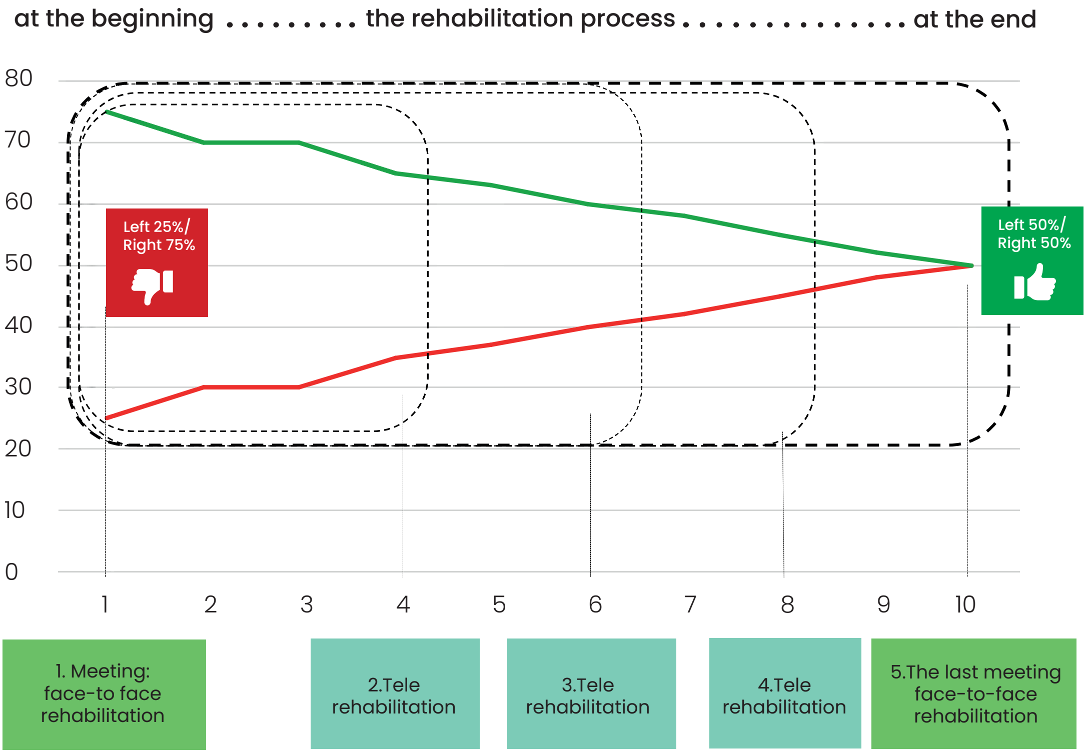


Figure 6. An example of remote-rehabilitation and wearable sensors: Change of the difference of weight distribution- Movesole Smart Insole.

6 Lessons learned during Sendoc demonstrator projects

Digital health care services and different equipment used, are going through fast development in all areas. Especially the Covid – 19 pandemic has accelerated the development, need and use of remote rehabilitation in countries. In the same time, it has been obvious that regulations under remote rehabilitation must also be developed and ethical aspects and data security must be considered all the time and developed in parallel. The end user's needs – both rehabilitees and therapists – must be taken into account but end user's responsibility is also to take part to development processes and follow the research care that necessary accuracy and usability demands are full filled.

Partners on the SENDoc project have been conducting research into wearable technology and have performed several demonstrator projects based on these technologies, both in their separate regions and collaboratively. The demonstrator projects have been conducted in collaboration with the associate partners of each region, who were mainly real rehabilitation working life organizations, and rehabilitation staff from therapy professions. Universities, health and therapy science staff, and computer science and technology staff were also involved in the demonstration projects.

Experiences gathered during the project activities, the demonstrator projects, and extensive literature reviews have all contributed to the Lessons Learned from SENDoc. The Lessons Learned documented below are a reflective piece given the SENDoc project's initial goals and agenda, while also considering the success of the entire project's life cycle.

Thoughts and experiences from the project were collected using a questionnaire, discussions held in meetings, and "off the record" discussions between the Partners. Our aim is that this collection of lessons learned will assist different professionals in growing the mutual understanding of the area in question – that is wearable sensors for remote rehabilitation.

Technical issues regarding wearables in remote circumstances:

Key aspects can be extracted from the answers to the following:

- Right position and independent or assisted dressing of the wearable device
- The design of both the wearable device and its application – must be comfortable and easy to use
- Access to raw data from off-the-shelf wearables
- Question of context – surroundings and environment
- Syncing and connection of systems
- Training and support of use
- Data collection and storage time
- Internet connection and battery life – effects on everyday life

The key aspects of technical issues concerning the use of wearable sensors in *home circumstances* are:

Obviously, many of the same key aspects are similar to the answers to the previous question. But some new experiences are mentioned too, for example:

- The therapist responsible may need training and education regarding the positioning, dressing and fitting of the sensor, as well as training for technical trouble shooting and to interpret the reports
- It is difficult to ensure the accuracy and validity of the device recorded in research and clinical use is maintained once deployed at home
- Monitoring at home may have an impact on avoiding “better than normal performance” often noted in the short clinical test usually preformed.
- Choosing the right rehabilitee and professional is very important.
- Technical support for both rehabilitee and rehabilitation professional

The key aspects of technical issues concerning the use of wearable sensors in *clinical circumstances*.

Some nuance differences can be found from the answers under this topic, which have not been mentioned so intensively before, though they are not insignificant in the previous ones.

- Time consuming factors that effect the use in practice (connectivity etc.) - time is limited.
- Once again accuracy, reliability.
- Relevant information of correct parameters that can be adopted to rehabilitation immediately.

The key aspects of developing algorithms for wearable sensors for rehabilitation purposes

The following collection of experiences has combined important views that increase the mutual understanding of activities and fields of different professionals. Combined experiences are that in order to build a good basis for the algorithm, the following is required:

- Enough participants in starting measures
- Target groups like age cohorts must be considered
- Effect of sensor position considered
- Quality – accurate, smart, dynamic, updated
- Co-operation with experts of different fields
- Basis of the development – actual need or build the need

Lessons learned about the usability of sensor systems

Compilation of themes and answers to lessons learned questions concerning "Usability, Utility and Usefulness of wearables in rehabilitation" is under the topic usability previously in this document.

Lessons learned from using wearable sensors with the older people

The Sendoc project has been particularly focused on older people and the viability for them to continue independent living with the use of wearable sensors for remote rehabilitation activities. With this in mind, the experiences and research-based views collected from older persons on the aspects of new technology and opinions on the use of wearables are especially important information for the future.

Combined experiences and learnings are:

- Choosing the right persons and ethical consideration: older persons self determination, required level of technical skills, attitude, interest and motivation. Awareness of possible barriers
- Technics: personalized technology, design (discrete, buttons, visual, comfortability), aesthetics and algorithm

Lessons learned from co-operation with different professions and work cultures

Co-operation and learning from others is necessary for this kind of activity. In order to achieve the maximum benefits, open mindedness to new ideas, knowledge, learning and flexible persons are all traits required. Additionally, one needs to be able to appreciate others views, as well as have the determination to survive language and other cultural differences (general culture in countries, work culture, different emphasis and concepts of professionals even in same basic profession).

Specific co-operation in wearable development and analysing - what is actually necessary, needed, sufficient, and possible – in different work processes, real life settings and end users is also required.

- The Digi-HTA: Health technology assessment framework for digital healthcare services has been developed for evaluating tools of different forms of services and equipment. https://journal.fi/finjehew/article/view/82538

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This Handbook Part II was developed to assist and orientate rehabilitation staff and organisations who are planning to start remote home rehabilitation activities, particularly with the elderly. The ideas and suggestions for the remote rehabilitation process in this document can be easily adopted to any kind of functional capacity problem in rehabilitation.

The Handbook Part II focuses on the attributes and aspects that you must consider when you start a remote rehabilitation process with remote connections and wearable sensor systems.

This Handbook Part II is a continuation from the Handbook of Wearable Technology Supported Home Rehabilitation Services in Rural Areas – Emphasis on Monitoring Structures and Activities of Functional Capacity, launched in 2019.

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